







Colusa Groundwater Authority &
Glenn Groundwater Authority

Colusa Subbasin Groundwater Sustainability Plan

FINAL REPORT – DECEMBER 2021

COLUSA SUBBASIN

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PREPARED FOR

Colusa Groundwater Authority &
Glenn Groundwater Authority

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Groundwater Sustainability Plan

Prepared for

Colusa Groundwater Authority
&
Glenn Groundwater Authority

COLUSA SUBBASIN

Project No. 277-60-20-11

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ACKNOWLEDGEMENTS

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Colusa Groundwater Authority GSA

Member Agencies

County of Colusa, City of Colusa, City of Williams, Glenn-Colusa Irrigation District, Maxwell Irrigation District, Westside Water District, Princeton-Codora-Glenn Irrigation District, Provident Irrigation District, Colusa County Water District, Reclamation District 108, Reclamation District 479, Colusa Drain Mutual Water Company, Two representatives of private groundwater pumpers

Glenn Groundwater Authority GSA

Member Agencies

City of Orland, City of Willows, County of Glenn, Glenn-Colusa Irrigation District, Glide Water District, Kanawha Water District, Monroeville Water District, Orland-Artois Water District, Princeton-Codora-Glenn Irrigation District, Provident Irrigation District

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In Remembrance of Byron Alan Clark, PE

(February 4, 1976 - April 3, 2021)
Thanks for his excellent leadership and foundational work in the development of the Colusa Subbasin GSP

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LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	Micrograms Per Liter
µS/cm	MicroSiemens Per Centimeter
3D	Three-Dimensional
AB	Assembly Bill
AEM	Airborne Electromagnetic
af	Acre-Feet
af/yr	Acre-Feet per Year
amsl	Above Mean Sea Level
AN	Above Normal Water Year
Authorities	Colusa Groundwater Authority and Glenn Groundwater Authority
AWMP	Agricultural Water Management Plan
bgs	Below Ground Surface
BMO	Basin Management Objective
BMP	Best Management Practice
BN	Below Normal Water Year
Brown Act	Ralph M. Brown Act (Government Code § 54950-54963)
C	Critically Dry Water Year
C&E Plan	Communication and Engagement Plan
C2VSimFG	California Central Valley Groundwater-Surface Water Simulation Model – Fine Grid
Cal Water	California Water Service Company
Caltrans	California Department of Transportation
CARB	California Air Resources Board
CASGEM	California's Statewide Groundwater Elevation Monitoring Program
CCP	Comprehensive Conservation Plan
CCR	California Code of Regulations
CCWD	Colusa County Water District
CDEC	California Data Exchange Center
CDFW	California Department of Fish and Wildlife
CDMWC	Colusa Drain Mutual Water Company
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	Cubic Feet per Second
CGA	Colusa Groundwater Authority
CGPS	Continuously Operating Global Positioning System
CIMIS	California Irrigation Management Information System
CNRA	California Natural Resources Agency

Colusa Drain	Colusa Basin Drainage Canal System
COOP	Cooperative Observer Network
Cr^{6+}	Hexavalent Chromium
CRC	California Rice Commission
CREP	Conservation Reserve Enhancement Program
CSAMT	Controlled Source Audio-Frequency Magnetotellurics
CT	Central Tendency
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
CWC	California Water Code
D	Dry Water Year
DAC	Disadvantaged Community
DDW	Division of Drinking Water
Delta	San Joaquin-Sacramento River Delta
DMS	Data Management System
DTSC	Department of Toxic Substance Control
DTW	Depth to Water
DWD	Dunnigan Water District
DWR	Department of Water Resources
EC	Electrical Conductivity
EDA	Economically Distressed Area
Eh	Redox potential
ESA	Endangered Species Act
ET	Evapotranspiration
ET_{aw}	Evapotranspiration of Applied Water
EWMP	Efficient Water Management Practices
eWRIMS	Electronic Water Rights Information Management System
Flood Board	Central Valley Flood Protection Board
Flood-MAR	Flood-Managed Aquifer Recharge
FSS	Facilitation Support Services
ft	Feet
ft bgs	Feet Below Ground Surface
ft/day	Feet Per Day
GAMA	Groundwater Ambient Monitoring and Assessment
GCC	Glenn County Code
GCID	Glenn-Colusa Irrigation District
GDE	Groundwater Dependent Ecosystems
GGA	Glenn Groundwater Authority

GIS	Geographic Information System Mapping
GMP	Groundwater Management Plan
GP	General Plan
gpm	Gallons Per Minute
GPS	Global Positioning System
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
GWE	Groundwater Elevations
GWS	Groundwater System
HCM	Hydrogeologic Conceptual Model
HUC	Hydrologic Unit Code
ICONS	Interconnected Surface Water in California's Central Valley
ID	Identification
IHM	Integrated Hydrologic Model
ILRP	Irrigated Lands Regulatory Program
InSAR	Interferometric Synthetic Aperture Radar
IRWMP	Integrated Regional Water Management Plan
IWFM	Integrated Water Flow Model
JPA	Joint Powers Authority
JPL	Jet Propulsion Laboratory
LAFCO	Local Agency Formation Commission
Ma	Million Years Ago
maf	Million Acre Feet
maf/yr	Million Acre Feet Per Year
MAR	Managed Aquifer Recharge
MCL	Maximum Contaminant Level
MG	Million Gallons
mg/L	Milligrams per Liter
MGD	Millions of Gallons Per Day
MHI	Median Household Income
MO	Measurable Objective
MSR	Municipal Service Reviews
MT	Minimum Threshold
NAD	North American Datum
NASA	National Aeronautics and Space Administration
NAVD 88	North American Vertical Datum of 1988
NCCAG	Natural Communities Commonly Associated with Groundwater
NCEI	National Centers for Environmental Information
NCWA	Northern California Water Association

NEPA	National Environmental Policy Act
NHD	National Hydrology Dataset
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NSV	Northern Sacramento Valley
NWIS	National Water Information System
O&M	Operation and Maintenance
OAL	Office of Administrative Law
OAWD	Orland-Artois Water District
OES	Office of Emergency Service
OSWCR	Online System of Well Completion Reports
OUWUA	Orland Unit Water Users Association
P&G	Proctor and Gamble
PBO	Plate Boundary Observatory
PCE	Tetrachloroethylene
PHG	Public Health Goal
Planned PMA	Planned Projects and Management Actions
PMA	Projects and Management Actions
ppb	Part Per Billion
ppm	Parts Per Million
RD108	Reclamation District 108
Reclamation	U.S. Bureau of Reclamation
RMN	Representative Monitoring Network
RPE	Reference Point Elevation
RWMP	Regional Water Management Plan
SAGBI	Soil Agricultural Groundwater Banking Index
SB	Senate Bill
SCADA	Supervisory Data and Control Acquisition
SDAC	Severely Disadvantaged Community
SDWIS	Safe Drinking Water Information System
SGMA	Sustainable Groundwater Management Act
SHPO	State Historic Preservation Office
SIP	Shelter-in-Place
SMC	Sustainable Management Criteria
SMCL	Secondary Maximum Contaminant Level
SRSC	Sacramento River Settlement Contractors
SSURGO	Soil Survey Geographic Database

Subbasin	Colusa Subbasin
SVHMP	Sacramento Valley Height Modernization Project
SVSim	Sacramento Valley Simulation Model
SVWQC	Sacramento Valley Water Quality Coalition
SWN	State Well Number
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
SWS	Surface Water System
TAC	Technical Advisory Committee
taf	Thousand Acre-Feet
taf/yr	Thousand Acre-Feet Per Year
TCC	Tehama-Colusa Canal
TCCA	Tehama-Colusa Canal Authority
TDS	Total Dissolved Solids
TNC	The Nature Conservancy
Tribes	California Native American Tribes
UC	University of California
UC-ANR	University of California Agriculture and Natural Resources
UNAVCO	University NAVSTAR Consortium
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UWMP	Urban Water Management Plan
W	Wet Water Year
WCR	Well Completion Report
WDL	Water Data Library
WDR	Waste Discharge Requirements
WMP	Water Management Plan
WRCC	Western Regional Climate Center

Preface

Development of the Colusa Subbasin Groundwater Sustainability Plan (GSP), like many others throughout California, has coincided with one of the most severe and extensive droughts that has ever gripped the western United States. As of this writing in December 2021, as the final Colusa Subbasin GSP is being assembled, drought conditions throughout most of California, including the Colusa Subbasin (Subbasin), are classified as "exceptional", the most extreme classification defined by the U.S. Drought Monitor (USDM)[1]. Historically, observed impacts during exceptional drought generally include: widespread water shortages, depleted surface water supplies, extremely low federal surface water deliveries, curtailment of water rights, extremely high surface water prices, increased groundwater pumping to satisfy water demands, dry groundwater wells, increased well drilling and deepening, increased pumping costs, wildfire, decreased recreational opportunities, and poor water quality, among other potential impacts reported by the USDM. All of these conditions are currently being experienced to some degree across California and, at least in part, within the Subbasin. In particular, surface water supplies available for irrigation were significantly reduced in both 2020 and 2021, resulting in reduced plantings of some annual crops (primarily rice), and increased groundwater pumping, primarily to sustain permanent tree crops and, to a lesser extent, some annual crops.

As of November 30, 2021, the County of Glenn had received 282 reports of problems associated with groundwater wells, with about 65 percent of those being reports of dry wells. While a few of the reported dry wells are in the foothills outside of the Subbasin, the large majority lie within the Colusa and Corning Subbasins, concentrated in areas around Orland and the northern portion of the County. As of November 30, 2021, the County of Colusa had received 30 landowner reports of problems associated with groundwater wells, with 20 of the reported wells being located within the Subbasin. Of those wells in the Subbasin, 18 are reported as dry. Most reported dry wells are used for domestic water supply. Counts of dry wells in both counties are likely to be low because some landowners choose not to report well problems to the counties. In addition to reported dry wells, there are anecdotal reports of land subsidence around the Arbuckle area in the Colusa County portion of the Subbasin.

At the State level and as a result of the unprecedented dry conditions, Governor Gavin Newsom declared a drought emergency on April 21, 2021, which was subsequently expanded on May 10 to include new drought-impacted areas, including the Sacramento-San Joaquin Delta Watershed. Most recently, on October 19, Governor Newsom issued a proclamation extending the drought emergency statewide. On August 20, the State Water Resources Control Board (SWRCB) issued surface water curtailment orders to approximately 4,500 water right holders in the Sacramento-San Joaquin Delta Watershed to protect drinking water supplies, prevent salinity intrusion into fresh water supplies, and minimize impacts to fisheries and the environment. Given that these curtailment orders are in place for a period of one year, these curtailments have immediate impacts on existing surface water supplies and could impact surface water suppliers' ability to store water this coming winter, thereby potentially impacting available surface water supplies for 2022 and beyond. Given the recent curtailments and an already bleak surface water

[1] The U.S. Drought Monitor (https://droughtmonitor.unl.edu/) is produced through a partnership between the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Center. Information for the State of California is available online at: https://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?CA.

supply condition, there is an increased reliance on groundwater. Currently, all of California's 58 counties have declared drought emergencies, including both Colusa and Glenn Counties.

The reported numbers of dry wells discussed above, many of which were reported relatively early in the dry season, are unprecedented in both counties, raising concerns among landowners and residents, and prompting mitigation and response actions by both counties. The counties are maintaining well reporting and tracking systems to identify localized areas where wells are going dry and/or where other groundwater issues may exist. The counties are also supporting the public through local and regional programs offered through the counties, the U.S. Department of Agriculture (USDA), the Rural Community Assistance Corporation (RCAC), DWR, and the SWRCB that assist with well assessments, well repair and replacement, installation or updates to household water systems, potable water hauling, and low-interest loans to businesses and organizations affected by drought. Both counties have applied for drought relief funding through DWR. At this time, prior to completion and adoption of the GSP, drought response efforts in the Subbasin are the responsibility of the counties, cities, and other local agencies. At some point following adoption of the GSP, those responsibilities may shift to or be coordinated with the GSAs. A strategy for guiding potential coordination between the GSAs, counties, cities, and other local agencies is described in Chapter 7 of the GSP. Coordination would ensure preservation of public health and safety (the purview of the counties and cities) and groundwater sustainability for all beneficial users and uses (the purview of the GSAs).

Technical work and related public involvement processes supporting development of the Colusa Subbasin GSP began in earnest in May 2020 and are nearing completion as of December 2021. Development of the GSP has utilized the best available science and tools, with the most sufficient and credible information and data available for the decisions being made and the time frame available for making those decisions. Current and historical groundwater conditions and water budgets have been evaluated for the Subbasin in alignment with the GSP regulations. The technical work is based primarily on historical records of surface water and groundwater conditions from 1966 through 2015, which includes the prior drought in 2014 to 2015, but not the current drought in 2020 to 2021.

Unfortunately, drought conditions in 2020 and 2021 have coincided with development of the GSP, a timing that has not permitted complete evaluation and inclusion of data from these years in the GSP at this time. Due to the schedule mandated by the Sustainable Groundwater Management Act (SGMA) for completion of GSPs by January 31, 2022, it has not been possible to include conditions that have manifested due to the current drought in development of the Subbasin GSP. Records of drought-related conditions in 2020 to 2021 will not be systematically compiled, quality-controlled, and made publicly available until after the Colusa Subbasin GSP has been adopted. However, those conditions will be factored into the required GSP annual reports and particularly the periodic (five-year) evaluations as they become available.

It is noted that ongoing management of the Subbasin under the GSP will follow an "adaptive management" strategy that involves active monitoring of Subbasin conditions and addressing any challenges related to maintaining groundwater sustainability by scaling and implementing projects and management actions (PMAs) in a targeted and proportional manner in accordance with the needs of the Subbasin. Notwithstanding the information noted above regarding the challenges with GSP preparation and the current drought, some of the planned projects contained within this GSP are being fast tracked

to address impacts associated with the current drought. GSP annual reports provide an opportunity each year to evaluate current Subbasin conditions and assess the need for further PMAs. During the periodic evaluations, the GSP will also be reviewed and revised, as needed and as more is known about the effects of current and future conditions.

Colusa County, Glenn County, and the stakeholders within the Subbasin recognize that this GSP isn't the finish line; it is the starting line for sustainable management of the Subbasin. As conditions within the Subbasin change, the GSAs within the Subbasin are committed to an open, transparent, and all-inclusive adaptive management strategy aimed at tackling the important local issues that they face. At the heart of SGMA is the power for locals to solve local problems with local resources. All parties in the Subbasin are committed to doing just that.

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In September 2014, the California legislature passed, and Governor Jerry Brown signed, the Sustainable Groundwater Management Act (SGMA), which was composed of Assembly Bill (AB) 1739, Senate Bill (SB) 1168, and SB 1319. SGMA is codified in Section 10720 et seq. of the California Water Code. The California Department of Water Resources (DWR) subsequently initiated development of regulations to implement SGMA. In February 2016, DWR released draft emergency regulations for the development of Groundwater Sustainability Plans (GSPs). In July 2016, DWR provided notice of proposed emergency rulemaking and submitted the emergency regulations to the Office of Administrative Law (OAL). These are in California Code of Regulations (CCR), Title 23 Waters, Division 2 Department of Water Resources, Chapter 1.5 Groundwater Management, Subchapter 2 Groundwater Sustainability Plans.

The practical implication of SGMA, and associated regulations to implement SGMA, is to provide for local control of groundwater resources while requiring sustainable management of the state's groundwater subbasins. Under the provisions of SGMA, local agencies must establish governance of their subbasins by forming Groundwater Sustainability Agencies (GSAs) with the authority to develop, adopt, and implement a Groundwater Sustainability Plan (GSP) for the subbasin. The GSP provides a full accounting and description of subbasin groundwater conditions and provides a roadmap for subbasin groundwater management. Under the GSP, GSAs must adequately define and monitor groundwater conditions in the subbasin and establish criteria to maintain or achieve sustainable groundwater management within 20 years of GSP adoption.

The timeline for GSP development and adoption depends on subbasin conditions that are defined by DWR in its Bulletin 118. The Colusa Subbasin (Subbasin) is defined in Bulletin 118 by DWR as a high priority subbasin. This means that the Colusa Subbasin GSAs must develop, adopt, and submit a GSP (or GSPs) covering the entire Subbasin to DWR by January 31, 2022 (CWC Section 10720.7(a)(2)). The Subbasin is managed by two GSAs: the Glenn Groundwater Authority (GGA) and the Colusa Groundwater Authority (CGA). The GSAs have worked collaboratively to develop this single GSP to meet the requirements under SGMA for the entire Subbasin.

The following subsections in this Executive Summary provide an overview of each section of the Colusa Subbasin GSP.

INTRODUCTION (GSP CHAPTER 1)

Groundwater serves as an important source of supply for agricultural, municipal, domestic, industrial, and environmental beneficial uses throughout the Subbasin[1], which underlies approximately 723,823 acres within Colusa and Glenn Counties. Agriculture in the Subbasin relies on approximately 500,000 acre-feet (af) of groundwater (and nearly 1.2 million af of surface water, plus precipitation) annually, on average, to produce an array of commodities that contribute to the agricultural economies of both Colusa County and Glenn County, which have a total combined value of over $1.7 billion dollars.[2] Groundwater also supports essentially all domestic, municipal, and industrial water use in both Counties. The sustainable

[1] Groundwater basin number 5-021.52, part of the Sacramento Valley Groundwater Basin, as defined by DWR Bulletin 118 (DWR, 2006) and updated in February 2019. Additional basin boundary modifications were submitted to DWR in June 2021; however, the modifications have not been approved as of the writing of this GSP.

[2] According to the Colusa County Department of Agriculture, the gross production value of agriculture in the County was $932,963,000 (Crop Report, 2019). According to the Glenn County Department of Agriculture/Weights and Measurements, the gross production value of all agricultural commodities in the County was $806,668,000 (Crop & Livestock Report, 2019).

management of groundwater in the Subbasin is important for long-term prosperity of the communities in the region.

Sustainable management of groundwater is defined under SGMA as the "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results" (California Water Code [CWC] Section 10721(v)). Undesirable results are associated with each of six sustainability indicators, including chronic lowering of groundwater levels, reduction of groundwater storage, seawater intrusion, degraded water quality, land subsidence, and depletions of interconnected surface water. Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators are caused by groundwater conditions occurring throughout the subbasin. Sea water intrusion, while a SGMA-defined sustainability indicator, was determined to be inapplicable to the Subbasin due to the distances between the Subbasin and the Pacific Ocean, bays, deltas, or inlets ranging from about 30 to 60 miles.

The purpose of this GSP is to characterize groundwater conditions in the Subbasin, evaluate and report on existing conditions relating to the six sustainability indicators, describe existing monitoring, management programs and policies relating to groundwater resource use, document public outreach and communication, establish sustainability goals, and describe projects and management actions (PMAs) the GSAs will implement to achieve sustainable groundwater management within 20 years of implementing the GSP (CCRs Title 23, Section 350.4 (f)).

PLAN AREA (GSP CHAPTER 2)

Figure ES-1 illustrates the Plan Area. The Plan Area, described in detail in Chapter 2 of the GSP, is defined as the Colusa Subbasin (5-021.52), part of the Sacramento Valley Groundwater Basin, as described in Bulletin 118 (DWR, 2006b) with Subbasin boundary updates approved by DWR in February 2019. The Subbasin is generally bounded by Stony Creek to the north, the Coast Ranges to the west, the Sacramento River to the east, and the Colusa-Yolo County boundary and the Colusa County Water District boundary to the south. The Subbasin currently includes about 2.4 square miles (1,500 acres) within Yolo County, but is otherwise located fully within Glenn and Colusa Counties. Additional basin boundary modifications were submitted to DWR in June 2021; however, the modifications have not been approved as of the writing of this GSP. The modifications would adjust the eastern Subbasin boundary to better conform to the boundary of Reclamation District 1004 in Colusa County and would reduce the area of the Subbasin to 1,129 square miles (722,768 acres). The vertical boundaries of the Subbasin are the land surface (upper boundary) and the definable bottom of the basin (lower boundary). The vertical extent of the Subbasin is subdivided into a surface water system (SWS) and groundwater system (GWS). The SWS represents the land surface down to the bottom of plant root zone[3], within the lateral boundaries of the Subbasin. The GWS extends from the bottom of the root zone to the bottom of the Subbasin as defined by the Hydrogeologic Conceptual Model (HCM), within the lateral boundaries of the Subbasin.

[3] The depth to the bottom of the root zone varies by crop, but typically ranges from 2 to 7 feet (ASCE, 2016).

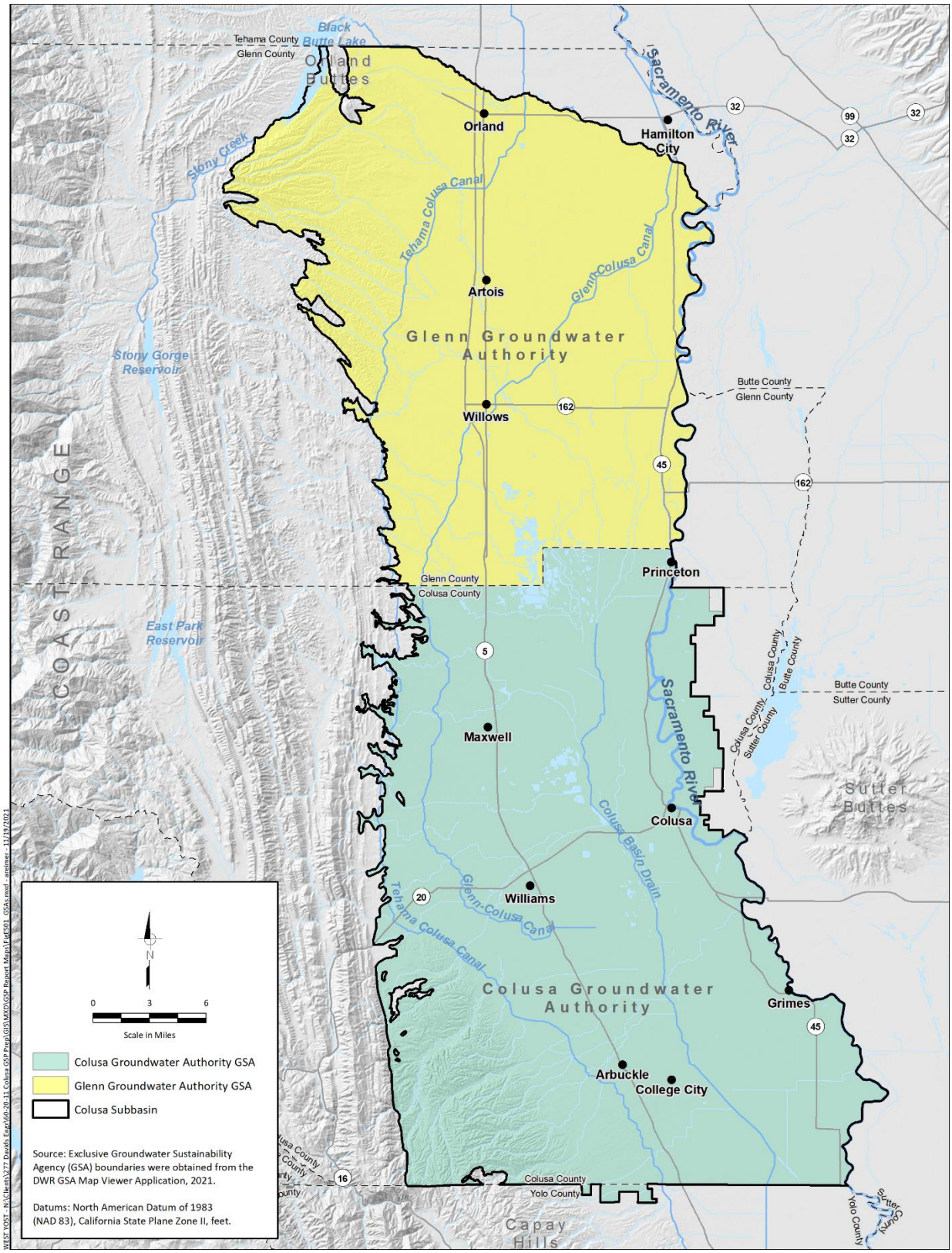

Figure ES-1. Colusa Subbasin GSAs

BASIN SETTING (GSP CHAPTER 3)

Chapter 3 describes the basin setting, including the HCM, current and historical groundwater conditions, and water budget information describing the movement of surface water and groundwater into, through and out of the Subbasin. Each of the three components of the basin setting are summarized below.

Hydrogeological Conceptual Model

The HCM provides the conceptual understanding of the hydrogeologic physical setting, characteristics, and processes that occur within the Subbasin and provides the foundation upon which the components of the water budget are based. The components of the HCM include surficial and subsurface features. Surficial features include topography, hydrology, water supply features, land use, soil types, and geologic outcrops. Subsurface features of the HCM include geologic formations and structures and the presence and characteristics of aquifers and aquitards.

Figure ES-2 shows the geologic component of the HCM. The Subbasin is underlain by one principal aquifer with interconnected unconfined and semiconfined to confined zones. Shallow groundwater in the Subbasin occurs under unconfined conditions in the Holocene stream channel deposits, except where these units are overlain by Holocene basin deposits, creating semiconfined to confined conditions. At greater depths, groundwater occurs under semiconfined to confined conditions in a single heterogeneous aquifer system, composed of predominantly fine-grained sediments enclosing discontinuous lenses of sand and gravel. The aquifer properties, including hydraulic conductivity and degree of confinement are dependent on the properties of the fine-grained units.

Most of the fresh groundwater within the Subbasin is contained within the Tehama Formation (shown as orange in Figure ES-2). The fraction of fresh groundwater contained within the Tehama Formation decreases in the northeastern portion of the Subbasin, where sediments of the Tuscan Formation are more prevalent (shown as pink in Figure ES-2). The interface between sediments of the Tehama and Tuscan Formations, referred to in this GSP as the Tehama-Tuscan Transition Zone, has been documented as mixed Tehama and Tuscan Formation sediments.

There are no defined principal aquitards within the Subbasin, however, the formations deposited under alluvial conditions or volcanic flows with lahars, such as exist in the Tehama and Tuscan Formations, respectively, tend to consist of thick low-permeability sediments interbedded with interconnected channels or lenses of higher-permeability sediment. The low-permeability sediments may impede vertical groundwater flow, but generally do not separate the aquifer system into separate, definable principal aquifers in the Subbasin.

Groundwater Conditions

Chapter 3 describes current and historical groundwater conditions in the Subbasin to support development and implementation of the GSP pursuant to the requirements of SGMA. Current and historical conditions are described for groundwater elevations, estimates of groundwater storage, groundwater quality, land subsidence, and interconnected surface waters. The description of current and historical groundwater conditions directly supports the development of sustainable management criteria presented in Chapter 5.

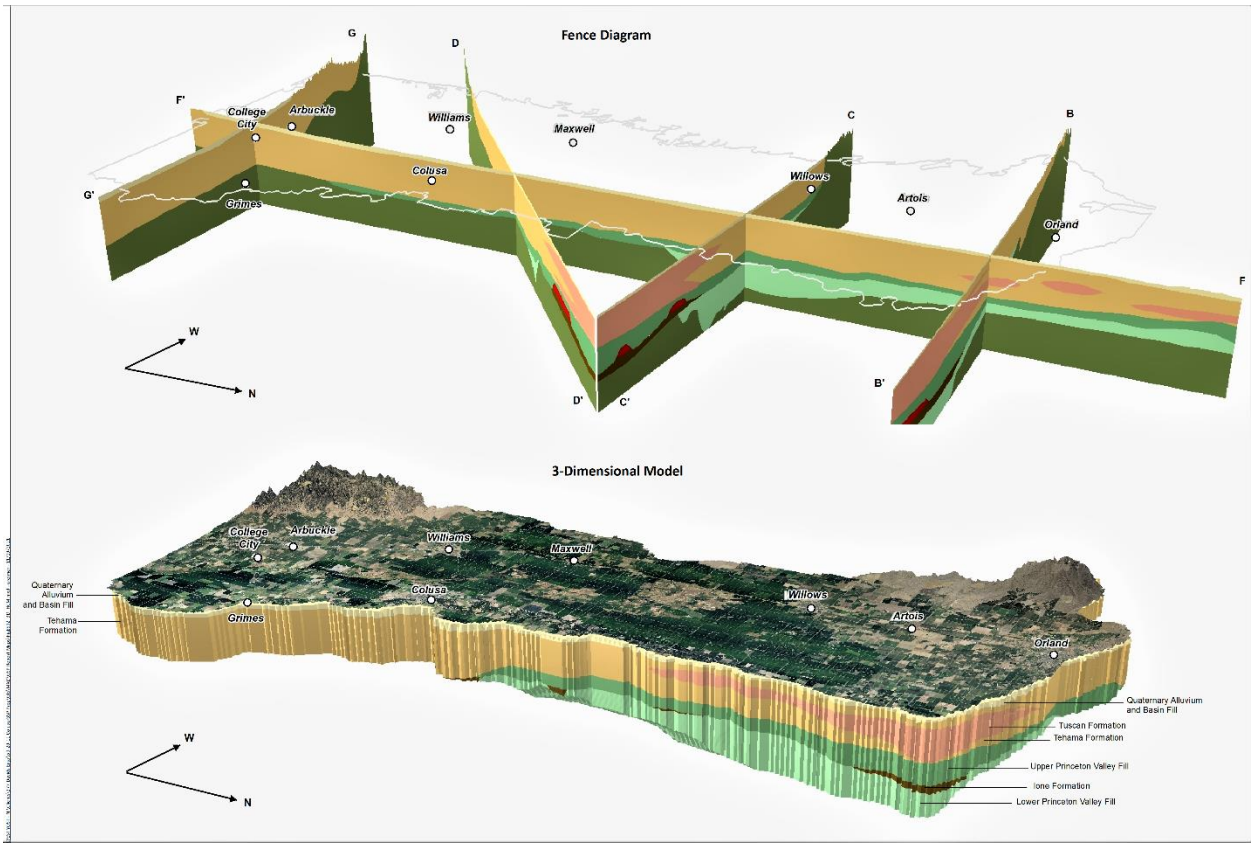

Figure ES-2. 3D Hydrogeologic Conceptual Model

Groundwater elevations measured in spring 2020 are shown on Figure ES-3. Regional groundwater flow within the Subbasin is generally eastward from the margins of the Sacramento Valley toward the Sacramento River and southward towards the Sacramento-San Joaquin Delta. For most of the Subbasin, the groundwater flows in a southeasterly direction, consistent with typical regional trends. South of Arbuckle, however, groundwater flows northeast down from the western uplands before flowing southeast down the valley.

Groundwater pumping has resulted in localized cones of depression that disrupt the regional groundwater flow gradients. Dry conditions and changes in land use have led to increased groundwater pumping in recent years.

Groundwater elevations throughout the Subbasin declined over the prolonged dry period beginning after 2006. The alternating years of average to dry conditions after 2006 have affected shallow wells, some of which have gone dry. The CGA and GGA support the State of California's policy on the Human Right to Water and recognize that drought emergencies have a disproportionate effect on California Native America Tribes (Tribes), Disadvantaged Communities (DAC) and Severely Disadvantaged Communities (SDAC) that rely on groundwater for their drinking water supplies. Many of the communities within the Subbasin are considered disadvantaged or severely disadvantaged. Nearly all of the Subbasin is considered an Economically Distressed Area. This GSP includes information on drought relief efforts coordinated by the Colusa and Glenn Interagency Drought Task Forces to address the effects of drought across the Subbasin and throughout these communities.

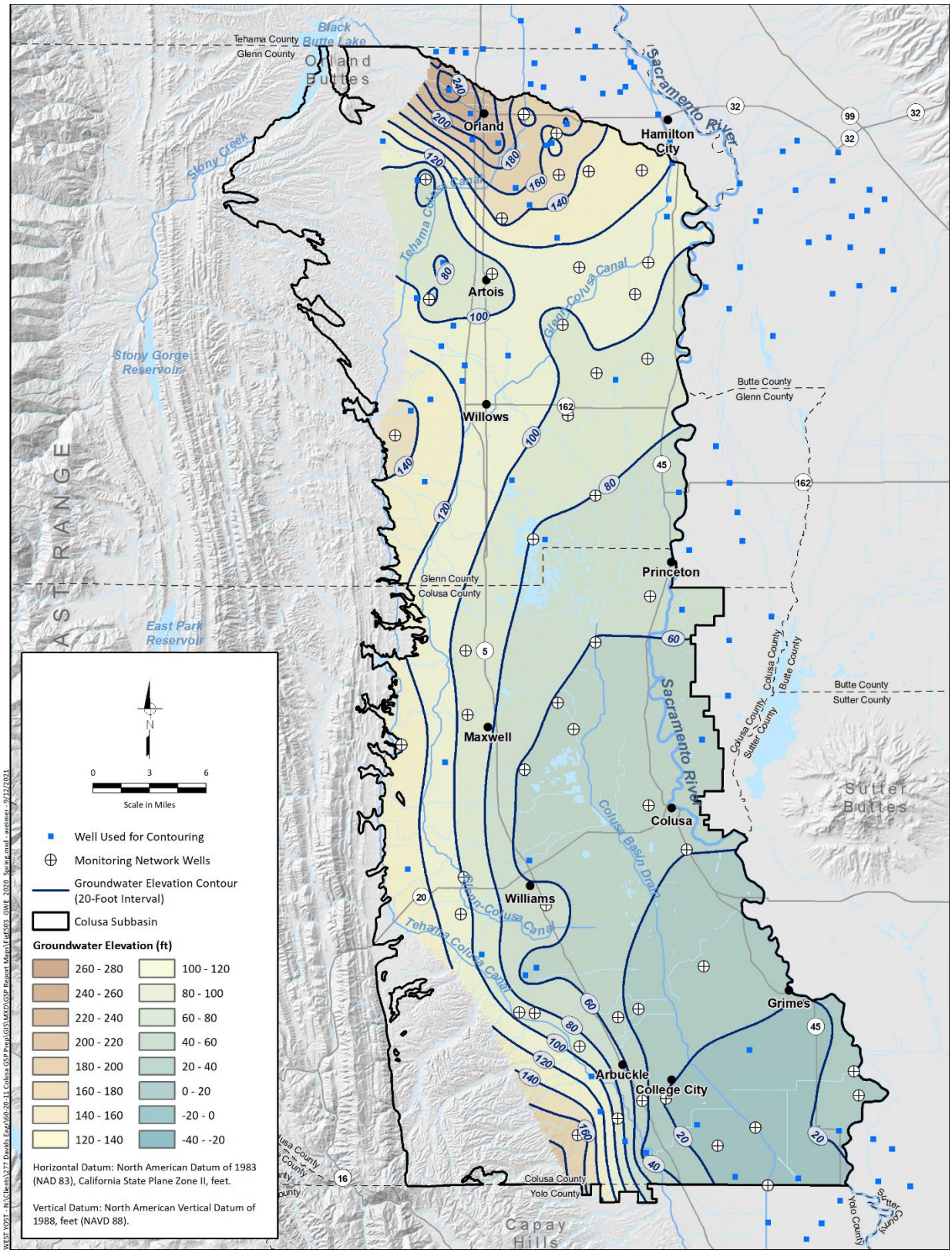

Figure ES-3. Groundwater Elevation Contours Spring 2020

Water Budget Information

A water budget is defined as a complete accounting of all water flowing into and out of a defined volume, which is the entire Subbasin within its defined horizontal and vertical boundaries, over a specified period of time. The water budget facilitates assessment of the total volume of groundwater and surface water entering and leaving the Subbasin over time, along with the change in the volume of water stored within the Subbasin. As required by the GSP emergency regulations, water budgets were developed for historical, current, and projected conditions. A numerical integrated groundwater-surface water flow model was developed based on the fine grid California Central Valley Groundwater-Surface Water Simulation Model (C2VSimFG) and used to support development of water budgets. Three water budgets were developed (including three climate scenarios for projected future conditions):

- A historical water budget evaluates availability or reliability of past surface water supplies and aquifer response to water supply and demand trends relative to water year type. The historical water budget was calculated for the 1990 through 2015 period, which was found to be reasonably representative of the long-term average conditions in the Subbasin. The historical water budget supports understanding of past groundwater conditions, considering surface water and groundwater supplies utilized to meet water demands.
- A current water budget establishes potential future baseline conditions under the assumptions of current land use and water supplies and historical hydrology. Current land use and water supplies are based on observed conditions in 2013 and 2015, representing Shasta Non-Critical and Shasta Critical years, respectively[4]. Historical hydrology from 1966 through 2015 was used to represent an analysis period from 2016 through 2065.
- Future water budgets establish potential future baseline conditions under different scenarios defined by different climate conditions. Three scenarios were developed: baseline without climate change, with 2030 climate change, and with 2070 climate change. The climate change scenarios correspond to the Central Tendency (CT) climate projections. These future water budgets are based on current land use over the same 50-year (1966 through 2015) historical hydrology as was used in the current water budget.

Table ES-1 summarizes the assumptions used in developing the water budgets.

[4] Because surface water supplies are curtailed in Shasta Critical years, the irrigated area and therefore water demands and use are less than in Shasta Non-Critical years.

Table ES-1. Summary of Water Budget Assumptions

Water Budget	Analysis Period	Hydrology	Land Use	Water Supplies
Historical Simulation	1990-2015	Historical	Historical	Historical
Current Conditions Baseline	2016-2065	Historical (1966-2015)	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively, for water diversions; 2006-2015 average for urban demands
Future Conditions, No Climate Change Baseline	2016-2065	Historical (1966-2015)	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively, for water diversions; 2006-2015 average for urban demands
Future Conditions, 2030 Climate Change Baseline	2016-2065	Historical (1966-2015), adjusted based on 2030 climate change with central tendency	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Same as Current (see above), adjusted for 2030 climate change
Future Conditions, 2070 Climate Change Baseline	2016-2065	Historical (1966-2015), adjusted based on 2070 climate change with central tendency	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Same as Current (see above), adjusted for 2070 climate change

1

2

Average annual water budget estimates for the historical water budgets and for the current and projected future water budget scenarios are summarized in Table ES-2 for the groundwater system. Volumes are reported in units of thousand af per year (taf/yr). It is anticipated that the water budgets will be refined and updated over time as part of GSP implementation.

Table ES-2. Average Annual Groundwater System Inflows, Outflows, and Changes in Storage in taf/yr

Component	Historical Simulation	Current Conditions Baseline	Future Conditions, No Climate Change Baseline	Future Conditions, 2030 Climate Change Baseline[a]	Future Conditions, 2070 Climate Change Baseline[a]
Inflows[b]					
Subsurface Water Inflows	200	203	203	205	209
Deep Percolation	441	416	415	415	411
Precipitation	174	162	162	160	156
Applied Surface Water	196	162	162	161	158
Applied Groundwater	72	92	91	94	97
Seepage	345	379	379	387	401
Streams	206	231	231	239	253
Canals and Drains	139	148	148	148	148
Total Inflow	**986**	**997**	**997**	**1,008**	**1,021**
Outflows					
Subsurface Water Outflows	146	149	149	148	147
Groundwater Pumping	502	499	499	525	559
Agricultural	463	458	458	484	516
Urban and Industrial	11	11	10	10	10
Managed Wetlands	28	30	30	31	32
Stream Gains from Groundwater (Stream Accretions)	366	349	349	337	323
Total Outflow	**1,014**	**997**	**996**	**1,011**	**1,028**
Change in Storage (Inflow - Outflow)	**-28**	**1**	**1**	**-3**	**-7**

(a) Central Tendency Climate Change Projections.
(b) Sacramento River Diversions and Stony Creek Diversions are diversions from boundary streams outside the Subbasin. About 20 percent of the total diversions come from streams within the Subbasin and are included in the Sacramento River Inflow.

GSP regulations require the water budget to quantify the sustainable yield for the Subbasin. Sustainable yield is dependent upon conditions in existence at the time, and therefore changes during the implementation period as projects are completed and climate conditions change. Provisional estimates of sustainable yield have been calculated from water budget parameters for each scenario as the long-term annual average groundwater pumping, minus the average annual decrease in groundwater storage. Using this approach, the Subbasin is estimated to have a sustainable yield between 500,000 af and 550,000 af per year.

MONITORING NETWORKS (GSP CHAPTER 4)

Chapter 4 of the GSP documents the Subbasin monitoring networks. Monitoring networks are required to better understand and evaluate changing conditions within the groundwater, surface water, and land surface systems.

To optimize data collection and analysis, the networks need to be easily accessible, spatially and temporally relatable to other monitoring networks, sufficient for demonstrating spatial and temporal trends, and representative of actual conditions. Four monitoring networks meeting these standards are defined for the Subbasin:

1. Groundwater Level Monitoring Network
2. Groundwater Quality Monitoring Network
3. Land Subsidence Monitoring Network
4. Surface Water Monitoring Network

The data collection objectives for the monitoring networks are to characterize:

- Groundwater levels, availability, and flow characteristics, including changes in groundwater storage;
- Groundwater quality;
- Extent and rate of land subsidence; and
- Surface water availability and interactions with groundwater, including impacts to native riparian land and groundwater dependent ecosystems (GDEs).

Data gaps were identified within all of the monitoring networks, and recommended actions are provided in Chapters 4 and 7. Annual reports and future revisions to the GSP will provide updates on actions taken to address data gaps in the monitoring networks over the reporting period.

Representative Monitoring Networks

Representative monitoring networks (RMN) were designated as subsets of the Subbasin monitoring networks. Per 23 CCR §354.36, "Each Agency may designate a subset of monitoring sites as representative of conditions in the basin or an area of the basin…" to evaluate or monitor for sustainability indicators. Representative monitoring locations were designated to evaluate undesirable results due to chronic lowering of groundwater levels, reduction of groundwater storage, degraded water quality, inelastic land subsidence, and depletions of interconnected surface water.

Per DWR's Sustainability Management Criteria Best Management Practice document (BMP), the sustainable management criteria for groundwater levels may be used as a proxy for sustainability indicators that have a significant, demonstrated correlation to groundwater levels. As documented in Chapters 3 and 5 and their supporting technical appendices, reduction of groundwater storage and depletions of interconnected surface water are significantly correlated to groundwater levels in the Subbasin, and therefore those sustainability indicators utilize groundwater levels as a proxy.

In addition to data collected using the RMNs, the GSAs will use data collected using the monitoring networks described in the following sections to evaluate groundwater conditions in the Subbasin. The monitoring networks will be periodically reviewed and modified as needed.

The following subsections provide a summary of each of the Subbasin monitoring networks and the RMNs used to assess groundwater conditions relative to the five sustainability indicators applicable to the Subbasin.

Groundwater Level Monitoring Network

The Subbasin groundwater level monitoring network is based on the existing groundwater monitoring networks of Colusa and Glenn Counties. There are 104 completions in 48 wells in the Subbasin groundwater level monitoring network. All of these wells are currently included in the California's Statewide Groundwater Elevation Monitoring Program (CASGEM) database.

Groundwater level monitoring network requirements documented in the DWR's Monitoring Network BMP and 23 CCR §354.34 were used to evaluate the groundwater monitoring wells in the Subbasin groundwater monitoring network. These requirements are addressed under the following categories:

- Known Construction Characteristics
- Nested Multiple Completion Wells
- Non-Dedicated Monitoring Wells
- Proximity to Streams and Interconnected Surface Waters
- Lateral and Vertical Density
- Accessibility and Usability

Data gaps within the groundwater monitoring network were evaluated for all criteria and categorized as follows:

- Usability of the monitoring site due to:
  - Wells screened across multiple water-bearing units and principal aquifer
- Spatial distribution of monitoring sites with regard to:
  - Presence near a surface water body
  - Lateral and vertical extent of coverage
  - Areas and depths with known groundwater level decline.

Recommended actions to address the data gaps include the addition of existing wells or the construction of new wells to add to the monitoring network. Field studies or surveys are recommended to verify well conditions and construction, and to identify wells to include in the network.

The RMN for chronic lowering of groundwater levels and reduction of groundwater storage sustainability indicators consists of one completion from each of the 48 wells in the groundwater monitoring network.

Groundwater Quality Monitoring Network

Existing regulatory programs address most water quality concerns in the Subbasin, and the CGA and GGA will coordinate with these programs, the lead regulatory agencies, and the regulated community during implementation of this GSP, including during development and implementation of PMAs.

The State Water Resources Control Board (SWRCB) and the Central Valley Regional Water Quality Control Board (CVRWQCB) regulate point and nonpoint source discharges to land that have potential to impact groundwater quality under a range of policy and regulatory programs, including the Basin Plan Amendment for the Salt and Nitrate Control Program, and the Irrigated Lands Regulatory Program (ILRP). The California Department of Toxic Substance Control regulates releases of toxic substances, including those that impact groundwater quality.

The California Safe Drinking Water Act addresses the regulation and control of public water systems in the State of California, including enforcing provisions of the federal Safe Drinking Water Act. The SWRCB Division of Drinking Water (DDW) is the lead agency responsible for enforcement in Colusa and Glenn Counties, including the entire Subbasin.

The CGA and GGA will rely on existing monitoring and reporting carried out by the regulated community within the Subbasin when and where possible to address water quality concerns. The CGA and GGA will conduct supplemental water quality monitoring using existing wells or new monitoring wells constructed for that purpose when and where necessary to fill data gaps and to develop and implement PMAs.

Groundwater quality in the Subbasin is generally good, with local exceedances of water quality objectives for some constituents. The sole groundwater quality concern not addressed by the existing groundwater quality regulatory programs is mobilization of saline water from deeper parts of the aquifer along faults, other geologic structures, or other naturally-occurring zones with high salinity as a result of GSP PMAs and other groundwater development.

Groundwater quality monitoring network locations for the Subbasin consist of wells identified and currently being monitored for salinity (i.e., total dissolved solids or electrical conductivity) under the ILRP and public drinking water supply systems regulated by DDW. The Subbasin groundwater quality monitoring network includes 54 monitoring sites.

The GSAs will coordinate and collaborate with other agencies regarding their monitoring programs, including changes to monitoring sites, monitoring protocols or frequencies, and management actions. Data gaps within the groundwater quality monitoring network were identified with regard to sampling frequency and spatial or vertical coverage in areas of concern.

The RMN for the degraded water quality sustainability indicator consists of 25 monitoring sites to monitor for groundwater quality degradation due to mobilization of brackish or saline groundwater.

Land Subsidence Monitoring Network

The Subbasin land subsidence monitoring network is comprised of benchmarks, continuous global positioning system (GPS) stations, extensometers, and remote sensing data. The land subsidence monitoring network sites and remote sensing programs are managed and monitored through the following agencies and programs.

- California DWR Ground Surface Displacement - Land Subsidence Monitoring Program
  - Includes five extensometers located in or within five miles of the Subbasin.
- University NAVSTAR Consortium (UNAVCO) Plate Boundary Observatory GPS/GNSS Network
  - Includes five continuous GPS stations.
- Sacramento Valley Height Modernization Project
  - Includes 76 benchmarks locations in or within five miles of the Subbasin.
- InSAR Remote Sensing
  - Includes studies and evaluations conducted by assorted federal and international agencies.

Inelastic land subsidence within the Subbasin is monitored at 63 sites in DWR's Sacramento Valley Subsidence Monitoring Benchmark Network.

Data gaps include insufficient benchmark density and insufficient frequency of measurements in the Sacramento Valley Subsidence Monitoring Benchmark Network. Additional benchmarks, continuous GPS stations and extensometers should be installed in areas with known or suspected subsidence, and the Sacramento Valley Subsidence Monitoring Benchmark Network should be resurveyed at least once every five years.

The RMN for land subsidence consists of the 63 Sacramento Valley Height Modernization Project benchmarks within the Subbasin. The benchmarks are evenly distributed throughout the Subbasin, including in areas with known land subsidence.

Surface Water Monitoring Network

Surface water monitoring is necessary for evaluating stream-aquifer relations. Comparing stream flows and stages with groundwater levels from specific monitoring wells can provide insight into how surface waters are interconnected with the groundwater system. The surface water monitoring network includes stream gages on rivers, streams, and canals. All of the stream gages included in the surface water monitoring network are managed and monitored via existing federal and state programs.

Data collected from the surface water monitoring network will be used to:

- Characterize flow conditions including surface water discharge, stage, and baseflows.
- Identify locations and flow periods of ephemeral and intermittent stream channels, if any. The DWR Monitoring Network BMP states that monitoring of ephemeral or intermittent streams should be conducted annually or as appropriate to characterize flow changes.
- Identify temporal trends due to localized, regional, and seasonal surface water discharge and groundwater extraction effects.

- Identify and collect information necessary to evaluate adverse effects to the beneficial use of surface water.
- Support evaluation of stream-aquifer interactions, including effects on surface water supplies due to changes in groundwater levels and effects on native riparian or groundwater dependent ecosystems.

There are 15 active stream gages in the Subbasin surface water monitoring network. The Subbasin surface water monitoring network was established using the best available data and science to identify, assess, and select existing monitor wells and stream gages meeting these requirements. However, significant data gaps exist, which need to be addressed during implementation of this GSP. Until these data gaps are filled, groundwater levels measured in selected wells are being used as a proxy for measurement of the volume and rates of depletions in interconnected surface waters.

The RMN for the depletions of interconnected surface waters sustainability indicator consists of 12 shallow wells from the groundwater level monitoring network meeting the following criteria:

- Constructed to a maximum depth of 200 feet.
- Located more than 2,000 feet and less than five miles from the interconnected surface water feature.

SUSTAINABLE MANAGEMENT CRITERIA (GSP CHAPTER 5)

Sustainable management criteria encompass several important components of GSP development, including a Subbasin sustainability goal that qualitatively describes the overall objectives of the GSP and desired conditions for the Subbasin, and undesirable results statements for each of the five sustainability indicators applicable to the Subbasin. For each of the applicable sustainability indicators, undesirable results occur when groundwater conditions cause significant and unreasonable effects on the beneficial uses and users of groundwater in the Subbasin. The Subbasin will be managed to achieve the sustainability goal and to avoid undesirable results, as consistent with the sustainable management criteria established for each sustainability indicator. Sustainable management criteria include measurable objectives (targets for management), interim milestones (evaluation points over time), and minimum thresholds (the point beyond which undesirable results could occur for a sustainability indicator).

Sustainability Goal

The sustainability goal for the Subbasin is:

> *…to maintain, through a cooperative and partnered approach, locally managed sustainable groundwater resources to preserve and enhance the economic viability, social well-being and culture of all Beneficial Uses and Users, without experiencing undesirable results.*

This goal was created through collaborative, public discussions and evaluation of historical, current, and projected future Subbasin conditions identified in the basin setting (Chapter 3), in alignment with the requirements of §354.24. Through implementation of planned monitoring, projects, management actions, and studies identified in this GSP, the Subbasin will be managed to its sustainability goal to avoid undesirable results for each applicable sustainability indicator.

Sustainability Indicators

The GSP regulations define undesirable results as occurring when significant and unreasonable effects are caused by groundwater conditions occurring for a given sustainability indicator. Significant and unreasonable effects occur when minimum thresholds are exceeded for one or more sustainability indicators. A summary of the sustainable management minimum thresholds, measurable objectives and undesirable results is provided in Table ES-3.

Undesirable results occur when significant and unreasonable effects to any of the six sustainability indicators defined by SGMA, five of which are applicable to the Subbasin, are caused by groundwater conditions occurring throughout the Subbasin. The overarching sustainability goal and the absence of undesirable results are expected to be achieved by 2042 through implementation of PMAs. The sustainability goal will be maintained through proactive monitoring and management by the GSAs. Table ES-4 summarizes whether, for each of the six sustainability indicators, undesirable results have occurred, are occurring, or are expected to occur in the future in the Subbasin without and with GSP implementation.

Table ES-3. Summary of Minimum Thresholds, Measurable Objectives, and Undesirable Results

Sustainability Indicator	Monitoring Network	Undesirable Result	Minimum Threshold (MT)	Measurable Objective (MO)
Chronic Lowering of Groundwater Levels	48 Representative Monitoring Network (RMN) wells monitored at least 2 to 3 times annually by DWR	25% (12 of 48) RMN wells fall continuously below their MT for 24 consecutive months	The lower of 50% of measured historical groundwater elevation range below the historical measured low elevation and the elevation corresponding to the 20th percentile of domestic well depths in the RMN well's Thiessen polygon, subject to interbasin coordination and consistency to ensure operational compatibility	Mean of the most recent 5 years of available groundwater elevation measurements up to 2020 subject to interbasin coordination and consistency to ensure operational compatibility; A fixed value, not a rolling average
Reduction in Groundwater Storage	48 RMN wells monitored at least 2 to 3 times annually by DWR (same as Groundwater Level monitoring network)	Use groundwater levels as proxy	Use groundwater levels as proxy	Use groundwater levels as proxy
Seawater Intrusion	Not applicable	Not applicable	Not applicable	Not applicable
Degraded Groundwater Quality	25 RMN wells monitored by others at variable intervals under existing State of California regulatory programs	Electrical conductivity (EC) in 25% (6 of 23) of the RMN wells exceeds the MT for two (2) consecutive years	The higher of EC of 900 microSiemens per centimeter (µS/cm) (the recommended California Secondary Maximum Contaminant Level) OR the pre-2015 historical maximum measured EC	EC of 700 µS/cm (corresponding to an agricultural water quality objective providing for no yield reduction for crops commonly grown in the Subbasin)
Land Subsidence	Existing Sacramento Valley Height Modernization Project (SVHMP) benchmarks (63 sites)	20% or more (13 of 63) monitoring sites (benchmarks) experience subsidence rates above the MT	0.5 feet per five years	0.25 feet per five years
Depletions of Interconnected Surface Waters	12 RMN wells less than 200 feet deep and between 2,000 feet and five miles of interconnected stream (Sacramento River, Colusa Drain, Stony Creek)	25% (3 of 12) RMN wells fall below their MT for 24 consecutive months	Ten (10) feet below the observed fall 2015 groundwater level (Fall 2015 level is the measured elevation recorded on the date closest to Oct 15)	Mean of last 5 years available groundwater elevation measurements subject to interbasin coordination and consistency to ensure operational compatibility; A fixed value, not a rolling average

1

Table ES-4. Summary of Undesirable Results Applicable to the Plan Area

Sustainability Indicator	Historical Period	Existing Conditions	Future Conditions without GSP Implementation	Future Conditions with GSP Implementation (after 2040)
Chronic Lowering of Groundwater Levels[(a)]	No	No	No	No
Reduction of Groundwater Storage	No	No	No	No
Land Subsidence[(b)]	No	No	Possible	No
Seawater Intrusion	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Degraded Water Quality	No	No	No	No
Depletion of Interconnected Surface Water	No	No	No	No

(a) Groundwater levels have declined in response to generally dry conditions after 2006, leading to localized cones of depression in the Orland-Artois area of Glenn County and the Arbuckle area of Colusa County. Dry wells have been reported in both counties during the 2014 and 2021 droughts. As described in Chapter 7, interagency drought task forces are responding to the drought emergency in both counties. These local efforts, which are coordinated with state and federal agencies, are expected to address short-term needs, and undesirable results requiring state intervention are not expected to be triggered.

(b) Historical rates of inelastic land subsidence have exceeded measurable objectives and minimum thresholds at some locations in the Subbasin but have not triggered undesirable results. Undesirable results are expected to be avoided through implementation of the GSP and associated PMAs.

Chronic Lowering of Groundwater Levels

An undesirable result for chronic lowering of groundwater levels in the Subbasin is experienced if sustained groundwater levels are too low to reasonably satisfy beneficial uses within the Subbasin over the planning and implementation horizon of this GSP. Undesirable results for the chronic lowering of groundwater levels have not occurred historically and are not currently occurring. The projected Subbasin water budget finds that these effects are not likely to occur under future scenarios, including under projected climate change.

Minimum thresholds for the chronic lowering of groundwater levels were developed primarily by considering historical and current groundwater conditions, with lesser emphasis on projected future groundwater conditions. The minimum threshold for each groundwater level representative monitoring well (48 in total) is calculated by the deeper of the 20th percentile of the shallowest domestic well depths in each monitoring well's Thiessen polygon or the 50 percent of range below the historical low groundwater elevation. The minimum threshold is calculated as the 20th percentile of the shallowest domestic well depths at a majority of sites (35 sites). The minimum thresholds align with the State's Human Right to Water policy by supporting the ability of drinking water beneficial users, including DACs, SDACs and Tribes, to access safe, clean, and affordable water for human consumption, cooking, and sanitary purposes.

Reduction of Groundwater Storage

An undesirable result for the reduction of groundwater storage is experienced if storage volumes are insufficient to reasonably satisfy beneficial uses within the Subbasin over the planning and implementation horizon of this GSP. This GSP uses groundwater level minimum thresholds as a proxy for

the reduction of groundwater storage sustainability indicator. Undesirable results related to groundwater storage have not occurred historically and are not currently occurring. The projected Subbasin water budget finds that these effects are not likely to occur under future scenarios, including under projected climate change.

Monitoring for a reduction of groundwater storage in the Subbasin uses groundwater levels as a proxy for determining sustainability, as permitted by 23 CCR §354.28(d). Minimum thresholds are defined using the groundwater levels criteria. Benefits to groundwater storage are expected to coincide with groundwater level management.

Seawater Intrusion

Seawater intrusion is not an applicable sustainability indicator because seawater intrusion is not present and is not likely to occur in the Subbasin due to the distances between the Subbasin and the Pacific Ocean, bays, deltas, or inlets ranging from about 30 to 60 miles.

Inelastic Land Subsidence

An undesirable result is experienced if groundwater withdrawal causes inelastic land subsidence that substantially interferes with the condition or functionality of critical infrastructure (e.g., roads, canals, pipelines) within the Subbasin over the planning and implementation horizon of this GSP. The thresholds set for inelastic land subsidence have been established so that when 20 percent of representative monitoring locations (i.e., 13 of 63 locations) exceed their minimum thresholds, an undesirable result is detected.

The minimum threshold for this sustainability indicator has been set at 0.5 feet per five years (6 inches), which was determined through review of historical subsidence conditions between 2008 and 2017 using data from DWR's Sacramento Valley Height Modernization Project.

Degraded Water Quality

An undesirable result for degraded water quality in the Subbasin is experienced if, as the result of PMAs implemented under the GSP or other groundwater development (such as groundwater extraction or groundwater recharge), groundwater quality for regulated constituents is degraded to levels exceeding historical levels existing prior to January 1, 2015, or applicable water quality objectives, including drinking water standards, whichever are greater over the planning and implementation horizon of this GSP. Existing regulatory programs address most water quality concerns, and the CGA and GGA will coordinate with these programs, the lead regulatory agencies, and the regulated community within the Subbasin during implementation of this GSP, including during development and implementation of PMAs.

The minimum threshold for degraded water quality has been established as the higher of either 900 microSiemens per centimeter (µS/cm) EC, which is consistent with the recommended California Secondary Maximum Contaminant Level (SMCL), or the pre-2015 historical maximum recorded EC value. In developing the minimum thresholds for groundwater quality, beneficial uses of groundwater as a drinking water supply and as an agricultural supply were considered. Setting minimum thresholds using this methodology is protective of beneficial users and uses of groundwater, including agricultural, municipal, and domestic uses in the Subbasin. The minimum threshold for degraded water quality is calculated to be at an EC level that allows for adequate flexibility within the pre-2015 historical maximum EC level, to compensate for changing groundwater conditions during drought periods, while protecting SMCLs established for aesthetic reasons, such as taste, odor, and color.

The minimum threshold aligns with the State's Human Right to Water policy by supporting the ability of drinking water beneficial users, including DACs, SDACs and Tribes, to access safe, clean, and affordable water for human consumption, cooking, and sanitary purposes.

Depletion of Interconnected Surface Water

An undesirable result for depletions of interconnected surface water is experienced if significant and unreasonable effects to stream flows, significant and unreasonable effects to riparian and riverine habitat, and significant and unreasonable effects to groundwater dependent ecosystems (GDEs) occur. This GSP uses minimum thresholds based on groundwater levels as a proxy for the depletion of interconnected surface water indicator. It is necessary to use groundwater levels as a proxy due to the surface water monitoring network being inadequate to monitor effects of groundwater on surface water flows. This is discussed in more detail in Chapter 5. The undesirable result for depletions of interconnected surface water is considered to occur during GSP implementation when 25 percent of representative monitoring wells (i.e., 3 of 12 wells) fall below their minimum groundwater elevation thresholds for 24 consecutive months. The three wells must be the same subset of wells, not any combination of three wells. These criteria were determined based on the evaluation of best available data pertaining to the Subbasin's specific conditions and characteristics, as described in the Plan Area and Groundwater Conditions sections of this GSP, in conjunction with input and feedback from the public, local stakeholders and GSA members.

The minimum thresholds set for managing depletions of interconnected surface water differ from the minimum thresholds set for managing chronic lowering of groundwater levels. Minimum thresholds for depletions of interconnected surface waters were determined based on evaluation of historical data from the monitoring network for interconnected surface water, which is composed of 12 monitoring wells no deeper than 200 feet located between 2,000 feet and five miles of interconnected streams in the Subbasin. The minimum thresholds set at these sites for assessing impacts to interconnected surface waters were calculated by finding the groundwater elevations in Fall of 2015 and adding 10 feet to that depth. Measurements selected for Fall 2015 were found by selecting measurements closest to October 15, 2015, considered to the be period of lowest groundwater elevations during the last drought based on review of historical groundwater levels and hydrologic data. The minimum threshold was selected such that groundwater levels near interconnected surface water courses would be protective of the beneficial use of shallower groundwater near streams and rivers, including those of shallower domestic users and potential groundwater dependent ecosystems. Levels from Fall 2015 represent conditions during a drought period but are generally believed to have still protected beneficial users at that time and therefore avoid undesirable results. The addition of 10 feet to the Fall 2015 groundwater depth to water is intended to provide an appropriate margin of operational flexibility in the future during GSP implementation based on recommendations made through discussion with the GSAs and stakeholders.

PROJECT AND MANAGEMENT ACTIONS (GSP CHAPTER 6)

The overarching sustainability goal and the absence of undesirable results are expected to be achieved by 2042 through implementation of PMAs. PMAs were formulated primarily to address possible future changes in Subbasin conditions that could cause undesirable results over the long term, and in the near term, to address effects of recent historical (2014-2015) and current (2020-2021) drought conditions that pose challenges to groundwater management in the northwest and southwest portions of the Subbasin respectively.

PMA development and implementation in the Subbasin applies an adaptive management approach informed by continued monitoring of groundwater conditions using the monitoring networks. Recognizing the GSP data gaps and uncertainties in the basin setting (per 23 CCR §354.44(d)), and recognizing known areas with declining groundwater levels, the adaptive management approach in the Subbasin includes:

- Planned PMAs that are expected to be implemented primarily to address current, localized declining groundwater levels in the Orland and Arbuckle areas. At full implementation, planned PMAs are expected to provide more than 80 taf/yr in combined gross average annual benefits that will offset groundwater pumping and support groundwater sustainability in the Subbasin.
- A portfolio of other ongoing and potential PMAs to achieve and maintain long-term sustainable groundwater management across the Subbasin, which will be implemented if established measurable objectives cannot be maintained and minimum thresholds are being approached.

Development of PMAs was informed by an evaluation of possible future changes in Subbasin conditions through comparison of the projected future water budget conditions without climate change and projected future water budget conditions adjusted by 2070 CT climate change factors. The aggregate changes in groundwater storage, 0.8 percent, and net stream accretion, 0.5 percent, across the Subbasin without PMAs are considered to be within standard modeling error for this type of analysis. However, there are localized declining groundwater levels that have occurred over the past 15 to 20 years in the northwest and southwest portions of the Subbasin near the cities of Orland and Arbuckle, respectively. Water budget analyses suggest that groundwater level decline in these areas is due primarily to drought. A series of mostly dry years beginning in about 2007 has resulted in increased irrigation demands, curtailments of Central Valley Project surface water supplies, and consequent increases in groundwater pumping in these areas. Similar dynamics exist in the Orland area, compounded by recent expansion of irrigated agriculture into previously undeveloped lands that rely on groundwater supplies only. Localized effects of declining groundwater levels include stranding of shallow domestic and irrigation wells and increased rates of land subsidence, raising concerns both locally and more broadly within the Subbasin that mitigation actions should be taken as soon as possible.

PMAs described in this GSP are expected to manage the balance of groundwater extractions and recharge to ensure that lowering of groundwater levels or depletion of supply during periods of drought is offset by increases in groundwater levels or storage in other years. In particular, PMAs that provide in-lieu and direct recharge benefits in the Orland and Arbuckle areas are planned to increase the use and recharge of available surface water supplies during wetter years, offsetting any potential increases in groundwater pumping during drought when curtailments of surface water supplies may occur.

PMAs are classified according to implementation status. Planned PMAs are those that will support sustainable groundwater management in the Subbasin over the GSP implementation period, and in the nearer-term will help to mitigate historical and current drought effects. Ongoing PMAs are those that have already been implemented and support groundwater management. Potential PMAs are a suite of options available to the GSAs if future monitoring indicates the need for such actions. Table ES-5 summarizes the planned PMAs for the Subbasin. The average annual gross benefit of these PMAs at full implementation is 84,000 af per year.

Table ES-5. Summary of Planned PMAs

Project	Project Type	Proponent	Year Implemented	Estimated Capital / Establishment Cost, $ (thousands)[a]	Gross Average Annual Benefit, taf/yr
Colusa County Water District (CCWD) In-Lieu Groundwater Recharge	In-Lieu GW[b] Recharge	CCWD	2021	$100	27
Colusa Drain MWC (CDMWC) In-Lieu Groundwater Recharge	In-Lieu GW Recharge	CDMWC	2021	$100	28
Colusa Subbasin Multi-Benefit Recharge	Direct GW Recharge	CGA, GGA, and TNC[c]	2021	$4 per site	5.2
Orland-Artois Water District (OAWD) Land Annexation and In-Lieu Groundwater Recharge	Direct and In-Lieu GW Recharge	OAWD	2020	$20,000	23
Sycamore Slough Groundwater Recharge Pilot Project	Direct GW Recharge	Landowner	2021	$28	0.5[d]

(a) Annual costs are summarized in the "Project Costs" sections of the project descriptions, below.
(b) GW = Groundwater
(c) TNC = The Nature Conservancy
(d) Project goal is to recharge 5 taf over 10 years.

PLAN IMPLEMENTATION (GSP CHAPTER 7)

The estimated average annual cost of implementing the GSP increases from approximately $1.5 million to about $9.5 million per year by 2027 (including annualized capital costs). Implementation costs are summarized across four categories:

- **One-Time Capital Costs and Studies**. These include capital costs that are not debt financed and studies to support GSP and PMA implementation. Studies include updates to the HCM to support required annual and five-year reports for DWR as well as other planning studies to support GSP implementation. To expand monitoring network data and evaluate Subbasin conditions more comprehensively, 15 GSP studies will be conducted. These include various planning, technical, and economic/fiscal studies that will aid in implementing PMAs and the monitoring of sustainability indicators outlined in Chapter 5. The studies are described in Chapter 7.
- **Debt-Financed Capital**. This includes capital costs that would likely be debt-financed. There is only one planned PMA that may be debt-financed, the OAWD land annexation project. GSP implementation costs shown below correspond to the annual debt service payment, not the total capital cost. Project proponents are concurrently working to refine estimated project costs

- **PMA Operations and Maintenance**. This includes annual expenses for the operation of planned PMAs, for example, annual water supply purchases for within-subbasin transfers to support in-lieu recharge.
- **GSA Administration**. These costs include operating expenses such as administration of the GSP, plan development, legal services, and communications for GSA staff and its technical advisers. This also includes costs for annual reporting and preparation of five-year assessments that must be submitted to DWR.

Table ES-6 summarizes the estimated annual expenses for each of these cost categories. The GSAs will continually evaluate GSP implementation progress and reassess the implementation plan and associated costs.

Table ES-6. Summary of Estimated Total GSP Implementation Costs

Cost Category	2022	2023	2024	2025	2026	2027+
Other Capital/Studies	$556,000	$1,120,000	$685,000	$460,000	$460,000	$630,000
Debt-Financed PMA Capital Repayment	-	$1,020,000	$1,020,000	$1,020,000	$1,020,000	$1,020,000
PMA O&M	-	$4,033,000	$6,675,000	$6,675,000	$6,675,000	$6,675,000
GSA Admin/Studies	$914,700	$987,900	$968,200	$968,200	$968,200	$1,148,200
Total	**$1,470,700**	**$7,160,900**	**$9,348,200**	**$9,123,200**	**$9,123,200**	**$9,473,200**

Development of this GSP was funded through a Proposition 1 Grant, and contributions from individual GSAs (e.g., through in-kind staff time, or separately contracted consulting services). Each GSA is also funding additional, ancillary studies and implementation efforts. To fund GSA operations and GSP implementation, the GSAs are developing a financing plan that will include one or more of the following financing approaches:

- **Grants and low-interest loans**. GSAs will continue to pursue grants and low interest loans to help fund planning studies and other GSA activities. However, grants and low-interest loans are not expected to cover most GSA operating costs for GSP implementation.
- **Other fees and charges**. Other fees may include permitting fees for new wells or development, transaction fees associated with contemplated groundwater markets, or commodity-based fees, all directed at aiding with sustainability objectives. Depending on the justification and basis for a fee, it may be considered a property-related fee subject to voting requirements of Article XIII D of the California Constitution (passed by voters in 1996 as Proposition 218).
- **Assessments**. Special benefit assessments under Proposition 218 could include a per-acre (or per parcel) charge to cover GSA costs. This could also include per acre-foot assessments, or a hybrid approach.
- **Taxes**. This could include general property related taxes that are not directly related to the benefits or costs of a service (ad valorem and parcel taxes), or special taxes imposed for specific purposes related to GSA activities.

The GSAs are pursuing a combined approach, targeting available grants and low interest loans, and considering a combination of fees and assessments to cover operating and program-specific costs. As required by statute and the Constitution, GSAs would complete a rate study and other analysis to document and justify any rate, fee, or assessment. GGA and CGA activities are currently supported under assessments associated with a rate study that runs through 2024.

The GSP implementation schedule allows time for GSAs to develop and implement PMAs and meets all sustainability objectives by 2042. While some sustainability projects began immediately after SGMA became law and are already contributing to Subbasin goals, the GSAs will begin implementing other GSP activities in 2022, with full implementation of PMAs to achieve sustainability by 2042. Figure ES-4 illustrates the GSP implementation schedule for PMAs implemented by each GSA. The GSP implementation schedule also shows mandatory reporting and updating for all GSAs, including annual reports and five-year periodic updates (evaluations) prepared and submitted to DWR.

Task Name	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
Plan Implementation																					
GSP Submittal to DWR	X																				
Memorandum of Understanding	X																				
Annual Reports	X	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
Five-Year Periodic Evaluation						X					X					X					X
Outreach and Communication																					
Monitoring and DMS																					
GSP Studies																					
Planned Projects and Management Actions																					
Colusa Subbasin Multi-Benefit Groundwater Recharge																					
OAWD District Land Annexation and In-Lieu Groundwater Recharge																					
Sycamore Slough Groundwater Recharge Pilot Project																					
CCWD In-Lieu Groundwater Recharge																					
Colusa Drain MWC In-Lieu Groundwater Recharge																					
Legend																					
Submittal	X																				
Planning and Development																					
Implementation																					
Ongoing Activity																					

Figure ES-4. Colusa Subbasin Implementation Schedule

CHAPTER 1
Introduction

1.1 PURPOSE OF THE GROUNDWATER SUSTAINABILITY PLAN

On September 16, 2014, Governor Jerry Brown signed into law a three-bill legislative package composed of Assembly Bill (AB) 1739, Senate Bill (SB) 1168, and SB 1319, collectively known as the Sustainable Groundwater Management Act (SGMA), which is codified in Section 10720 et seq. (§10720) of the California Water Code.

This legislation created a statutory framework for sustainable groundwater management in California and required local agencies of high- and medium-priority groundwater basins to halt overdraft and bring basins into balanced levels of pumping and recharge within 20 years. SGMA empowered local agencies to form Groundwater Sustainability Agencies (GSAs) to manage basins sustainably and required GSAs to adopt Groundwater Sustainability Plans (GSPs) for non-critically overdrafted medium- and high-priority groundwater basins in California by calendar year 2022.

SGMA defines sustainable groundwater management as *"management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results"* (SGMA Regulations §10721(v)). Undesirable results are defined by SGMA as the following effects:

1. Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply
2. Significant and unreasonable reduction of groundwater storage
3. Significant and unreasonable seawater intrusion
4. Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies
5. Significant and unreasonable land subsidence that substantially interferes with surface land uses
6. Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water

The Colusa Groundwater Authority (CGA) and Glenn Groundwater Authority (GGA), or Authorities, are exclusive GSAs covering the entire geographic extent of the Colusa Subbasin (Subbasin). The CGA GSA and GGA GSA are referred to as the Subbasin GSAs. The Authorities and their member agencies are discussed more in Chapter 2. The Authorities have worked collaboratively with all interested stakeholders to prepare this GSP. The purpose of this GSP is to characterize groundwater conditions in the Subbasin; evaluate and report on existing conditions relating to the six sustainability indicators; describe existing monitoring programs, management programs, and policies relating to groundwater resource use; identify data gaps within the aforementioned GSP topics and provide recommended actions to address those data gaps[1]; document public outreach and communication;; establish sustainability goals; and describe programs and management actions the GSAs will implement to achieve sustainable groundwater management within

[1] Chapter 3 defines data gaps within the hydrogeologic conceptual model and provides recommendations to close them. Chapter 4 of the GSP describes analyses of existing data gaps in the Subbasin, and proposed actions to address data gaps in each monitoring network. Chapter 7 further describes proposed studies and actions to address and fill data gaps identified throughout the Colusa Subbasin GSP.

20 years of implementing the GSP (California Code of Regulations [CCR] Title 23 Section 350.4(f) [23 CCR §350.4(f)]).

While the GSP focuses on groundwater projects and management actions by the Subbasin GSAs, these actions are considered in the context of the entire basin setting. The Authorities have and will continue to coordinate the actions of other GSAs in the region in an effort to achieve sustainability at a regional level.

1.2 SUSTAINABILITY GOAL

As mandated under 23 CCR §354.24, the Subbasin GSAs have established a *"sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline."*

The sustainability goal for the Subbasin GSP is:

> *… to maintain, through a cooperative and partnered approach, locally managed sustainable groundwater resources to preserve and enhance the economic viability, social well-being and culture of all Beneficial Uses and Users, without experiencing undesirable results.*

Chapter 5, Sustainable Management Criteria, of the GSP describes the sustainability goal for the GSAs and is based on information from the basin setting, discussions of the measures that will be implemented to ensure that the Subbasin will be operated within its sustainable goal, and an explanation of how the sustainability goal is likely to be achieved and maintained within the 20-year planning and implementation horizon. The Subbasin GSAs can and should continue to assess the reasonableness of the sustainability goal in the years to come.

1.3 AGENCY INFORMATION

The CGA and the GGA have led the effort to develop a single GSP for the Subbasin, in collaboration with interested Subbasin stakeholders and interbasin agencies (described extensively in Section 2.7). Collectively, these two GSAs have been deemed exclusive GSAs and cover the entire Subbasin.

The Subbasin is located within the larger Sacramento Valley Groundwater Basin and spans the eastern portions of Colusa and Glenn Counties. It is generally bounded by Stony Creek to the north, the Coast Ranges to the west, the Sacramento River and the Reclamation District 1004 western boundary to the east, and the Colusa-Yolo County boundary and the Colusa County Water District Boundary to the south.

The Subbasin has been designated as a high-priority basin by the California Department of Water Resources (DWR) with implications under the SGMA. In compliance with SGMA deadlines, the Subbasin GSP will be completed, adopted, and submitted to DWR by January 31, 2022. Both the CGA and GGA will adopt the GSP and continue to work collaboratively on GSP implementation.

1.3.1 Agency Organization and Management Structure

The CGA and the GGA have been deemed the exclusive GSAs that cover the entire Subbasin. The CGA was formed on June 29, 2017 as a 12-member Joint Powers Authority (JPA) with 12 Director seats. It is the exclusive GSA for the Colusa County portion of the Subbasin, and a small portion of the Butte Subbasin in Colusa County. Members of the CGA Board include:

- County of Colusa
- City of Colusa
- City of Williams
- Glenn-Colusa Irrigation District
- Maxwell Irrigation District and Westside Water District
- Princeton-Codora-Glenn Irrigation District and Provident Irrigation District
- Colusa County Water District
- Reclamation District 108
- Reclamation District 479
- Colusa Drain Mutual Water Company
- Two (2) Private Pumper Representatives recommended by the Colusa County Groundwater Commission and appointed by the Colusa County Groundwater Board of Supervisors

The GGA was formed on June 20, 2017, as a nine-member JPA with eight Director seats. The JPA was later amended on October 14, 2019, to add a tenth member and one additional Director seat, for a total of nine Director seats. The GGA is the exclusive GSA for the Glenn County portion of the Subbasin. Members of the GGA include:

- City of Orland
- City of Willows
- County of Glenn
- Glenn-Colusa Irrigation District
- Glide Water District
- Kanawha Water District
- Monroeville Water District
- Orland-Artois Water District
- Princeton-Codora-Glenn Irrigation District
- Provident Irrigation District

Each GSA Board has final authority for GSP implementation. Except for the Private Pumper Representatives, Board members are chosen in public meetings by the respective governing boards of the Member Agencies. Alternates for each Board member are chosen in the same manner by the same Member Agencies. Private Pumper Representatives on the CGA Board are recommended by the Colusa County Groundwater Commission and appointed by the Colusa County Board of Supervisors in a public meeting.

Contact information for each GSA Manager is provided below:

Colusa Groundwater Authority:

Denise Carter, County Supervisor
(530) 458-0502
1213 Market Street
Colusa, CA 95932
dcarter@countyofcolusa.com

Glenn Groundwater Authority:

Lisa Hunter, Water Resources Coordinator
(530) 934-6540
225 North Tehama Street
Willows, CA 95988
lhunter@countyofglenn.net

1.3.1.1 Coordination Agreements

23 CCR §357.4(a) states that "*Agencies intending to develop and implement multiple Plans pursuant to Water Code Section 10727(b)(3) shall enter into a coordination agreement to ensure that the Plans are developed and implemented utilizing the same data and methodologies, and that elements of the Plans necessary to achieve the sustainability goal for the basin are based upon consistent interpretations of the basin setting.*"

The two Subbasin GSAs have jointly prepared one GSP for the entire Colusa Subbasin. As such, coordination agreements are neither required nor applicable to the Subbasin.

1.3.2 Legal Authority

On May 14, 2018, the CGA and GGA notified DWR of their intent to prepare a GSP for the Subbasin (5-021.52). The preparation of the GSP is being coordinated and overseen by the GSAs. The Authorities hold regular meetings that are open to the public and have formed a Joint Technical Advisory Committee (TAC) to coordinate Subbasin-wide activities. Periodic TAC meetings, which are also open to the public, allow coordination with the technical consulting team tasked with preparing the GSP and coordination activities in adjacent subbasins. All meeting materials and information relevant to SGMA planning and implementation are readily available to the public via websites, newsletters, emails, presentations, and public meetings. Public engagement, notices, and communication records are discussed in Chapter 2.

1.3.3 Estimated Implementation Cost and Agencies' Approach to Meet Costs

Total GSP implementation costs are estimated to increase from approximately $1.5 million per year in 2022 to approximately $9.5 million per year by 2027. These estimated costs are inclusive of all currently envisioned GSP-related activities required for successful implementation. This includes GSA administrative costs and technical studies that are required for annual updates and five-year reporting requirements totaling around $1 million per year. Projects and management action (PMAs) capital repayment costs are estimated at approximately $1 million (the total capital outlay is approximately $20 million). Project and management action development technical studies and non-debt financed capital is estimated to equal $0.5 to $1.1 million per year. Annual operations and maintenance (O&M) for projects is approximately $4 to $6.7 million per year. A substantial share of project O&M costs are attributed to water purchases for in-lieu recharge projects providing approximately 84,000 acre-feet of benefits at full implementation. Table 1-1 summarizes estimated annual GSP implementation costs for the Subbasin as a whole.

Table 1-1. Total Estimated Annual GSP Implementation Cost Summary

Cost Category	2022	2023	2024	2025	2026	2027+
Other Capital/Studies	$556,000	$1,120,000	$685,000	$460,000	$460,000	$630,000
Debt-Financed PMA Capital Repayment	-	$1,020,000	$1,020,000	$1,020,000	$1,020,000	$1,020,000
PMA O&M	-	$4,033,000	$6,675,000	$6,675,000	$6,675,000	$6,675,000
GSA Admin/Studies	$914,700	$987,900	$968,200	$968,200	$968,200	$1,148,200
Total	**$1,470,700**	**$7,160,900**	**$9,348,200**	**$9,123,200**	**$9,123,200**	**$9,473,200**

Development of this GSP was primarily funded through a Proposition 1 Sustainable Groundwater Planning Grant. In addition, the GSAs' activities were funded by fees collected under separate rate studies covering the five-year period spanning fiscal years 2019/20 through 2023/24. These were prepared as property-related fees for water service under Proposition 218. The implementation of the GSP and future SGMA compliance will be a substantial undertaking. It will likely require GSAs and other local entities to collect some combination of fees, assessments, and taxes, as well as seek additional outside funding, grants, and low-interest borrowing. The Subbasin GSAs will develop a financing plan for the overall implementation of the GSP that will specify funding sources and cost-allocation approaches across entities for the different GSP implementation activities (see Chapter 7 and Appendix 7A for a description of existing options).

1.4 GSP ORGANIZATION

The GSP is organized in accordance with 23 CCR §354 as follows:

- **Preface** sets the context for development and adoption of the GSP during a drought emergency
- **Executive Summary** provides a summary of the major topics discussed in the GSP
- **Chapter 1** introduces the Subbasin GSAs and the development of this GSP
- **Chapter 2** provides a summary of the Plan Area, monitoring and management programs, land uses, additional GSP elements and notice and communication
- **Chapter 3** discusses the Basin Setting, including the hydrogeologic conceptual model for the Subbasin, water features and conveyance infrastructure, groundwater conditions, and water budget analyses
- **Chapter 4** reviews the Monitoring Networks within the Subbasin pertaining to groundwater levels, water quality, inelastic land subsidence, and depletions of interconnected surface water
- **Chapter 5** identifies Sustainable Management Criteria, including goals, measurable objectives, minimum thresholds, and undesirable results
- **Chapter 6** identifies Projects and Management Actions that work to achieve the GSAs' sustainability goal
- **Chapter 7** discusses Plan Implementation, including anticipated costs, schedule of implementation, and annual reporting and evaluations
- **Chapter 8** provides References cited in the GSP

To facilitate DWR review and provide references to the applicable GSP regulations, Table 1-2, Checklist for GSP Submittal, cross-references the chapters of this GSP to applicable GSP regulations. Terminology used in this GSP is consistent with the SGMA definitions provided in California Water Code (CWC) §10721 and in 23 CCR §351. Appendix 1A provides a glossary of terms.

Table 1-2. Preparation Checklist for GSP Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Chapter/Section in GSP	Initial Page Number in GSP
Article 3. Technical and Reporting Standards					
352.2		Monitoring Protocols	• Monitoring protocols adopted by the GSA for data collection and management • Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin	• Chapter 4.2 • Chapter 4.2	• 4-1 • 4-1
Article 5. Plan Contents, Subarticle 1. Administrative Information					
354.4		General Information	• Executive Summary • List of references and technical studies	• Executive Summary • Chapter 8	• ES-1 • 8-1
354.6		Agency Information	• GSA mailing address • Organization and management structure • Contact information of Plan Manager • Legal authority of GSA • Estimate of implementation costs	• Chapter 1.3.1 • Chapter 1.3.1 • Chapter 1.3.1 • Chapter 1.3.2 • Chapters 1.3.3, 7	• 1-3 • 1-3 • 1-3 • 1-4 • 1-4, 7-1
354.8(a)	10727.2(a)(4)	Map(s)	• Area covered by GSP • Adjudicated areas, other agencies within the basin, and areas covered by an Alternative • Jurisdictional boundaries of federal or State land • Existing land use designations • Density of wells per square mile	• Figure 2-1 • Figures 2-3, 2-4 • Figures 2-4, 2-5 • Figure 2-8 • Figure 2-7	• 2-3 • 2-6, 2-7 • 2-7, 2-12 • 2-16 • 2-15
354.8(b)		Description of the Plan Area	• Summary of jurisdictional areas and other features	• Chapter 2.1.2	• 2-4
354.8(c) 354.8(d) 354.8(e)	10727.2(g)	Water Resource Monitoring and Management Programs	• Description of water resources monitoring and management programs • Description of how the monitoring networks of those plans will be incorporated into the GSP • Description of how those plans may limit operational flexibility in the basin • Description of conjunctive use programs	• Chapter 2.2 • Chapter 2.2.1 • Chapter 2.2.2 • Chapter 2.2.4	• 2-17 • 2-17 • 2-25 • 2-26

Table 1-2. Preparation Checklist for GSP Submittal					
GSP Regulations Section	Water Code Section	Requirement	Description	Chapter/Section in GSP	Initial Page Number in GSP
354.8(f)	10727.2(g)	Land Use Elements or Topic Categories of Applicable General Plan	• Summary of general plans and other land use plans	• Chapter 2.3.1	• 2-27
			• Description of how implementation of the GSP may change water demands or affect achievement of sustainability and how the GSP addresses those effects	• Chapter 2.3.2	• 2-29
			• Description of how implementation of the GSP may affect the water supply assumptions of relevant land use plans	• Chapter 2.4	• 2-31
			• Summary of the process for permitting new or replacement wells in the basin	• Chapter 2.5	• 2-32
			• Information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management	• Chapter 2.3.3	2-31
354.8(g)	10727.4	Additional GSP Contents	**Description of Actions related to:**		
			• Control of saline water intrusion	• Chapter 3.2.4	• 3-66
			• Wellhead protection	• Chapter 2.5.3	• 2-33
			• Migration of contaminated groundwater	• Chapter 4.2.2, 4.2.5	• 4-15, 4-30
			• Well abandonment and well destruction program	• Chapter 6.5.2	• 6-83
			• Replenishment of groundwater extractions	• Chapter 6	• 6-1
			• Conjunctive use and underground storage	• Chapter 2.2.4, 6.5.1	• 2-26, 6-59
			• Well construction policies	• Chapter 2.2.3, 2.5	• 2-26, 2-32
			• Addressing groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects	• Chapter 6	• 6-1
			• Efficient water management practices	• Chapters 2.2.1, 6	• 2-17, 6-1
			• Relationships with State and federal regulatory agencies	• Chapter 2.7, 7	• 2-34, 7-1
			• Review of land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity	• Chapter 2.3	• 2-27
			• Impacts on groundwater dependent ecosystems	• Chapters 4.2.5, 5.3.6, 6.5.1	• 4-30, 5-15, 6-59

Table 1-2. Preparation Checklist for GSP Submittal					
GSP Regulations Section	Water Code Section	Requirement	Description	Chapter/Section in GSP	Initial Page Number in GSP
354.10		Notice and Communication	• Description of beneficial uses and users • List of public meetings • GSP comments and responses • Decision-making process • Public engagement • Encouraging active involvement • Informing the public on GSP implementation progress	• Chapter 2.7.1 • Chapter 2.7.2 • Appendix 2B • Chapter 2.7.1 • Chapter 2.7.2 • Chapter 2.7.1 • Chapter 2.7.3	• 2-34 • 2-39 • Appendix 2B • 2-34 • 2-39 • 2-34 • 2-43
Article 5. Plan Contents, Subarticle 2. Basin Setting					
354.14		Hydrogeologic Conceptual Model	• Description of the Hydrogeologic Conceptual Model • Two scaled cross-sections • Map(s) of physical characteristics: topographic information, surficial geology, soil characteristics, surface water bodies, source and point of delivery for imported water supplies	• Chapter 3.1 • Figures 3-11, 3-12, 3-13 • Figures 3-4, 3-5, 3-6, 3-7, 3-8, 3-9, 3-10	• 3-1 • 3-22, 3-23, 3-24 • 3-8, 3-9, 3-11, 3-12, 3-14, 3-18, 3-21
354.14(c)(4)	10727.2(a)(5)	Map of Recharge Areas	• Map delineating existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas	• Figures 3-18, 3-19, 3-20	• 3-45, 3-47, 3-48
	10727.2(d)(4)	Recharge Areas	• Description of how recharge areas identified in the plan substantially contribute to the replenishment of the basin	• Chapter 3.1.11	• 3-43
354.16	10727.2(a)(1) 10727.2(a)(2)	Current and Historical Groundwater Conditions	• Groundwater elevation data • Estimate of groundwater storage • Seawater intrusion conditions • Groundwater quality issues • Land subsidence conditions • Identification of interconnected surface water systems • Identification of groundwater-dependent ecosystems	• Chapter 3.2.2 • Chapter 3.2.3 • Chapter 3.2.4 • Chapter 3.2.5 • Chapter 3.2.6 • Chapter 3.2.7 • Chapter 3.2.8	• 3-55 • 3-65 • 3-66 • 3-66 • 3-73 • 3-76 • 3-81

Table 1-2. Preparation Checklist for GSP Submittal					
GSP Regulations Section	Water Code Section	Requirement	Description	Chapter/Section in GSP	Initial Page Number in GSP
354.18	10727.2(a)(3)	Water Budget Information	• Description of inflows, outflows, and change in storage • Quantification of overdraft • Estimate of sustainable yield • Quantification of current, historical, and projected water budgets	• Chapter 3.3 • Chapter 3.3.6 • Chapter 3.3.7 • Chapter 3.3.4	• 3-84 • 3-111 • 3-111 • 3-93
	10727.2(d)(5)	Surface Water Supply	• Description of surface water supply used or available for use for groundwater recharge or in-lieu use	• Chapter 6	• 6-1
354.20		Management Areas	• Reason for creation of each management area • Minimum thresholds and measurable objectives for each management area • Level of monitoring and analysis • Explanation of how management of management areas will not cause undesirable results outside the management area • Description of management areas	• Chapter 3.4 • Not applicable • Not applicable • Not applicable • Not applicable	• 3-112 • Not applicable • Not applicable • Not applicable • Not applicable
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria					
354.24		Sustainability Goal	• Description of the sustainability goal	• Chapter 5.2	• 5-3
354.26		Undesirable Results	• Description of undesirable results • Cause of groundwater conditions that would lead to undesirable results • Criteria used to define undesirable results for each sustainability indicator • Potential effects of undesirable results on beneficial uses and users of groundwater	• Chapter 5.3 • Chapter 5.3 • Chapter 5.3 • Chapter 5.3	• 5-4 • 5-4 • 5-4 • 5-4
354.28	10727.2(d)(1) 10727.2(d)(2)	Minimum Thresholds	• Description of each minimum threshold and how they were established for each sustainability indicator • Relationship for each sustainability indicator • Description of how selection of the minimum threshold may affect beneficial uses and users of groundwater • Standards related to sustainability indicators • How each minimum threshold will be quantitatively measured	• Chapter 5.4 • Chapter 5.4 • Chapter 5.4 • Chapter 5.4 • Chapter 5.4	• 5-17 • 5-17 • 5-17 • 5-17 • 5-17

Table 1-2. Preparation Checklist for GSP Submittal					
GSP Regulations Section	Water Code Section	Requirement	Description	Chapter/Section in GSP	Initial Page Number in GSP
354.30	10727.2(b)(1) 10727.2(b)(2) 10727.2(d)(1) 10727.2(d)(2)	Measurable Objectives	• Description of establishment of the measurable objectives for each sustainability indicator	• Chapter 5.4	• 5-17
			• Description of how a reasonable margin of safety was established for each measurable objective	• Chapter 5.4	• 5-17
			• Description of a reasonable path to achieve and maintain the sustainability goal, including a description of interim milestones	• Chapter 5.4	• 5-17
Article 5. Plan Contents, Subarticle 4. Monitoring Networks					
354.34	10727.2(d)(1) 10727.2(d)(2) 10727.2(e) 10727.2(f)	Monitoring Networks	• Description of monitoring network	• Chapter 4.2	• 4-1
			• Description of monitoring network objectives	• Chapter 4.1	• 4-1
			• Description of how the monitoring network is designed to: demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features; estimate the change in annual groundwater in storage; monitor seawater intrusion; determine groundwater quality trends; identify the rate and extent of land subsidence; and calculate depletions of surface water caused by groundwater extractions	• Chapter 4.2	• 4-1
			• Description of how the monitoring network provides adequate coverage of Sustainability Indicators	• Chapter 4.2	• 4-1
			• Density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends	• Chapter 4.2	• 4-1
			• Scientific rational (or reason) for site selection	• Chapter 4.2	• 4-1
			• Consistency with data and reporting standards	• Chapter 4.2	• 4-1
			• Corresponding sustainability indicator, minimum threshold, measurable objective, and interim milestone	• Chapter 5.4	• 5-17
			• Location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used	• Chapter 4.2; Figures 4-1, 4-2, 4-3, 4-4, 4-5; Tables 4-1, 4-4, 4-5, 4-6; Appendix 4B	• 4-1, 4-4, 4-11, 4-17, 4-23, 4-28, 4-5, 4-16, 4-22, 4-27, Appendix 4B

Table 1-2. Preparation Checklist for GSP Submittal					
GSP Regulations Section	Water Code Section	Requirement	Description	Chapter/Section in GSP	Initial Page Number in GSP
			• Description of technical standards, data collection methods, and other procedures or protocols to ensure comparable data and methodologies	• Chapter 4.2	• 4-1
354.36		Representative Monitoring	• Description of representative sites • Demonstration of adequacy of using groundwater elevations as proxy for other sustainability indicators • Adequate evidence demonstrating site reflects general conditions in the area	• Chapter 4.2.5 • Chapters 5.3, 5.4; Appendix 5B • Chapter 4.2.5	• 4-30 • 5-4, 5-17; Appendix 5B • 4-30
354.38		Assessment and Improvement of Monitoring Network	• Review and evaluation of the monitoring network • Identification and description of data gaps • Description of steps to fill data gaps • Description of monitoring frequency and density of sites	• Chapter 4.2 • Chapter 4.2 • Chapter 4.2 • Chapter 4.2	• 4-1 • 4-1 • 4-1 • 4-1
Article 5. Plan Contents, Subarticle 5. Projects and Management Actions					
354.44		Projects and Management Actions	• Description of projects and management actions that will help achieve the basin's sustainability goal • Measurable objective that is expected to benefit from each project and management action • Circumstances for implementation • Public noticing • Permitting and regulatory process • Time-table for initiation and completion, and the accrual of expected benefits • Expected benefits and how they will be evaluated • How the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included. • Legal authority required • Estimated costs and plans to meet those costs • Management of groundwater extractions and recharge	• Chapter 6.2 • Table 6-3 • Chapter 6.3 • Chapter 6.3 • Chapter 6.3 • Chapter 6.3 • Chapter 6.3 • Chapter 6.3 • Chapter 6.3 • Chapter 6.3 • Chapter 6	• 6-6 • 6-13 • 6-15 • 6-15 • 6-15 • 6-15 • 6-15 • 6-15 • 6-15 • 6-15 • 6-1
354.44(b)(2)	10727.2(d)(3)		• Overdraft mitigation projects and management actions	• Chapter 6	• 6-1

Table 1-2. Preparation Checklist for GSP Submittal					
GSP Regulations Section	Water Code Section	Requirement	Description	Chapter/Section in GSP	Initial Page Number in GSP
Article 8. Interagency Agreements					
357.4	10727.6	Coordination Agreements – Shall be submitted to the Department together with the GSPs for the basin and, if approved, shall become part of the GSP for each participating Agency.	**Coordination Agreements shall describe the following:** • A point of contact • Responsibilities of each Agency • Procedures for the timely exchange of information between Agencies • Procedures for resolving conflicts between Agencies • How the Agencies have used the same data and methodologies to coordinate GSPs • How the GSPs implemented together satisfy the requirements of SGMA • Process for submitting all Plans, Plan amendments, supporting information, all monitoring data and other pertinent information, along with annual reports and periodic evaluations • A coordinated data management system for the basin • Coordination agreements shall identify adjudicated areas within the basin, and any local agencies that have adopted an Alternative that has been accepted by the Department	Chapter 1.3.1	1-3

(a) The California Water Code and regulation sections, GSP requirements, and requirement descriptions listed in this table were taken verbatim from the California Department of Water Resources *Guidance Document for the Sustainable Management of Groundwater: Preparation Checklist for GSP Submittal* (December 2016).

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CHAPTER 2
Plan Area

2.1 SUMMARY OF JURISDICTIONAL AREAS AND OTHER FEATURES

2.1.1 Groundwater Basin Boundaries

The Plan Area is defined as the Colusa Subbasin (Groundwater Basin No. 5-021.52), which is part of the Sacramento Valley Groundwater Basin, as described in California Department of Water Resources (DWR) Bulletin 118 (DWR, 2006a) with boundary updates approved in February 2019. The current configuration of the Subbasin covers approximately 1,131 square miles (723,823 acres).

The Subbasin is generally bounded by Stony Creek to the north, the Coast Ranges to the west, the Sacramento River to the east, and the Colusa-Yolo County boundary and the Colusa County Water District to the south. The Subbasin currently includes about 2.4 square miles (1,500 acres) within Yolo County. Additional basin boundary modifications were submitted to DWR in June 2021; however, the proposed basin boundary modifications have not been approved as of the submittal of this GSP. The modifications would adjust the eastern Colusa Subbasin (Subbasin) boundary to better conform to the boundary of Reclamation District 1004 in Colusa County and would reduce the area of the Subbasin to 1,129 square miles (722,768 acres).

The vertical boundaries of the subbasin are the land surface (upper boundary) and the definable bottom of the subbasin (lower boundary). The definable bottom was established as part of development of the hydrogeologic conceptual model (HCM) discussed in Chapter 3. The vertical extent of the subbasin is subdivided into a surface water system (SWS) and groundwater system (GWS). The SWS extends from the land surface down to the bottom of root zone, within the lateral boundaries of the subbasin. The GWS extends from the bottom of the root zone to the base of the aquifer system, as defined in the HCM based on the base of freshwater and bedrock structural contours, within the lateral boundaries of the subbasin.

The Subbasin is hydraulically connected with surrounding subbasins along shared boundaries, the western boundary of Reclamation District 1004, and the Glenn and Colusa County boundaries. The Subbasin adjoins the following subbasins (Table 2-1 and Figure 2-1):

- Corning Subbasin (5-021.51) to the north
- Butte Subbasin (5-021.70) to the east/northeast
- Sutter Subbasin (5-021.62) to the east/southeast
- Yolo Subbasin (5-021.67) to the south

No groundwater subbasins border the western portion of the Subbasin.

Table 2-1. Adjacent Subbasins and Associated GSAs

Subbasin	SGMA Basin Priority	GSA(s)
Corning Groundwater Subbasin 5-021.51	High	• Tehama County Flood Control & Water Conservation District GSA • Corning Subbasin GSA
Butte Groundwater Subbasin 5-021.70	Medium	• Biggs-West Gridley Water District GSA • Butte County GSA • Butte Water District GSA • City of Biggs GSA • City of Gridley GSA • Colusa Groundwater Authority GSA • Glenn County GSA • Reclamation District 1004 GSA • Reclamation District 2106 GSA • Richvale Irrigation District GSA • Western Canal Water District GSA
Sutter Groundwater Subbasin 5-021.62	Medium	• Butte Water District GSA • City of Live Oak GSA • City of Yuba City GSA • Reclamation District No. 70 GSA • Reclamation District No. 1500 GSA • Reclamation District No. 1660 GSA • Sutter County GSA • Sutter Extension Water District GSA • Sutter Community Service District GSA
Yolo Groundwater Subbasin 5-021.67	High	• Yolo Subbasin GSA

1

2

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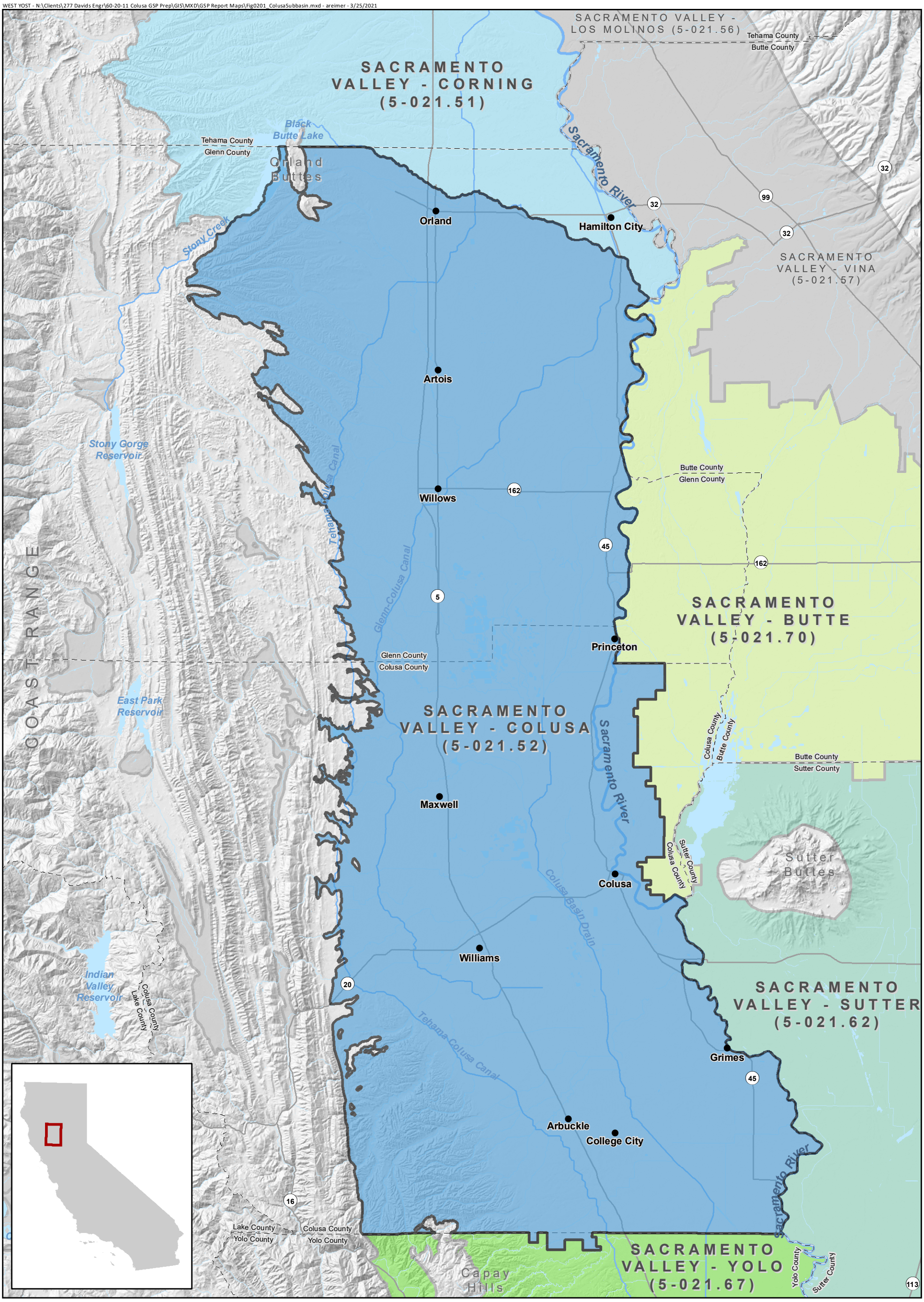

Source: California DWR Bulletin 118 Groundwater Basins v.6.1, revised in 2019.

Datums: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Colusa Subbasin (5-021.52)

Non-Adjacent Groundwater Basins

Adjacent Groundwater Basins

Corning Subbasin (5-021.51)

Butte Subbasin (5-021.71)

Sutter Subbasin (5-021.62)

Yolo Subbasin (5-021.67)

N

0 2.5 5

Scale in Miles

Figure 2-1

Area Covered by this GSP: Colusa Subbasin

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

2.1.2 Groundwater Sustainability Plan Area

The Subbasin is divided among two GSAs for GSP development (Figure 2-2). Figure 2-3 shows the agencies comprising each GSA. The Colusa Groundwater Authority (CGA) for the Colusa County portion of the Subbasin is a Joint Powers Authority (JPA) with 12 member agency representatives/Director seats. The CGA is comprised of Colusa County, two cities, six[1] water districts, two reclamation districts, a water company, and two appointed private groundwater pumper representatives. The Glenn Groundwater Authority (GGA) is similarly a JPA for the Glenn County portion of the Subbasin. The GGA is comprised of ten member agency representatives including Glenn County, two cities, and seven water/irrigation districts.

Primary urban areas within the Subbasin include the incorporated cities of Orland and Willows in Glenn County and the cities of Colusa and Williams in Colusa County as well as the unincorporated communities of Artois, Princeton, Maxwell, Arbuckle, Grimes and College City. Interstate 5 and State Route 45 traverse the Subbasin north to south while State Routes 20, 32, and 162 are the primary east-west thoroughfares.

There are no adjudicated areas or areas addressed in an alternative to a GSP within the Subbasin.

2.1.2.1 Water Purveyors

The Subbasin is served by several water purveyors, providing water for urban, agricultural, and environmental resource uses (Figure 2-4). These water purveyors include cities, special districts, mutual water companies, reclamation districts, and investor-owned water utilities

Municipal Water Purveyors

Municipal water purveyors and municipal water users in the Subbasin rely on groundwater to meet domestic water needs. Refer to Table 2-2, Municipal Water Purveyors, for the municipal water purveyors in the Subbasin. A description of each of the incorporated cities' water services facilities is provided further below.

Several small water systems are located in the Subbasin. State small water systems provide piped water to the public for human consumption; serve at least five, but not more than 14, service connections; and do not regularly serve drinking water to more than an average of 25 individuals daily for more than 60 days out of the year (California Health and Safety Code §116275). State small water systems may rely on either groundwater or surface water supply.

In addition to the municipal water purveyors and State small water systems, rural domestic water needs are typically met with groundwater from individual private wells. These private groundwater pumpers are represented on the CGA Board by two appointed private groundwater pumper representatives that serve on the Colusa County Groundwater Commission. Glenn County private groundwater pumpers are represented in GGA by Glenn County and Monroeville Water District.

Municipal and rural domestic water supplies in the Subbasin largely serve Disadvantaged Communities (DACs), Severely Disadvantaged Communities (SDACs), and Economically Distressed Areas (EDAs). As described in Section 2.1.2.3, nearly all of the Subbasin is considered an EDA and many communities within the Subbasin are considered DACs, including the City of Orland, the City of Willows, the City of Colusa, and the communities of Artois, Princeton, and Grimes. Additionally, many of the rural residential and agricultural properties located within the unincorporated areas of Glenn County and Colusa County are identified as DACs or SDACs. These users typically rely on groundwater to meet their water needs.

[1] Four water agencies are represented by two member agency representatives/Director seats. Maxwell Irrigation District and Westside Water District share one Director seat. Princeton-Codora-Glenn Irrigation District and Provident Irrigation District also share one Director seat.

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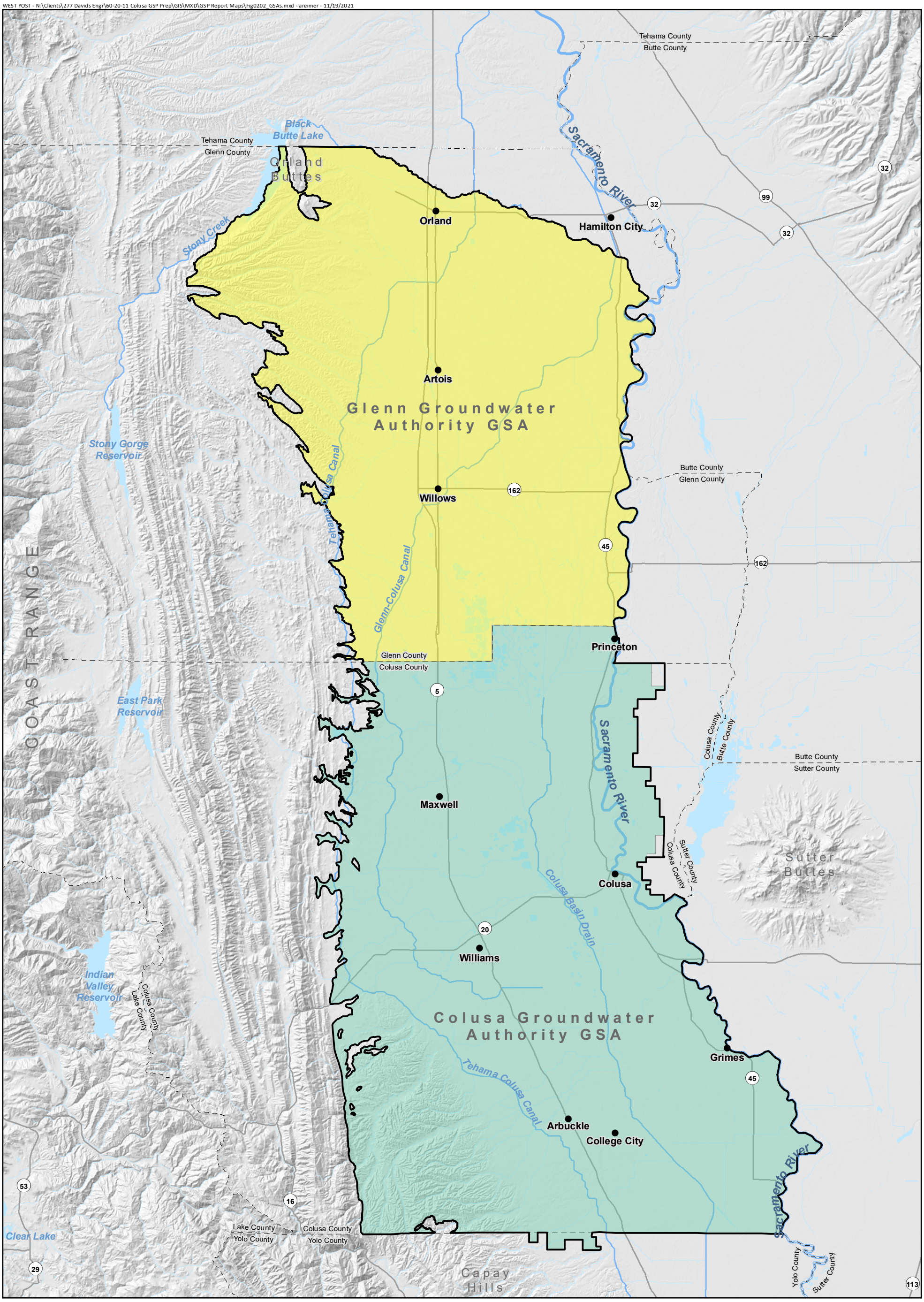

Source: Exclusive Groundwater Sustainability Agency (GSA) boundaries were obtained from the DWR GSA Map Viewer Application, 2021.

Datums: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

- Colusa Subbasin
- Colusa Groundwater Authority GSA
- Glenn Groundwater Authority GSA

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0 2.5 5

Scale in Miles

Figure 2-2

Colusa Subbasin GSAs

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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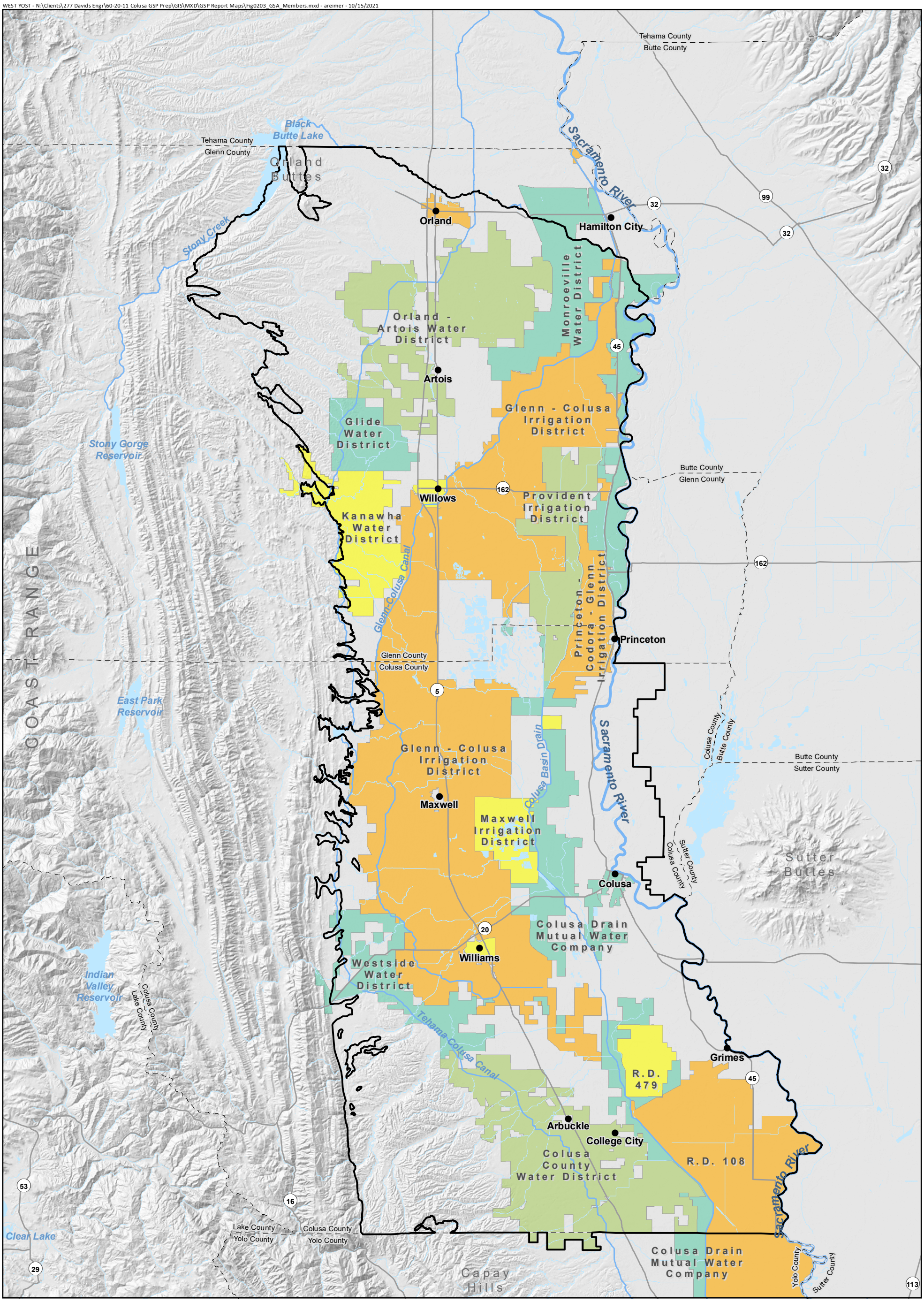

Source: Member agency boundaries were obtained from the California Natural Resources Agency website (2020). Agency boundaries not included in that dataset were obtained from other sources.

Datums: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Note:
1. Colusa County and Glenn County are also GSA Member Agencies. They are not shown on this map, but represent the white-areas not belonging to the other Member Agencies. There are also two private pumper representatives from the Colusa County Groundwater Commission on the CGA Board.
2. Where service areas overlap, only one agency is shown.

- City of Williams; City of Willows; Kanawha Water District; Maxwell Irrigation District; Reclamation District No. 479
- City of Orland; Glenn - Colusa Irrigation District; Princeton - Codora - Glenn Irrigation District; Reclamation District No. 108
- Colusa County Water District; Orland - Artois Water District; Provident Irrigation District
- City of Colusa; Colusa Drain Mutual Water Company; Glide Water District; Monroeville Water District; Westside Water District
- Colusa Subbasin

N

0 2.5 5

Scale in Miles

Figure 2-3

Colusa Subbasin GSA Member Agencies

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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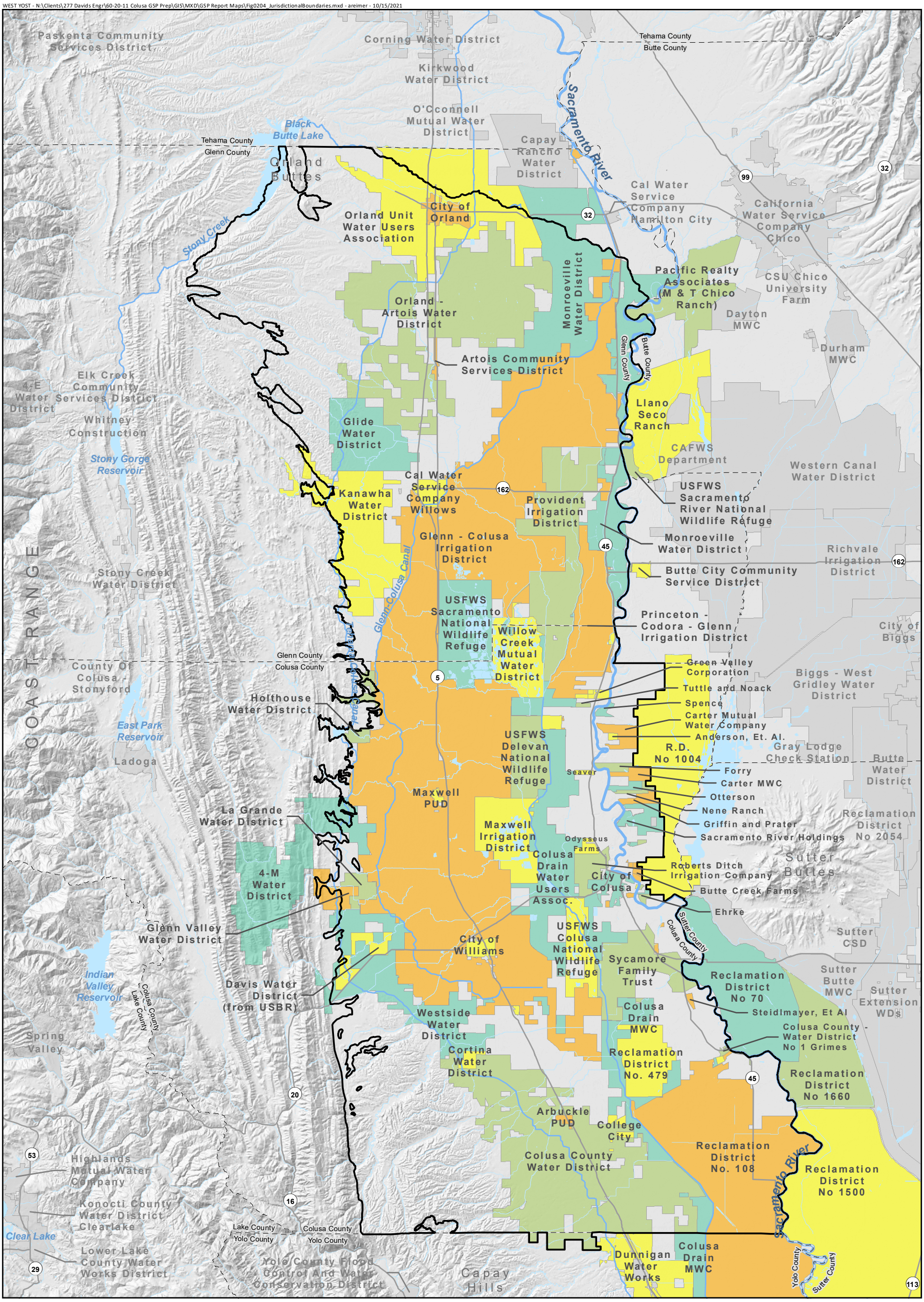


Source: Member agency boundaries were obtained from the California Natural Resources Agency website (2020). Agency boundaries not included in that dataset were obtained from other sources.

Datums: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Note:
1. Where service areas overlap, only one agency is shown.
2. Butte County is listed as water district in the CNRA file. Butte County, like Colusa or Glenn County, is not shown as a distinct water district on this map.
3. Small water services agencies are not labeled on this map.

Colusa Subbasin

Water Agencies not Within or Adjacent to the Colusa Subbasin

Water Agencies Within or Adjacent to the Colusa Subbasin are Displayed in the Colors Shown Below and Labelled in the Map

N

0 2.5 5

Scale in Miles

Figure 2-4

Water Districts and Jurisdictional Boundaries

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

Table 2-2. Municipal Water Purveyors within the Colusa Subbasin

County	Colusa Subbasin Water Purveyor	GSA Member Agency		Service Area Population	No. Connections	No. Wells	Annual Volume Served
		CGA	GGA				
Colusa	City of Colusa	X		5,698	2,126	5	1675 af
Colusa	City of Williams	X		5,287	2,100	3	1039 af
Colusa	Arbuckle Public Utility District			2,300	794	4	
Colusa	Del Oro Water Company Arbuckle District			188	55	2	48 af[(a)]
Colusa	Colusa County Waterworks District #1 - Grimes			381	123	1	3.5 af
Colusa	Colusa County Waterworks District #2 - Princeton			303	125	2	
Colusa	Maxwell Public Utility District			1,294	392	3	242 af
Glenn	City of Orland		X	7,501	2,315	6	2504 af
Glenn	City of Willows/Cal Water Willows District		X	7,118	2,371	7	1044 af
Glenn	Del Oro Water Company Black Butte District			284	85	1	46 af[(a)]
Glenn	Artois Community Services District			198	53	2	75 af[(b)]

(a) Average annual acre-feet (af) from 2016-2020
(b) Public Water System Annually Reported Water Production and Deliver Information - 2016 average annual

City of Colusa, Colusa County

The City of Colusa provides domestic water for residential, commercial, and industrial uses within the City limits. The City obtains water from five groundwater wells that are 200 feet or more in depth. Based on the 2007 General Plan Update Master Environmental Impact Report, there were 2,126 service connections and a population of approximately 5,698. Of the service connections, 1,914 are residential land uses, 195 commercial uses, and the remainder are industrial and other uses. In 2006, the annual production for all five wells was approximately 545.8 million gallons (mg) or 1,675 acre-feet (af).

City of Williams, Colusa County

The City of Williams provides domestic water for residential, commercial, and industrial uses within the City limits. According to the 2012 General Plan, there were approximately 2,100 service connections serving an estimated population of 5,287. Water is supplied by three active and two standby groundwater wells, pumping a total of approximately 2,800 gpm. The wells are approximately 120 to 500 feet deep. The average annual water flow is about 400,000 gallons per day up to 1.2 to 1.5 mg on a peak day; the month of July is historically the peak month with approximately 36.5 mg or 1,039 af pumped in 2016.

City of Orland Water System, Glenn County

The City of Orland's primary water system consists of six wells distributed throughout the City. The wells have an average depth of approximately 200 feet, and the average depth to groundwater is generally between 20 and 50 feet. The wells produce between approximately 500 and 1,200 gpm each. The water transmission and distribution systems consist of approximately 30 miles of pipeline for a population of 7,501 residents and 2,315 service connections.

City of Willows/Cal Water Willows District, Glenn County

Domestic water service in the City of Willows, and the adjacent unincorporated area, is provided by the California Water Service Company (Cal Water), Willows District (District). The District operates seven groundwater wells, two storage tanks, and 36 miles of pipeline. From 2010 to 2015, the District delivered an average of 1.2 mg of water per day to more than 2,342 service connections. The 2015 Urban Water Management Plan prepared by Cal Water, contains many of the elements required by SGMA and thus already serves as a road map toward the implementation of SGMA for the District. Some of these components include actions to develop additional water supplies to maintain supply reliability, water quality, and recycled water.

The City of Willows Water Department owns and operates a small water system just south of the District boundaries, south of Road 53, which consists of one well and three service connections.

Agriculture Water Purveyors

Table 2-3 summarizes the main agricultural water purveyors in the Subbasin, excluding smaller Central Valley Project (CVP) contractors and diverters with service areas less than 1,000 acres.

National Wildlife Refuges

There are three National Wildlife Refuges within the Subbasin, the Sacramento National Wildlife Refuge, Delevan National Wildlife Refuge, and Colusa National Wildlife Refuge. These three refuges along with the Sutter Refuge, Sacramento River Refuge, and three wildlife management areas comprise the Sacramento National Wildlife Refuge Complex. Figure 2-4 shows the locations of the refuges.

The Sacramento National Wildlife Refuge is 10,819 acres and is comprised of 7,086 acres of managed wetlands and 3,360 acres of unmanaged wetlands, grasslands, alkali meadow, vernal pools and riparian habitats.

The Delevan Refuge consists of 5,877 acres and is comprised of approximately 4,600 acres of managed wetlands and approximately 984 acres of unmanaged wetlands, grasslands, alkali meadows, vernal pools, and riparian habitats.

The Colusa Refuge consists of over 4,686 acres. It is comprised of approximately 3,347 acres of managed wetlands and 1,191 acres of unmanaged wetlands, grasslands, alkali meadows, vernal pools, and riparian habitats. The Refuge is bisected by the Colusa Basin Drain, which drains the Subbasin southeast to the Sacramento River.

A Comprehensive Conservation Plan (CCP) guides the management of the Refuges and includes a variety management tools, including Water Management Plans. The recurring five-year Water Management Plan updates document water use, identify water supply system needs, and outline steps required to improve both efficiency and quantity of water used. The preparation of these plans is a requirement of the Central Valley Project Improvement Act, which requires the U.S. Bureau of Reclamation (USBR) to purchase and deliver water to these Refuges.

Table 2-3. Agricultural and Other Water Purveyors within the Colusa Subbasin

County	Water Purveyor	GSA Member Agency		Service Area Size, acres[a]	Primary Water Source	Annual Surface Water Supply Volume, af[b]	Supply Volume Description
		CGA	GGA				
Agricultural Water Purveyor[c]							
Colusa/Glenn	Glenn-Colusa Irrigation District	X	X	160,000	SW	704,100	Average annual supplies under all rights and contracts, 2003 to 2012 (2012 WMP)
Colusa	Reclamation District No. 108	X		59,000	SW	155,000	Average annual supplies under all rights and contracts, 2003 to 2012 (2012 WMP)
Colusa	Colusa County Water District	X		46,000	SW	51,000	Average annual USBR CVP deliveries from Tehama-Colusa Canal, 1990 to 2015
Colusa	Colusa Drain Mutual Water Company	X		37,000	SW	variable	Surface water supply available to the CDMWC consists solely of the Colusa Drain and its tributaries; depends on return flow or drainage water from other districts.
Colusa	4-M Water District			18,000	SW	1,900	Average annual USBR CVP deliveries from Tehama-Colusa Canal, 1990 to 2015
Colusa/Glenn	Provident Irrigation District	X	X	17,000	SW	67,800	Average annual supplies under all rights and contracts, 2003 to 2012 (2012 WMP)
Colusa/Glenn	Princeton-Codora-Glenn Irrigation District	X	X	11,000	SW	68,200	Average annual supplies under all rights and contracts, 2003 to 2012 (2012 WMP)
Colusa	Westside Water District	X		15,000	SW	29,000	Average annual supplies under all rights and contracts, 2001 to 2010 (2010 WMP)
Colusa	Maxwell Irrigation District	X		9,000	SW	7,800	Average annual USBR CVP supplies, 1990 to 2015
Colusa	Sycamore Family Trust			8,000	SW	31,800	Max. CVP Contract Amount (Contract 14-06-200-2146A-R-1)
Colusa	Reclamation District No. 479	X		6,000	SW	drain water	Conveys drain water and relies on the RD 2047 to convey drainage water to the Sacramento River.
Colusa	Carter MWC			2,000	SW	7,100	Max. CVP Contract Amount (Contract 14-06-200-2401A-R-1)
Colusa	Davis Water District			2,000	SW	2,300	Average Annual USBR CVP deliveries from Tehama-Colusa Canal, 1990 to 2015
Colusa	Glenn Valley Water District			2,000	SW	900	Average annual USBR CVP deliveries from Tehama-Colusa Canal, 1990 to 2015
Colusa	Holthouse Water District			2,000	SW	1,100	Average annual USBR CVP deliveries from Tehama-Colusa Canal, 1990 to 2015
Colusa	Roberts Ditch Irrigation Company			2,000	SW	4,400	Max. CVP Contract Amount (Contract 14-06-200-935A-R-1)
Colusa	La Grande Water District			1,000	SW	4,300	Average annual USBR CVP deliveries from Tehama-Colusa Canal, 1990 to 2015
Colusa	Cortina Water District			< 1,000	SW	800	Average annual USBR CVP deliveries from Tehama-Colusa Canal, 1990 to 2015
Colusa/Glenn	Willow Creek Mutual Water Company			8,000	SW	2,500	Typical average diversions in years when water is available, 2010-2020 (eWRIMS A028238)
Glenn	Monroeville Water District		X	37,000	GW	N/A	Formed and approved in 2016 as a water district representing groundwater users
Glenn	Orland-Artois Water District		X	30,000	SW	53,000	Max. CVP Contract Amount (Contract 14-06-200-8382A)
Glenn	Orland Unit Water Users Association			27,000	SW	88,000	Average annual diversions, 2002-2016 (2017 AWMP)
Glenn	Kanawha Water District		X	17,000	SW	26,000	Average annual USBR CVP deliveries from Tehama-Colusa Canal, 1990 to 2015
Glenn	Glide Water District		X	10,000	SW	11,400	Average annual USBR CVP deliveries from Tehama-Colusa Canal, 1990 to 2015
National Wildlife Refuges							
Colusa/Glenn	USFWS Sacramento National Wildlife Refuge			11,000	SW	33,000 (50,000)[d]	Average annual supplies under all rights and contracts, 1995 to 2004 (2006 WMP) CVPIA Full Level 4 volumes shown in parentheses
Colusa	USFWS Delevan National Wildlife Refuge			6,000	SW	21,000 (30,000)[d]	Average annual supplies under all rights and contracts, 1995 to 2004 (2006 WMP) CVPIA Full Level 4 volumes shown in parentheses
Colusa	USFWS Colusa National Wildlife Refuge			4,000	SW	19,000 (25,000)[d]	Average annual supplies under all rights and contracts, 1995 to 2004 (2006 WMP) CVPIA Full Level 4 volumes shown in parentheses

(a) Area from water district shapefiles, rounded to 1,000 acres.
(b) Volume rounded to 100 acre-feet (af). Average annual, typical annual, or maximum contract annual volume (see description).
(c) Main agricultural water purveyors in the Colusa Subbasin, excluding most smaller purveyors and diverters with service areas of less than 1,000 acres and smaller purveyors and diverters without publicly available information.
(d) Annual Full Level 4 water supplies during unconstrained conditions are shown in parentheses. During constrained conditions, these same refuges generally are provided 75% of this quantity, as stipulated in their water delivery agreements with the U.S. Bureau of Reclamation. CVPIA Full Level 4 supply quantities were not used in the projected water budgets due to the uncertainty in those quantities actually being provided.

GW = Groundwater
SW = Surface water
N/A = Not Available

2.1.2.2 Jurisdictional Boundaries of Other Agencies

There are federal, tribal, and state public lands within the Subbasin, as shown on Figure 2-5.

Federal lands located within the Subbasin include portions of land managed by the Bureau of Land Management and USBR. There are three Wildlife Refuges within the Subbasin managed by the United States Fish and Wildlife Service including the Sacramento National Wildlife Refuge, Delevan National Wildlife Refuge, and Colusa National Wildlife Refuge. These Wildlife Refuges are discussed in preceding sections of this GSP.

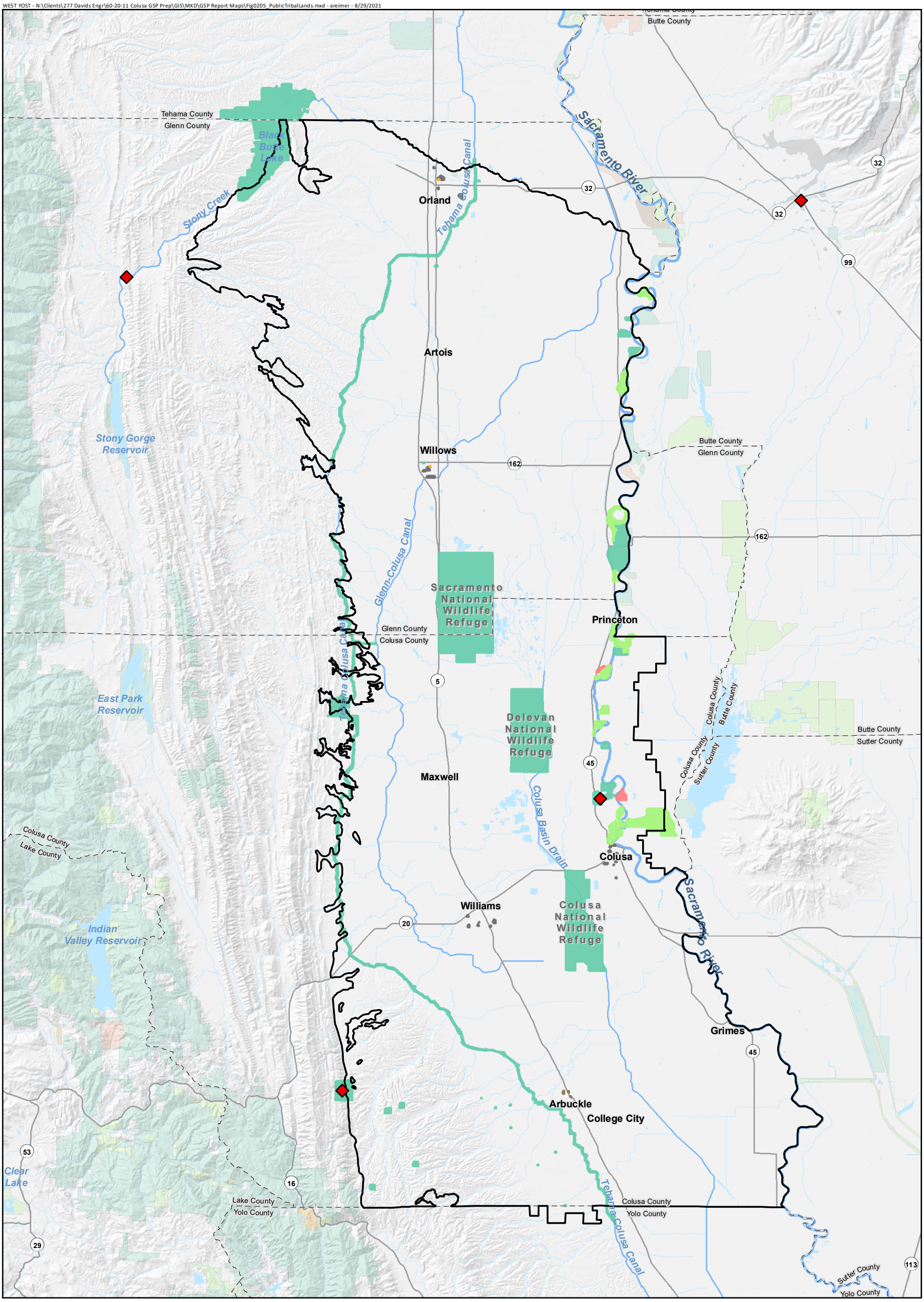
Tribal lands within the Subbasin are owned by the Cachil Dehe Band of Wintun Indians/Colusa Rancheria and the Cortina Indian Rancheria of Wintun Indians Public and Tribal Lands (Figure 2-5).

State lands managed by the California Department of Fish and Wildlife are primarily located along the Sacramento River.

2.1.2.3 Disadvantaged Communities

Many of the communities within the Subbasin are considered either a DAC, a community whose median household income (MHI) is less than 80 percent of the statewide MHI, or an SDAC, a community whose MHI is less than 60 percent of the statewide MHI. Disadvantaged communities are shown on Figure 2-6. The Cities of Orland, Willows, and Colusa, as well as the communities of Artois, Princeton, and Grimes are classified as census place DACs. Most of Subbasin includes rural residential and agricultural properties located within the unincorporated portions of Glenn County and Colusa County. The majority of these areas are identified as DACs or SDACs based on census blocks and census tracts.

Additionally, nearly all of the Subbasin is considered an EDA because it is rural, has a low population density, and has an MHI of less than 85 percent of the statewide MHI. The only area within the Subbasin that is not considered an EDA is the portion of the Subbasin that exists within Yolo County. The entirety of the Subbasin that is within Glenn and Colusa Counties is considered an EDA.



Source: Public and tribal lands were obtained from the State of California Governor's Office of Emergency Services (CalOES) GIS Data Hub, 2020.

Horizontal Datum: North American Datum of 1983, California State Plane Zone II, feet.

Note: Land designations outside of the Colusa Subbasin are faded back.

- Tribal Land
- Federal Land
- State Land
- County Land
- City Land
- Special District
- Non Profit Area
- Colusa Subbasin

N

0 2.5 5

Scale in Miles

Figure 2-5

Public and Tribal Lands

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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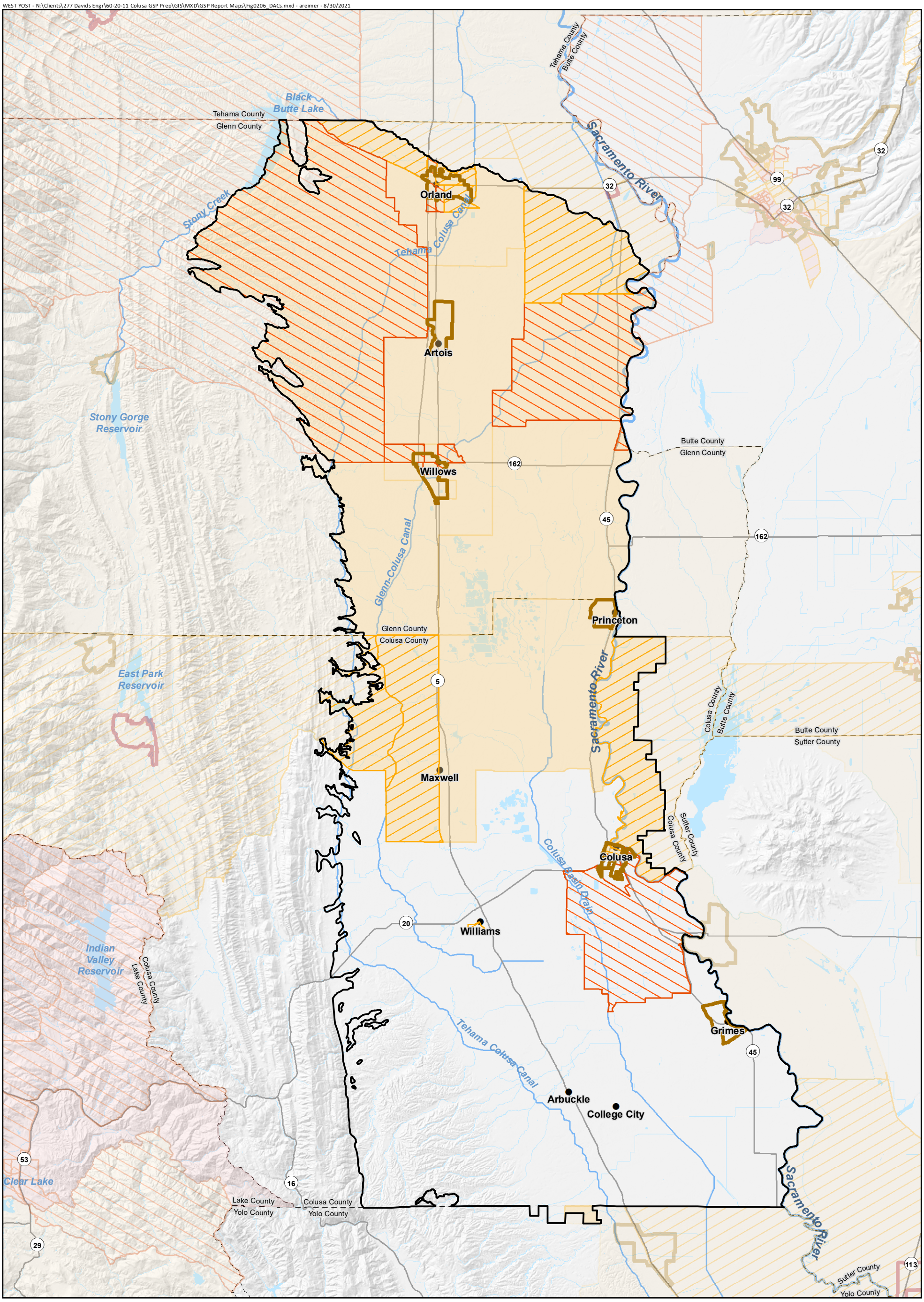


Source: Disadvantaged Comminity (DAC) and Severely Disadvantaged Community (SDAC) areas were obtained from the DWR DAC Mapping Tool website. Census and income data are based on the Census American Community Survey (ACS) 2012-2016 dataset.

Horizontal Datum: North American Datum of 1983, California State Plane Zone II, feet.

Notes:
1. DAC/SDAC designations outside of the Colusa Subbasin are faded back.
2. All of the Colusa Subbasin except for the small area that falls within Yolo County is categorized as an economically distressed area (EDA).

Colusa Subbasin

Census Place Disadvantaged Communities

DAC SDAC

Census Block Disadvantaged Communities

DAC SDAC

Census Tract Disadvantaged Communities

DAC SDAC

N

0 2.5 5

Scale in Miles

Figure 2-6

Disadvantaged Communities

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

2.1.2.4 Well Density per Square Mile

The densities of public water supply, domestic, and agricultural wells per public land survey section within the Subbasin are shown in panels from left to right on Figure 2-7. Each section is approximately one square mile. The number of wells reported by section was determined using data from the California DWR Online System of Well Completion Reports (OSWCR) well completion report (WCR) database provided via the California Open Data Portal (DWR, 2021a). The downloaded dataset only includes wells with WCRs that have been submitted to DWR and is only as accurate as the information provided on the WCRs. Well locations are based on either information provided in the WCRs or are located at the center of their designated public land survey township, range, and section. As such, the well densities shown on Figure 2-6 and reported here are representative of well distribution but may not reflect the actual number of existing or active wells per well use type within the subbasin (i.e., public water supply, domestic, or agricultural well).

Public water supply wells are mostly concentrated in urban areas near cities and towns. Domestic water supply wells are more spread out throughout the Subbasin but occur in higher numbers surrounding urban areas and along the Sacramento River. The densest square mile concentration of domestic wells exceeds 100 wells and occurs near Orland. Agricultural wells are more widespread than public wells and tend to be concentrated outside the urban areas. The densest square mile concentration of agricultural wells exceeds 10 wells, an order of magnitude less than that of domestic wells.

According to the WCR database, there are approximately 73 public supply wells, 3,500 domestic wells, and 2,600 agricultural wells within the Subbasin. Averaged over the entire Subbasin, this is equivalent to approximately 0.06 public supply wells, 3.1 domestic wells, and 2.3 agricultural wells per square mile. Wells not planned for groundwater extraction, based on information provided on the WCRs, or with an unknown or unspecified use designation were not included in this analysis.

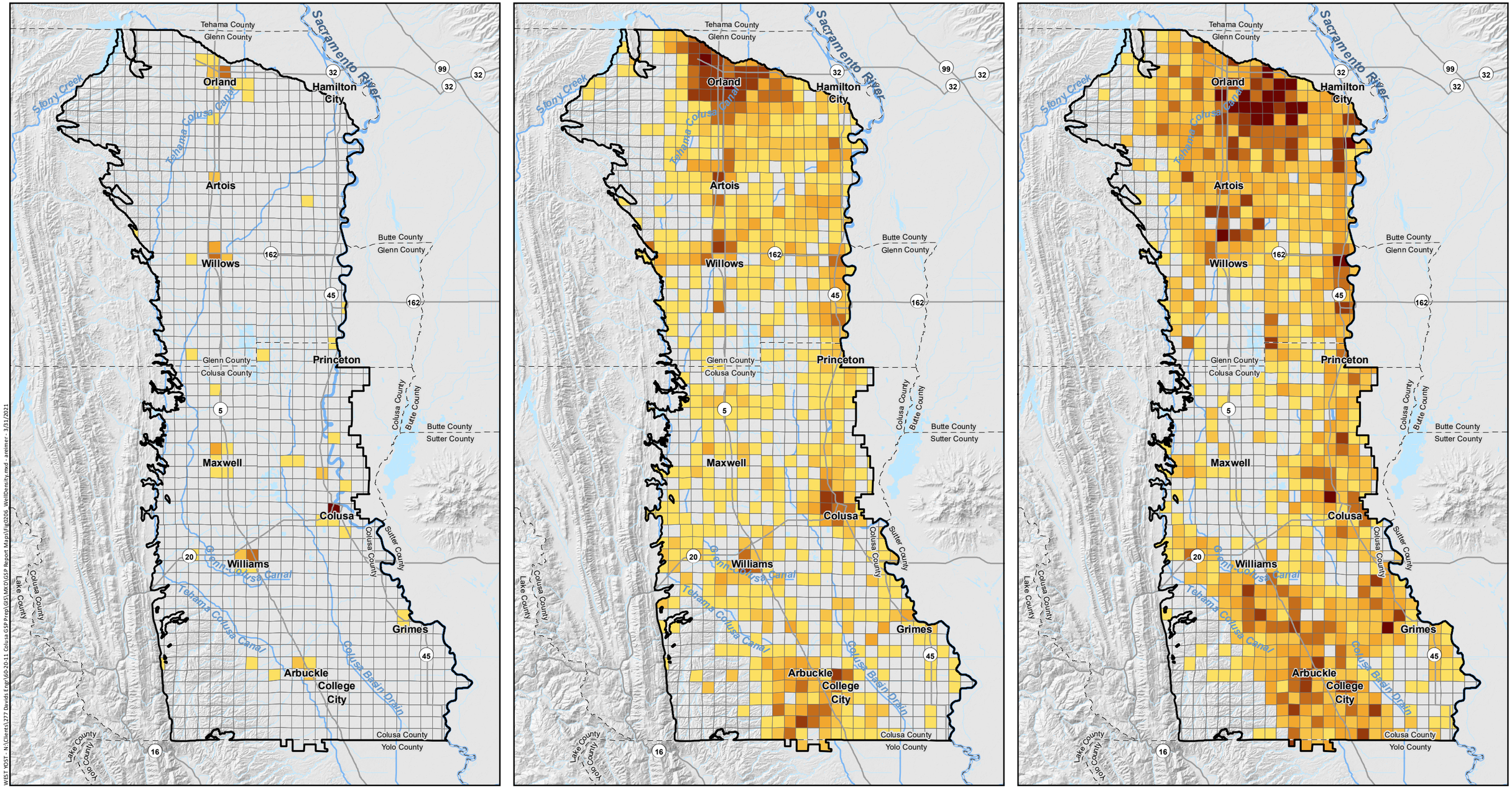
2.1.3 Existing Land Use Designations

Land use areas in the Subbasin are broadly classified across three sectors: agricultural, urban, and native vegetation (Figure 2-8). Agricultural land use (and water use) encompasses all agricultural crops reported in the Subbasin. Urban land uses are associated with the cities and communities within the Subbasin and typically include residential, commercial, industrial, public and quasi-public, and semi-agricultural land. Native lands are designated as native lands that are either privately managed or managed by the U.S. Fish and Wildlife Service as wildlife refuges.

Public Water Supply Well Density

Domestic Water Supply Well Density

Agricultural Water Supply Well Density



Source: Well locations are those included in the Online System for Well Completion Reports (OSWCR) and were obtained from the California Open Data Portal.

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Note:
1. The well database was filtered based on the planned use for each well. The planned use designated in the database may not match what the well is/was actually used for.
2. Wells with unknown use or uses other than water supply were not included in this analysis.

Colusa Subbasin

Public Water Supply Wells per Square Mile

0	4
1	5
2	> 5
3	

Domestic Water Supply Wells per Square Mile

0	11 - 25
1 - 2	26 - 100
3 - 5	> 100
6 - 10	

Agricultural Water Supply Wells per Square Mile

0	6 - 7
1	8 - 10
2 - 3	> 10
4 - 5	

N

0 4 8

Scale in Miles

Figure 2-7

Density of Wells within the Colusa Subbasin

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

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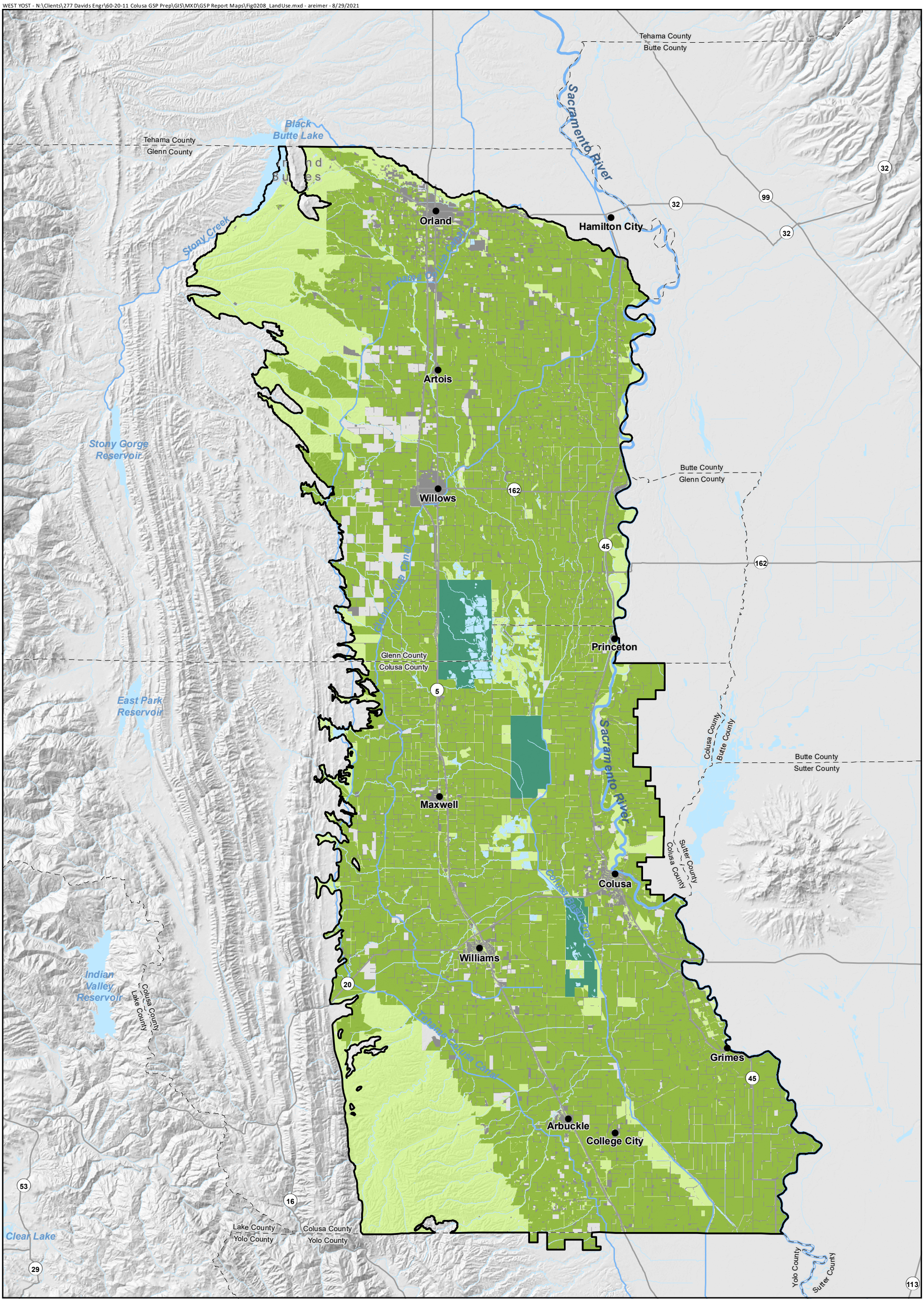


Source: Source: Land uses depicted in this map were surveyed in 2014 for Colusa, Glenn, and Yolo Counties via the Department of Water Resources Land Use Survey.

Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Note:
1. Land use outside of the Colusa Subbasin is not shown on this map.

Colusa Subbasin

Land Use (2014)

- Agriculture
- Native
- Native - Wildlife Refuge
- Urban
- Idle

N

0 2.5 5

Scale in Miles

Figure 2-8

Land Use

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

2.2 WATER RESOURCES MONITORING AND MANAGEMENT PROGRAMS

2.2.1 Monitoring and Management Programs

Existing surface and groundwater monitoring and management programs within the Subbasin are identified below with a summary of water planning documents applicable to the Subbasin GSAs. Existing groundwater, surface water, and land subsidence monitoring locations included in the monitoring and management programs below were considered for incorporation into the Subbasin monitoring networks, as discussed in Chapter 4.

Continued monitoring is required to track the progress of the GSP implementation by providing data on groundwater and surface water availability in the Subbasin. See Chapter 6 for more details of applicable projects that require additional monitoring to fill data gaps. See Chapter 7 for details about proposed GSP studies that will fill those data gaps.

2.2.1.1 Water Planning Documents

The local agencies that formed the Subbasin GSAs have prepared and adopted water planning documents that discuss surface and groundwater supplies, distribution infrastructure, and implementation and monitoring programs.

Development and implementation of this GSP has and will continue to consider the interests of all beneficial uses and users of groundwater, including agricultural water users, municipal water users, DACs, SDACs, groundwater dependent ecosystems (GDEs) and environmental users, tribes, and other stakeholders. Implementation of this GSP will support GSP goals for the protection of DACs, SDACs, natural resources, and GDEs, in coordination with implementation of the plans listed below, consistent with SGMA regulations.

Regional Water Plans

- **Northern Sacramento Valley (NSV) Integrated Regional Water Management Plan (IRWMP) (approved 2014, updated 2020, adopted 2021):** The six counties of Butte, Colusa, Glenn, Shasta, Sutter, and Tehama have been working together to take an integrated approach to water-related issues such as economic health and vitality; water supply reliability; stormwater and flood management; water quality improvements; and ecosystem protection and enhancement. The NSV IRWMP is a collaborative effort to enhance coordination of the water resources in a region. The NSV IRWMP involves multiple agencies, stakeholders, tribes, individuals and groups to address water-related issues and offer solutions which can provide multiple benefits to the region. The NSV IRMWP was adopted by the NSV Board on April 14, 2014 and received final approval from the California DWR on July 24, 2014. The NSV IRWMP was updated in 2019/2020 to comply with new DWR requirements. In March 2020, the NSV Board adopted the Revised Draft NSV IRWMP.

- **Sacramento Valley Regional Water Management Plan (RWMP) (adopted 2006, updated 2012):** The RWMP focuses on four subbasins, including the Colusa Subbasin, and addresses water supply and water use of participating water districts. The RWMP discusses regional water measurement programs; provides analysis of water management quantifiable objectives; and actions to implement and achieve quantifiable objectives. The geographic boundary of the area covered by the Sacramento Valley RWMP and served by the participating Sacramento River Settlement Contractors (SRSC) is the portion of the Sacramento River Basin from Shasta Dam to the Sacramento metropolitan area.
- **Agricultural Water Management Plan (2012) – Participating Sacramento River Settlement Contractors:** The 2012 Sacramento Valley Regional Water Management Plan Annual Update (2012 RWMP Annual Update) was prepared by the SRSC in cooperation with the USBR, in accordance with the Regional Criteria for Evaluating Water Management Plans for the Sacramento River Contractors (Regional Criteria). The Regional Criteria specifies that the participating SRSCs will jointly file an annual update every subsequent year to report on implementation actions taken, along with any additions and revisions to the RWMP.
- **Colusa Basin Watershed Management Plan (2012):** This Watershed Management Plan focuses on the following eight goals as identified by stakeholders and the Technical Advisory Committee (TAC):
    1. Protect, maintain, and improve water quality.
    2. Promote activities to ensure a dependable water supply for current and future needs.
    3. Preserve agricultural land and open space.
    4. Manage and reduce invasive plant populations.
    5. Reduce destructive flooding.
    6. Enhance soil quality and reduce erosion.
    7. Preserve and enhance native habitat.
    8. Address unknown future effects of climate change.

Water Management Plans

- U.S. Fish and Wildlife Service (USFWS) Comprehensive Conservation Plan for the Sacramento, Delevan, Colusa, and Sutter National Wildlife Refuges – Water Management Plans
- Colusa County Water District Water Management Plan (2015)
- Orland-Artois Water District Water Management Plan (2020)

Urban Water Management Plans

- Willows District Urban Water Management Plan (2015)

Groundwater Management Plans

- **Colusa County Groundwater Management Plan (adopted 2008):** The Colusa County Groundwater Management Plan was adopted in 2008. In preparing the Groundwater Management Plan, Colusa County intended that it be applicable countywide and serve the following purposes:
    1. To be responsible stewards of the water resources in Colusa County.
    2. To be eligible for grant funding to increase the understanding of the groundwater basins underlying Colusa County.
    3. To retain local control of water management decisions.

  Colusa County's goals for groundwater management (as developed with input from the public through meetings, workshops, and surveys) are to:
    1. Ensure a Reliable Water Supply
    2. Ensure Long-Term Groundwater Sustainability
    3. Optimize Conjunctive Use of Surface Water and Groundwater
    4. Protect Water Rights
    5. Maintain Local Control
    6. Prevent Unnecessary Restrictions on Groundwater Use
- **Glenn County Groundwater Management Plan (adopted 2000, revised 2012):** The Glenn County Groundwater Management Plan was adopted in 2000 (Ordinance No. 1115), and later revised in 2012 (Ordinance No. 1237) with an aim to protect the County's groundwater resource. Incorporation of the Preliminary Plan and the Export Water Transfer Guidelines in Ordinance No. 1237 was especially important for this goal. The Glenn County Groundwater Management Plan uses the Basin Management Objective (BMO) of Groundwater Basin Management, which encompasses six key elements:
    1. Management Areas and Sub-Areas, which groups groundwater users together who have the same vested interest in maintaining the groundwater resource at mutually agreeable levels.
    2. BMO Parameters requires management objectives for minimum groundwater levels.
    3. Public input is provided through the Glenn County Water Advisory Committee.
    4. Establishing a groundwater quality monitoring network.
    5. Adaptive management to resolve non-compliance with management objectives.
    6. Enforcement and conflict resolution when a BMO threshold is exceeded.

Drought Management Plans

- **Sacramento River Settlement Contractors Drought Management Plan (2016):** Water contracts with various entities specify contractual water deliveries be made except during dry periods. During periods of reduced water supplies, deliveries are decreased in accordance with the curtailment terms in the contracts. CVP contractors along the Sacramento River can generally be grouped into two major categories: SRSCs and CVP Water Service Contractors. SRSCs within the Subbasin include Glenn-Colusa Irrigation District, Provident Irrigation District, Princeton-Codora-Glenn Irrigation District, and Reclamation

District 108. CVP Water Service Contractors within the Subbasin include 4-M Water District, Colusa County Water District, Cortina Water District, Davis Water District, Glenn Valley Water District, Glide Water District, Holthouse Water District, Kanawha Water District, La Grande Water District, Myers-Marsh Mutual Water District, Orland-Artois Water District, and Westside Water District.

General Plans (refer to Section 2.3.1)

- Colusa County General Plan
- Glenn County General Plan
- City of Colusa General Plan
- City of Williams General Plan
- City of Orland General Plan
- City of Willows General Plan

Municipal Service Reviews

- The Local Agency Formation Commission (LAFCO) in each County conducts reviews of municipal services provided in a county by region, subregion or other designated geographic area, as appropriate, for the service or services provided by a governing entity. Municipal Service Reviews (MSRs) provide written summaries of the six topics pertaining to service infrastructure:
    1. Growth and population projections for the affected area.
    2. The location and characteristics of any disadvantaged unincorporated communities within or contiguous to the sphere of influence.
    3. Present and planned capacity of public facilities and adequacy of public services, including infrastructure needs or deficiencies.
    4. Financial ability of agencies to provide services.
    5. Status of, and opportunities for shared facilities.
    6. Accountability for community service needs, including governmental structure and operational efficiencies.
- The following GSA member agencies have readily available MSRs:
    1. City of Colusa MSR (Draft 2021)
    2. City of Orland MSR (2014)
    3. City of Willows MSR (2014)
    4. Kanawha / Glide Water District MSR (2020)
    5. Orland-Artois Water District MSR (2019)

2.2.1.2 Surface Water Monitoring and Management Programs

Surface water flows into and within the Subbasin are monitored through existing federal, state, regional, and local programs. Data and spatial information from these monitoring programs were used to support GSP development, including water budget development, per 23 CCR Section 354.18.

Federal, State, and Regional Programs

Table 2-4 lists the existing surface water monitoring networks with publicly available data and their respective websites.

Table 2-4. Existing Surface Water Monitoring Programs

Surface Water Monitoring Network	Responsible Agency	Surface Water Monitoring Type	Website
National Water Information System (NWIS)	U.S. Geological Survey (USGS)	Discharge	https://waterdata.usgs.gov/nwis
Water Data Library (WDL)	California Department of Water Resources (DWR)	Discharge	http://wdl.water.ca.gov/waterdatalibrary/
California Data Exchange Center (CDEC)	California DWR and U.S. Bureau of Reclamation	Discharge; Reservoir Conditions	http://cdec.water.ca.gov/cdecstation2/ https://www.usbr.gov/

Local Programs

Local monitoring programs in the Subbasin include:

- Colusa County Water District's Supervisory Control and Data Acquisition (SCADA) system, which is used to automate and measure incoming flows to the distribution system from canal side pumping facilities (2010 Water Management Plan [WMP]).
- Colusa County Water District's use of SonTek, McCrometer, and Venturi flow meter devices to measure and record inflows.
- GCID's diversion metering and publicly-available online reporting system, in compliance with SB 88 (https://www.gcid.net/sb88compliance).
- GCID's main canal SCADA and automation project (https://www.gcid.net/operations-main-canal).
- GCID's drain outflow monitoring project, with water measurement and telemetry equipment at key outflow sites (https://www.gcid.net/operations-drain-outflow).
- Orland-Artois Water District's (OAWD) distribution system metering and SCADA system (2020 WMP), including:
  - Metered inflows using Venturi meters and Doppler meters across five locations.
  - SCADA system used for monitoring and operating pumps.

- Orland Unit Water Users Association's (OUWUA) SCADA system, which has been expanded and enhanced in recent years to include more than 10 additional sites and additional outflow monitoring capabilities (2017 Agricultural Water Management Plan [AWMP]).
- OUWUA's use of Rubicon FlumeGates, SonTek acoustic Doppler meters, propeller meters, and McCrometer magnetic flow meters (among other) to measure and record deliveries (2017 WMP).
- OUWUA's records of grower deliveries in its water orders database (2017 WMP).
- Westside Water District's Tehama-Colusa Canal delivery monitoring system, including McCrometer propellers and SonTek meters installed at canal mileposts 71.46 through 90.00 (2010 WMP).
- RD108's SCADA system used to measure incoming flows.
- RD108's delivery measurement system and water accounting database.

Efficient Water Management Practices

Water conservation and water use efficiency are important considerations in achieving groundwater sustainability. Efficient water management practices (EWMPs), as defined in CWC §10902, include all reasonable and economically justifiable programs to improve the delivery and use of water used for agricultural purposes. Broad efforts to improve water use efficiency in areas across the Subbasin are identified in the General Plans of counties and cities that overlie the Subbasin.

For agricultural water suppliers that must develop, adopt, and implement AWMPs, CWC §10608.48 identifies key EWMPs that suppliers must implement, some without exception and some if locally cost-effective and technically feasible. Non-exempted agricultural water suppliers throughout the Subbasin have adopted and are currently implementing AWMPs. Information on specific activities, programs, and efforts to implement key EWMPs can be found in those AWMPs.

For CVP contractors that must develop, adopt, and implement WMPs, implementation of key Best Management Practices (BMPs) is also described throughout their WMPs. These BMPs generally align with EWMPs described in the AWMPs and are aimed at improving water use efficiency. CVP contractors throughout the Subbasin are actively implementing WMPs. Information on specific activities, programs, and efforts to implement key BMPs can be found in those WMPs.

Irrigated Lands Regulatory Program

The Central Valley Regional Water Quality Control Board (CVRWQB) has adopted waste discharge requirements (WDRs) for discharges from irrigated commercial croplands to protect both surface water and groundwater supplies. When land is in agricultural production it is generally irrigated and fertilized. It is assumed that portions of the soil amendments, particularly fertilizer, are converted to nitrate, which has the potential to percolate into the groundwater. The Irrigated Lands Regulatory Program (ILRP) regulates such discharges. Growers can manage the loading of nitrate to groundwater through the implementation of effective management practices. Commercial irrigated lands, including managed wetlands, are required to obtain regulatory coverage.

2.2.1.3 Groundwater Monitoring and Management Programs

Both Counties currently have wells included in California's Statewide Groundwater Elevation Monitoring Program (CASGEM) program. Glenn County also has a Basin Management Objective groundwater level monitoring well network. Colusa County's current groundwater monitoring network consists of wells

originally identified in its Groundwater Management Plan (GMP) but has since been revised. These and other existing groundwater monitoring programs are described in more detail in the following sections. Proposed new groundwater monitoring sites were evaluated based on existing sites from DWR and USGS groundwater monitoring networks, and recommendations from County staff.

Groundwater Level Monitoring

Table 2-5 lists existing groundwater level monitoring programs with publicly available data and their respective websites.

Table 2-5. Existing Groundwater Level Monitoring Programs

Groundwater Monitoring Network	Responsible Agency	Website
National Water Information System (NWIS)	U.S. Geological Survey (USGS)	https://waterdata.usgs.gov/nwis
Water Data Library (WDL)	California Department of Water Resources (DWR)	http://wdl.water.ca.gov/waterdatalibrary/
California's Statewide Groundwater Elevation Monitoring Program (CASGEM)	California DWR	https://www.casgem.water.ca.gov/ Note: site requires a username and password
County-Specific Groundwater Level Monitoring Programs	County of Colusa and County of Glenn	Colusa County: http://countyofcolusa.org/index.aspx?NID=660 Glenn County: http://www.countyofglenn.net/committee/water-advisory-committee/management-plan

Groundwater Extraction Monitoring

The replenishment of groundwater extractions occurs through various forms of recharge. The types and amounts of historical and current recharge are described in detail in Section 3.3 (Water Budget Information), and future estimates of recharge are discussed in Chapter 3 and detailed in Appendix 3D (Groundwater Model Documentation). Future replenishment of groundwater extractions that will occur with implementation of projects and management actions (PMAs) for this GSP are described in detail in Chapter 6.

Groundwater Quality Monitoring

Table 2-6 lists the groundwater quality monitoring networks with publicly available data and their respective websites.

Violations of drinking water quality regulations, which could impact access to clean drinking water and violate California Water Code Section 106.3, are included in the U.S. Environmental Protection Agency (USEPA) Safe Drinking Water Information System (SDWIS) website, which is listed in Table 2-6.

Table 2-6. Existing Groundwater Quality Monitoring Programs

Groundwater Monitoring Network	Responsible Agency	Website
National Water Information System (NWIS)	U.S. Geological Survey (USGS)	https://waterdata.usgs.gov/nwis
Water Data Library (WDL)	California Department of Water Resources (DWR)	http://wdl.water.ca.gov/waterdatalibrary/
Public Water Agencies and Municipalities	State Water Resources Control Board (SWRCB) Division of Drinking Water (DDW) and U.S. Environmental Protection Agency (USEPA)	https://data.ca.gov/dataset/drinking-water-public-water-system-information , https://sdwis.waterboards.ca.gov/PDWW/ , https://www.epa.gov/enviro/sdwis-search
GeoTracker and GeoTracker Groundwater Ambient Monitoring and Assessment (GAMA) Programs	SWRCB	http://geotracker.waterboards.ca.gov/ , http://geotracker.waterboards.ca.gov/gama/
Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS)	Central Valley Salinity Coalition	https://www.waterboards.ca.gov/centralvalley/water_issues/salinity/ [(a)]
Irrigated Lands Regulatory Program (ILRP)	Central Valley Regional Water Quality Control Board	https://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/ , Surface Water: http://ceden.waterboards.ca.gov/AdvancedQueryTool Groundwater: Not available online[(a, b)]
Glenn County Annual Water Quality Sampling Program	County of Glenn	http://www.countyofglenn.net/committee/water-advisory-committee/water-quality[(a)]

(a) Groundwater quality data are not available online. Groundwater quality monitoring data as part of these monitoring programs should be obtained directly from the responsible agencies.

(b) Some groundwater quality data collected under ILRP by the California Rice Commission and the Sacramento Valley Water Quality Coalition is available through the GeoTracker GAMA and USGS NWIS websites. The full groundwater quality dataset should be obtained directly from the responsible coalition.

Land Subsidence Monitoring

Table 2-7 lists the existing land subsidence monitoring networks and data sets with publicly available data, and their respective websites.

Table 2-7. Existing Land Subsidence Monitoring Programs

Subsidence Monitoring Network	Responsible Agency	Website
Interferometric Synthetic Aperture Radar (InSAR) Surveys[a]	European Space Agency; Japanese Space Exploration Agency; Italian Space Agency; Canadian Space Agency; German Aerospace Center; National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL)	http://www.esa.int/ESA , http://global.jaxa.jp/ , http://www.asi.it/en , http://www.asc-csa.gc.ca/eng/ , http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10002/ , https://data.cnra.ca.gov/dataset/nasa-jpl-insar-subsidence
Continuous Global Positioning System (GPS) Benchmarks	National Geodetic Survey; University NAVSTAR Consortium (UNAVCO); Berkeley Seismological Laboratory	https://www.ngs.noaa.gov/NGSDataExplorer/# , http://www.unavco.org/data/data.html , http://seismo.berkeley.edu/networks/index.html
Extensometers	California Department of Water Resources (DWR)	http://wdl.water.ca.gov/groundwater/landsubsidence/LSmonitoring.cfm
Sacramento Valley Height-Modernization Project	California DWR Northern District and U.S. Bureau of Reclamation	Not Available[b]

(a) The InSAR sources currently house unprocessed raw survey data but not interpretative reports for specific regions. Some of the reports using InSAR to study subsidence specific to California can be found on DWR's website

(b) Sacramento Valley Height-Modernization project data are not available online.

2.2.2 Impacts to Operational Flexibility

There are existing groundwater management and/or monitoring programs that may limit the operational flexibility during implementation of the GSP, including design criteria, flood control programs, measures that limit groundwater pumping, or limitations on surface water deliveries reducing surface water supplies available for conjunctive use programs. Ongoing coordination with the entities responsible for these programs will support operational flexibility. Ongoing coordination with the entities responsible for the surface water and groundwater monitoring programs described above will support GSP implementation.

2.2.3 Groundwater Ordinances

Colusa County Code, Chapter 43, Groundwater Management, provides guidance for groundwater transfers and groundwater substitution practices to assure the overall economy and environment of the County is protected by fostering prudent water management practices.

Glenn County Code Section 20.030, Groundwater Coordinated Resource Management Plan, provides guidance for the continued availability of groundwater by limiting the extraction of groundwater through groundwater monitoring, protecting groundwater quality, and minimizing land subsidence. In addition, Section 20.080 provides well drilling requirements prior to the drilling or abandonment of a well, and Exhibit C contains export water transfer guidelines.

2.2.4 Conjunctive Use Programs

Surface water and groundwater are used conjunctively throughout the Subbasin to meet water management objectives. Generally, within each agricultural water purveyor's service area, available surface water is used on a preferential basis to satisfy crop water requirements, with groundwater pumped by private landowners as needed to supplement available surface water supplies. The amount of groundwater pumped in any given year depends primarily on the crop water requirements (which vary by the crop types planted each year and weather conditions), and on the quantity of surface water available during that year.

For the agricultural water purveyors with highly reliable and adequate surface water supplies, including the SRSCs, private groundwater pumping is generally small compared to surface water use, except in years when their surface water supplies are reduced according to settlement contract terms, and in years when surface water is transferred (both within and outside the Subbasin), and groundwater is pumped to substitute for transferred surface water.

The CVP Water Service Contractors along the Tehama Colusa Canal have federal contracts that provide less reliable surface water supplies, which can vary from zero to 100 percent of their maximum contract quantities and is dependent on annual CVP water allocation decisions made by USBR. Consequently, groundwater pumping is highly variable depending on each year's water allocation and, to a lesser extent, variability in crop water demands.

Conjunctive use also occurs across purveyor boundaries involving transfers of temporarily available excess surface water from some agricultural water purveyors to others who desire to use more surface water to conserve groundwater supplies. In some years, surface water transfers occur from entities outside the Subbasin to Subbasin purveyors, also reducing the amount of groundwater pumping.

Colusa County Code, Chapter 43, Groundwater Management, encourages the conjunctive use of surface water and groundwater supplies.

2.3 LAND USE ELEMENTS OR TOPIC CATEGORIES OF APPLICABLE GENERAL PLANS

This section provides information on the general plans within the Subbasin.

2.3.1 Summary of General Plans/Other Land Use Plans

California Government Code (§65350-65362) requires that each county and city in the state develop and adopt a General Plan. The General Plan is a comprehensive long-term plan for the physical development of the county or city and must contain eight state-mandated elements including: land use, housing, circulation, conservation, noise, safety, open space, and environmental justice. The General Plan may also contain other voluntary elements.

General Plans and information from other land use planning activities were compiled for review and consideration during GSP preparation and for coordination during GSP implementation. This section includes a summary of those plans being implemented in the Subbasin.

Two counties and four cities share land use planning responsibilities and authorities for the Subbasin. These include:

- Colusa County
- Glenn County
- City of Colusa
- City of Williams
- City of Orland
- City of Willows

Most of the General Plans prepared by these entities contain goals, objectives, and policies relating to water supplies, water use, water quality, and water resources. Land use designations, assumptions on growth, preservation of agricultural lands, or protection of environmental resources are examples of land use planning that could result in changes in water use over the planning horizon.

As part of the GSP preparation, General Plans for Colusa and Glenn Counties and the cities of Colusa, Williams, Orland, and Willows were reviewed. City and County boundaries are shown in Figure 2-1.

There are no other land use plans applicable within the Subbasin.

2.3.1.1 Colusa County General Plan

In July 2012, Colusa County adopted its 2012 Comprehensive General Plan Update (Colusa County, 2012). The General Plan area covers the entire County, which overlies the Colusa County portion of the Subbasin, as shown in Figure 2-1. Although the protection of natural resources in the County is addressed throughout the General Plan, key goals with respect to water resources are contained in the Agriculture Element and Conservation Element. Table 1 of Appendix 2A identifies the selected Colusa County General Plan Goals and Policies applicable to water resources management.

2.3.1.2 Glenn County General Plan

Glenn County's current General Plan was last updated in 1993, and thus is undergoing a comprehensive update. It is anticipated that the General Plan Update will take place from 2019 through the fall of 2021. The General Plan area covers the entire County, which overlies the Glenn County portion of the Subbasin, as shown in Figure 2-2. The General Plan goals, policies, and implementation presented in Table 2 of Appendix 2A are from the 1993 General Plan and are divided into three subject areas: Natural Resources, Public Safety, and Community Development. Table 2 of Appendix 2A identifies the selected Glenn County General Plan Goals, Policies, and Implementation measures applicable to water resources management.

2.3.1.3 City of Colusa General Plan

In October 2007, the City of Colusa adopted its 2005-2025 General Plan Update (City of Colusa, 2007). The General Plan area covers the City of Colusa, which is located adjacent to the Sacramento River in the eastern portion of Colusa County within the Subbasin, as shown in Figure 2-1. Although the protection of natural resources in the City is addressed throughout the General Plan, key goals with respect to water resources are contained in Land Use Element; Community Character and Design Element; Safety Element; the Parks, Recreation and Resource Conservation Element, of which includes water resources; and Municipal Facilities Element. Table 3 of Appendix 2A identifies the selected City of Colusa General Plan Goals, Policies, and Implementation Actions applicable to water resources management.

2.3.1.4 City of Williams General Plan

In May 2012, the City of Williams adopted its 2010 General Plan Update (City of Williams, 2010). The General Plan area covers the City of Williams, which is located in the central portion of Colusa County within the Subbasin, as shown in Figure 2-1. Key goals with respect to water resources are contained throughout the General Plan Elements. Table 4 of Appendix 2A identifies the selected City of Williams General Plan Goals and Policies applicable to water resources management.

2.3.1.5 City of Orland General Plan

The City of Orland is located in the northeast portion of Glenn County within the Subbasin, as shown in Figure 2-1. In 2003, the City of Orland updated its General Plan through a comprehensive review of all elements. Previous to that, minor revisions to the General Plan had been made in 2000, with the original adoption of the Plan in 1974. The 2008-2028 General Plan Update revises the 2003 General Plan, in order to reflect upon changing conditions and issues, and to provide a direction for the future growth of the City. The Orland General Plan is a comprehensive document that provides policies and guidelines for the future expansion and development of the community. The City addresses key goals and policies with respect to water resources within in Safety Element and Open Space, Conservation and Public Facilities Element. Table 5 of Appendix 2A identifies the selected City of Orland General Plan Goals, Policies, and Programs applicable to water resources management.

2.3.1.6 City of Willows

The City of Willows is located in the southern portion of Glenn County within the Subbasin, as shown in Figure 2-1. The City of Willows General Plan was adopted in 1999, with land use amendments made in 2000 and 2010. The Willows General Plan provides policies and guidelines for the future expansion and development of the community. The City addresses key goals and policies with respect to water resources. Table 6 of Appendix 2A identifies the selected City of Willows General Plan Goals, Policies, and Programs applicable to water resources management.

2.3.2 Implementation Effects on Water Demands and Sustainability

All six of the county and city General Plans in the Subbasin were adopted prior to the development of the GSAs and this GSP. Consequently, these General Plans have not directly considered the potential implications or impacts of this GSP's implementation on urban water demands or supplies within these jurisdictions. It should be noted that Glenn County is currently preparing a comprehensive General Plan Update and may take into consideration sustainable water actions identified in this GSP.

Each of the General Plan's land use elements and land use plans forecast future land development and make assumptions for future urban and agricultural water demands.

Typically, unincorporated communities depend on community water systems that may rely on either surface or groundwater, or both. Rural residential land uses not part of a community system typically rely on individual groundwater wells. Developed urban land uses, such as that within cities, typically rely on groundwater supplies accessed by municipal wells. Therefore, when cities grow or rural densities increase, generally surface water use decreases and groundwater demand increases. The GSP incorporates actions that encourage land use agencies to participate in efforts to increase groundwater recharge to offset increased water demands. Depending on changing future conditions in the Subbasin, the GSP also incorporates potential demand management actions that could be implemented, if needed, to offset water demands and support groundwater sustainability (see Section 6.5.2).

2.3.2.1 Effects on Colusa County Water Demands

Several goals and policies of the Colusa County General Plan work to balance agricultural land uses with preserving and protecting waters, soils, and natural resources necessary to ensure agricultural operations. Policies support water development projects that provide additional sources of water for agricultural use, yet also encourage the preservation of water resources. In addition, the General Plan requires that new residential development connect to municipal water systems and requires development to demonstrate sufficient water supplies are available. The General Plan encourages conservation of water resources including the conservation of biological communities that protect wetlands, riparian habitat, and aquatic resources and thus contribute to the protection of groundwater resources and water quality. The General Plan includes goals and policies that work to ensure a sustainable and long-term supply of reliable water to meet the needs of residents, businesses, and agricultural land uses. Land use policies provide for the harmonious use of land and the preservation of the County's resources, including water. Lastly, the General Plan encourages local, regional, and state multi-agency planning efforts as well as coordination with water providers to manage water supplies and avoids groundwater overdraft, water quality degradation and other adverse environmental impacts. Refer to Appendix 2A for selected Colusa County General Plan Goals and Policies.

GSP implementation is anticipated to be consistent with the Colusa County General Plan's goals to balance agricultural land uses with the preservation and protection of water resources necessary to ensure agricultural operations. The GSP supports these policies by identifying and considering PMAs that work to reduce groundwater extraction, promote groundwater recharge, and utilize additional surface water for irrigation. Although implementation of the GSP would alter the source of water for irrigation to promote groundwater sustainability, it does not alter water demands.

2.3.2.2 Effects on Glenn County Water Demands

The Glenn County General Plan is undergoing a comprehensive update. However, the existing General Plan does address the protection of water resources in connection with the preservation of agricultural lands and the recognition of the value of agricultural land uses, particularly ricelands for habitat, watershed management, and groundwater recharge. General Plan policies oppose the exportation of groundwater, protect groundwater recharge areas and groundwater quality, encourages water conservation and education, promotes interagency coordination. The General Plan also addresses wetlands, aquatic resources, and riparian habitat protection in conjunction with supporting efforts to improve water availability for agricultural users. Water quality policies include the protection of groundwater to ensure that the holding capacity of the area is not exceeded. The General Plan address coordination between the County and water purveyors including creating uniform policies and standards for providing cost-effective water services, particularly in unincorporated areas located within city urban limits.

Refer to Appendix 2A for selected Glenn County General Plan Goals and Policies applicable to water demand.

GSP implementation is anticipated to be consistent with the Glenn County General Plan's goals to protect water resources and aquatic resource habitat in connection with the preservation of agricultural land uses. The GSP supports these policies by identifying and considering PMAs that reduce groundwater extraction and focuses on using surface water for agricultural irrigation and groundwater recharge. Although implementation of the GSP would alter the source of water for irrigation to promote groundwater sustainability, it does not alter water demands.

2.3.2.3 Effects on City of Colusa Water Demands

The City of Colusa's General Plan Goals and Policies provide for a logical land use planning process that includes adequate management of public services, including water supply. As part of the implementation of the General Plan the City has prepared water and storm drainage master plans to address water quality, supply, recycling, distribution, and water conservation. The General Plan also works to ensure that new development respects the natural environment, protects the City's water resources, and minimizes the development of new water sources and facilities while providing water services. Refer to Appendix 2A for selected City of Colusa General Plan Goals and Policies applicable to water demand and management.

GSP implementation focuses on the protection of groundwater resources and identifies and considers PMAs that focus on surface water use for agricultural irrigation and groundwater recharge. Implementation of the GSP would not conflict with the City's water supply, service, and conservation goals nor would it alter water demands.

2.3.2.4 Effects on City of Williams Water Demands

The City of Williams General Plan identifies policies that pertain to water supply and associated demand in the land use and character, public safety and facilities as well as open space and conservation elements. New development in the City requires that adequate public services, including water supply, is available. In addition, although not specifically related to water demand, the preservation of water related resources, including wetlands, riparian areas, and other aquatic habitats provides for improved water quality of water supply sources, including groundwater. Implementing actions identify the need for groundwater protection measures in subdivisions as well as developing water efficient landscaping standards for new development. Refer to Appendix 2A for selected City of Williams General Plan Goals, Policies, and Implementing Actions that address water demand and management.

GSP implementation focuses on the protection of groundwater resources and identifies and considers PMAs that focus on surface water use for agricultural irrigation and groundwater recharge. Implementation of the GSP would not conflict with the City's water quality, aquatic resources, and water conservation goals nor would it alter water demands.

2.3.2.5 Effects on City of Orland Water Demands

The City of Orland General Plan Safety Element policies address the potential for subsidence associated with groundwater extraction. Goals include the conservation, enhancement, and management of water resources to protect water quality and ensure adequate long-term supply for domestic, agricultural, and industrial land uses. Policies support maintaining groundwater infiltration, improving groundwater quality, and encourages water conservation. Refer to Appendix 2A for selected City of Orland General Plan Goals and Policies applicable to water demand and supply.

GSP implementation focuses on the protection of groundwater resources and identifies and considers PMAs that focus on surface water use for agricultural irrigation and groundwater recharge. Implementation of the GSP would not conflict with the City's water quality, subsidence, and water conservation goals nor would it alter water demands.

2.3.2.6 Effects on City of Willows Water Demands

The City of Willows General Plan Land Use Element addresses new growth and the desire to maintain flexibility to changing conditions. Goals include the provision of adequate services, including water. Refer to Appendix 2A for selected City of Willows General Plan goals, objectives, and policies. It is anticipated that implementation of the GSP and the PMA addressing urban water conservation for the City of Willows would reduce water demands and thereby reduce groundwater extraction thereby promoting groundwater sustainability.

2.3.3 Effects of Land Use Plans Outside Subbasin

Outside the Subbasin, other land use plans have been developed as part of the general plans for Tehama County to the north, Butte and Sutter Counties to the east, and Yolo County to the south. These general plans are similar in scope to the Colusa and Glenn County General Plans described above in that they each contain goals, policies, and implementing actions that address water supply, water quality, conservation, enhancement, and management of water resources for a variety of land uses. In addition, the subbasins surrounding the Subbasin, which include Corning Subbasin to the north; Vina, Butte, and Sutter Subbasins to the east; and Yolo Subbasin to the south, have been identified as either high or medium priority and are also required to prepare and be managed under a GSP by January 31, 2022. As such, future land use changes in the jurisdictions within these subbasins will also need to be managed to achieve sustainability. As long as these subbasins are managed to achieve sustainability, each jurisdictions' General Plan and corresponding land use plan are not expected to affect the ability of the Subbasin GSAs to achieve sustainable groundwater management.

2.4 GSP IMPLEMENTATION EFFECTS ON WATER SUPPLY ASSUMPTIONS

Implementation of the GSP will require the Subbasin to operate sustainably by 2042. The GSP includes PMAs that focus on balancing groundwater pumping with expanded surface water use and groundwater recharge. Implementation of GSP PMAs generally alter the source of water supplies (i.e., using surface water to supplement groundwater supplies); however, planned PMAs do not reduce the supplies necessary to meet the water demands of the various land uses within the Subbasin.

2.5 SUMMARY OF PERMITTING PROCESS FOR WELLS IN COLUSA SUBBASIN

The GSAs in the Subbasin will seek to work with Colusa and Glenn Counties to align future well permitting with the Subbasin's sustainability goal established under this GSP. Also, in alignment with the findings of California's Third Appellate District, the GSAs will work with their respective counties to address the need to prevent impact on public trust values in surface water from new wells, depending on how this issue evolves in the State.

2.5.1 Human Right to Water

The State recognizes the Human Right to Water pursuant to California Water Code Section 106.3, which states, "*every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes*." The human right to water extends to all Californians, including disadvantaged individuals and groups and communities in rural and urban areas (SWRCB, 2021). The GSAs will seek to work with their respective counties, SWRCB staff and stakeholders in support of SWRCB's efforts, "*to develop new systems or enhance existing systems to collect data and identify and track communities that do not have, or are at risk of not having, safe, clean, affordable, and accessible water for drinking, cooking, and sanitary purposes*" (SWRCB, 2021). These efforts may have a nexus with well permitting by Colusa and Glenn Counties.

The CGA and GGA are committed to working cooperatively to achieve the core values in California Water Code Section 106.3. Private groundwater pumper representation within the GSAs and community engagement via public workshops and outreach are venues through which those potentially most vulnerable to loss of clean drinking water are able to share information and concerns throughout the GSP development and implementation process. During preparation of this GSP, public meetings were held at times, places and in a manner that supported and allowed for effective engagement of all stakeholders.

2.5.2 Colusa County

Within Colusa County, including the Subbasin, the Colusa County Environmental Health Division is entrusted with all permitting and enforcement for the construction, reconstruction, and destruction of wells. Wells under their oversight include agricultural/irrigation wells, observation/monitoring wells, exploratory/boring wells, and domestic water supply wells.

In order to provide minimum standards for the proper regulation of well drilling and abandonment, Colusa County has adopted the State of California, DWR Bulletin 74-81 and 74-90 water and well standards. In addition, the County provides guidance for the construction or destruction of wells, including well location to protect from pollution or contamination, well casing requirements, and minimum depths of annular seal for various well types.

The application process for Water Well Permits is handled online through the Colusa County Permits Online website: https://www.countyofcolusa.org/725/Water-Wells. This site provides the information necessary to apply and provides a link to submit an application online.

2.5.3 Glenn County

Within Glenn County, including the Subbasin, the Glenn County Environmental Health Department is responsible for all permitting and enforcement for the construction, reconstruction, destruction, and renewals of wells.

Glenn County Code (GCC), Title 20, Chapter 80 - Water Well Drilling Permits and Standards, details the well drilling requirements necessary for the protection of groundwater within the County. A permit is required for any type of well for the extraction of groundwater. An application is required to be submitted for review and approval. Permits to construct expire one year after issuance. In order to provide minimum standards for the proper regulation of well drilling and abandonment, Glenn County has adopted the State of California, DWR Bulletin 74-81 and 74-90 water and well standards. In addition to DWR standards, the County has established standards for annular well seals and well casings (GCC Section 20.080.060). In addition, an inspection is required before grouting occurs and a drilling log is to be submitted to the building inspector. Permits can be revoked if a violation to the County Code has been determined.

Information and fees associated with the well permit process can be found online at:

https://www.countyofglenn.net/dept/planning-community-development-services/environmental-health/eh-resources .

2.5.4 Wellhead Protection

Wellhead protection refers to both the immediate location of the well in terms of well and pump station design features (e.g., well pad, annual seal) and the broader area surrounding the well. Both Colusa and Glenn Counties establish annular seals and other design requirements as part of well design standards.

2.6 ADDITIONAL GSP ELEMENTS

SGMA requires that the following topics are addressed in the GSP. See below for references to where each topic is addressed.

- **Control of seawater water intrusion:** See Chapter 3, Section 3.2.4 for an explanation of why the seawater intrusion sustainability indicator does not apply to the Subbasin.
- **Migration of contaminated groundwater:** Migration of contaminated groundwater is discussed in Chapter 4, Section 4.2.
- **Replenishment of groundwater extractions:** Recharge projects are discussed in Chapter 6.
- **Activities implementing, opportunities for, and removing impediments to, conjunctive use or underground storage:** Projects and management actions are discussed in Chapter 6.
- **Well construction policies:** Well construction policies are contained in Section 2.5.
- **Measures addressing groundwater contamination cleanup, groundwater recharge, in-lieu use, diversions to storage, conservation, water recycling, conveyance, and extraction projects:** Projects and management actions are discussed in Chapter 6.
- **Efficient water management practices, as defined in CWC §10902, for the delivery of water and water conservation methods to improve the efficiency of water use:** Details on efficient water management practices are discussed in Section 2.2.1.

- **Efforts to develop relationships with state and federal regulatory agencies:** Details on this topic can be found in Section 2.7.
- **Processes to review land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity:** Details on this topic can be found in Section 2.3.
- **Impacts on GDEs:** GDEs are discussed in Chapter 3, Chapter 4, and Chapter 5.

2.7 NOTICE AND COMMUNICATION

This section documents public notice and communication of GSP activities.

2.7.1 Overview

SGMA requires broad and diverse stakeholder involvement in GSA activities and the development and implementation of the Colusa Subbasin GSP. The intent of SGMA is to ensure successful, sustainable management of groundwater resources at the local level. Success requires engagement by beneficial users (defined below). Engagement is far more likely when beneficial users receive consistent messaging of information and are provided opportunities to shape the path forward as it relates to SGMA.

Section 354.10. (Notice and Communication) of the GSP Regulations states the following requirements:

> *Each Plan shall include a summary of information relating to notification and communication by the Agency with other agencies and interested parties including the following:*
>
> *(a) A description of the beneficial uses and users of groundwater in the basin, including the land uses and property interests potentially affected by the use of groundwater in the basin, the types of parties representing those interests, and the nature of consultation with those parties.*
>
> *(b) A list of public meetings at which the Plan was discussed or considered by the Agency.*
>
> *(c) Comments regarding the Plan received by the Agency and a summary of any responses by the Agency.*
>
> *(d) A communication section of the Plan that includes the following:*
>
> *(1) An explanation of the Agency's decision-making process.*
>
> *(2) Identification of opportunities for public engagement and a discussion of how public input and response will be used.*
>
> *(3) A description of how the Agency encourages the active involvement of diverse social, cultural, and economic elements of the population within the basin.*
>
> *(4) The method the Agency shall follow to inform the public about progress implementing the Plan, including the status of projects and actions. The following addresses these requirements.*

To guide and facilitate beneficial user engagement in the GSP process, a Communication and Engagement Plan (C&E Plan) was created by the GSAs in the Subbasin to:

- Provide the GSAs and beneficial users guidance to ensure consistent messaging of SGMA requirements and related Subbasin data and information,
- Provide a roadmap to the GSAs and beneficial users to ensure everyone has an opportunity for meaningful input into GSA decision-making, including GSP development,
- Describe processes that are experienced by beneficial users as fair and respectful to the diverse range of interests in the Subbasin,
- Make transparent to beneficial users, their opportunities to contribute to the development of a GSP, and
- Ensure that information reaches all beneficial users who have an interest in the Subbasin.

Like many components of this GSP, the C&E Plan has and will periodically be updated throughout GSP development and SGMA implementation. Said updates will reflect changing conditions in the subbasin and responses by the GSAs to address these changes and to ensure effective outreach and communication take place with beneficial users. These updates reflect the role of the C&E Plan as a "living document" that provides a compilation and repository of various engagement activities implemented or planned to be implemented by the GSAs.

The above C&E Plan topics are discussed in the subsections below. Supporting information and record-keeping files are included in the appendices and/or on the respective websites of the Subbasin GSAs (described below):

- Appendix 2B: Comment tracking, copies of received comments, and responses to comments regarding project management actions, draft GSP chapters, and general inquiries
- Appendix 2C: Coordination meeting and outreach contact distribution lists
- Appendix 2D: Engagement and media materials for interbasin coordination meetings, information workshops, public meetings and hearings, SGMA workshops, public events, and Subbasin branding
- Appendix 2E: Communication and Engagement Plan

2.7.1.1 COVID-19 Global Pandemic

In March 2020, the COVID-19 global pandemic necessitated changes in all aspects of California society including public gatherings and the rules defining how public agencies conduct events. Several Executive Orders were issued by Governor Newsom to address necessary changes in the Ralph M. Brown Act (Government Code § 54950-54963) (Brown Act) which dictates the rules and manner in which local public agencies notice and conduct their sponsored meetings and ensures public transparency of, and accessibility to, almost all aspects of said gatherings. Under statewide "shelter-in-place" (SIP) mandates, all public gatherings were prohibited by the State government. These changes required that between March 13, 2020, and continuing to May 25, 2021, all meetings individually and jointly convened by the GSAs were conducted through web-based, virtual meeting and telephone-based methods, consistent with protocols allowable through the COVID-related Executive Orders. The CGA and GGA resumed in-person Board meetings on May 25 and July 12 (respectively) with an accommodation for conference call participants.

The following sections describe actions and events employed to ensure that GSA meetings and GSP development were conducted with the required level of transparency and accessibility. Activities and events that took place prior to March 2020 SIP mandates were conducted in person and virtually thereafter. Despite the June 15, 2021 "Reopening" of California, the GSAs chose to retain virtual meeting methods for TAC meetings and some public engagement events. Other events were and are expected to be conducted in person (described below). Lastly, the following sections also note additional steps taken by the GSAs during the COVID-19 pandemic to modify public engagement and information and ensure that beneficial users remained fully informed of GSA efforts and GSP content. Input received by the GSAs during outreach events or via email correspondence, as well as comments received on the draft GSP are tabulated in Appendix 2B.

2.7.1.2 Description of Beneficial Uses and Users in the Basin

Under the requirements of SGMA, all beneficial uses and users of groundwater must be considered in the development of GSPs, and GSAs must encourage "*the active involvement of diverse social, cultural, and economic elements of the population."* As defined in SGMA (CWC §10723.2), "*the GSA shall consider the interests of all beneficial uses and users of groundwater, as well as those responsible for implementing groundwater sustainability plans. These interests include, but are not limited to, all of the following:*

(a) Holders of overlying ground water rights, including:
(1) Agricultural users.
(2) Domestic well owners.
(b) Municipal well operators.
(c) Public water systems.
(d) Local land use planning agencies.
(e) Environmental users of groundwater.
(f) Surface water users, if there is a hydrologic connection between surface and groundwater bodies.
(g) The federal government, including, but not limited to, the military and managers of federal lands.
(h) California Native American Tribes.
(i) Disadvantaged communities (DAC), including, but not limited to, those served by private domestic wells or small community water systems.
(j) Entities listed in Section 10927 that are monitoring and reporting ground water elevations in all or a part of a groundwater basin managed by the groundwater sustainability agency."

In this context, the GSAs have approached SGMA engagement as needing to include any stakeholders who have an interest in groundwater use and management in the Subbasin. Their interest may be related to GSA activities, GSP development and implementation, and/or water access and management in general. To assist identifying categories of beneficial uses and users in the Subbasin, the C&E Plan included a Stakeholder Engagement Chart for GSP Development (Table 2-8 and Appendix 2E) (consistent with guidance promulgated by DWR). To facilitate regular communication with said stakeholders, the GSAs have maintained and continually updated, distribution lists of GSA-specific Beneficial Users (also known as Interested Parties Lists). These lists are presented in Appendix 2C and described below in Section 2.7.3.1.

Table 2-8. Stakeholder Engagement Chart for GSP Development

Category of Interest	Examples of Stakeholder Groups	Engagement Purpose
General Public	• Citizens groups • Community leaders • Interested individuals • Universities/Academia	Inform to improve public awareness of sustainable groundwater management
Land Use	• Municipalities • Local land use agencies • Regional land use agencies • Community Service Districts	Consult and involve to ensure land use policies are supporting GSPs and there are no conflicting policies between the GSAs / GSP and said local government agencies
Private Users	• Private pumpers (domestic and agricultural) • Schools and colleges • Hospitals	Inform and involve in assessing impacts to groundwater users
Urban/ Agricultural Users	• Water agencies • Irrigation districts • Municipal water companies • Mutual water companies • Resource conservation districts • Farmers/Farm Bureaus • Water Districts • Water user associations • Irrigated Lands Regulatory Program Coalition	Collaborate to ensure sustainable management of groundwater
Industrial Users	• Commercial and industrial self-suppliers • Local trade associations or groups	Inform and involve in assessing impacts to users
Environmental and Ecosystem Uses	• Federal and State agencies • Wetland managers • Environmental groups	Inform and involve to consider / incorporate potential ecosystem impacts to GSP process
Surface Water Users	• Irrigation Districts • Water Districts • Water user associations • Agricultural users	Inform and involve to collaborate to ensure sustainable water supplies
Economic Development	• Chambers of commerce • Business groups/associations • Elected officials • State Assembly members • State Senators • Economic Development Team	Inform and involve to support a stable economy
Human Right to Water	• Disadvantaged communities • Small water systems • Environmental justice groups/community-based organizations • De minimis well owners	Inform and involve to provide safe and secure groundwater supplies to all communities reliant on groundwater
Tribes	• Federally Recognized Tribes: — Cachil Dehe Band of Wintun Indians — Kletsel Dehe Wintun Nation (Cortina Rancheria) • Non-Federally Recognized Tribes	Inform, involve and consult with tribal government
Federal Lands	• U.S. Fish and Wildlife Service • U.S. Bureau of Reclamation • U.S. Army Corps of Engineers	Inform, involve and collaborate to ensure basin sustainability
Integrated Water Management	• Regional water management groups (IRWM regions) • Flood agencies	Inform, involve and collaborate to improve regional sustainability

2.7.1.3 Decision-Making Processes

As noted above, SGMA is implemented in the Subbasin by the CGA and GGA. The GSAs have jointly developed this GSP and as such, the respective Boards are the final decision-makers for GSP content. To ensure effective governance of the GSP process including robust technical analysis and discussions, and associated public engagement, the GSAs convened a TAC and an Executive Committee for each GSA. The GSAs are legal public agencies, formed as Joint Powers Authorities through the execution of Joint Powers Agreements consistent with the Joint Exercise of Powers Act, as codified in California Government Code Section 6500. The Boards, in concert with the TACs and Executive Committees, create the primary structure for governance, information exchange, and decision making for each GSA. From the inception of each GSA, all meetings of all entities within their jurisdictional purview have been conducted with an effort to be inclusive to all stakeholders. All meetings requiring Brown Act compliance were conducted in such a manner, with appropriate public noticing of meeting agendas, associated meeting materials and subsequent availability of meeting summaries. All such materials are and have been available at the respective CGA and GGA websites:

- Colusa Groundwater Authority website: https://colusagroundwater.org/
- Glenn Groundwater Authority website: https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority

Prior to and after necessary adjustment in public engagement due to COVID, the TACs have played a particularly key role to ensure public disclosure of all technical information, public discussion of technical factors, and transparent development of technical recommendations that have then been delivered to the respective Boards for their consideration and decision making. The TACs have met in approximately monthly joint sessions. They include members of each GSA Board and other advisory representatives appointed by each Board and who deliberate on technical topics.

Regarding decision-making procedures by the Boards, to ensure compliance with GSP regulations regarding "…*opportunities for public engagement and…how public input and response will be used*" (and additive to Brown Act requirements) the GSAs have adopted a comprehensive tabular GSP comment tracking system as part of the GSP Administrative Record to continually record beneficial user input and to regularly update the respective Boards on said input. Appendix 2B presents the comment tracking system (including GSP development comments and responses). The comment tracking system is updated on a regular basis by facilitation staff and is then included in the agenda packet for each GSA Board meeting. General input comments have been tracked since 2019, and comments on the draft GSP have been tracked since draft chapters were released beginning in spring 2021. The agenda for each Board meeting includes a specific item calling attention to the updated comment tables and allowing time for each Board to make inquiry about and discuss any comments received. Prior to key GSP decision milestones, each Board agenda defines said decision as a formal action which could include discussion by each Board about associated public input recorded in the comments tables that might inform their decision-making. Further, consistent with and expanding on Brown Act requirements, each Board and TAC meeting includes the following periods of public comment on their respective agendas:

- Introductory public comment period at the beginning of the meeting for topics not included in the current agenda
- Public comment periods for each agenda item
- Public comment periods to be held prior to any formal action taken by the Board and/or TAC

2.7.2 Engagement Opportunities

2.7.2.1 Public Engagement Opportunities

Prior to formation of the legal GSAs (2015 through June 2017), and thereafter through October 2021, the parties that make up the CGA and GGA have collectively sponsored, publicized and conducted 242 separate meetings including:

- 40 Pre-Agency Formation SGMA governance meetings,
- 181 GSA meetings (Boards, Committees, Subcommittees and Joint Meetings), and
- 21 public meetings and workshops.[2]

Prior to the respective GSA's being formed as legal public agencies, interested parties and organizations already noticed to the State as intending to form individual GSAs began meeting in the respective counties of Colusa and Glenn. These meetings were funded by DWR's Facilitation Support Services (FSS) program in an effort to support GSA formation. Respectively titled the Colusa GSA Work Group and the Glenn Governance Work Group, all meetings of these groups were publicly noticed and associated information was posted on the websites of the respective counties' websites. In total, the Colusa GSA Work Group met 25 times (including full Work Groups and topic specific subcommittees) between January 2016 and June 2017 (at which point the legal GSA was formed as per statute). Similarly, the Glenn Governance Work Group met 15 times between April 2016 and June 2017 when their work similarly culminated in the formation of the legal GSA as per statute.

Following the formation of the CGA and GGA as legal public agencies, there have been collectively 196 more meetings at which the public has had the opportunity to engage prior to and during the GSP development process.

As referenced above, for all GSA meetings (full and joint Board meetings, Committee and Subcommittee meetings) requiring compliance with the Brown Act, agendas are posted no less than 72 hours before a meeting and all materials presented in said meetings are made accessible for the public to access through either of the respective GSA's websites or through hard copies available at the respective GSA's administrative offices.

For meetings not required to be compliant with the Brown Act, presentation materials and event agendas were posted on the respective GSA websites either before or at the latest, immediately after each event. Once the GSAs had jointly established a social media presence (fall 2020), all public outreach meetings were similarly publicized through Facebook and Twitter. This included TAC, Board, and Executive Committee meetings as well as SGMA Series and other public events.

All meetings described below as "Public Meetings and Workshops" were noticed to the standing lists of media organizations and outreach partners (Appendix 2C), with press releases and associated requests for said organizations to publicize said events through public notices, feature articles, newsletters, email listservs, and similar. The following provides a general description of the engagement venues provided by

[2] "Public meetings" are open to the public and allow comments and feedback from the public, but are not exclusively held for that purpose (e.g., Board meetings, TAC meetings). "Public workshops" and "public outreach meetings" are open to the public and are primarily designed to engage with the public and stakeholders to solicit their opinions and feedback.

the GSAs. Appendix 2D presents background outreach materials for most of the events described below (if said materials are not already accessible through the respective GSA websites):

- **Individual GSA Meetings**: Each GSA in the Subbasin held regular, publicly-noticed, publicly accessible meetings, generally on a monthly schedule. From legal inception to date and as consistently compliant with the Brown Act:
  - The CGA has held 43 GSA Board Meetings.
    - The CGA has also held 9 Long-Term Funding Committee Meetings.
  - The GGA has held 54 GSA Board Meetings.
- **GSA Executive Committee Meetings**: Consistent with their respective by-laws, each GSA formed and then regularly convened an Executive Committee to address high-level administrative decisions. To date and as consistently compliant with the Brown Act:
  - The CGA has held 10 Executive Committee Meetings.
  - The GGA has held 36 Executive Committee Meetings.
  - The CGA and GGA have held 4 joint Executive Committee Meetings.
- **Joint GSA meetings:** The GSAs convened 4 times for publicly-noticed, publicly accessible joint meetings. The intent of the joint GSA meetings was to provide a forum for representatives from each GSA to share perspectives and information about GSP development and SGMA implementation, and near the end of the GSP development process, to ensure shared expectations and approvals of the GSP.
- **Inter-basin SGMA Coordination Meetings:** On a regular basis, inter-basin meetings of representatives from the Colusa Subbasin met with representatives from the adjacent Corning, Butte, Sutter and Yolo Subbasins (and other non-adjacent subbasin representatives) to discuss interconnected groundwater conditions, potential impacts and other factors related to groundwater management across the larger Sacramento Valley Basin.
- **GSA-specific and Joint Technical Advisory Committee Meetings:** As previously described, GSA-specific TACs were formed to review technical content, work with the technical consultant team and advise their respective GSA Boards on GSP development. The TACs generally met on a monthly basis and always in publicly-noticed, publicly accessible meetings.
  - The CGA and GGA have held 19 Joint TAC Meetings.
  - The CGA has held 1 GSA-Specific TAC Meeting.
  - The GGA has held 1 GSA-Specific TAC Meeting.
- **GSA Formation Working Group Meetings:** As described above, in the initial stages of GSA formation, close to 40 separate, eligible GSA organizations noticed the DWR of their intent to form separate GSAs. Using funding provided through DWR's FSS program, all said parties convened into two Subbasin Working Groups which convened every 4 to 8 weeks for close to two years to negotiate mutual governance agreements that became the basis for the two JPAs to be formed as the respective CGA and GGA. The meetings took place in person; always as publicly-noticed and publicly accessible events held in Colusa and Willows, California.

- **Public Meetings and Workshops**: In 2015, three initial meetings were held to discuss general SGMA information and were co-sponsored by the Glenn County Water Advisory Committee, the Glenn County Farm Bureau, and the University of California Cooperative Extension. In January 2016 (including in advance of the CGA and GGA being legally formed), Subbasin representatives started public events to inform beneficial users about SGMA.
  - **General Education / Information: January and March 2016** - A series of 2 kickoff public meetings were held respectively at the Colusa County Fairgrounds and Orland Memorial Hall to describe SGMA requirements and background, early governance and implementation steps, anticipated methods for public engagement and to provide an opportunity for public question and answer sessions with a panel of eligible GSA leaders actively involved in the governance development process.
  - **GSA Financing – Proposition 218 Public Information Meetings: January and April 2019 -** In support of the respective GSA's efforts to establish long range funding, 4 public information meetings were held respectively at the Colusa Indian Community Events, the Glenn Success Square Conference Center, the City of Willows City Council Chambers and the Ord Bend Community Hall. The meetings included background about SGMA implementation and compliance, presentations about Proposition 218, discussion of associated financing options and requirements, and opportunities for questions and answers.
  - **GSA Financing – Proposition 218 Public Ballot Hearings: June and July 2019** - In support of the respective GSA's efforts to establish long range funding, 2 final Proposition 218 ballot hearings were held respectively at the Colusa Industrial Properties and the City of Willows Council Chambers. Meetings were held as formal GSA Board meetings with an allowance for public feedback on the ballot process, followed by a formal counting of submitted ballots and a final determination of election outcomes.
  - **SGMA General Information, Basin Setting and Sustainable Management Criteria Workshops: 2019** - The GSAs sponsored a series of public workshops in 2019. Two GSA-specific events were held respectively at the Colusa Veterans of Foreign Wars Hall and the Glenn Success Square Conference Center. The purpose of each workshop was to provide an update on Basin Setting conditions, Subbasin Water Budget, modelling efforts, conduct small group exercises about potential significant and unreasonable conditions associated with sustainability indicators, and to conduct question and answer sessions. Individual and small group worksheets were prepared by workshop participants providing collective beneficial user input to the GSAs about potential groundwater sustainability problem areas in the Subbasin.
    - **Town Hall Meetings 2019:** The CGA in partnership with the Colusa County Groundwater Commission sponsored 3 locally focused Town Hall meetings in March 2019 to informally update them on GSA and GSP status and how they could participate. Appendix 2D-4 included example materials from these meetings. These meetings were focused respectively on the following communities:
      - Arbuckle / Williams / College City
      - Colusa / Princeton / Grimes
      - Maxwell / Williams

- **SGMA Series** – Beginning in February 2020 and extending in virtual and then virtual and in-person formats through October 2021, the GSAs sponsored a series of 8 paired public meetings (one in daytime / one in evening). These meetings focused on the following:
  - **February 2020** – On-Farm, Groundwater Recharge Workshop (co-sponsored with The Nature Conservancy)
  - **December 2020** – (2 workshops) Status of Basin Setting conditions, education on Sustainable management Criteria terms, requirements and processes; Projects and Management Actions terms and next steps
  - **January 2021** – Well Monitoring Program Public Workshop to inform the public about and solicit applicants for the program
  - **July 2021** – (2 workshops) Current and Historical Groundwater Conditions, Historical, Current, and Projected Water Budgets, Draft Sustainability Goal, Draft Significant and Unreasonable Conditions
  - **October 2021** – (2 workshops) Public Draft GSP Review and Public Discussion

2.7.2.2 Soliciting Written Comments

In addition to soliciting feedback at all meetings described above, opportunities were provided to offer written comments on the GSP via an online comment form, email or letter. A series of chapter-specific review periods was initiated in April 2021, providing beneficial users the opportunity to provide iterative feedback. Table 2-9 presents the schedule used for this process. All comments received during these periods were admitted into the Administrative Record and the associated comment tracking system for subsequent review by the GSA Boards and beneficial users. The written comments and responses can be found in Appendix 2B and its associated subsections.

Table 2-9. GSP Review Schedule

GSP Chapter/Activity	Start Date	End Date	Duration, days
Public Draft Review	4/7/2021	5/5/2021	28
Chapter 1 – Introduction Chapter 2 – Plan Area Chapter 3 – Basin Setting Chapter 4 – Monitoring Networks			
Public Draft Review	7/16/2021	8/13/2021	28
Chapter 5 – Sustainable Management Criteria Chapter 6 – Projects and Management Actions			
Public Draft Review	9/13/2021	10/31/2021	48
Preface Executive Summary Revised Chapters 1 through 6 Chapter 7 – Plan Implementation Chapter 8 – References and Technical Studies			
Technical Team Finalize GSP	11/1/2021	12/3/2021	33
Complete GSP			
GSP Adoption by Agencies and Submittal to DWR	12/3/2021	1/31/2022	59
Final Submitted Colusa Subbasin GSP			

2.7.3 Informing the Public about GSP Development Progress

2.7.3.1 Interested Parties List

Email distribution lists of GSA-specific beneficial users were developed for outreach supporting the GSP planning process. The lists are maintained and updated by the CGA and GGA Program Managers, respectively, and are summarized in Appendix 2C. (To protect sensitive information, actual contact information of interested parties is not appropriate to publish as part of this GSP). Any interested member of the public could be added to the lists by signing up via online entry options located on the CGA website and through email sign up options or requesting by phone for each GSA.

Tribal Engagement

As noted in the C&E Plan (Appendix 2E) and in Table 2-8 above, the Cachil DeHe Band of Wintun Indians of the Colusa Indian Community of the Colusa Rancheria is a federally recognized tribe of Wintun Indians from central California. The Tribe has been consistently identified as an Interested Party since the preliminary days of Subbasin governance (2015 – 2017) and has similarly, been a consistent entity on the Interested Parties list for both GSAs since their respective inception. A Tribal representative attended CGA and GGA meetings regularly from 2015 through December 2019, at which time, said representative departed Tribal employment. The CGA and GGA have continued their inclusive communication of all SGMA information to the Tribe; however, Tribal participation has been limited since January 2020. Likewise, the GSAs' inclusive communication of all SGMA information has been available to the Cortina Rancheria of Wintun Indians of California (Kletsel Dehe Wintun Nation); however, there has been no participation by a representative from the Cortina Rancheria in the GSP process.

2.7.3.2 Distribution of Meeting Information

Before each public meeting and workshop, agenda-based flyers were created in English and Spanish with key information provided. The flyers were emailed out to the Interested Party list, traditional media as well as to key outreach leads with various organizations and the member agencies of each GSA to ensure maximum distribution to the widest range of beneficial users feasible (Appendix 2C). Meeting and workshop flyers are presented in Appendix 2D.

2.7.3.3 Outreach and Branding

To provide Subbasin outreach materials with a consistent look and feel that ensure user awareness of messaging and a sense of organizational cohesion, the respective GSA Boards jointly recommended the development and ultimate approval of a Colusa Subbasin Logo and associated graphics standards to be used consistent on all outreach collateral and online materials. The new Colusa Subbasin logo has been included on this GSP and is also presented in Appendix 2D.

2.7.3.4 Traditional Media Outreach

In advance of each public meeting and workshop, press releases were issued to a local media contact list (Appendix 2C). Local media proved to be highly responsive and the Subbasin efforts collectively received media coverage for most public events described above. Related to this, the GSA Chairpersons wrote and the GSA's jointly approved, the release of an Op-Ed Piece for regional distribution regarding the nexus of the 2021 drought and SGMA planning and implementation (Appendix 2D).

2.7.3.5 Social Media Outreach

Based on a comprehensive outreach proposal submitted to and approved by the respective GSA Boards in October 2020, GSA staff launched social media sites on Facebook and Twitter:

- Facebook Page - https://www.facebook.com/search/top?q=Colusa%20Subbasin%20SGMA
- Twitter - https://twitter.com/colusasubbasin?lang=en

Through these sites, regular content updates were then conducted on average of a bi-monthly basis to ensure user interest and readability and to avoid information on said sites getting "stale." In addition to photographic images and SGMA / GSA / GSP content being regularly updated, the GSAs used Facebook Live to simulcast all events in the SGMA Series to ensure maximum availability for members of the public to view all outreach events from late 2020 through and including public review and subsequent GSA approval of the GSP.

2.7.3.6 GSA Websites

Throughout the planning process, the GSAs have maintained respective websites (as presented above).

These websites are populated with information about Subbasin-wide SGMA planning efforts. While the layout of these websites vary, in general, each includes the following:

- Reference documents regarding GSA creation, incorporation, governance and similar
- Reference documents regarding SGMA background information
- Calendar of public meetings and other upcoming events
- GSA Board, Executive Committee and TAC meeting agendas and materials including post meeting summaries and Zoom recordings (when available after March 2020)
- Information about past public meetings, including relevant meeting materials
- Links to external sites and research (e.g., Department of Water Resources SGMA portal, DWR Subsidence Studies) and other resources
- GSP Chapters, Appendices, Figures, Tables, Comment Forms and related materials
- Links to submit contact information into the Interested Parties Lists
- Reference and submission information for associated voluntary programs such as the Multi-benefit On-farm Managed Aquifer Recharge Program, and the Colusa Subbasin Well Monitoring Program and OpenET, an evapotranspiration data access project
- A link to the website of the respective other GSA
- Colusa Subbasin Social Media links
- Media links and strategy documents including press-releases and Op-Ed materials
- Information about other interbasin efforts
- GSP background documents
- Fact sheets and Subbasin maps

2.7.3.7 Beneficial User Input and Responses

As referred to above, the engagement opportunities described above provided various avenues for beneficial users to provide input on GSP development for the GSAs to be informed thereof. Appendices 2B and 2D present the input received and supports how this input influenced decision-making in GSP development.

CHAPTER 3
Basin Setting

Chapter 3 describes the basin setting, including the hydrogeologic conceptual model (HCM), current and historical groundwater conditions, and water budget information describing the movement of surface water and groundwater into, through and out of the Colusa (Subbasin). This chapter was prepared through a coordinated effort between the CGA and the GGA, the GSAs responsible for managing the Subbasin.

3.1 HYDROGEOLOGIC CONCEPTUAL MODEL

This section describes the Subbasin HCM. The HCM supports development and implementation of a GSP pursuant to the requirements of SGMA.

3.1.1 Regulatory Requirements

Title 23 Section 354.14 of the California Code of Regulations (23 CCR §354.14) requires that each GSP "*shall include a descriptive hydrogeologic conceptual model of the basin based on technical studies and qualified maps that characterizes the physical components and interaction of the surface water and groundwater systems in the basin*" and shall include written descriptions for the following HCM components:

- Regional geology and structure (Section 3.1.7)
- Lateral basin boundaries (Section 3.1.8.1)
- Definable bottom of the basin (Section 3.1.8.2)
- Principal aquifers and aquitards, including formation names, vertical and lateral extent, aquifer properties, restrictions to flow, water quality, and primary uses (Section 3.1.10)
- Any data gaps and uncertainties identified in the previously listed topics (Section 3.1.12)

In accordance with 23 CCR §354.14, the HCM shall also include maps of each of the following physical components of the HCM. All maps shall be informative, labeled, and include the datum (23 CCR §352.4(d)). Information regarding key data sources is also included on each of the maps.

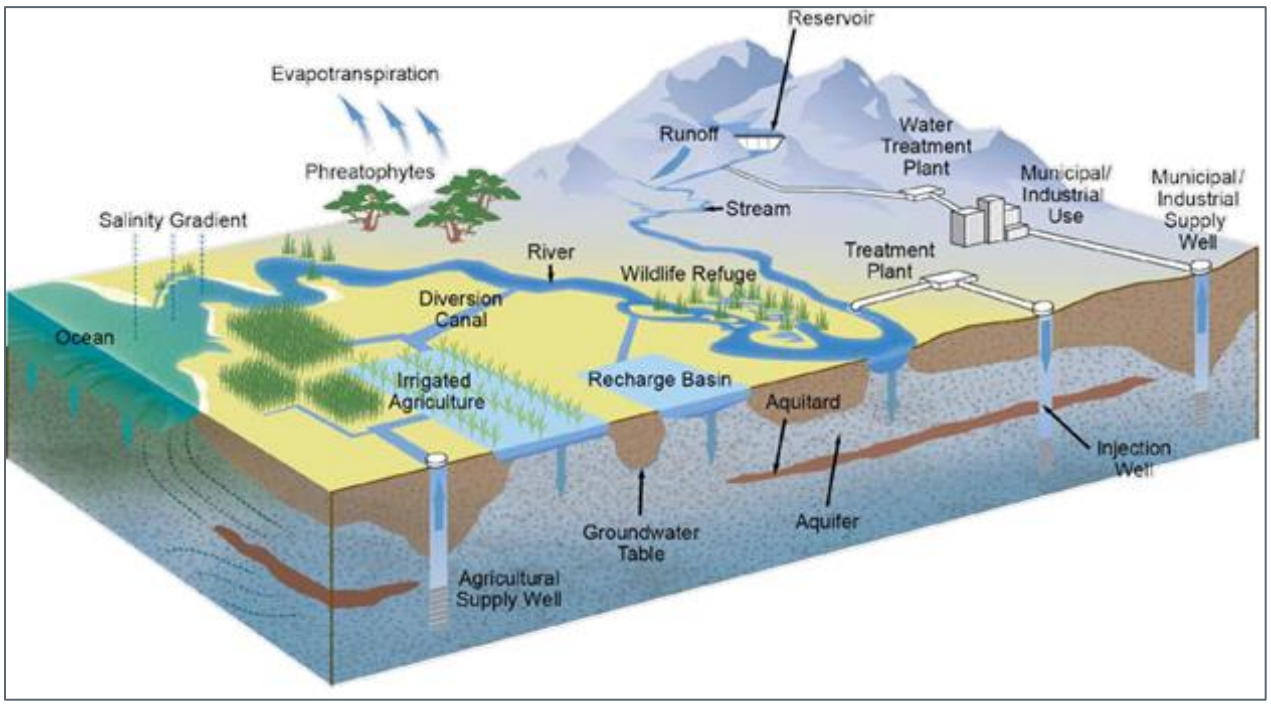
- Topography
- Surface geology and a minimum of two cross sections
- Soil properties
- Recharge and discharge areas
- Surface water features
- Sources and points of delivery of imported water

This section addresses the requirements using currently available data and information in accordance with the Department of Water Resources (DWR) Best Management Practice (BMPs) for the Sustainable Management of Groundwater: Hydrogeologic Conceptual Model BMP (DWR, 2016a). Additionally, components of this HCM have been compared to and updated based on information included in the California Central Valley Groundwater-Surface Water Simulation Model – Fine Grid (C2VSimFG), the selected integrated hydrologic model (IHM) chosen to support the Colusa Subbasin GSAs. This section provides a comparison of the HCM and IHM. Data gaps, uncertainties, and recommended actions are also presented in this section (Section 3.1.12).

3.1.2 Background Information

The HCM provides the general understanding of the hydrogeologic physical setting, characteristics, and processes that occur within the Subbasin and provides the foundation upon which the IHM and components of the water budget are based.

Figure 3-1 depicts a generalized HCM (DWR, 2016a). The main components of the HCM include surficial and subsurface features. Surficial features include topography, hydrology, water supply features, land use, soil types, and geologic outcrops. Subsurface features of the HCM include geologic formations and structures and the presence and characteristics of aquifers and aquitards. These HCM components, except for land use, are discussed in this chapter. Land use is discussed in both Chapter 2 Plan Area, and Section 3.3 Water Budget sections of this Colusa Subbasin GSP.



Reference: California Department of Water Resources, 2016, Best Management Practices for the Sustainability Management of Groundwater: Hydrogeologic Conceptual Model: California Department of Water Resources, December 2016.

Figure 3-1. Hydrogeologic Conceptual Model Representation

The Colusa Subbasin HCM was developed using information provided in a variety of existing studies, dissertations, reports, and datasets. Table 3-1 documents the primary data sources and references used to develop the HCM. All references and citations used for the Colusa Subbasin GSP are listed in Chapter 8.

Table 3-1. Hydrogeologic Data Sources

File Content	File Format	Responsible Agency	Source Reference	Website
Base of Fresh Water	PDF	USGS	Olmsted, F.H. and Davis, G.H., 1961, Geologic Features and Ground-Water Storage Capacity of the Sacramento Valley, California: U.S. Geological Survey in cooperation with the California Department of Water Resources Water Supply Paper WSP-1497, plate 5.	https://pubs.er.usgs.gov/
Bulletin 118 Groundwater Basin	GIS Shapefile	DWR	DWR, 2019, Bulletin 118 Basin Boundary GIS Data, v.6.1: California Department of Water Resources (DWR).	https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118
Elevation DEM	GIS Raster	USGS	USGS, 2016, 1/3 arc-second National Elevation Dataset (NED) Digital Elevation Model (DEM): U.S. Geological Survey (USGS), 1x1-degree tiles N39W122, N39W123, N40W122, N40W123, downloaded 2016.	http://viewer.nationalmap.gov/
Geologic Structural Contours	PDF	USGS	Harwood, D.S. and Helley, E.J., 1987, Late Cenozoic Tectonism of the Sacramento Valley, California: U.S. Geological Survey Professional Paper PP-1359, plate 1.	https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html
Geology	PDF	DWR	DWR, 2014, Geology of the Northern Sacramento Valley: prepared by the California Department of Water Resources Northern Region Office, Groundwater and Geologic Investigations Section.	https://www.water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Data-and-Tools/Files/Regional-Reports/Geology-of-the-Northern-Sacramento-Valley-California-June-2014.pdf
Geology	GIS Geodatabase	USGS	Helley, E.J. and Harwood, D.S., 1985, Geologic Map of the Late Cenozoic Deposits of the Sacramento Valley and Northern Sierran Foothills, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1790, scale 1:62,500.	Not Available Online
Geology	PDF	CGS[(a)]	Jennings, C.W. and Strand, R.G., 1960, Geologic Map of California, Olaf P. Jenkins edition, Ukiah Sheet: Department of Natural Resources Division of Mines and Geology (CDMG) Geologic Atlas Map GAM-24, third printing 1992, scale 1:250,000.	https://maps.conservation.ca.gov/cgs/publications/
Geology	PDF	CGS	Koenig, J.B., 1963, Geologic Map of California, Olaf P. Jenkins edition, Santa Rosa Sheet: California Department of Natural Resources Division of Mines and Geology Geologic Atlas Map GAM-22, scale 1:250,000.	https://maps.conservation.ca.gov/cgs/publications/
Geology	GIS Shapefile; PDF	DWR	DWR, 2009, Glenn-Colusa Irrigation District Test-Production Well Installation and Aquifer Testing: prepared by the California Department of Water Resources Northern District Groundwater Section in cooperation with Glenn-Colusa Irrigation District, March 2009, GIS shapefiles provided by DWR 2008.	http://wdl.water.ca.gov/pubs/geology/glenn-colusa_irrigation_district_test-production_well_installation_and_aquifer_testing__2009_/glenn-colusa_irrigation_district_test-production_well_installation_and_aquifer_testing__2009_.pdf
Groundwater Dependent Ecosystems	GIS Geodatabase; PDF	TNC	DWR, 2018, Summary of the "Natural Communities Commonly Associated with Groundwater" Dataset and Online Web Viewer: California Department of Water Resources, April 2018.	https://data.cnra.ca.gov/dataset/natural-communities-commonly-associated-with-groundwater
Hydrography - Hydrology and Watersheds	GIS Geodatabase	USGS	USGS, 2016, USGS National Hydrography Dataset (NHD) Downloadable Data Collection: U.S. Geological Survey National Geospatial Technical Operations Center (NGTOC), Region 1802.	http://viewer.nationalmap.gov/
Natural Communities Commonly Associated with Groundwater	GIS Shapefile	DWR	DWR, 2020, Natural Communities Commonly Associated with Groundwater (NCCAG) Dataset: California Department of Water Resources, California Department of Fish and Wildlife, and The Nature Conservancy.	https://gis.water.ca.gov/app/NCDatasetViewer/#
Soil Suitability for Recharge	GIS Shapefile	UCD &UC-ANR	University of California Davis (UCD) California Soil Resource Lab and University of California Division of Agriculture and Natural Resources (UC-ANR), 2017, Soil Agricultural Groundwater Banking Index (SAGBI), GIS shapefiles received 2017. O'Geen, A.T. et al, 2015, Soil Suitability Index Identifies Potential Areas for Groundwater Banking on Agricultural Lands: California Agriculture, Volume 69, Number 2, pp 75-84, April 2015.	https://casoilresource.lawr.ucdavis.edu/sagbi/
Soils	GIS Shapefile; Access Database	NRCS	NRCS, 2013 & 2017, Soil Survey Geographic Database (SSURGO): Natural Resources Conservation Service (NRCS) Web Soil Survey (WSS), Colusa County (CA011), Spatial Data V3 (2013), Tabular Data V11 (2017).	http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
Soils	GIS Shapefile; Access Database	NRCS	NRCS, 2014 & 2017, Soil Survey Geographic Database (SSURGO): Natural Resources Conservation Service Web Soil Survey, Glenn County (CA021), Spatial Data V5 (2014), Tabular Data V12 (2017).	http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
Soils	GIS Map Package	ESRI	ESRI, 2017, NRCS Compiled 2017 SSURGO Downloader: Environmental Systems Research Institute (ESRI), Big Chico Creek - Sacramento River, Butte Creek, Honcut Headwaters - Lower Feather, Sacramento - Stone Corral, Upper Cache, and Upper Stony watersheds.	http://esri.maps.arcgis.com/apps/View/index.html?appid=cdc49bd63ea54dd2977f3f2853e07fff
Stream Gauge and Reservoir Stations	Tabular	CDEC	DWR, 2017, California Data Exchange Center (CDEC): California Department of Water Resources, downloaded 2017.	http://cdec.water.ca.gov/index.html
Stream Gauges	Tabular	USGS	USGS, 2017, National Water Information System (NWIS) - Web Interface: U.S. Geological Survey, downloaded 2017.	https://waterdata.usgs.gov/nwis
Water Quality Data	Tabular	SWRCB	SWRCB, 2020a, GeoTracker Groundwater Ambient Monitoring and Assessment: California State Water Resources Control Board.	http://geotracker.waterboards.ca.gov/gama
Water Quality Data	Tabular	USGS	USGS, 2020, National Water Information System (NWIS) - Web Interface: U.S. Geological Survey, download 2020.	https://waterdata.usgs.gov/nwis/qw
Wetlands	GIS Geodatabase	FWS	U.S. Department of the Interior, 2014, Classification of Wetlands and Deepwater Habitats of the United States: U.S. Department of the Interior (USDI) Fish and Wildlife Service (FWS), Washington D.C., FWS/OBS-79-31.	https://www.fws.gov/wetlands/data/data-download.html

(a) California Division of Mines and Geology is now the California Geological Survey.

3.1.3 Climate and Precipitation

The Subbasin has a Mediterranean climate with cool, wet winters and hot, dry summers. Regionally, temperature and precipitation vary with elevation, with lower temperatures and higher precipitation typically occurring at higher elevations. The region is subject to wide variations in annual precipitation, and experiences periodic dry periods. Summers can be hot, with temperatures commonly exceeding 100 degrees Fahrenheit.

Based on the historical data obtained from Western Regional Climate Center (WRCC) National Oceanic and Atmospheric Administration (NOAA) Cooperative Observer Network (COOP) stations in Colusa (Station 041948) and Orland (Station 046506), the recorded average monthly temperatures within the subbasin range from 46 to 80 degrees Fahrenheit, but the extreme low and high daily temperatures have been 15 and 120 degrees Fahrenheit, respectively (WRCC, 2020).

The average annual precipitation varies from about 21 inches in the northern portion of the subbasin to about 15 inches in the south. Due to the variable topographic relief of the subbasin, temperature and precipitation can vary greatly with location.

The Colusa station has recorded precipitation for water years 1949 through 2019 and the Orland station for 1905 through 2019. The water year starts October 1, ends on September 30, and is denoted by the calendar year of its end date. Figure 3-2 shows the annual water year precipitation measured at Colusa and Orland for water years 1949 through 2020. Water years missing more than 30 days of data during the rainy season were considered incomplete and were not included in this evaluation. The rainy season is interpreted to be October through April (Figure 3-2). Data was incomplete for water years 1952-1953, 1974, 1982, 1993-1998, and 2011-2013 at Colusa and water years 1906-1907, 1910, 1914, 1916-1920, 1941, 1981, 1994, 1996, and 2011-2012 at Orland. Historical precipitation shown on Figure 3-2 for these years is the minimum precipitation measured for the water year.

Multiple-year dry periods experienced in the Subbasin roughly correspond with state-wide multiple-year droughts. Multiple-year dry periods recorded within the Subbasin area include:

- 1949-1950
- 1954-1955
- 1959-1962
- 1964-1966
- 1971-1972
- 1976-1977
- 1987-1991
- 2007-2009
- 2012-2016

Figure 3-3 shows the exceedance curves for the Colusa and Orland precipitation data. The entire period of record except for water years with incomplete data was used for each station's exceedance curve. The figure shows the frequency at which a given level of annual precipitation was met or exceeded. The curve can be used to gauge how frequently the precipitation recorded in any given year was equaled or exceeded in the past. For example, the minimum historical precipitation of 8.15 inches recorded in Orland occurred in 1924 and was met or exceeded in 100 percent of years throughout Orland's period of record. Similarly, 90 percent of water years over Orland's period of record met or exceeded the 11.5 inches of precipitation measured in 2014.

Figure 3-2. Historical Precipitation

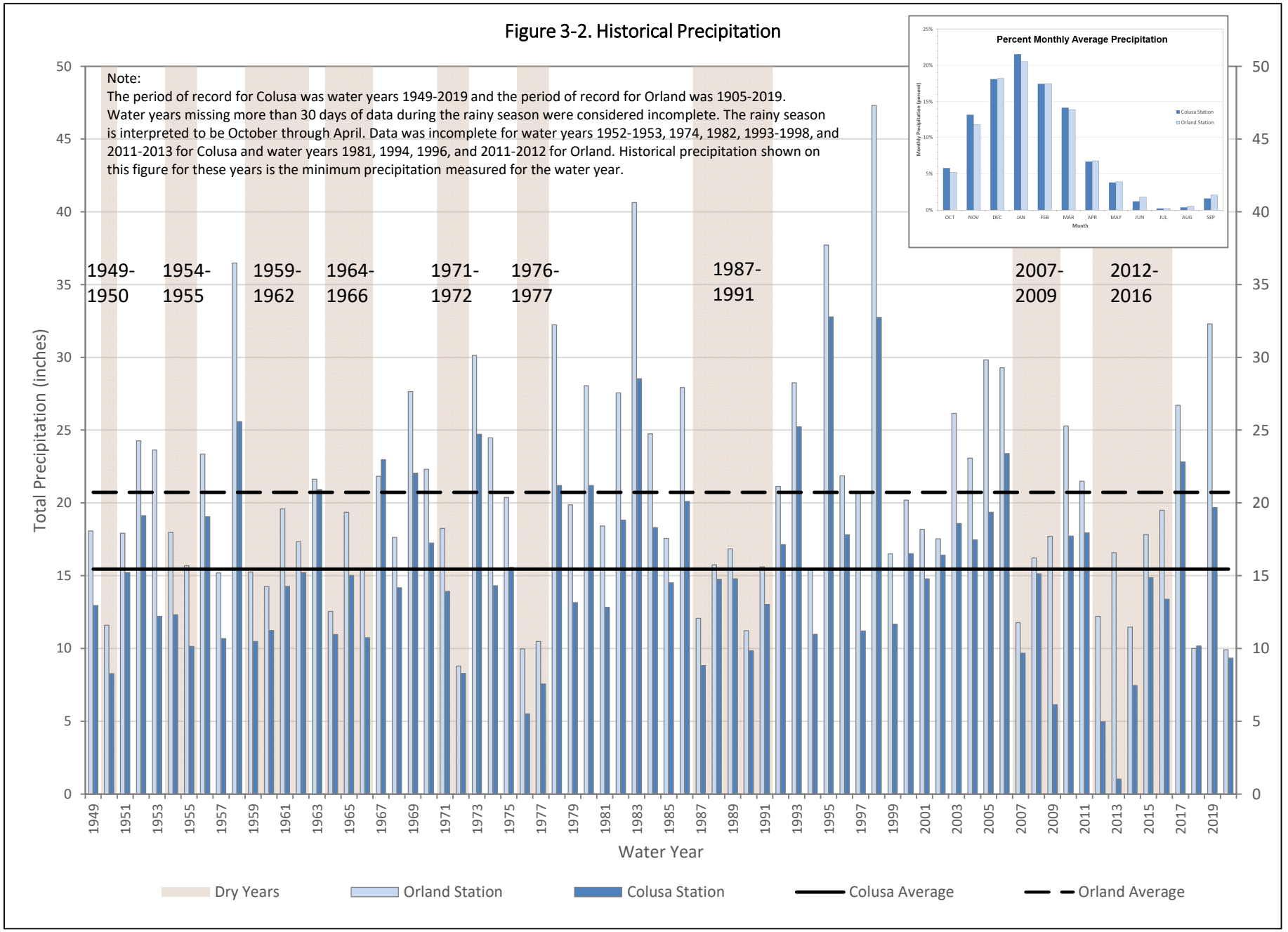
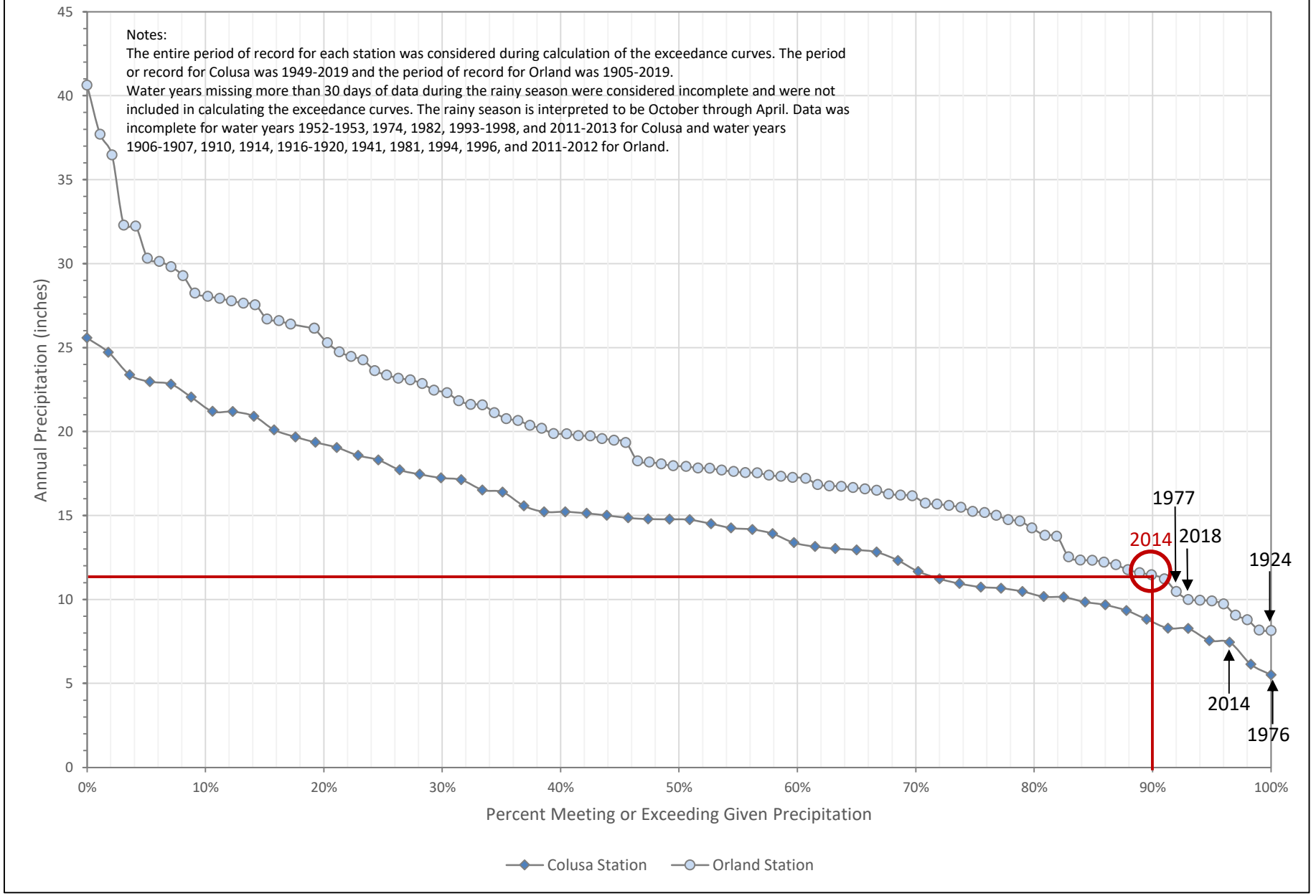


Figure 3-3. Precipitation Exceedance Curve



3.1.4 Topography

Figure 3-4 shows the topography of the Subbasin. The topography throughout the subbasin encourages drainage east towards the Sacramento River and south towards the San Joaquin-Sacramento River Delta (Delta). The western side of the subbasin is elevated and includes low foothills that transition to the higher elevation Coast Range. Streams from the Coast Range drain eastward through low alluvial plains towards the Sacramento River.

Elevations greater than 1,000 feet North American Vertical Datum of 1988 (NAVD 88) occur within the northwestern and the southwestern portion of the subbasin. These areas of high terrain are associated with the Coast Range foothills near Black Butte Lake and the northernmost extent of the Capay Hills. Minimum land surface elevations of less than 30 feet NAVD 88 occur in the southern portion of the subbasin between the Colusa Basin Drainage Canal System (Colusa Drain) and the Sacramento River. Elevations along the Sacramento River range from about 150 feet NAVD 88 at the northeast boundary of the subbasin to about 40 feet NAVD 88 near the southeast boundary of the subbasin.

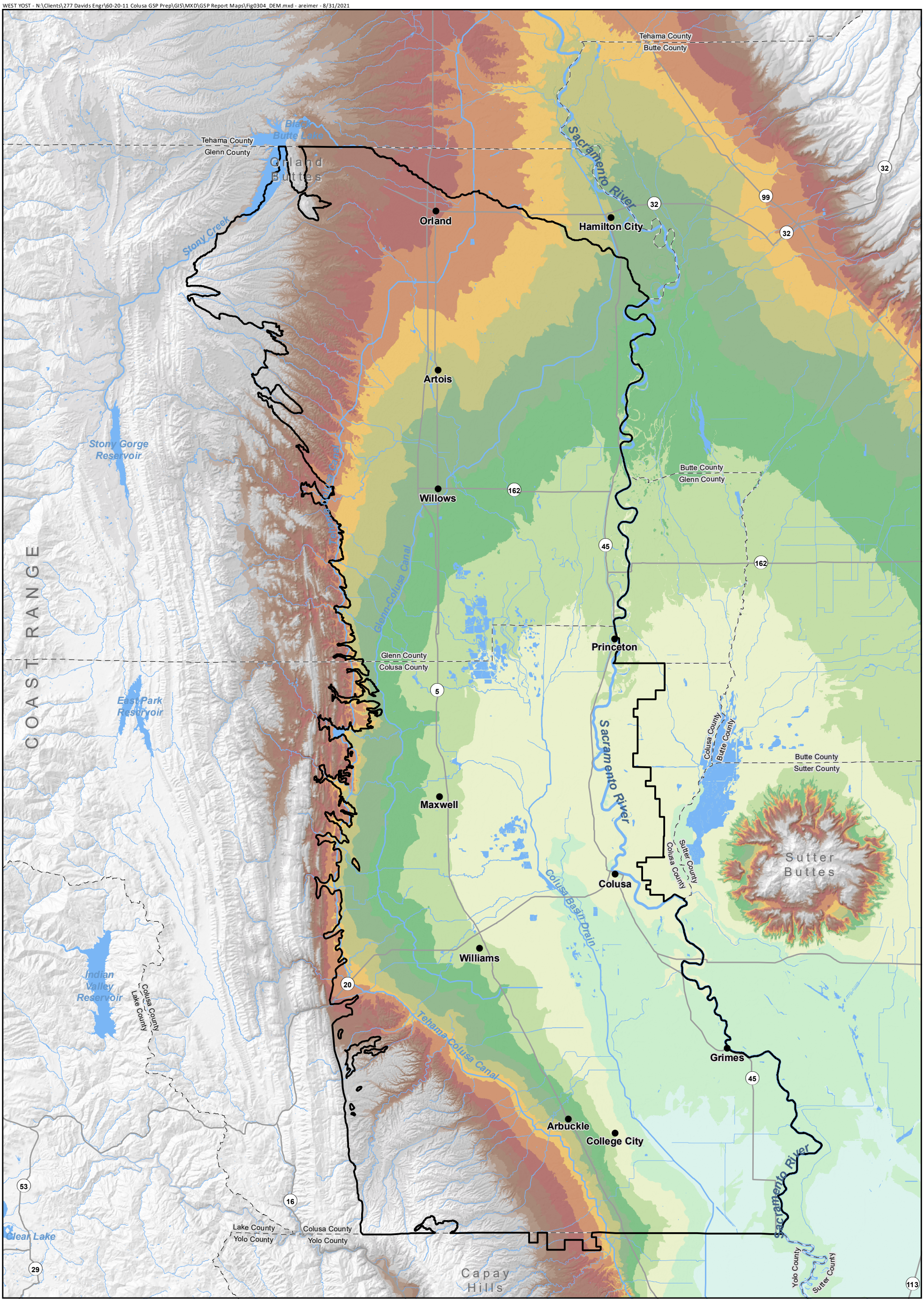
3.1.5 Hydrology

The physical hydrology of the Subbasin is influenced by the underlying geology, geomorphology and topography of the region and the Sacramento Valley's large agriculture industry. Chemical hydrology of waters within the Subbasin are similarly impacted by geology, lithology, and geomorphology, as different geologic and lithologic sediments can leach or filter chemicals into or out of groundwater solution. Hydrogeologic structures can also impact flow paths of waters within the subsurface and up to stream beds, allowing or impeding mixing of waters with different chemical signatures. Physical surface water hydrology is discussed in this section. Stratigraphic features that can impact water flow regime are discussed in Section 3.1.9. Groundwater quality is discussed in Section 3.1.10.3 and Section 3.2.5.

Figure 3-5 shows watersheds and natural waterways in the Subbasin. The Sacramento River is the principal stream in the subbasin and contributes significantly to the statewide water supply. Most of the streams within the region drain the Sierra Nevada to the east and the Coast Ranges to west and are tributary to the Sacramento River.

The drainage watersheds of these tributary streams within or adjacent to the Colusa Subbasin include:

- Big Chico Creek Sacramento River watershed (hydrologic unit code 08 [HUC08] 18020157), which drains into the Sacramento River at the northern boundary of the Subbasin;
- Upper Stony Creek watershed (HUC08 18020104), which drains into Stony Creek along the northern boundary of the Subbasin;
- Butte Creek watershed (HUC08 18020158), which drains into the west-central portion of the Subbasin, east of the Sacramento River;
- Honcut Headwaters – Lower Feather River watershed (HUC08 18020159), which drains into the Sacramento River south of the City of Colusa and flows along the Subbasin boundary; and
- Sacramento Stone Corral watershed (HUC08 18020104), which drains the Coast Range foothills west of the Subbasin, as well as the majority of the Subbasin, itself.



Source: USGS 1/3-arcsecond National Elevation Dataset (NED) Digital Elevation Model (DEM) N39W122, N39W123, N40W122, and N40W123.

Datums: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet. North American Vertical Datum of 1988, feet (NAVD 88).

Note:
1. Elevations greater than 1,000 ft NAVD 88 are shown as white on this map.

Colusa Subbasin

Land Surface Elevation (NAVD88, feet)

< 30	100 - 125	200 - 250	400 - 450
30 - 50	125 - 150	250 - 300	450 - 500
50 - 75	150 - 175	300 - 350	500 - 750
75 - 100	175 - 200	350 - 400	750 - 1,000
			> 1,000

N

0 2.5 5

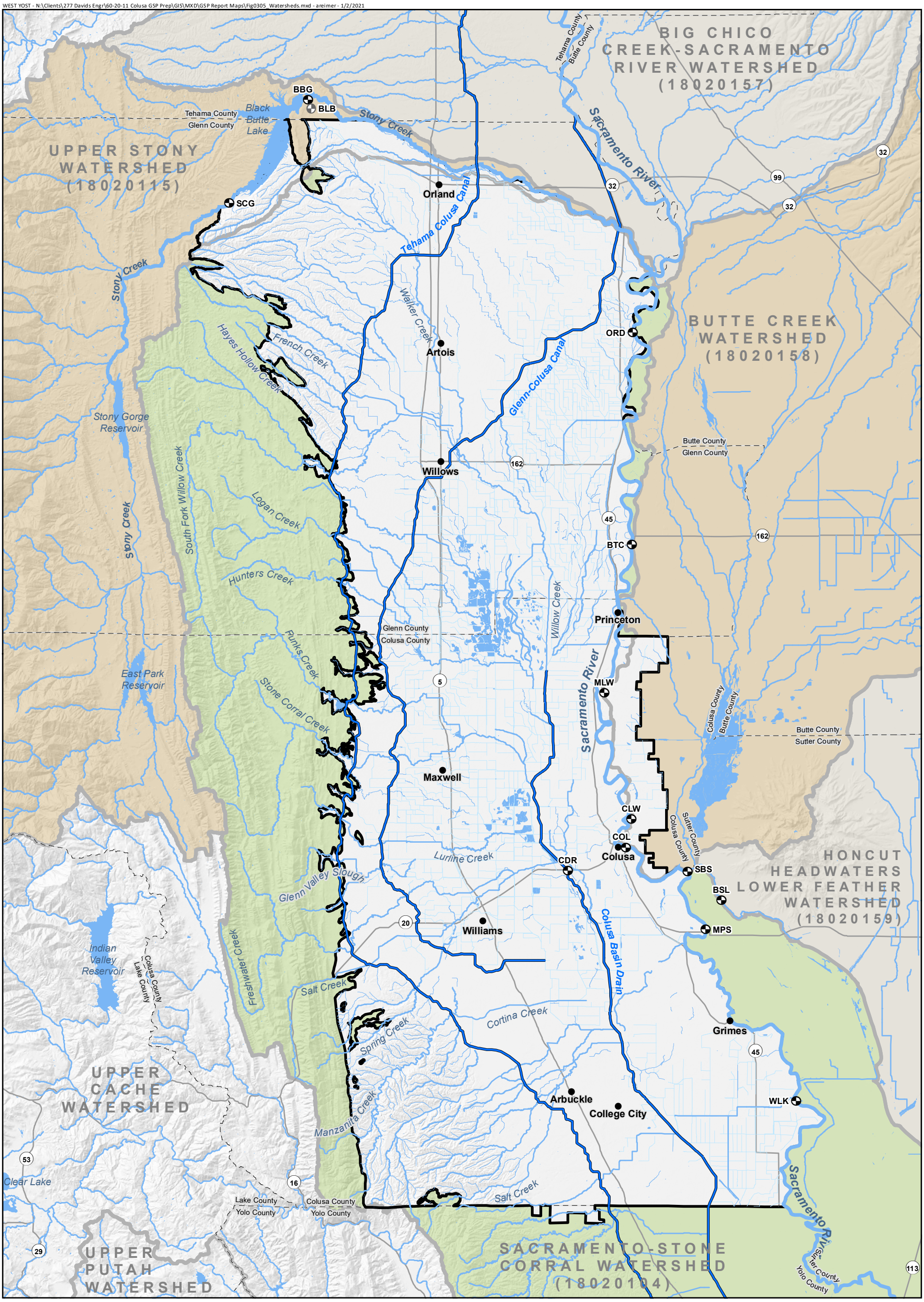
Scale in Miles

Figure 3-4

Topography

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

WEST YOST - N:\Clients\277 Davids Engr\60-20-11 Colusa GSP Prep\GIS\MXD\GSP Report Maps\Fig0305_ Watersheds.mxd - areimer - 1/2/2021



Source: Water features and watersheds boundaries are from the National Hydrography Dataset (NHD) for Region 1802. Watersheds shown are the Hydrologic Unit Code 8 watershed basins (HUC 8).

Horizontal Datum: North American Datum of 1983, California State Plane Zone II, feet.

- Surface Water Flow Station
- Reservoir Station
- Major Waterways
- Minor Waterways
- Other Waterways
- Major Conveyance Infrastructure
- Other Water Conveyance Infrastructure
- Water Bodies
- Colusa Subbasin
- Watersheds (HUC 8)

Inflow Watersheds (HUC 8)

- Big Chico Creek-Sacramento River; Honcut Headwaters-Lower Feather
- Sacramento-Stone Corral
- Butte Creek; Upper Stony Creek

N

0 2.5 5

Scale in Miles

Figure 3-5

Watersheds and Natural Waters

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

The dominant north-northwesterly south-southeasterly structural trends in the Coast Range west of the Subbasin result in long narrow valleys and ridges. These topographic features have produced a drainage network that routes most of the Coast Range runoff to the Subbasin via Stony Creek, which flows north in the Coast Range through Stony Gorge Reservoir to Black Butte Lake before entering the Subbasin along its northern boundary and discharging into the Sacramento River. To the southwest in the Coast Range, similar geologic, geomorphic and topographic influences route most of the runoff through the Upper Cache Creek watershed in a southeasterly direction where it contributes to flows in Cache Creek. Cache Creek enters the Sacramento Valley south of the Subbasin in the Yolo Subbasin. As a consequence of the dominance of the Upper Stony and Upper Cache Creek watersheds in capturing most of the runoff from the higher elevations in the Coast Range, the remainder of the other Coast Range streams influent to the subbasin have relatively small catchment areas in low elevation areas of the Coast Range. These streams are intermittent and drain the foothills that border the Coast Ranges to the west.

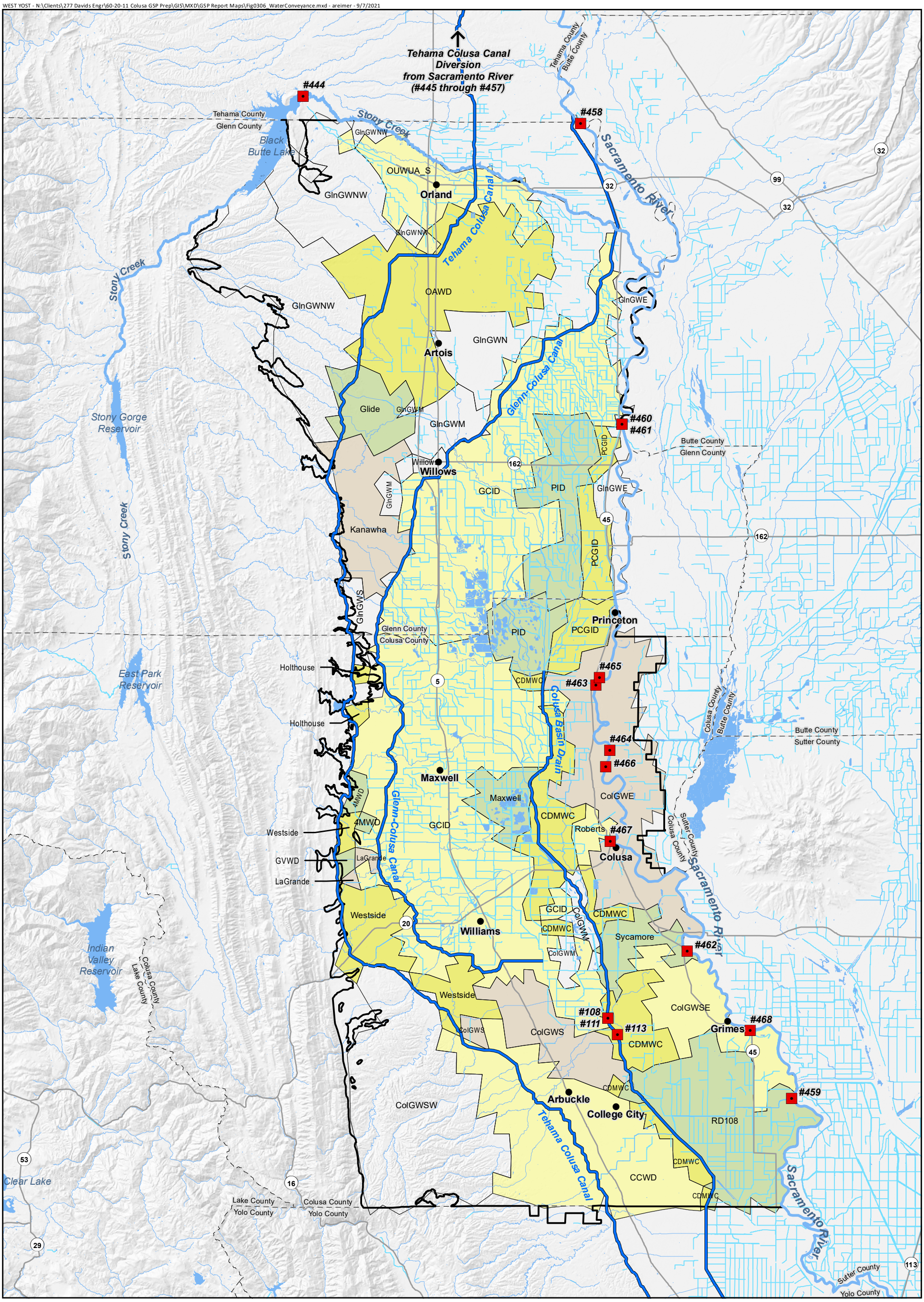
Canals and drains intersect streams and creeks to provide a water supply and drainage network, which is shown on Figure 3-6. Major water features and conveyance infrastructure that serve agencies within the Subbasin include the Sacramento River, Stony Creek, Black Butte Lake, the Tehama-Colusa Canal, Glenn-Colusa Canal, and the Colusa Drain. The major water features and conveyance infrastructure are discussed in the following section. More detailed information regarding flows and volumes are discussed in the water budget chapter.

3.1.5.1 Natural Surface Waters and Conveyance Infrastructure

The regional watersheds and natural waterways are shown on Figure 3-5. The major natural waterways flowing into, through, or along the boundary of the Subbasin include the Sacramento River and Stony Creek. Many smaller intermittent streams drain the foothills that abut the Coast Ranges west of the Subbasin. Three major water conveyance infrastructures also exist within the subbasin. These are the Tehama-Colusa Canal, the Glenn-Colusa Canal, and the Colusa Drain. Smaller canal and channel systems transport water between the natural waterways and conveyance infrastructure. The natural and man-made water channels within the Subbasin are interconnected. Figure 3-5 and Figure 3-6 show the surface hydrology of the Subbasin. The major waterways are discussed in the following subsections.

3.1.5.1.1 Black Butte Lake and Stony Creek

The Upper Stony Creek watershed drains an approximately 770 square mile area of the Coast Range, foothills, and uplands, most of which is situated west of the Subbasin. Stony Creek south of the Glenn-Tehama County line defines the boundary between the Colusa and Corning Subbasins. The Stony Creek headwaters are in the Coast Range terrain of western Colusa County. Stony Creek flows north toward Stony Gorge Reservoir, which was constructed in 1928. Water discharged from Stony Gorge Reservoir continues northeast to Black Butte Lake, where most of the drainage within the Stony Creek watershed is eventually captured. According to data listed on the CDEC website and shown on Figure 3-7, storage within Black Butte Lake has been between 1,200 af and 140,000 af since 1963, when it was constructed. The lowest lake storage was recorded in Fall 1977, a critically dry year. Releases from Black Butte Lake, monitored by the USBR and available on CDEC, from 1996 to 2020 fluctuated between 0 and 24,000 cubic feet per second (cfs) (CDEC, 2020). Discharges from Black Butte Lake flow into either Stony Creek or canals that irrigate agricultural lands of the Colusa and Corning Subbasins. Stony Creek eventually drains into the Sacramento River. Historical streamflow in Stony Creek near Hamilton City from 1941 to 1963, prior to the construction of Black Butte Lake, ranged between 0 and 30,000 cfs.



Source: Water features are from the National Hydrography Dataset (NHD) for Region 1802. Diversion points and model subareas were extracted from the C2VSimFG-Colusa hydrologic model.

Horizontal Datum: North American Datum of 1983, California State Plane Zone II, feet.

Note:
1. Diversions 445 to 457 are located where the Tehama Colusa Canal diverts water from the Sacramento River and are not shown on this map.

- Major Waterways
- Minor Waterways
- Major Conveyance Infrastructure
- Other Conveyance Infrastructure
- Water Bodies
- Colusa Subbasin

- Modeled Surface Water Diversion

Modeled Subareas that Receive Diverted Water

- 4MWD, GVWD, Glide, Maxwell, PID, RD108, Sycamore
- CCWD, ColGWSE, GCID, OUWUA_S, Roberts
- CDMWC, Holthouse, OAWD, PCGID, Westside
- ColGWE, ColGWS, Kanawha, LaGrande
- Subareas that Do Not Receive Delivered Water: ColGWM, ColGWSW, GlnGWE, GlnGWM, GlnGWN, GlnGWNW, GlnGWS, Willows

N

0 2.5 5

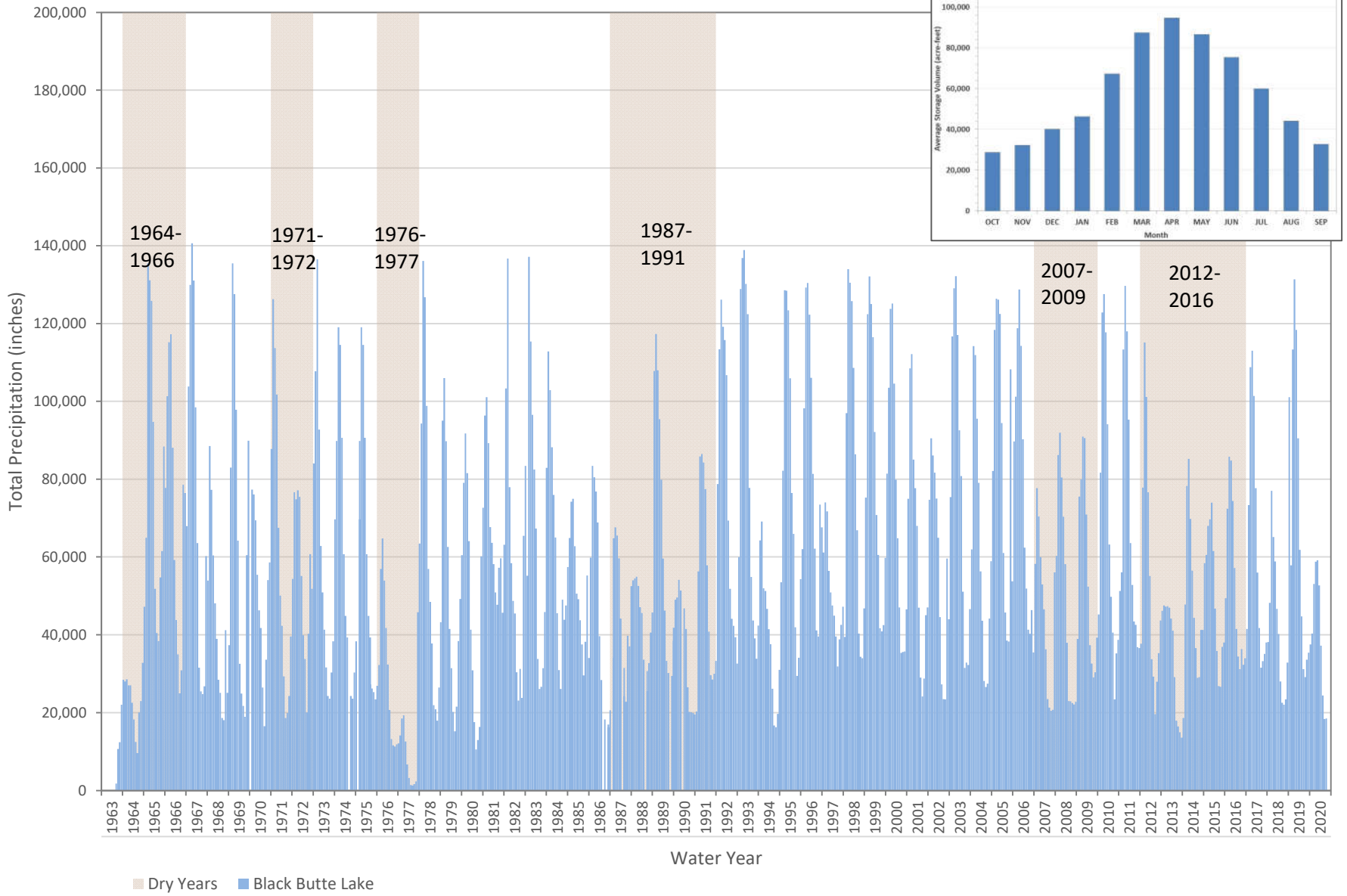
Scale in Miles

Figure 3-6

Water Conveyance Infrastructure

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

Figure 3-7. Black Butte Reservoir Storage



3.1.5.1.2 Sacramento River

The Sacramento River flows north to south along the eastern boundary of the Subbasin. The Sacramento River provides approximately 80 percent of the inflow to the Delta and is the largest and most important riverine ecosystem in the State of California (DWR, 2009a). In addition to providing flows to the Delta, the Sacramento River is the primary water source for irrigation water suppliers and certain landowners within the subbasin. Sacramento River stream flows measured at the Ord Ferry-Main Channel stream gage, in the northern part of the Subbasin, varied between 200 and 160,000 cfs during the 1984 to 2020 time period, with extreme low flows measured in the spring of 1990. River flows at Butte City (Station USGS 113890000) were record between 1939 and 2020 and ranged between 170,000 and 1,400 cfs. Stream flows measured at the stream gage below Wilkins Slough (Station USGS 11390500), south of Grimes, varied between 2,400 and 33,000 cfs for its entire period of record 1939 to 2020. Ord Ferry and Butte City are both located northwest of the Sutter Buttes and upstream of the confluence with Butte Creek, while Grimes is south of the Sutter Buttes. Figure 3-8 depicts the historical flows at these two locations. Flows at Wilkins Slough have historically remained fairly stable with the primary exceptions being critically dry years. Flows in the upstream stations are more seasonally and climatically variable and depict more of a response to dry years. Overall streamflows at all three stations have declined since 1995.

3.1.5.1.3 Tehama-Colusa Canal

The Tehama-Colusa Canal is operated and maintained by the Tehama-Colusa Canal Authority (TCCA), located near Willows, Glenn County. The TCCA service area covers approximately 150,000 acres and extends from Tehama County to Yolo County and provides irrigation water to farmers growing a variety of permanent and annual crops within the Subbasin. The Tehama-Colusa Canal originates north of the Subbasin at the Red Bluff Pumping Plant and Fish Screen in Tehama County, runs along the west side of the Colusa, and terminates south of the subbasin near Dunnigan Water District, Yolo County. Of the approximately 140 miles of TCCA water supply system, 75 miles of the Tehama-Colusa Canal traverses the Subbasin.

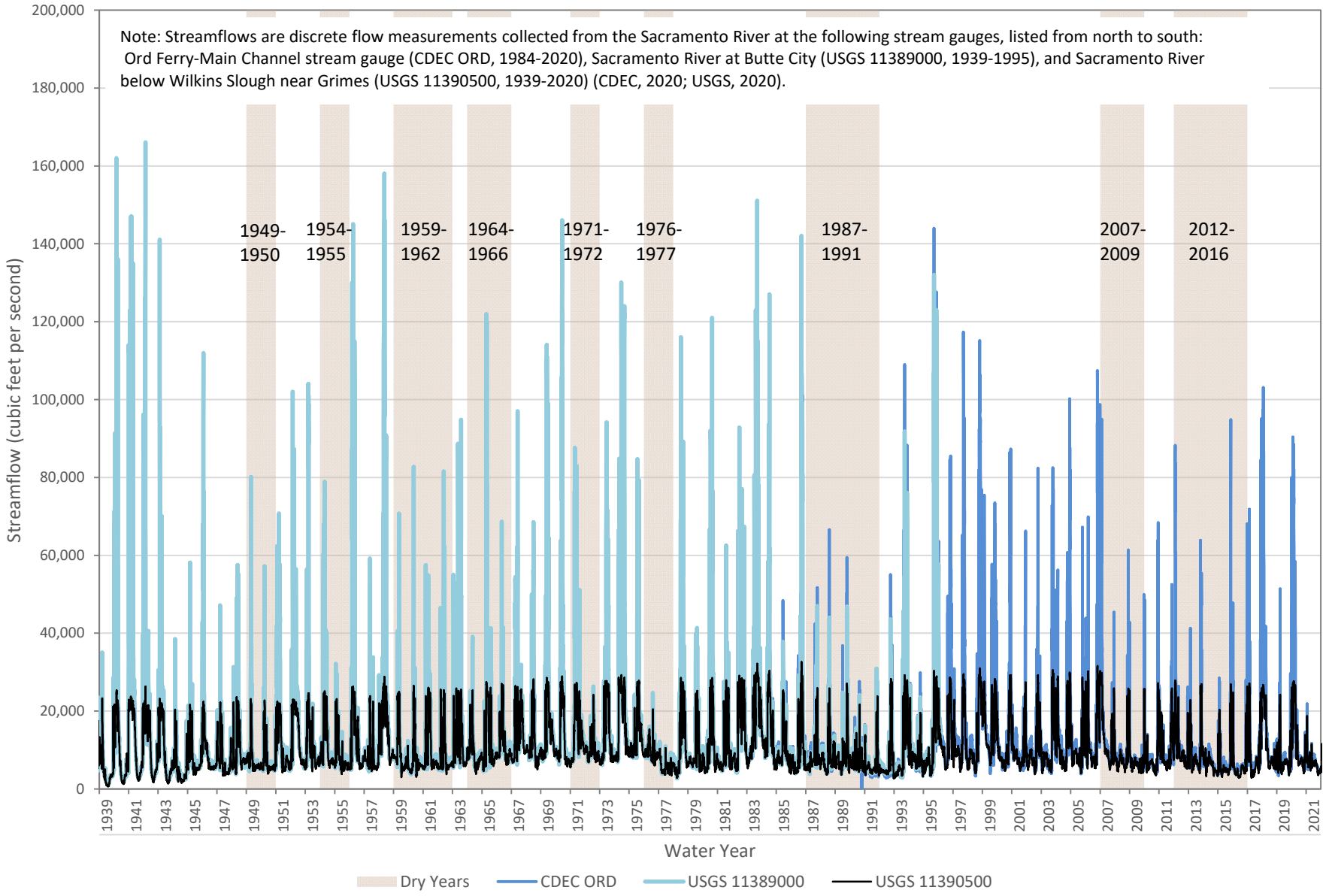
3.1.5.1.4 Glenn-Colusa Canal

The Glenn-Colusa Canal system is situated east of the Tehama-Colusa Canal and west of the Sacramento River. The Glenn-Colusa Canal originates on the Sacramento River north of the Subbasin and extends south of Williams, Colusa County, where it flows into the local canal system. The Glenn-Colusa Canal is operated by the Glenn-Colusa Irrigation District (GCID), located in Willows. GCID covers approximately 175,000 acres; of which, approximately 140,000 acres are farmed, making it the largest irrigation district in the Sacramento Valley (GCID, 2017). In addition to serving agricultural lands, GCID services approximately 1,200 acres of private habitat land and 20,000 acres of protected federal wildlife land. The main canal is approximately 65 miles long and conveys water into a complex system of nearly 1,000 miles of canals, laterals, and drains.

3.1.5.1.5 Colusa Basin Drainage Canal System

The Colusa Basin Drainage Canal System, or Colusa Drain, is a drainage system that transports rainfall runoff, agricultural runoff and return flows away from the agricultural lands in the Subbasin to the Sacramento River and the Tule Canal near Knights Landing, Yolo County. Many of the smaller natural streams of the region, including Willow Creek, drain into the Colusa Drain. Some of the water within the Colusa Drain is captured and reused prior to being discharged into the Sacramento River.

Figure 3-8. Sacramento River Streamflows



3.1.5.1.6 Other Streams

Walker Creek (near Artois) and Willow Creek (near Willows) are north-south trending streams largely contained within the subbasin (Figure 3-5). There are many ephemeral and intermittent streams that flow into or through the subbasin. These include ephemeral and intermittent streams that drain the foothills between the Subbasin and the higher elevation areas of the Coast Ranges. Historically, some of these streams were connected to springs at their headwaters or along their drainage reaches, where shallow groundwater would discharge into the channel. These foothill drainages and their tributaries are classified as part of the Sacramento-Stone Corral Watershed, as defined by the National Hydrology Dataset (NHD). The following streams comprise the Sacramento Stone Corral watershed, which bounds most of the Subbasin on its western side:

- Walker Creek
- Willow Creek
- French Creek
- Hayes Hollow Creek
- South Fork Willow Creek
- Logan Creek
- Hunters Creek
- Funks Creek
- Stone Corral Creek
- Lurline Creek
- Glenn Valley Slough
- Freshwater Creek
- Salt Creek (which flows past Williams, Colusa County)
- Spring Creek
- Manzanita Creek
- Cortina Creek
- Salt Creek (which flows past Arbuckle, Colusa County)
- Hambright Creek

Runoff in these ephemeral and intermittent streams generally begins in late fall when the rainy season starts and may continue until late spring. Inter-annual runoff patterns from streams such as these are highly variable, and many, if not all, of these streams flow into drainage canals within the subbasin. For example, Walker Creek and Willow Creek flow into the upstream end of the Colusa Drain, and other creeks, including Stone Corral Creek and both Salt Creeks, flow into the Colusa Drain's lower reaches (Figure 3-5).

3.1.5.2 Imported Water Sources and Points of Delivery

The primary surface water bodies through, or from, which imported waters are delivered to entities within the Subbasin include the Sacramento River and Stony Creek, with the Tehama-Colusa Canal and the Glenn-Colusa Canal being the primary conveyances of Sacramento River water. These surface water features, along with the regional and local water conveyance infrastructure, are shown on Figure 3-6. Water delivered via the Tehama-Colusa Canal, Sacramento River, Stony Creek, and other Central Valley Project contracts are managed by USBR.

Modeled points of surface water diversions included in the C2VSimFG-Colusa model and their delivery areas are shown on Figure 3-6 and listed in Table 3-2. The sources and delivery points for imported waters are described in more detail in the model development and calibration Technical Memorandum prepared by Woodard & Curran and Davids Engineering (2021) (Appendix 3D).

Table 3-2. Surface Water Diversions Delivered to Land

Model Diversion ID[(a)]	Description	Modeled Delivery Subarea	Data Source
444	Orland Unit Water Users' Association (OUWUA) (South Canal only)	OUWUA_S	USBR
445	Colusa County WD	CCWD	USBR
446	Orland-Artois WD (OAWD)	OAWD	USBR
447	Glenn-Colusa ID (Tehama-Colusa Canal)	GCID	USBR
448	Westside WD	Westside	USBR
449	Kanawha WD	Kanawha	USBR
450	Glide WD	Glide	USBR
451	La Grande WD	LaGrande	USBR
452	Davis WD	Westside	USBR
453	4-M WD	4MWD	USBR
454	Holthouse WD	Holthouse	USBR
455	Glenn Valley WD	GVWD	USBR
456	Cortina WD	CCWD; ColGWS	USBR
457	Myers-Marsh MWC	GCID; ColGWS	USBR
458	Glenn-Colusa ID Main Canal	GCID	USBR, GCIDWIS, and eWRIMS
459	Reclamation District #108	RD108	USBR
460	Princeton-Codora-Glenn ID	PCGID	USBR
461	Provident ID	PID	USBR
462	Sycamore MWC	Sycamore	USBR
463	Maxwell ID	Maxwell	USBR
464	Carter Mutual Water Company	ColGWE	USBR
465	Misc Sac River Riparian Diversions	ColGWE	USBR
466	Misc Sac River Riparian Diversions	ColGWE	USBR
467	Misc Sac River Riparian Diversions	ColGWE; Roberts	USBR
468	Andreotti, Arnold and Arthur, et al	ColGWSE	USBR
108	Colusa Drain to Princeton-Codora-Glenn ID, Provident ID, Maxwell ID for Ag (08N_SA1)	PID; PCGID	C2VSimFG Beta2
111	Colusa Drain to Colusa NWR (08S_PR)	CDMWC	C2VSimFG Beta2
113	Colusa Drain to Colusa Drain MWC for Ag (08S_PA)	CDMWC	C2VSimFG Beta2

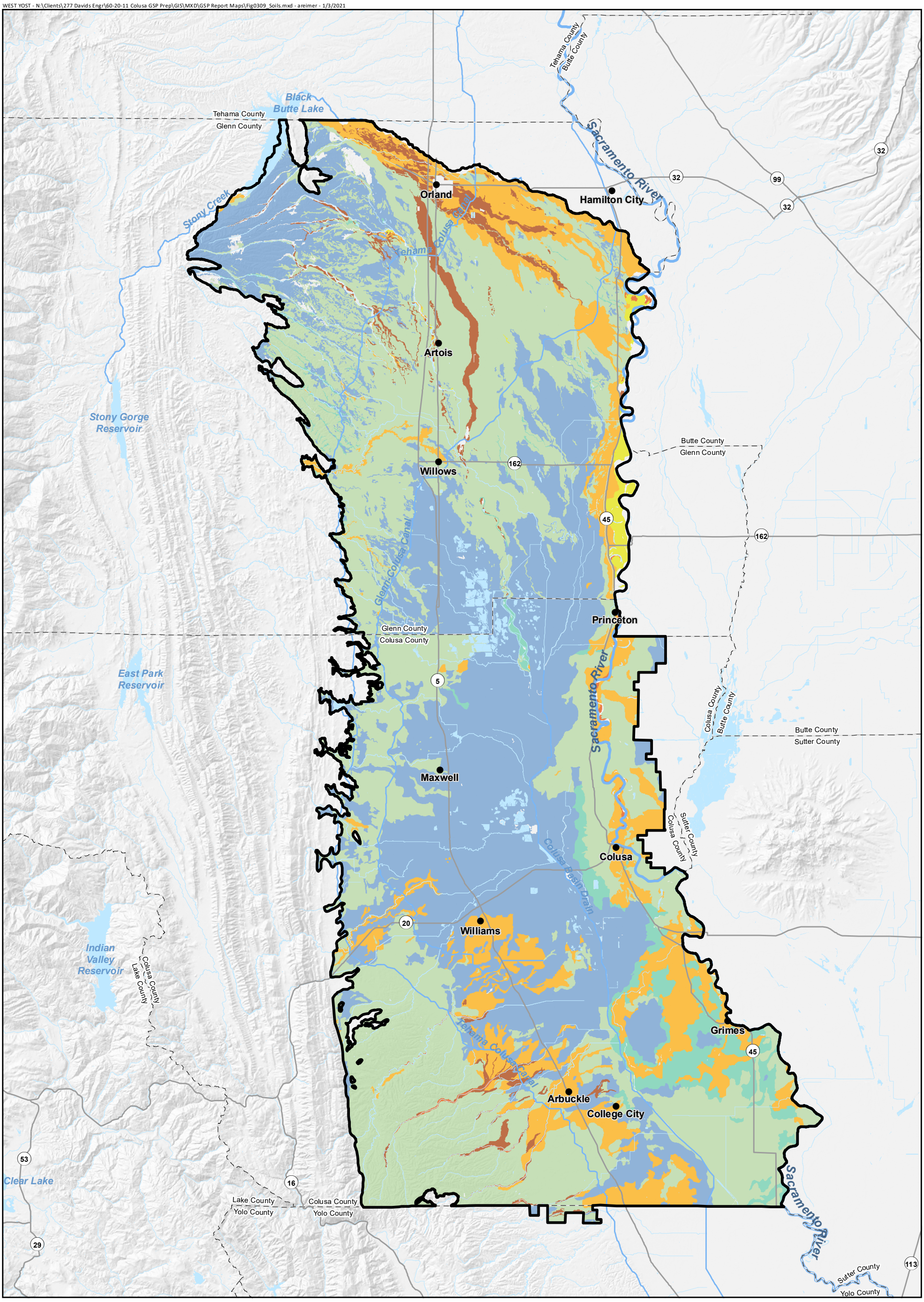
(a) Diversion ID in the C2VsimFG-Colusa model. C2VsimFG-Colusa was adapted from the C2VSimFG Beta2 model.

1

3.1.6 Soils

According to DWR (1978), which summarizes work performed by the USGS (Bertoldi, 1974), most soils in the Subbasin are either: 1) "soils containing hardpan or other consolidated horizons that restrict the vertical flow of water, including soils over bedrock", such as occurs in the western upland areas; or 2) "soils containing clay in sufficient quantities to impede the vertical flow of water", such as occurs in the former flood basins of the Sacramento River. Exceptions to this generalization are the soils in the vicinity of Stony Creek and stream channel deposits adjacent to the Sacramento River, which have "few barriers to the vertical flow of water" (DWR, 1978). These general patterns are supported by more recent soil surveys conducted by the Natural Resources Conservation Service (NRCS). Areas containing soils with few barriers to vertical flow have higher potential to recharge the underlying aquifers.

Figure 3-9 contains the NRCS Soil Survey Geographic Database (SSURGO) hydrologic soil group designations. Much of the Subbasin is classified as hydrologic groups C and D, which are defined as soils with slow or very slow infiltration rates when saturated (NRCS, 1986). Slow infiltration rates, as defined by NRCS, can be due to the presence of fine-textured layers, clays with high shrink-swell potential, shallow water tables, or shallow soil layers underlain by near-impervious layers. The Stony Creek alluvial fan, the Sacramento River historic channel, and runoff areas of northern Dunnigan Hills contain hydrologic soil groups A and B, which are defined as areas with high and moderate infiltration rates when saturated, respectively, occasionally mixed with soil group D (NRCS, 1986). Soils classified as mixed D soils (A/D, B/D, or C/D) typically correspond to soils near shallow water tables. These mixed D soils exhibit very low infiltration rates when undrained (characteristic of soil group D), and the alternate level of infiltration when drained (characteristic of soil group A, B, or C).



Source: Soil Survey Geographic Database (SSURGO) soils were downloaded via the 2014 SSURGO Downloader for the Big Chico Creek - Sacramento River, Butte Creek, Honcut Headwaters - Lower Feather, Sacramento Stone Corral, Upper Cache, and Upper Stony watershed subbasins.

Horizontal Datum: North American Datum of 1983, California State Plane Zone II, feet.

Note:
1. SSURGO soil designations outside of the study area are not shown in this map.

Study Area
Water

Hydrologic Soil Type

- A
- A/D
- B
- B/D
- C
- C/D
- D

N

0 2.5 5

Scale in Miles

Figure 3-9

Soils

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

3.1.7 Geologic Framework

This section describes the geologic framework for the Subbasin, per the BMP (DWR, 2016a) and 23 CCR §354.14(b). The regional geologic and structural setting of the subbasin and surrounding area are described, including faults and other geologic structures that may influence groundwater flow and quality.

3.1.7.1 Regional Geologic History

Table 3-3 lists the geologic units within the Subbasin and characterizes their age, lithologic character, thickness, and water bearing character (WRIME, 2003a; WRIME, 2003b). Figure 3-10 shows detailed surface geologic mapping for the Subbasin and surrounding region, and the locations of five geologic cross sections through the Subbasin. Cross sections are provided on Figure 3-11 through Figure 3-13, and a three-dimensional (3D) representation of the HCM is provided on Figure 3-14. Figure 3-15 shows the Tehama and Tuscan Formation surficial outcrops and subsurface extents, including an approximation of the subsurface Tehama-Tuscan Transition Zone, in which Tehama and Tuscan Formation deposits are intermixed (DWR, 2009b). Figure 3-16 includes elevation contours for the top of the Cretaceous rocks. These contours represent the structural base of the freshwater aquifer system (Harwood and Helley, 1987).

The cross sections were developed based on DWR's Geology of the Northern Sacramento Valley report (DWR, 2014a). Some of the original DWR cross sections were expanded and new or extended cross sections were generated to provide a geologic representation of the subsurface throughout the entire Subbasin (Figure 3-10). The revised and new cross sections were based on land surface information, well completion reports, and other geologic references for the region. References to the data used to generate the cross sections are provided in Table 3-1 and Chapter 8. The cross sections were used to generate a 3D model of the post-Cretaceous water bearing formations, and for assessment of the groundwater monitoring network.

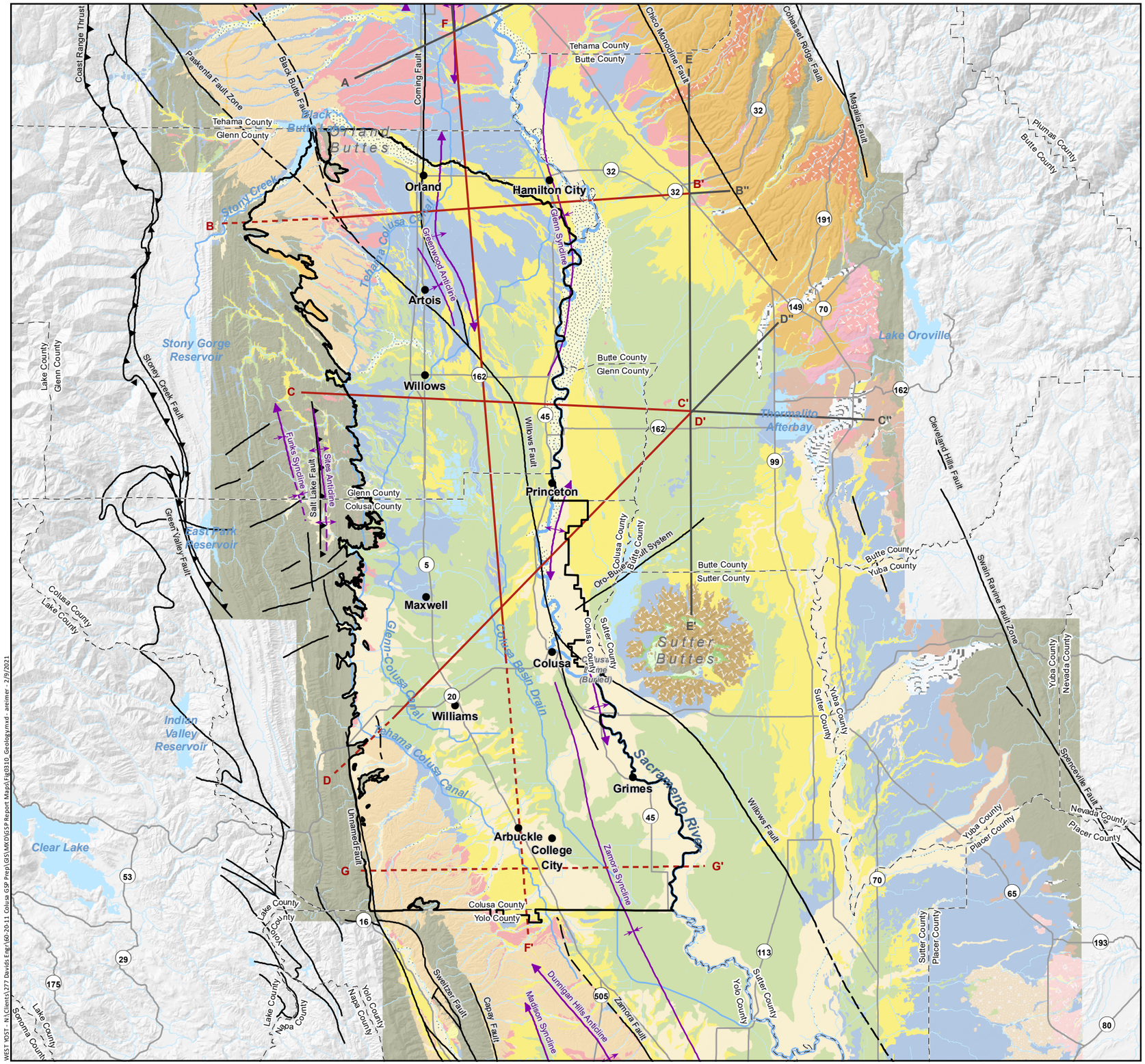
From the Late Jurassic (approximately 159 million years ago [Ma]) through the Miocene (approximately 23 Ma), much of what is now the Northern Sacramento Valley was a marine basin created in the forearc of the Pacific-North American plate subduction zone. The western boundary of the subbasin was formed by uplifting of volcanic, metamorphic and sedimentary rocks of marine origin, which would later become the Coast Ranges. This marine basin was bounded to the east by the Klamath-Sierran terrane formed during the Nevadan orogeny (approximately 155 Ma). Thick sequences of sediments eroded from the uplifted Klamath-Sierran terrane were deposited into the inland sea during the Cretaceous period. The resulting marine siltstones, sandstones, shales, and conglomerates comprise the Great Valley Sequence. Outcrops of the Great Valley Sequence define the western boundary of the Subbasin (Figure 3-10). The fresh groundwater-bearing formations overlie the Great Valley Sequence within most of the Subbasin, making it a major component of the structural base of the subbasin. The Great Valley Sequence is included in the pre-Paleogene and Cretaceous rocks referenced in the maps and within the report text. Figure 3-16 shows contours of the elevation of the top of the Cretaceous rocks in the Subbasin.

Table 3-3. Description of Geologic Units

Series		Unit	Lithologic Character	Thickness[a], ft	Water-Bearing Character
Quaternary	Holocene	Alluvium, Qa	Unconsolidated unweathered gravel, sand, silt, and clay[a].	80	Deposits are moderately to highly permeable with high permeability gravelly zones yielding large quantities to shallow wells[b]. Although deposits along Stony, Chico, and Thomes Creeks are important recharge areas[b], extensive water-bearing capacity is restricted by thickness and areal extent[a].
		Basin Deposits, Qb	Unconsolidated[e] fine-grained silts and clays, locally interbedded with stream and channel deposits along the Sacramento River[a].	150	Deposits are typically saturated nearly to the ground surface[b]. The low to moderate permeability results in yields of small quantity and poor groundwater quality to domestic wells[a,b].
	Pleistocene	Modesto Formation, Qm	Poorly sorted[e] unconsolidated weathered and unweathered gravel, sand, silt, and clay[c].	200	Moderately to highly permeable[a].
		Riverbank Deposits, Qr	Poorly sorted[e] unconsolidated to semi-consolidated[c] pebble and small cobble gravels interlensed with reddish clay, sand, and silt[a].	200	Water-bearing capability is limited by thickness. These poorly to highly permeable deposits supply moderate groundwater amounts to domestic and shallow irrigation wells. Deeper irrigation wells may be supplied if the wells contain multiple perforation zones[a].
		Red Bluff Formation, Qrb	Highly weathered, sandy gravels[g].	30[g]	Water-bearing capability is limited by thickness. Fresh groundwater may occur as a perched aquifer[g].
Neogene & Quaternary	Pliocene & Pleistocene	Tehama Formation, Tte	Fluviatile moderately consolidated pale green, gray, and tan sandstone and siltstone enclosing lenses of sand and gravel; silt and gravel; and cemented conglomerate derived from the Coast Ranges[a,c].	2,000	Local high permeability zones within this characteristically low to moderate permeability unit, widespread distribution, and deep thickness cause this formation to be the principal water bearing unit in the area. Deep well yields are typically moderate, but are highly variable[b].
Neogene	Pliocene	Tuscan Formation, Tt	This series of volcanic flows, consolidated tuff breccia, tuffaceous sandstone, and volcanic ash derived from the Cascade Range interfingers with the Tehama Formation as it westerly grades into volcanic sands, gravels, and clays[a,b]. The formation is divided by layers of thin tuff or ash units into four lithologically similar units A-D[a].	1,500	Within this formation, moderately to highly permeable volcanic sediments are hydraulically confined by layers of tuff breccias and clays[b]. Units A and B are the primary water-bearing zones and are composed of volcanic conglomerate, sandstone, and siltstone layers interbedded with lahars. Stratigraphically higher, the massive lahar deposits of unit C confine groundwater in the permeable beds of units A and B1.
		Nomlaki Tuff Member	Tuff breccias and white tuffs of dacitic composition. This member of the Tehama and Tuscan Formations serves as an important stratigraphical marker bed in northern Sacramento Valley[e].	60[e]	Poorly permeable.
	Miocene	Neroly Formation, Tn	Marine to non-marine tuffaceous andesitic sandstone interbedded with tuffaceous shales and tuff layers. Contains local conglomerate lenses[c].	500	This formation of variable permeability contains interstitial fresh water under confined conditions(d), however, deposits of the Neroly Formation are typically located below the base of fresh water.
		Upper Princeton Valley Fill, Tupg	Non-marine sandstone containing mudstone, conglomerate, and sandstone conglomerate interbeds[c].	1,400	Largely non-water bearing or contains interstitial confined fresh to brackish water[g].
		Lovejoy Basalt, Tl	Black, dense, hard microcrystalline basalt[c].	65	Largely non-water bearing.
Paleogene	Eocene	Ione Formation, Ti	Marine gravels[f], sandstone with claystone, and carbonaceous interbeds[g].	500(f)	Largely non-water bearing or contains interstitial confined fresh to brackish water.
		Lower Princeton Submarine Valley Fill, Tlpg	Marine conglomerate and sandstone interbedded with silty shale[c].	2,400	Largely non-water bearing or contains saline water.
Cretaceous		Great Valley Sequence, JKgvs	Marine siltstone, shale, sandstone, and conglomerate[c].	15,000	Largely non-water bearing or contains saline water[b].
Pre-Cretaceous		Basement Complex, pTb	Metamorphic and igneous rocks.	n/a	May contain groundwater, mainly saline, in fractures and joints.

Source: This table was originally included as part of the hydrogeologic conceptual model for the Stony Creek Fan IGSM (WRIME, 2003)[h]. The table has been revised and expanded to include the hydrogeologic conceptual model units for the study area represented in this report.

(a) Department of Water Resources web page (www.wq.water.ca.gov).
(b) Department of Water Resources, Bulletin 118-6, 1978.
(c) Department of Water Resources, Bulletin 118-7 (Draft, not published).
(d) Department of Water Resources, Sacramento River Basin-Wide Water Management Plan-Draft, 2000.
(e) Department of Water Resources, Groundwater Levels in the Sacramento Valley Groundwater Basin, Glenn County, 1997.
(f) Springhorn dissertation, 2008.
(g) Department of Water Resources, Geology of the Northern Sacramento Valley, 2014.
(h) WRIME, Stony Creek Fan Integrated Groundwater and Surface Water Model (SCFIGSM) Hydrogeology and Conceptual Model, 2003.



Northern Sacramento Valley Geology Cross Section Used for the Hydrogeologic Conceptual Model

Section Extension or New Cross Section

Northern Sacramento Valley Geology Cross Section Not Used for the Hydrogeologic Conceptual Model

Study Area

N

0 4 8

Scale in Miles

Geologic Structures

- Anticline
- Syncline
- Plunging Anticline
- Plunging Syncline
- Doubly Plunging Anticline
- Double Plunging Syncline
- Fault
- Thrust Fault

Geologic Units

- Stream Channel Deposits (Holocene)
- Alluvial Deposits (Holocene)
- Basin Deposits (Holocene)
- Landslides (Quaternary)
- Modesto Formation (Pleistocene)
- Riverbank Formation (Pleistocene)
- Red Bluff Formation (Pleistocene)
- Turlock Lake Formation (Pleistocene)
- Volcanic Rocks and Lacustrine Deposits of Sutter Buttes (Pleistocene - Pliocene)
- Basaltic Rocks (Pleistocene - Pliocene)
- Tehama Formation (Pliocene)
- Nomlaki Tuff Member (Pliocene)
- Putah Tuff Member (Pliocene)
- Tuscan Formation (Pliocene)
- Laguna Formation (Pliocene)
- Sutter Formation of Williams and Curtis (1977) (Pliocene - Oligocene)
- Channel Deposits (Pliocene - Miocene)
- Mehrten Formation (Pliocene - Miocene)
- Lovejoy Basalt (Miocene)
- Ione Formation (Eocene)
- Sedimentary Rocks in Sutter Buttes Area (Eocene)
- Metamorphic, Igneous, and Sedimentary Rocks (pre-Paleogene)
- Tailings

Source:

1. California Department of Water Resources, 2014, Geology of the Northern Sacramento Valley: prepared by the California Department of Water Resoures Northern Region Office, Groundwater and Geologic Investigations Section, updated September 2014.
2. Helley, E.J. and Harwood, D.S., 1985, Geologic Map of the Late Cenozoic Deposits of the Sacramento Valley and Northern Sierran Foothills, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1790, scale 1:62,500, GIS geodatabase.
3. Jennings, C.W. and Strand, R.G., 1960, Geologic Map of California, Olaf P. Jenkins Edition, Ukiah Sheet: Department of Natural Resources Division of Mines and Geology, third printing 1992, scale 1:250,000.
4. Koenig, J.B., 1963, Geologic Map of California, Olaf P. Jenkins Edition, Santa Rosa Sheet: California Department of Natural Resources Division of Mines and Geology, scale 1:250,000.
5. Springhorn, S.T., 2008, Stratigraphic Analysis and Hydrogeologic Characterization of Cenozoic Strata in the Sacramento Valley near the Sutter Buttes: Master of Science Dissertation, California State University, Chico, 2008.

Horizontal Datum: North American Datum of 1983, California State Plane Zone II, feet.

Notes:

1. The Helley and Harwood mapping is used where available and is supplemented or revised using geologic mapping from the California Department of Natural Resources Division of Mines and Geology documents and information provided in the Springhorn dissertation (2008)
2. Geologic structures are dashed where approximated.

Figure 3-10

Geologic Map

Colusa Groundwater Authority
and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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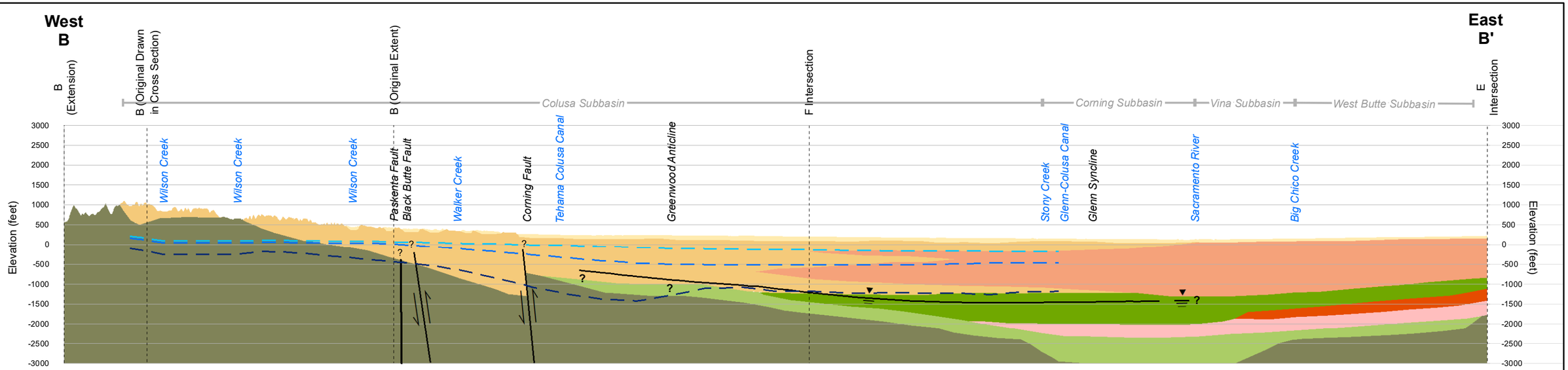
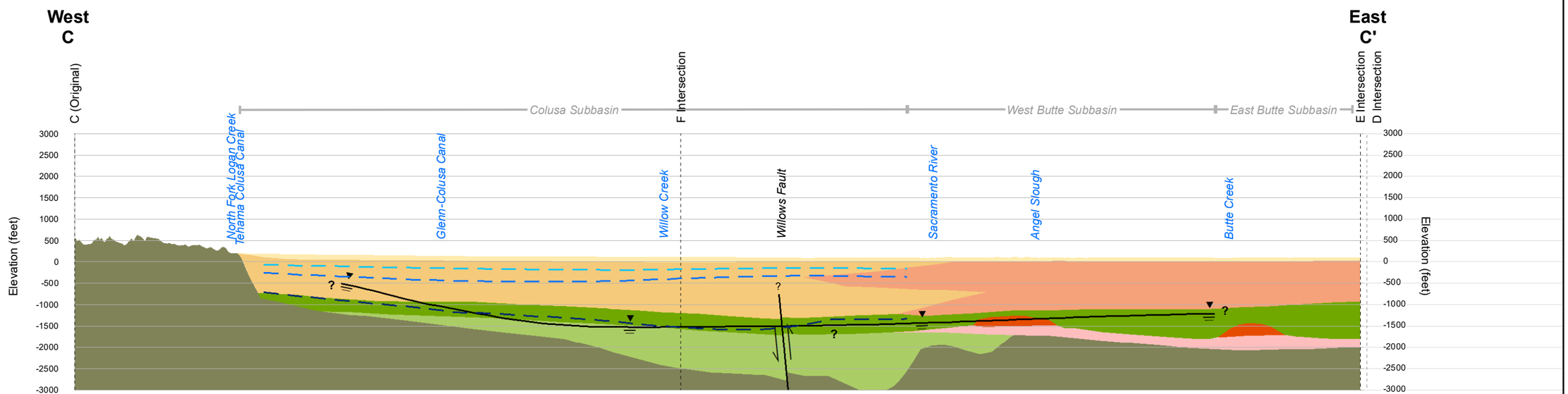
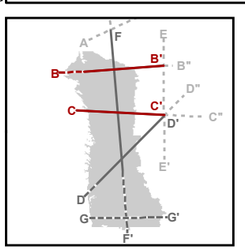


Cross Section B-B'



Cross Section C-C'



Inset Map Symbology

- Selected NSV Geology Cross Section Used for HCM
- Selected Section Extension or New Cross Section
- NSV Geology Cross Section Used for HCM
- Section Extension or New Cross Section
- NSV Geology Cross Section Not Used for HCM
- Colusa Subbasin

Cross Section Symbology

- Fault
- Base of Fresh Water (~2,000 mg/L TDS)
- Base of Model Layer 1 and Modeled Unconfined Aquifer
- Base of Model Layer 2 and Modeled Confined Aquifer Pumping
- Base of Model Layer 3 and Modeled Base of Fresh Water (~3,000 mg/L TDS)

Geologic Units

- Alluvium
- Tehama Formation
- Tuscan Formation
- Upper Princeton Valley Fill
- Lovejoy Basalt
- Ione Formation
- Lower Princeton Valley FIll
- Cretaceous Rocks (pre-Paleogene)

Notes:

1. Elevations are in North American Vertical Datum of 1988, feet (NAVD 88).
2. Cross sections shown are digitized versions of the cross sections included in the Department of Water Resources (DWR) Geology of the Northern Sacramento Valley, California report (DWR, 2014). Existing cross sections were extended and new cross sections were added, as needed, to provide coverage for the entire Colusa Groundwater Subbasin.
3. Cross sections B, C, and D were not digitized beyond their intersection with section E.
4. Base of fresh water was digitized from Olmsted and Davis (1961) and is not shown beyond the extent of the original base of freshwater contouring. Base of fresh water was defined by Olmsted and Davis as approximately 2,000 mg/L of total dissolved solids (TDS).
5. The preliminary approximation of the base of the groundwater subbasins within the study area is based on geologic formation boundaries.

0 1.25 2.5

Scale in Miles

Vertical Exaggeration: 5.28

Figure 3-11

Cross Sections B-B' and C-C'

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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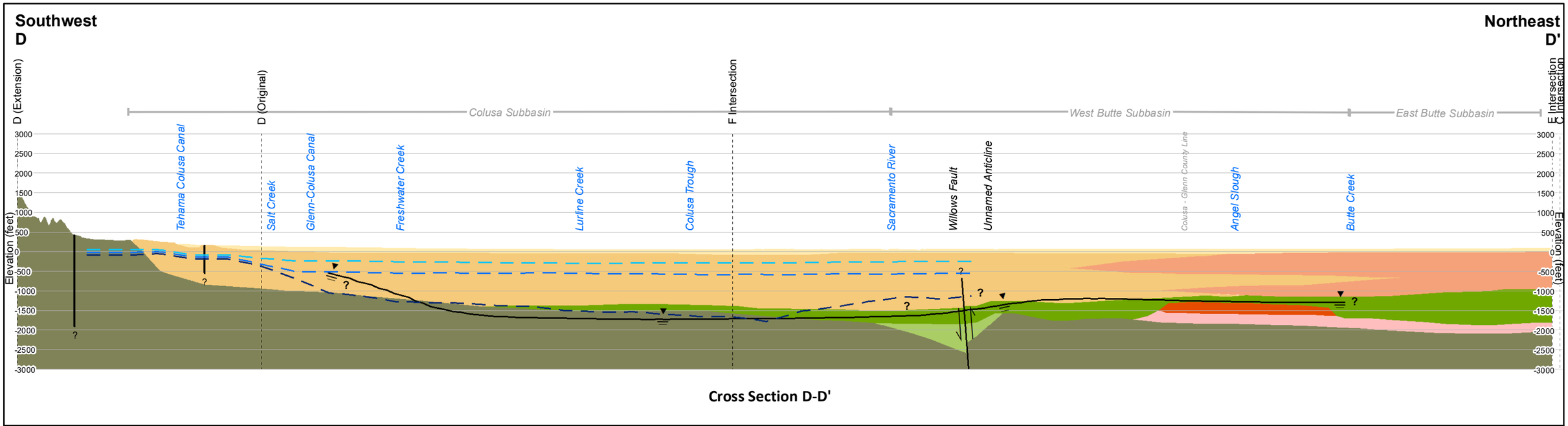
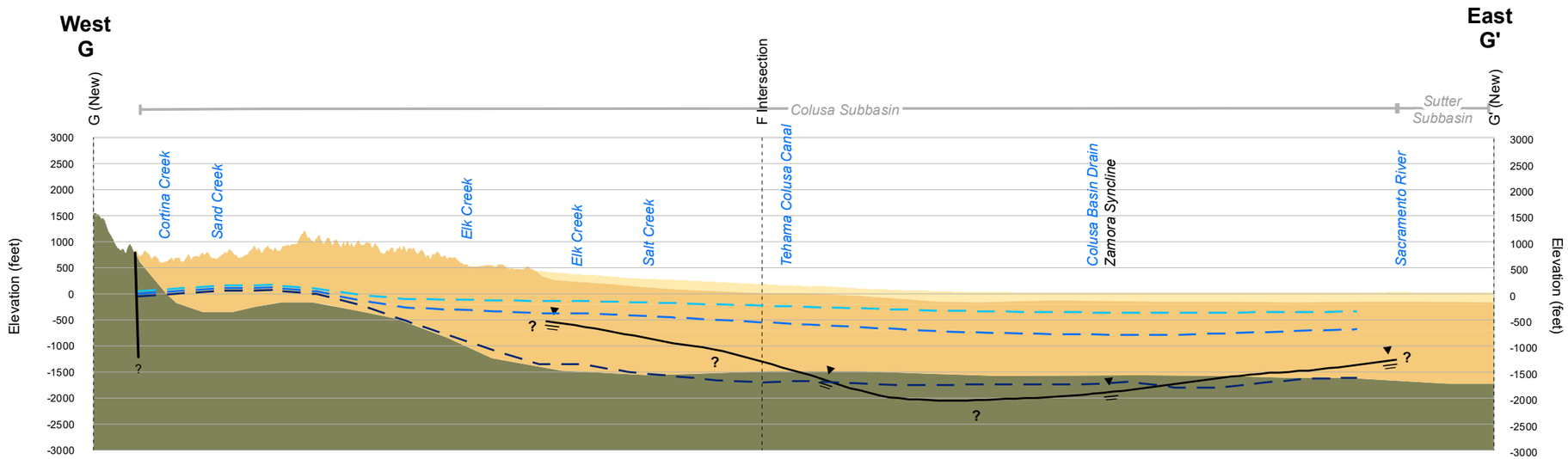
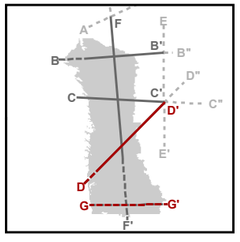


Cross Section D-D'



Cross Section G-G'



Inset Map Symbology

- Selected NSV Geology Cross Section Used for HCM
- Selected Section Extension or New Cross Section
- NSV Geology Cross Section Used for HCM
- Section Extension or New Cross Section
- NSV Geology Cross Section Not Used for HCM
- Colusa Subbasin

Cross Section Symbology

- Fault
- Base of Fresh Water (~2,000 mg/L TDS)
- Bottom of Model Layer 1 and Modeled Base of Unconfined Aquifer
- Bottom of Model Layer 2 and Modeled Base of Confined Aquifer Pumping
- Bottom of Model Layer 3 and Modeled Base of Fresh Water (~3,000 mg/L TDS)

Geologic Units

- Alluvium
- Tehama Formation
- Tuscan Formation
- Upper Princeton Valley Fill
- Lovejoy Basalt
- Ione Formation
- Lower Princeton Valley FIll
- Cretaceous Rocks (pre-Paleogene)

Notes:
1. Elevations are in North American Vertical Datum of 1988, feet (NAVD 88).
2. Cross sections shown are digitized versions of the cross sections included in the Department of Water Resources (DWR) Geology of the Northern Sacramento Valley, California report (DWR, 2014). Existing cross sections were extended and new cross sections were added, as needed, to provide coverage for the entire Colusa Groundwater Subbasin.
3. Cross sections B, C, and D were not digitized beyond their intersection with section E.
4. Base of fresh water was digitized from Olmsted and Davis (1961) and is not shown beyond the extent of the original base of freshwater contouring. Base of fresh water was defined by Olmsted and Davis as approximately 2,000 mg/L of total dissolved solids (TDS).
5. The preliminary approximation of the base of the groundwater subbasins within the study area is based on geologic formation boundaries.

0 1.25 2.5
Scale in Miles

Vertical Exaggeration: 5.28

Figure 3-12

Cross Sections D-D' and G-G'

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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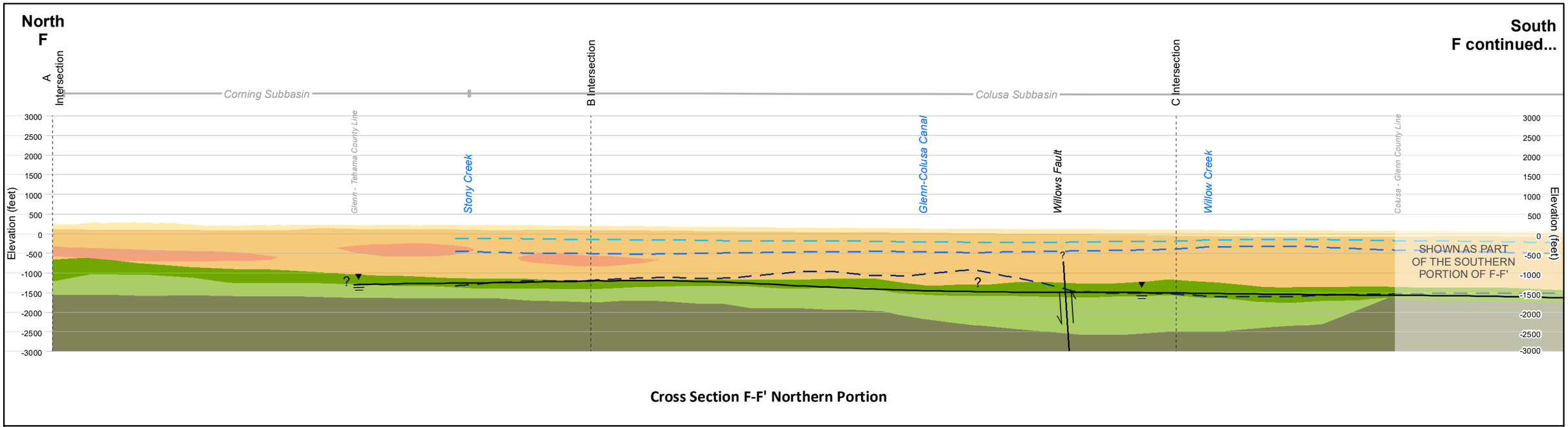
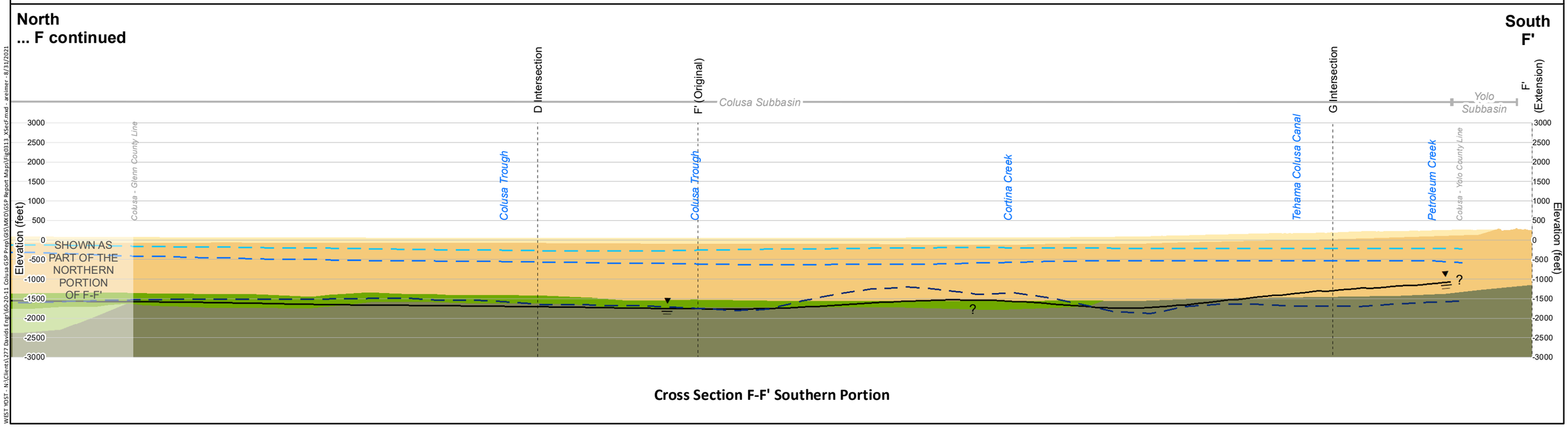


Cross Section F-F' Northern Portion



Cross Section F-F' Southern Portion

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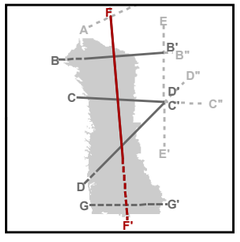


Inset Map Symbology

- Selected NSV Geology Cross Section Used for HCM
- Selected Section Extension or New Cross Section
- NSV Geology Cross Section Used for HCM
- Section Extension or New Cross Section
- NSV Geology Cross Section Not Used for HCM
- Colusa Subbasin

Cross Section Symbology

- Fault
- Base of Fresh Water (~2,000 mg/L TDS)
- Bottom of Model Layer 1 and Modeled Base of Unconfined Aquifer
- Bottom of Model Layer 2 and Modeled Base of Confined Aquifer Pumping
- Bottom of Model Layer 3 and Modeled Base of Fresh Water (~3,000 mg/L TDS)

Geologic Units

- Alluvium
- Tehama Formation
- Tuscan Formation
- Upper Princeton Valley Fill
- Lovejoy Basalt
- Ione Formation
- Lower Princeton Valley FIll
- Great Valley Sequence

Notes:

1. Elevations are in North American Vertical Datum of 1988, feet (NAVD 88).
2. Cross sections shown are digitized versions of the cross sections included in the Department of Water Resources (DWR) Geology of the Northern Sacramento Valley, California report (DWR, 2014). Existing cross sections were extended and new cross sections were added, as needed, to provide coverage for the entire Colusa Groundwater Subbasin.
3. Cross sections B, C, and D were not digitized beyond their intersection with section E.
4. Base of fresh water was digitized from Olmsted and Davis (1961) and is not shown beyond the extent of the original base of freshwater contouring. Base of fresh water was defined by Olmsted and Davis as approximately 2,000 mg/L of total dissolved solids (TDS).
5. The preliminary approximation of the base of the groundwater subbasins within the study area is based on geologic formation boundaries.

0 1.25 2.5

Scale in Miles

Vertical Exaggeration: 5.28

Figure 3-13

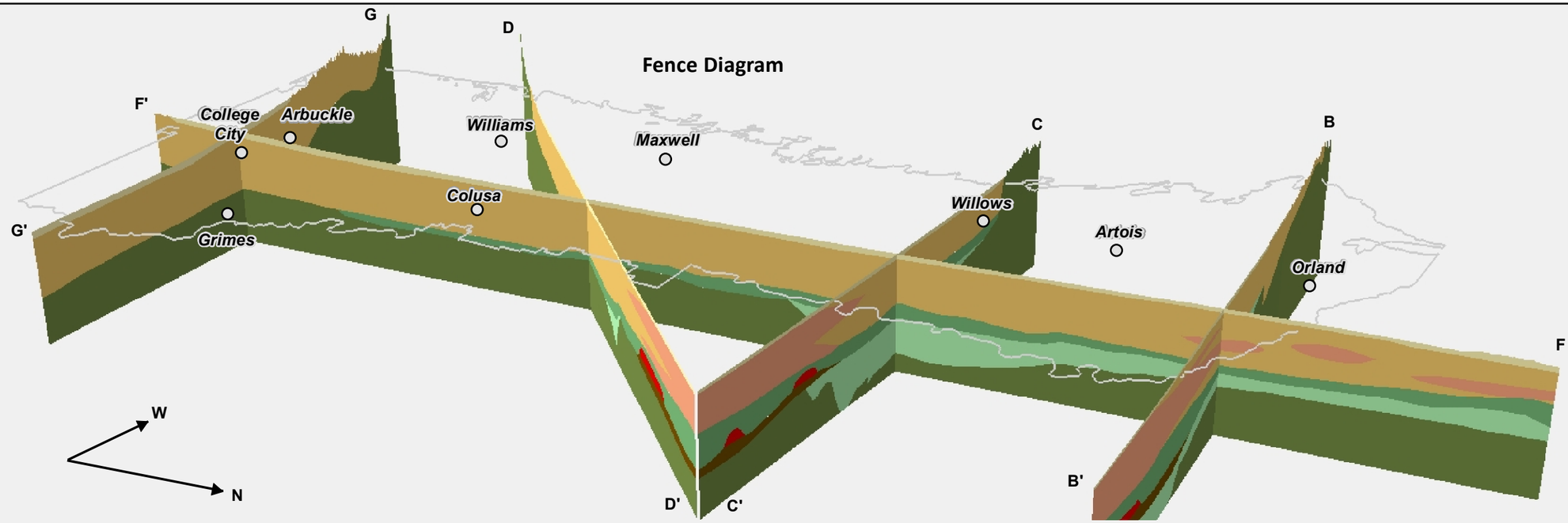
Cross Section F-F'

Colusa Groundwater Authority and Glenn Groundwater Authority

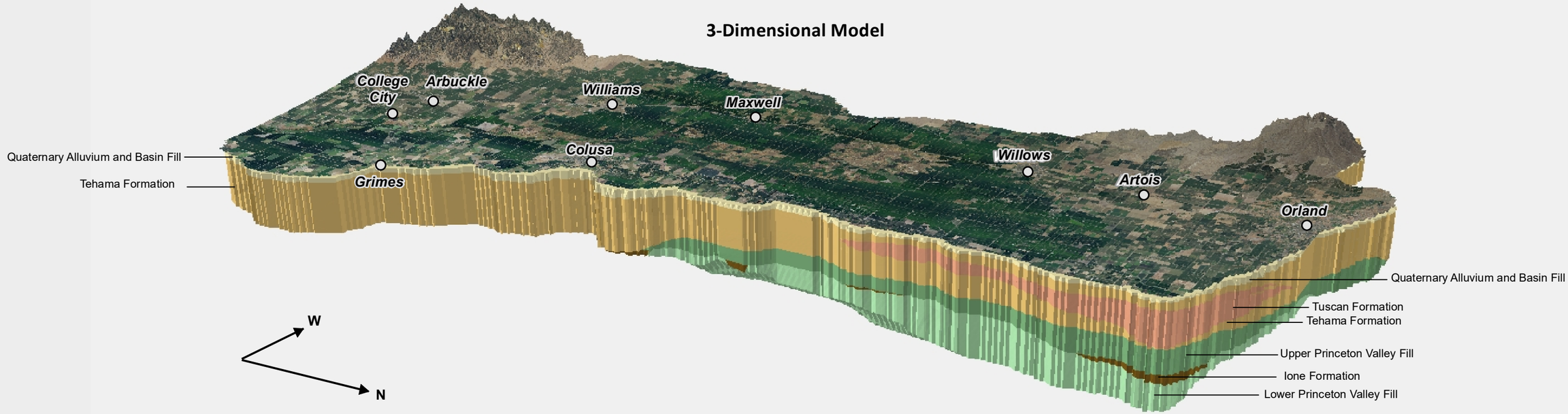
Colusa Subbasin

Groundwater Sustainability Plan

Fence Diagram



3-Dimensional Model



Datums: North American Datum of 1983, California State Plane Zone II, feet. North American Vertical Datum of 1988, feet.

Notes:
1. Vertical exaggeration is 10x.
2. Elevations are in North American Vertical Datum of 1988, feet (NAVD 88).
3. The fence diagram and 3-dimensional (3D) model are based on the cross sections included in the California Department of Water Resources (DWR) Geology of the Northern Sacramento Valley, California report (DWR, 2014) and have been updated and expanded upon based on available well completion reports to represent the water-bearing formations.
4. The 3D model excludes the Lovejoy Basalt.

Hydrogeologic Formation

- Quaternary Alluvium and Basin Fill
- Tehama Formation
- Tuscan Formation
- Upper Princeton Valley Fill
- Lovejoy Basalt
- Ione Formation
- Lower Princeton Valley Fill
- Cretaceous Rocks (pre-Paleogene)

Figure 3-14

3D Hydrogeologic Conceptual Model

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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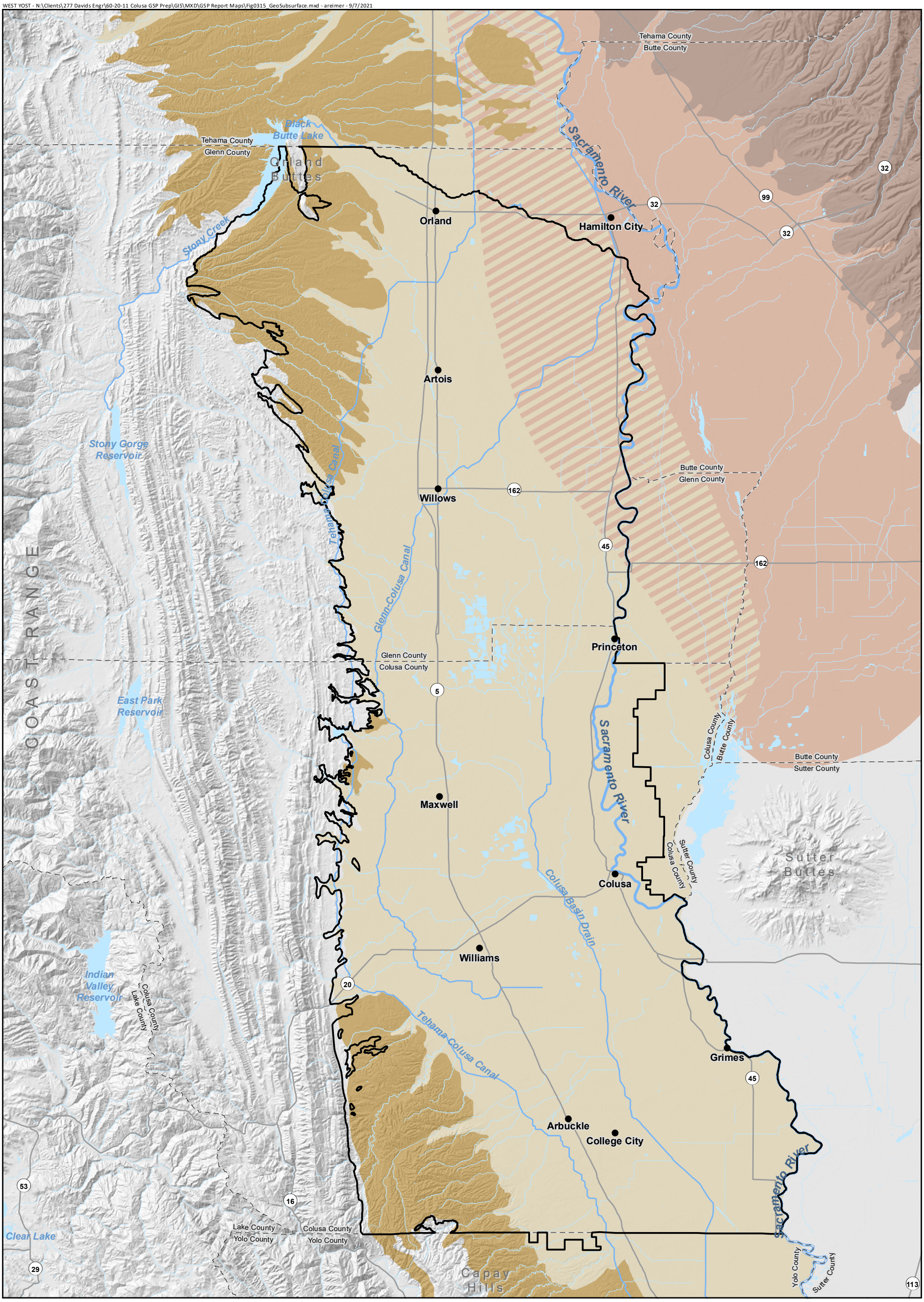


Source: DWR, 2009, Glenn-Colusa Irrigation District Test-Production Well Installation and Aquifer Testing: prepared by the California Department of Water Resources (DWR) Northern District Groundwater Section in cooperation with Glenn-Colusa Irrigation District, March 2009, GIS shapefiles provided by DWR 2008.

Horizontal Datum: North American Datum of 1983, California State Plane Zone II, feet.

- Colusa Subbasin
- Tuscan Outcrop
- Tehama Outcrop
- Tehama-Tuscan Subsurface Transition Zone
- Tehama Subsurface
- Tuscan Subsurface

N

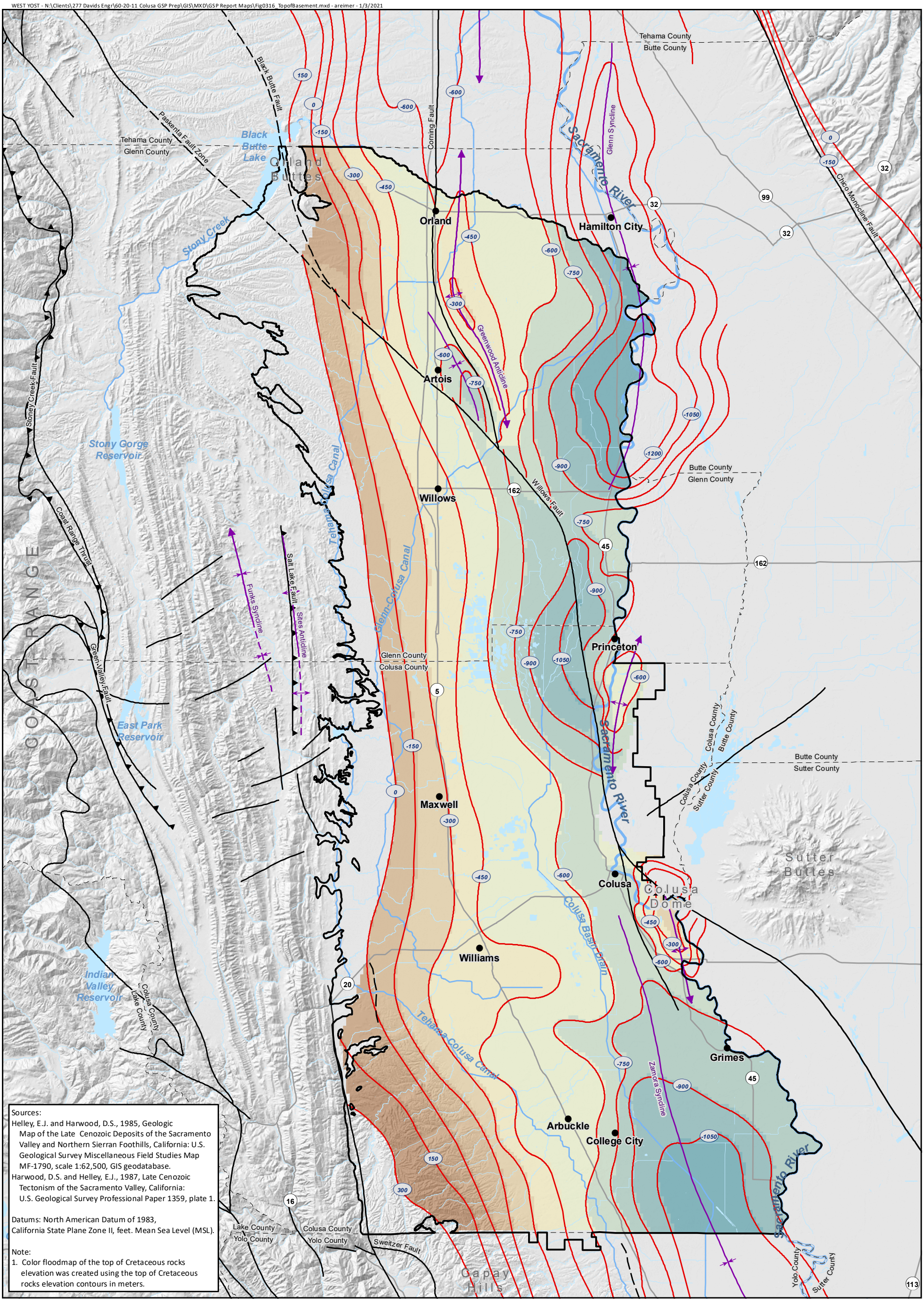
0 2.5 5

Scale in Miles

Figure 3-15

Extent of Tehama and Tuscan Formations

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan



Sources:
Helley, E.J. and Harwood, D.S., 1985, Geologic Map of the Late Cenozoic Deposits of the Sacramento Valley and Northern Sierran Foothills, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1790, scale 1:62,500, GIS geodatabase.
Harwood, D.S. and Helley, E.J., 1987, Late Cenozoic Tectonism of the Sacramento Valley, California: U.S. Geological Survey Professional Paper 1359, plate 1.

Datums: North American Datum of 1983, California State Plane Zone II, feet. Mean Sea Level (MSL).

Note:
1. Color floodmap of the top of Cretaceous rocks elevation was created using the top of Cretaceous rocks elevation contours in meters.

Anticline, Certain
Syncline, Certain
Plunging Anticline, Certain
Plunging Syncline, Certain
Doubly Plunging Anticline, Certain
Anticline, Approximate
Syncline, Approximate

Fault, Certain
Thrust Fault, Certain
Fault, Approximate

Top of Cretaceous Rocks Elevation Contours (MSL, meters)
Colusa Subbasin

Top of Cretaceous Rocks Elevation (MSL, meters)

< -1,050	-750 - -600	-300 - -150	> 150
-1,050 - -900	-600 - -450	-150 - 0	
-900 - -750	-450 - -300	0 - 150	

N
0 2.5 5
Scale in Miles

Figure 3-16

Top of Cretaceous Rocks Structural Contours Map

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

The shoreline of the sea migrated westward throughout the Paleogene period due to continued subduction of the Pacific plate beneath the North American plate. During this period of regression, drainage from ancestral mountain ranges located north of the Subbasin eroded a submarine valley into the marine deposits (DWR, 2014a; Redwine, 1984). This valley, called the Princeton Submarine Valley, extends from the northern end of what is now the Sacramento Valley towards the City of Woodland in Yolo County, south of the Subbasin. Continued regression of the inland sea and ongoing drainage from the surrounding ancestral hills resulted in a mix of marine and continental deposits filling the Princeton Submarine Valley and surrounding basin. The incised nature of the Princeton Submarine Valley within the Great Valley Sequence can best be seen in the west to east trending Cross Sections B-B', C-C', and D-D' on Figure 3-11 and Figure 3-12. Cross Section F-F', on Figure 3-13, approximately follows the axis of the valley.

The lowest extents of the submarine valley were unconformably filled with Lower Princeton Valley Fill deposits during the Eocene. The Lower Princeton Valley Fill, deposited via turbidity flows, consists of interbedded sandstones and shale (DWR, 2014a; Springhorn, 2008). The Lower Princeton Valley Fill was conformably overlain by the Ione Formation in the Eocene (approximately 40 Ma) via stream drainage from the Sierra Nevada. The western extent of the Ione Formation is characterized by shallow marine deposition in the remnants of the inland sea, while the eastern extent of the formation is characterized by non-marine deltaic deposition (Redwine 1984; Springhorn, 2008). The Ione Formation unconformably overlies the Great Valley Sequence and crystalline and metasedimentary rocks near the eastern portion of the Sacramento Valley and is used as a marker bed to distinguish the Upper and Lower Princeton Valley Fill deposits.

Around this time, the tectonic regime of the northern Sacramento Valley began transitioning from a subduction zone to a transform zone as the Mendocino Triple Junction (composed of the Pacific, North America, and Juan de Fuca-Gorda plates) approached the Subbasin from the south. The transition from subduction to transform movement resulted in the creation of faults and folds, many of which are north-south trending due to the direction of compression applied by the transform system.

Volcanic activity during the Miocene resulted in the deposition of the Lovejoy Basalt (approximately 16.4 Ma), which unconformably overlies the Ione Formation and older formations, where they exist (Figure 3-11 and Figure 3-12). These basaltic flows originated near Honey Lake in the eastern Sierras and flowed westward, following channels towards and through what is now the northern Sacramento Valley (Helley and Harwood, 1985). Due to its distribution as flows in preexisting channels, the presence of Lovejoy Basalt is widespread but discontinuous.

Unconformably overlying the Lovejoy Basalt and older formations is the Upper Princeton Valley Fill. Upper Princeton Valley Fill was originally thought to have been deposited in Late Miocene to Oligocene, however age dating of the Lovejoy Basalt has constrained the age of the Upper Princeton Valley Fill to the Miocene epoch (approximately 16.4 Ma) (Springhorn, 2008). Upper Princeton Valley Fill consists of sandstone, with occasional interbeds of mudstone and conglomerate deposited in a fluvial floodplain system (Redwine, 1984). Because of its depositional history, groundwater within the Upper Princeton Valley Fill is fresh to brackish in quality.

Uplift of the Coast Ranges in the Pliocene epoch eventually gave form to the Sacramento Valley as it exists today. Alluvial, fluvial, and floodplain deposits derived from the Coast Ranges eventually accumulated as the Tehama Formation along the western side of the valley, while volcanic activity within the southern Cascade Ranges produced basalt and andesite flows that would eventually become reworked into the Tuscan Formation. The Tehama and Tuscan Formations were deposited concurrently during the late Pliocene to Pleistocene, interfingering with one another beneath the valley floor in what is referred to as the Tehama-Tuscan Transition Zone (Figure 3-15). The interlayering of the Tehama and Tuscan Formations can

be seen in Cross Sections B-B', C-C', D-D', and F-F' (Figure 3-11 through Figure 3-13). The Tuscan Formation appears as isolated lenses in north-south trending Cross Section F-F', but these lenses are integral with the main body of the Tuscan Formation, as depicted in the west-east trending cross sections. In the late Pliocene epoch, volcanic activity within the southern Cascade Range caused the widespread deposition of the Nomlaki Tuff across the northern Sacramento Valley. The Nomlaki Tuff has been radiometrically dated to 3.4 Million Years Ago (Ma) (Evernden, 1964) and provides an age constraint on the Tehama and Tuscan Formations because it is found in the basal deposits of both formations. The age of the upper boundary of the Tuscan Formation is further constrained to 1.5 Ma based on age dating of a rhyolite flow that overlies the Tuscan Formation near Mineral, Tehama County (Lydon, 1968).

Additional faults and folds were created as the Mendocino Triple Junction continued to move northward. These include the Corning Fault, Glenn Syncline, Greenwood Anticline, and an assortment of domes and buttes within the Subbasin. The Sutter Buttes are thought to have formed in part due to the compressional tectonics associated with the migration of the Mendocino Triple Junction (Hausback and Nilsen, 1999). The most recent Sutter Buttes volcanism occurred approximately 2 Ma (Hausback and Nilsen, 1999).

Quaternary geologic deposits are characterized by alluvial pediments and fans, and basin floodplain deposits of the Red Bluff Formation (an erosional surface, or pediment), Riverbank Formation, Modesto Formation, and basin deposits. These are collectively referred to as "Alluvium" on the cross sections found on Figure 3-11 through Figure 3-13 because of their limited thicknesses relative to the older formations (Table 3-3).

The Red Bluff Formation is a thin sand and gravel deposit resting on a pediment or erosional surface on the Tehama Formation (Figure 3-10). The Red Bluff Formation was formed when the Sacramento Valley was a closed drainage basin, which resulted in lacustrine depositional environments. The Red Bluff Formation is thought to represent the paleoshores of this ancient lacustrine system (DWR, 2014a; Springhorn, 2008). The age of the Red Bluff Formation is constrained to 0.6 to 1.09 Ma by radiometrically determined ages of the Rockland ash bed and the Deer Creek basalt, respectively (Harwood et. al., 1981; Harwood and Helley, 1987; Lanphere et. al., 1999). This constrains the age of the Tehama Formation to be no younger than 0.6 to 1.09 Ma.

Lacustrine environments resulting from the basin's internal drainage during deposition of the Red Bluff Formation also resulted in the deposition of diatomaceous clays similar to the Corcoran Clay of the San Joaquin Valley. This diatomaceous clay layer within the Sacramento Valley is referred to as the Turlock Lake Formation (Harwood and Jaworowski, 1985). This indicates that potentially subsidence-prone compressible sediments of approximately 0.6 to 1.09 Ma age are located near the top of the Tehama Formation. Boreholes east and south of the Sutter Buttes have encountered the Turlock Lake Formation. While similar sediment lithologies have been encountered in boreholes west of the Sutter Buttes, Turlock Lake Formation has not yet been identified in boreholes within the Subbasin. One borehole drilled near the Colusa Drain near Zamora in Yolo County, referred to as the USGS Zamora borehole, encountered a diatomaceous clay layer of about 10-feet thick at an approximate depth of 534 to 544 feet with properties similar to those of the diatomaceous clay from the Corcoran Clay of the San Joaquin Valley (Page, 1998; Page and Bertoldi, 1983).

The limited fresh groundwater found within the Red Bluff Formation tends to be present under perched conditions (DWR, 2014a). The Red Bluff Formation is therefore not further discussed in the following sections of this report.

Glacial activity during the Pleistocene epoch resulted in the Riverbank and Modesto Formations (Busacca et. al., 1989). The age of the Riverbank Formation ranges from 0.13 to 0.45 Ma and corresponds to the Illinoisan and older glacial stages. The age of the Modesto Formation ranges from approximately 0.01 to 0.042 Ma and correlates to the Wisconsin glacial stage.

The youngest deposits of the Subbasin consist of Holocene-aged basin deposits and stream channel deposits.

3.1.7.2 Primary Freshwater-Bearing Formations

The geologic formations forming the freshwater aquifer comprise a single aquifer system. The geologic formations comprising the freshwater aquifer system are discussed below.

3.1.7.2.1 Tuscan Formation

Tuscan Formation deposits are characterized by their Cascade Range origin and volcanic signature. This extensive series of basaltic and andesitic volcanic flows, consolidated tuff breccia, tuffaceous sandstone, and volcanic ash is primarily located on the northeastern portion of the Sacramento Valley. Figure 3-10 and Figure 3-15 show the approximate surface and subsurface extents of the Tuscan Formation in the vicinity of the Subbasin. The Tehama-Tuscan Transition Zone is also visible in the 3D hydrogeologic conceptual model shown on Figure 3-14. The Tuscan Formation comprises the oldest freshwater aquifer in the eastern half of the northern Sacramento Valley. The Tuscan Formation is exposed on the eastern side of the Sacramento Valley and occurs as interfingering layers with the Tehama Formation at depth near the center of the Sacramento Valley. This interfingering of the Tehama Formation with Tuscan Formation units is referred to as the Tehama-Tuscan Transition Zone (Figure 3-15). In the Subbasin, these deposits occur at depths greater than the depths of most existing domestic wells.

Moderately to highly permeable volcanic sediments are hydraulically confined by layers of tuff breccias and clays within the Tuscan Formation. The Tuscan Formation contains four map units, which are designated A through D, with A being the oldest (DWR, 2006a). The low permeability lahar, or mudflow, deposits of Unit C are confining beds for the underlying older Tuscan Units A and B. Although Unit C contains permeable volcanic sandstone and conglomerate interbeds, this unit is characterized by an overall low yield of water to wells within the Subbasin. Units A and B are much coarser-grained than the overlying Unit C, and they are the primary water-bearing zones of the eastern Sacramento Valley. The lower Tuscan Formation (Tuscan Units A and B) is present at depths below 700 feet in the northeastern part of the Subbasin and consists of volcanic conglomerate, sandstone, siltstone, and interbedded lahars overlain by tuffaceous breccias, sandstone and conglomerate. Tuscan Unit D is not present within the Subbasin.

The permeability of the Tuscan Formation varies, and irrigation wells range in well yield from 7 to 4,000 gallons per minute (gpm).

3.1.7.2.2 Tehama Formation

Figure 3-10 and Figure 3-15 show the approximate surface exposures and subsurface extents of the Tehama Formation. The Tehama Formation forms the oldest, deepest, and thickest part of the freshwater aquifer in the western half of the northern Sacramento Valley. The Tehama Formation consists of up to nearly 2,000 feet of moderately compacted silt, clay, and silty fine sand enclosing thin, discontinuous lenses of sand and gravel deposited in a fluvial (river-borne) environment (DWR, 2006a; Olmsted and Davis, 1961). Based on the mineralogy of surface exposures, the sediments were derived from erosion of the Coast Ranges and Klamath Mountains to the west and northwest. They were deposited under floodplain conditions on the west side of a broad valley of low relief (Brown and Caldwell, 2007; Russell, 1931).

The Tehama and Red Bluff Formations are exposed at the land surface on the western side of the Sacramento Valley, in the northwest, and the southwest. The outcrop of the Tehama and Red Bluff Formations and pinchout of the younger valley sediments coincide with an increase in terrain, as seen in Figure 3-4. There are few wells drilled in these areas and local residents report that existing wells yield little groundwater. Geologic mapping shows outcropping of older Cretaceous-aged sedimentary rocks in the northwestern portion of the subbasin near the Orland Buttes and west of the Tehama-Colusa Canal (Figure 3-10). Based on these observations, the Tehama Formation is relatively thin and has a low permeability where it outcrops. The Tehama Formation is buried beneath younger sediments to the east and interfingers with the Tuscan Formation throughout the Tehama-Tuscan Transition Zone in the northeast portion of the Subbasin (Figure 3-15).

The permeability of the Tehama Formation varies but is generally less than in the overlying unconsolidated alluvial deposits. Because of the thickness of the producing zones, production from the Tehama Formation can be up to several thousand gallons per minute per well (DWR, 2006a), but is typically less than that exhibited by the Tuscan Formation.

3.1.7.2.3 Riverbank and Modesto Formations

The late Pleistocene-aged Riverbank and Modesto Formations uncomfortably overlie the Tuscan and Tehama Formations. The thickness of the formation ranges from less than 10 feet to nearly 200 feet across the valley floor (DWR, 2006a; Helley and Harwood, 1985). These formations consist of loose to moderately compacted silt, silty clay, sand and gravel deposited in alluvial depositional environments during periods of world-wide glaciation (DWR, 2006a; Lettis, 1988; Weissmann et. al., 2002). The formations were deposited in response to changes in base level and increased precipitation during the glacial periods. The increased stream gradients and precipitation resulted in greater stream discharge and competency than observed today. The greater competency of the streams led to scouring of stream channels in preexisting geologic deposits, followed by transport, deposition and burial of sands and gravels in the channels as the glacial cycles progressed.

Figure 3-10 shows the spatial distribution of the Riverbank and Modesto Formation in the Subbasin. The formations are exposed at the land surface along the channels of creeks and along the western margin of the Subbasin, where they form a series of coalescing alluvial fans, emanating from the mouths of the creeks. The Riverbank and Modesto Formations typically form terraces along stream channels. The oldest terraces occur furthest from the channel and at the highest elevations. Successively younger terraces are incised into the next oldest deposit and, therefore, occur closer to the stream channel and at lower elevations. The Riverbank Formation forms the older terrace deposits that occur at a higher topographic level. In the Stony Creek Fan area, these terraces are well-defined, but they are absent or poorly defined along other minor streams in the Subbasin.

The Riverbank Formation consists of poorly to highly permeable pebble and small cobble gravels interbedded with reddish clay, sand, and silt. The Modesto Formation consists of moderately to highly permeable gravels, sands, and silts. The Riverbank Formation is distinguished from the Modesto Formation by interbedded clay layers. These formations contain fresh water (DWR, 2006a; Harwood and Helley, 1987).

Wells penetrating the sand and gravel units of the Riverbank and Modesto Formations produce up to about 1,000 gpm; however, the production varies depending on local formation thickness (DWR, 2006a). Wells screened in the Riverbank and Modesto Formations are generally domestic and shallow irrigation wells (DWR, 2006a).

3.1.7.2.4 Stream Channel and Basin Deposits

Holocene stream channel and basin deposits are the youngest sediments in Subbasin, with ages of roughly 10,000 years or younger (Helley and Harwood, 1985). The stream channel and basin deposits consist of up to 80-foot sections of unconsolidated clay, silt, sand, and gravel reworked from older formations by streams. According to DWR (2006a), which also refers to these deposits as younger alluvium, these deposits form a shallow, unconfined aquifer of moderate to high permeability, but with limited capacity due to the relatively restricted lateral and vertical extents of the deposits.

Holocene flood basin deposits are very young surficial deposits formed during flood events when streams overtopped their natural levees, flooding the surrounding area. As the flood water spread, the current velocity and stream competency decreased, resulting in deposition of silts, clays, and fine sands. Flood basin deposits reach thicknesses of up to 150 feet and may be interbedded with stream channel deposits (DWR, 2006a). Because of their low permeability, limited extent, and generally poor water quality, flood basin deposits are typically not used for groundwater production (DWR, 2006a).

3.1.7.3 Geologic Structures

Figure 3-16, from Harwood and Helley (1987), shows the structural contours in meters delineating the top of the Cretaceous marine sedimentary rocks in the vicinity of the Subbasin. The shaded color intervals on Figure 3-16 conform to the structural contours of the top of the Cretaceous rocks. The structural contours were based on the Cretaceous rocks because the resulting surface produces a single structural datum throughout the western Sacramento Valley. This datum helps reveal some of the geologic structures (folds and faults) that affect the Subbasin.

Figure 3-10 shows the significant structural features near the Subbasin, including, but not limited to the Willows Fault, Corning Fault, Glenn Syncline, and the Zamora Syncline in addition to other smaller unnamed geologic structures. These structural features affect geologic units at least as young as the Red Bluff Formation, which indicates that structural deformation was occurring as recently as 0.45 Ma – the oldest potential age of the overlying Riverbank Formation – and may be continuing at present (Harwood and Helley, 1987).

3.1.7.3.1 Faults

Faults may affect groundwater flow by bringing geologic materials with different hydraulic properties into contact across the fault plane or by fracturing the materials, which could either increase or decrease permeability, depending on the degree of fracturing and other geologic processes, such as mineralization, active within the fault zone. The fault might, therefore, act as a boundary or barrier affecting the lateral flow of groundwater between adjacent areas and might act as a conduit allowing vertical or lateral flow within the fault zone. The faults that were analyzed as part of this report include the Zamora Fault, Willows Fault, Corning Fault, Black Butte Fault, and the Paskenta Fault. These faults are shown on Figure 3-10 and discussed in the following subsections.

3.1.7.3.1.1 Zamora Fault

The Zamora Fault is a northwest-trending, east-dipping normal fault mapped along the eastern edge of Dunnigan Hills, south of the Subbasin. The Dunnigan Hills escarpment is partially attributed to the displacement along the Zamora Fault (Harwood and Helley, 1987). Local topography and geology indicate that the fault may extend further northward towards Arbuckle.

3.1.7.3.1.2 Willows Fault

The Willows Fault is a north-south trending reverse fault that dips 74 degrees to the east and extends from near Stockton, San Joaquin County to the north end of the Sacramento Valley (Harwood and Helley, 1987). The reverse movement of the fault juxtaposes Mesozoic-aged marine formations against the Tehama Formation, as seen in portions of Cross Sections B-B', C-C', and D-D', and the northernmost portion of Cross Section F-F' (Figure 3-11 through Figure 3-13). Additionally, there is evidence that the Willows Fault influenced not only the position of the Lower Princeton Valley Fill thalweg, but also offset the fill during deposition (Redwine, 1984). Displacement along the Willows Fault is approximately 1,600 feet at the top of the Cretaceous rocks and approximately 1,560 feet at the top of the Eocene formations (Harwood and Helley, 1987). The most recent activity along the Willows Fault affects the lower Tehama Formation. The slip rate on the Willows Fault is estimated to be 0.00055 inches per year (McPherson and Garven, 1999).

Groundwater elevations exhibit a localized lowering of the water levels where the northern extent of the Willows Fault splits into the Black Butte and Paskenta Fault zones. This is discussed more in the Existing and Historical Groundwater Conditions sections of the GSP (Section 3.2).

3.1.7.3.1.3 Corning Fault

The Corning Fault is an offshoot of the Willows Fault that extends north of Artois, Glenn County. It is a north-trending reverse fault of similar structure to the Willows Fault, which has no surface expression, but offsets the Pleistocene-age Red Bluff Formation and the underlying Tehama Formation (Harwood and Helley, 1987). Additionally, Late Cretaceous deposits in the region exhibit offsets of approximately 1,000 feet due to the Corning Fault (Helley and Hardwood, 1985), which can be seen in Cross Section B-B' (Figure 3-11). William Lettis and Associates (2002) concluded that "the Corning Fault is an active seismic source" with an estimated slip rate between 0.0008 and 0.002 inches per year.

3.1.7.3.1.4 Black Butte Fault

The Black Butte Fault is a northwest trending fault that separates the Orland Buttes from Black Butte Lake. Movement along the fault may have caused the uplift of the Orland Buttes (Russell, 1931). Mapping by Helley and Harwood (1985) included on Figure 3-10 depicts the Black Butte Fault as a northward offshoot of the Willows Fault, much like the Corning Fault.

3.1.7.3.1.5 Paskenta Fault

Displacement along the Paskenta Fault impacts the Cretaceous rocks but has not been observed within the Tehama and younger formations, constraining its most recent activity to approximately 3.3 Ma (DWR, 2014a). There are two main interpretations of the geologic nature of the Paskenta Fault zone. One interpretation is that the fault zone is a northwest trending, left lateral, transtensional strike slip fault (Moxon, 1990). The other interpretation is that the fault zone originated as an east-striking north-dipping normal fault zone that has been subjected to uplift and tilting to its current northwest trend (DWR, 2014a; Jones et. al., 1969; Moxon, 1990). Additionally, some studies represent the fault zone as truncating near Black Butte Lake or transitioning into an anticlinal form while others have mapped the fault as a splay fault from the Willows Fault, as shown on Figure 3-10 (DWR, 2014a).

3.1.7.3.2 Folds

Folds may affect groundwater conditions because folding causes the elevation and thickness of geologic units to vary from place to place. Synclines are typically characterized by thickening of younger units near the axis of the fold and potential exposure of older more consolidated units near the margins of the fold. Anticlines are the opposite and can expose less permeable rock formations along their axis and may

exhibit thickening of younger less consolidated formations near their margins. Additionally, the permeability and other material properties of sedimentary rocks, such as the Tehama Formation, are typically naturally anisotropic due to the alignment of mineral grains along bedding planes during deposition of the sediments. This alignment of the mineral grains results in higher permeability along rather than across bedding planes, which typically results in a maximum permeability horizontally and a minimum permeability vertically. Subsequent folding of bedding planes causes a reorientation of the direction of the mineral grains, and therefore a reorientation of the maximum and minimum permeability direction, which may affect groundwater flow rates and directions. The folds that were analyzed as part of this report include the Zamora Syncline, the Glenn Syncline, and the Greenwood Anticline. These folds are shown on Figure 3-10 and discussed in the following subsections.

3.1.7.3.2.1 Zamora Syncline

The Zamora Syncline is located in the subsurface east of Arbuckle, Colusa County and extends into Yolo County (Figure 3-10). The Zamora Syncline has no topographic expression, which means that the thickness of post-Cretaceous sediments, including the Tehama Formation, is greater along the axis of the syncline than on the limbs. This means that the aquifer thickness is greatest along the axis of the syncline. The effects of the Zamora Syncline on the older Cretaceous formations can be seen on Figure 3-16, where the elevation of the top of the Cretaceous formations is depressed west and south of College City, Colusa County.

3.1.7.3.2.2 Glenn Syncline

The Glenn Syncline is located near Hamilton City, Glenn County and was formed during the same compressional regime as the Corning Fault (DWR, 2014a). The Glenn Syncline roughly follows the direction of the Sacramento River (Figure 3-10). The effects of the Glenn Syncline on the Cretaceous formations can be seen in the elevation contours of the top of the Cretaceous rocks on Figure 3-10, where a depression in the top of the Cretaceous formations corresponds to the axis of the Glenn Syncline. Folding of the geologic formations along the Glenn Syncline can also be seen in Cross Section B-B' (Figure 3-11). Due to the vertical exaggeration of the cross section, folding is not as evident as the presence of the Princeton Submarine Valley, but a slight depression can be seen in the Great Valley Sequence and Upper Princeton Valley Fill near the Glenn Syncline.

3.1.7.3.2.3 Greenwood Anticline

The Greenwood Anticline and an unnamed syncline are located near Artois, Glenn County. These structures are on opposing sides of the Corning Fault and mimic the change in strike directions displayed by the Corning Fault (Helley and Harwood, 1985). It is believed that the Greenwood Anticline and the unnamed syncline coincided with the formation of the Corning Fault, under the same tectonic stress regimes (DWR, 2014a). Comparing Figure 3-10 and Figure 3-16, highs in the top of the Cretaceous formations are associated with the locations of the anticlines.

3.1.7.3.3 Orland Buttes

The Orland Buttes are located along the eastern shore of Black Butte Lake in Glenn County. The buttes are composed of Cretaceous rocks capped by Lovejoy Basalt, which were thought to have been uplifted due to movement along the Black Butte Fault (Russell, 1931). Seismic refraction data and a recent study by Williams Lettis and Associates (2002), however, suggest that the Orland Buttes were exposed via uplift and subsequent eastward tilting along a blind west-dipping thrust fault.

3.1.7.3.4 Sutter Buttes

The Sutter Buttes rise about 2,080 feet above the Sacramento Valley floor east of Colusa and are composed of igneous, metasedimentary and metavolcanic rocks about 2.4 to 1.4 Ma in age (Harwood and Helley, 1987). The formation of the Sutter Buttes occurred in two phases. The first phase caused Upper Cretaceous and Lower Paleogene formations to be arched into a dome rising above land surface during a period of magma injection. This was followed by rapid erosion and heavy faulting of the dome structure, causing the relatively older formations to be exposed prior to the second phase. The second phase consisted of explosive volcanism, producing the rampart tuffs and breccias surrounding the Sutter Buttes. Like many of the other geologic structures of the region, the Sutter Buttes express characteristics representative of the stress regime produced by the Mendocino Triple Junction (Harwood and Helley, 1987).

3.1.7.3.5 Colusa Dome

The Colusa Dome is a subsurface structure located approximately six miles west-southwest of the Sutter Buttes (Harwood and Helley, 1987). The dome is oblong in shape, approximately 12 miles long in the north-south direction and approximately 3 miles wide. Formation of the Colusa Dome, proposed by Harwood and Helley (1987), is due to both drag on the Willows Fault and/or a related south-trending fault splay and localized magmatic intrusion, potentially during the same period as the formation of the Sutter Buttes. The Colusa Dome is associated with uplift of Cretaceous to Eocene formations. Uplift of the Cretaceous rocks can be seen on Figure 3-16. The Cretaceous rocks have been uplifted to approximately 1,500 feet below ground surface (bgs) while the younger Eocene deposits have been uplifted to approximately 500 feet bgs (Springhorn, 2008; Williams and Curtis, 1977).

3.1.8 Basin Boundaries

Per the BMPs (DWR, 2016a) and 23 CCR §354.14(b), the lateral basin boundaries can be defined as geologic, hydrologic, or structural features that significantly affect groundwater flow. The lower boundary of the basin can be defined based on physical properties (such as depth to bedrock) or geochemical properties (such as base of fresh water).

3.1.8.1 Lateral Boundaries

Historically, the lateral boundaries of the Subbasin were defined hydrologically and consisted of Stony Creek to the north, the Sacramento River to the east, Cache Creek to the south, and the foothills of the North Coast Ranges to the west. The hydrologic rationale for these boundaries is that the streams are, or may be, coincident with groundwater divides (boundary zones of either converging or diverging groundwater flow) and the low-permeability Coast Ranges rocks create a barrier to groundwater flow at their contact with the alluvial sediments of the Subbasin.

The modified Subbasin extents have defined the southern boundary to be the Colusa-Yolo County line and the southern extent of the Colusa County Water District, both of which are jurisdictional boundaries (DWR, 2016d). The northern boundary is Stony Creek, where the Subbasin exists within Glenn County, and the Glenn-Tehama County line where Stony Creek exists in Tehama County. Stony Creek and the Coast Ranges comprise the western extent of the Subbasin. The Sacramento River demarks the eastern boundary of the Subbasin with the exception of lands within Colusa County east of the Sacramento River and west of Reclamation District 1004, which were added after the groundwater basin boundary modifications of 2018 (DWR, 2019).

3.1.8.2 Vertical Boundaries

Figure 3-16 provides elevation contours of the top of Cretaceous-age rocks within the Subbasin (Harwood and Helley, 1987). These contours provide one approximation of the physical base of the principal aquifer in the Subbasin (Harwood and Helley, 1987). Harwood and Helley (1987) contoured the top of the igneous crystalline and metasedimentary rocks where depth information was available and contoured the top of the Cretaceous rocks where wells were not deep enough to reach the crystalline and metasedimentary rocks. The contours on Figure 3-16 do not account for the post-Cretaceous Lower Princeton Valley Fill and Ione Formation, which were deposited in marine environments, or the Upper Princeton Valley Fill, which can contain fresh or brackish groundwater, and are therefore not considered part of the fresh groundwater aquifer system (Redwine, 1984). These formations lie above the elevation contours shown on Figure 3-16.

The base of the groundwater subbasins can also be defined chemically as the base of fresh water. The map in Figure 3-17 and the cross sections in Figure 3-11, Figure 3-12, and Figure 3-13 depict the base of fresh water as defined by USGS (Olmsted and Davis, 1961). According to Olmsted and Davis (1961), the base of fresh water is where specific conductance of the water exceeds 3,000 micromhos, or approximately 2,000 milligrams per liter (mg/L) total dissolved solids (TDS). DWR is preparing an updated map of the base of freshwater within the Central Valley, which will be based on a TDS concentration of 1,000 mg/L, as defined the SWRCB maximum contamination level (MCL) for TDS (DWR, 2016a). The base of fresh water defined by C2VSim is defined by a TDS concentration of 3,000 parts per million (ppm) (3,000 mg/L) and was based on available geophysical logs (DWR, 2020a). The differences in the definition of the “base of fresh water” is a data gap that will be addressed in future versions of the HCM, as more recent studies are issued, and an industry standard is adopted. Data gaps and uncertainties associated with the base of freshwater and recommendations to address them are discussed in Section 3.1.12.

The cross sections shown on Figure 3-11 through Figure 3-13 contain an approximate delineation of the vertical extent of the subbasin. The physical base of the subbasin was defined as the base of the Tuscan or Tehama Formations. This definition excludes Cretaceous-age formations, post-Cretaceous age sediments of marine origin (Lower Princeton Valley Fill and the Ione Formation). The post-Cretaceous, non-marine Upper Princeton Valley Fill is excluded because it can contain brackish groundwater, where saline waters from the marine deposits mix with freshwater from the continental deposits. This delineation is similar to the delineation based on the chemically defined basin extent, except near the western margins of the Subbasin where brackish groundwater occurs above the Upper Princeton Valley Fill in the Tehama Formation.

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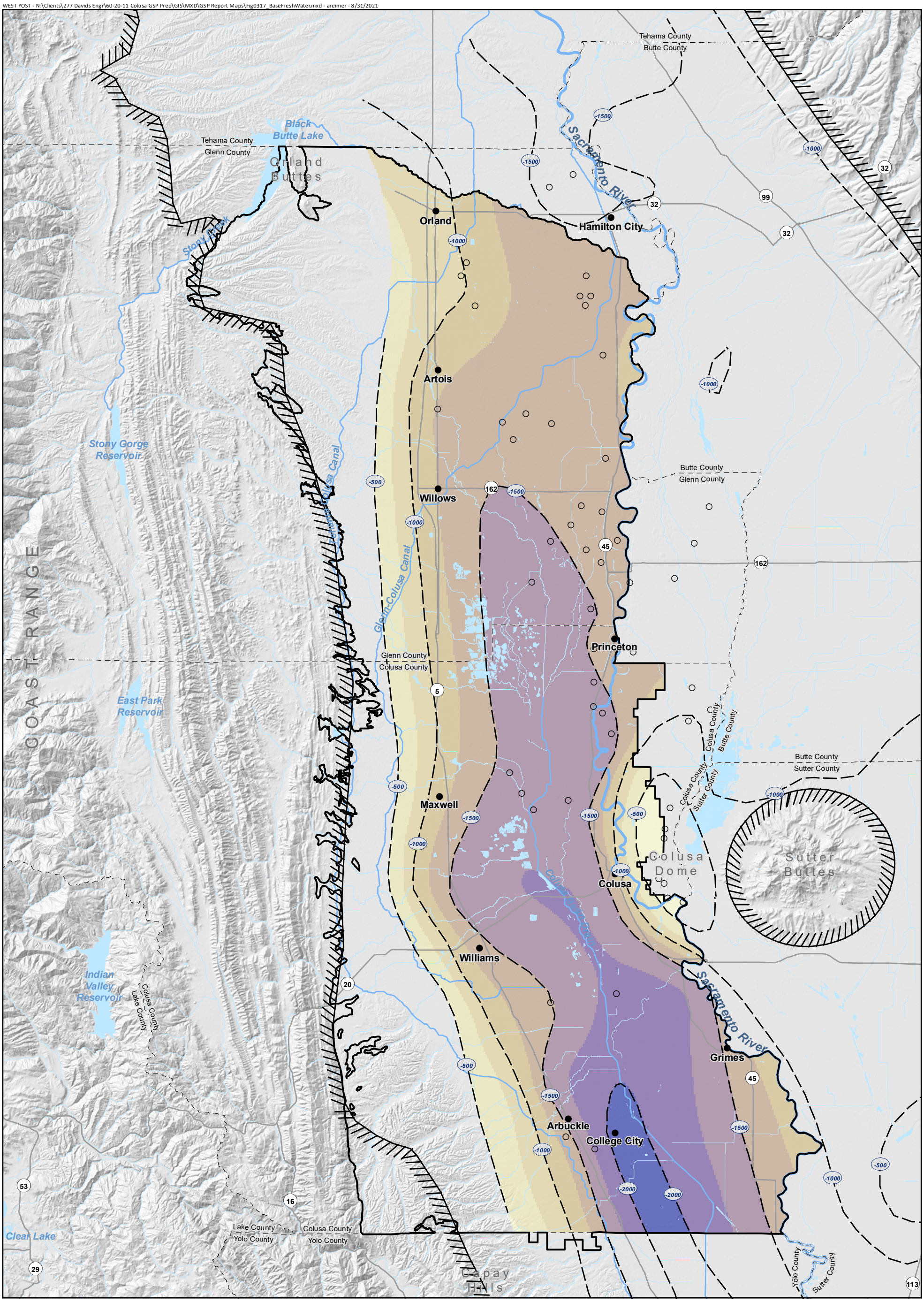


Source: Olmsted, F.H. and Davis, G.H., 1961, Geologic Features and Ground-Water Storage Capacity of the Sacramento Valley, California: prepared by U.S. Geological Survey in cooperation with the California Department of Water Resources, Water Supply Paper 1497, plate 5.

Horizontal Datum: North American Datum of 1983, California State Plane Zone II, feet.

Vertical Datum: Mean Sea Level (MSL).

Note:
1. Fresh water is defined as having a specific conductance less than 3,000 micromhos (approximately 2,000 mg/L of total dissolved solids)

- Well Used for Contouring
- Base of Fresh Water Elevation Contour (feet, dashed where
- Colusa Subbasin
- Edge of Sierra Nevada, Cascade Range, and Coast

Elevation of Base of Fresh Water (MSL, feet)

> -500	-1,250 - -1,000	-2000 - -1,750
-750 - -500	-1,500 - -1,250	<-2,000
-1000 - -750	-1,750 - -1,500	

N

0 2.5 5

Scale in Miles

Figure 3-17

Base of Fresh Water

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

3.1.9 Stratigraphic and Structural Features Potentially Affecting Flow

Stratigraphic and structural features that could potentially impact groundwater flow were introduced in Section 3.1.7.3. The structures discussed below are not necessarily subbasin boundaries but may impede or enable groundwater flow within the aquifer system.

3.1.9.1 Topography

Topographic relief impacts flows at shallower depths in the aquifer system, for example where permeable beds pinch out on elevated topography and the older, less permeable units are exposed on the surface.

3.1.9.2 Faults

Geologic investigations have shown displacement of the hydrogeologic formations along the Willows and Corning Faults. This is evident in the cross sections of Figure 3-11 through Figure 3-13. These faults may act as barriers or conduits to fresh groundwater flows. Deep-seated faults that intersect base of freshwater boundary may impact water quality if the fault zone sediments are relatively permeable compared to the native formations. Fault zone sediments with higher permeability will encourage groundwater mixing of the deeper brackish or saline waters and shallower fresh groundwater.

Displacement along the Paskenta Fault zone has not been observed in the fresh groundwater bearing hydrogeologic formations, however, measured and interpolated water levels near the Paskenta and Willows Fault zones near Artois, Glenn County exhibit a consistent localized lowering of the groundwater elevations along the trace of the fault. Additional study of the groundwater conditions would be needed to determine if the fault is acting as a conduit for flow along the fault trace, is impeding flows traverse to the fault, or both. Faults that act as conduits to groundwater flow can lead to degradation of water quality if contaminated or low-quality waters are mixed with freshwater sources.

3.1.9.3 Folds

Synclines are the folding in of the stratigraphic formations, deepening younger formations along the axis of the syncline and potentially exposing the older formations along the margins. Synclines can indicate locations of increased permeability or aquifer connectivity. This is seen within the subbasin near the Zamora Syncline where the Tehama Formation is characterized by highly pervious, loose, and well bedded layers (DWR, 2006a). Folds can also cause reorientation of naturally anisotropic units causing decreased permeability within the aquifer; however, this effect on permeability has not yet been quantified within the subbasin.

3.1.9.4 Stratigraphic Pinchouts

Stratigraphic pinchouts can occur at different scales. At a geologic scale, pinchouts can be found at the lateral extents of the formation, where the formation thickness tapers out. Examples of this within the study include the overlapping fingers of the Tehama and Tuscan Formations throughout the transition zone (Figure 3-15) or where the alluvial and basin deposits truncate against the uplands of the Coast Ranges (Figure 3-10). Pinchout can also be seen in the cross sections on Figure 3-11 through Figure 3-13.

Pinchouts can also occur at a larger scale. Structured heterogeneity of a geologic formation can result in higher permeable sediment occurring within lower permeable material. The Tehama Formation is especially heterogeneous given its depositional history of alluvial and fluvial deposits and is composed of predominantly fine-grained sediments enclosing discontinuous lenses of sand and gravel, which by definition are pinchouts.

3.1.9.5 Manmade Features

Structural features that may impact groundwater flow are not limited to naturally occurring geologic structures. Subsurface manmade features can also act to impede or encourage groundwater flow. Sediment mixing or digging may inhibit shallow groundwater flows. Structures with leaky subsurface infrastructure, such as basements, may impede natural groundwater flow by trapping shallow groundwater within the structure. Conversely, manmade structures that can encourage groundwater flows include boreholes such as water wells, oil and gas wells, or exploratory drilling shafts. Groundwater can use unsealed or leaky boreholes to quickly move vertically through the aquifer system. This can impact not only groundwater levels, but also groundwater quality.

3.1.10 Principal Aquifers and Aquitards

The Subbasin is underlain by one principal aquifer with interconnected unconfined, semiconfined, and confined zones.

Shallow groundwater in the Subbasin occurs under unconfined conditions in the Holocene stream channel deposits, except where these units are overlain by Holocene basin deposits, creating semiconfined to confined conditions (DWR, 1978). At greater depths, groundwater occurs under semiconfined to confined conditions in a single heterogeneous aquifer system, composed of predominantly fine-grained sediments enclosing discontinuous lenses of sand and gravel. The aquifer properties, including hydraulic conductivity and degree of confinement are dependent on the properties of the fine-grained units (Bertoldi et. al., 1991; Williamson et. al., 1989). The physical, chemical, and hydraulic hydrogeologic properties of the principal aquifer are discussed in the following subsections.

Most of the fresh groundwater within the Subbasin is contained within the Tehama Formation. The fraction of fresh groundwater contained within the Tehama Formation decreases in the northeastern portion of the Subbasin, where sediments of the Tuscan Formation are more prevalent (Figure 3-15). The interface between the Tehama Formation and Tuscan Formation, referred to in this report as the Tehama-Tuscan Transition Zone, has been documented as mixed Tehama and Tuscan Formation sediments (DWR, 2009b). These mixed sediment zones grade into the Tehama and Tuscan Formations and probably result in continuity of flow between the Tehama and the Tuscan Formations.

There are no defined principal aquitards within the Subbasin, however, the formations deposited under alluvial conditions or volcanic flows with lahars, such as the Tehama and Tuscan Formations, respectively, tend to consist of thick low-permeability sediments interbedded with interconnected channels or lenses of higher-permeability sediment. The low-permeability sediments may impede vertical groundwater flows, but generally do not separate the aquifer system into separate, definable principal aquifers.

3.1.10.1 Physical and Structural Properties

The lateral extent of the principal aquifer is the same as the lateral extent of the subbasin and is discussed in Section 3.1.8.1.

The principal aquifer extends to the base of fresh water, which is discussed in Section 3.1.8.2.

The unconfined to semi-confined portion of the principal aquifer primarily consists of Riverbank and Modesto Formations, as well as the overlying Holocene stream channel and basin deposits. These sediments can be up to approximately 200 feet thick and are comprised of unconsolidated to semi-consolidated materials. These sediments are found throughout the subbasin but pinch out near the western margin of the Subbasin where the foothills and uplands of the Coast Ranges commence, and the Tehama Formation outcrops. Geologic mapping and well records support that the Tehama Formation is relatively thin where it outcrops and does not produce much groundwater. This is discussed more in Section 3.1.7.2.2.

The confined portion of the principal aquifer consists of the Tehama Formation, Tuscan Formation, and to a lesser extent, the Upper Princeton Valley Fill. The Tehama Formation is the primary water-bearing formation within the principal aquifer. The Tehama Formation is heterogeneous with discontinuous sand and gravel lenses. Thicknesses of the Tehama Formation can be as much as approximately 2,000 feet (Olmsted and Davis, 1961). The Tehama Formation exists throughout the Subbasin but pinches out along the western margin of the Subbasin with the Coast Ranges and also to the east within the Tehama-Tuscan Transition Zone (Figure 3-15). The Tuscan Formation is composed of interbedded lahars, conglomerate, volcanic sandstone, and volcanic ash layers and can be found at depths greater than 700 feet bgs. The Tuscan Formation within the subbasin exists almost solely within the Tehama-Tuscan Transition Zone but can be found as far east as the foothills of the Sierra Nevada Mountain Range. The Upper Princeton Valley Fill is located at depths greater than 1,000 feet bgs where it exists within the subbasin and is predominantly composed of sandstone. Table 3-4 contains the ranges of vertical and horizontal hydraulic conductivity, transmissivity, storativity, and specific yield values for the principal aquifer's unconfined and confined hydrogeologic units as listed in published reports on aquifer testing. Analytical models such as the Theis or Hantush-Jacob methods commonly enable the estimation of transmissivity and storativity from aquifer test data. Transmissivities can then be used to determine hydraulic conductivity of a water-bearing unit. Hydraulic conductivities are a measure of the aquifer's ability to transmit water horizontally or vertically. Aquifer materials generally have higher horizontal hydraulic conductivity than vertical hydraulic conductivity. Confining units are generally the limiting factor when evaluating vertical movement of water through the aquifer system.

Horizontal hydraulic conductivity of the unconfined to semi-confined zone ranges from 10 to 229 feet per day (ft/day).

A typical horizontal hydraulic conductivity of the Tehama Formation is approximately 27 ft/day. Within the permeable units of the Tuscan Formation (Units A and B), horizontal hydraulic conductivities range from 11 to 88 ft/day. One study estimated horizontal hydraulic conductivity within the confining unit of the Tuscan Formation (Unit C) to be 321 to 571 ft/day (Brown and Caldwell, 2013), an order of magnitude larger than those estimated within the more permeable units. Typically, the horizontal hydraulic conductivity of low-permeability strata is lower than that of its more permeable counterparts. This discrepancy in hydraulic conductivity values may be due to aquifer testing conducted within highly permeable zones within Unit C. More investigation into the discrepancy is recommended, as discussed in Section 3.1.12.2.

Vertical hydraulic conductivity for the confining unit in the Tehama-Tuscan Transition Zone was estimated to be 0.0036 ft/day based on data obtained during an aquifer test using a multiple completion observation well with separate completions perforated above and below the confining unit (West Yost, 2012).

Table 3-4. Hydraulic Properties

Hydraulic Property per Source	Unconfined to Semi-Confined	Confined (Tehama Formation)	Confined (Tuscan Formation)		
			Unit C	Unit B	Unit A
Transmissivity, ft^2/day					
Stony Creek Fan Aquifer Performance Testing[(a)]	--	2,466 - 4,727	--	2,705 - 8,902	2,705 - 8,902
Tuscan Aquifer Investigation[(b)]	--	--	11,550 - 20,540	2,322 - 3,078	12,230 - 23,650
Horizontal Hydraulic Conductivity, ft/day					
Stony Creek Fan Aquifer Performance Testing[(a)]	--	26.6	--	11.4 - 13.2	11.4 - 13.2
Stony Creek Fan Feasibility Study[(c)]	10 - 229	--	--	--	--
Tuscan Aquifer Investigation[(b)]	--	--	321 - 571	66 - 88	41 - 79
Vertical Hydraulic Conductivity, ft/day					
Stony Creek Fan Aquifer Performance Testing[(a)]	--	--	0.0036	--	--
Storativity, unitless					
Stony Creek Fan Aquifer Performance Testing[(a)]	--	0.0003 - 0.001	--	0.0009 - 0.003	0.0009 - 0.003
Tuscan Aquifer Investigation[(b)]	--	--	0.0003 - 0.0005	0.00004 - 0.00009	0.00004 - 0.001
Specific Yield, unitless					
USGS Water Supply Paper 1497[(d)]	0.034 - 0.185	--	--	--	--

(a) West Yost, 2012
(b) Brown and Caldwell, 2013
(c) Montgomery Watson Harza (unpublished) via WRIME, 2003
(d) Olmsted and Davis, 1961

Water released from storage within confined aquifer systems is characterized by the storativity of the aquifer units. Storativity is estimated to range from 0.0003 to 0.001 for the Tehama Formation and 0.00004 to 0.003 for the Tuscan Formation. Storativity of Unit A of the Tuscan Formation (the deepest unit) is generally higher than that of Unit B (Brown and Caldwell, 2013), but still lower than that of the Tehama Formation. Storativity values are not reported for the unconfined portion of the Tuscan Formation.

Specific yield represents the water released from drainage from the pore space between the individual grains that comprise the aquifer sediment. Specific yield is only specified for the unconfined portion of the principal aquifer. Specific yield for the unconfined portion of the principal aquifer is approximately 0.034 to 0.185 (3.4 percent to 18.5 percent) (Olmsted and Davis, 1961).

Structural properties that could impact groundwater flows within the principal aquifer are discussed in more detail in Section 3.1.9.

3.1.10.2 Primary Uses

There are approximately 90 public water service agencies that provide potable water within the Subbasin (Figure 2-4). These stakeholders include municipalities, water agencies, irrigation districts, wildlife refuges, and reclamation districts. Not shown are private and domestic pumpers located in the "white-space" of the Subbasin and State small water systems. The primary uses of groundwater within the principal aquifer include agricultural, irrigation, domestic, industrial, and municipal supply (DWR, 2006a).

3.1.10.3 Water Quality

Historical groundwater quality concerns within the Subbasin include locally elevated levels of salinity, TDS, adjusted sodium absorption ratio, boron, nitrate, and manganese (DWR, 2006a; Wood Rodgers, 2008). Many of the entities within Glenn and Colusa Counties that monitor groundwater for quality either use wells that have multiple or long perforated intervals that access groundwater from both the unconfined and confined portions of the principal aquifer, or report water quality results from their wells collectively, without specifying what depth(s) the well was screened in. This data gap is discussed in more detail in Section 3.1.12 of this report.

Recent groundwater quality concerns within the Subbasin include salinity, boron, nitrate, heavy metals, including arsenic, and hexavalent chromium. High concentrations of sodium, chloride, and sulfate, all of which are related to salinity have been observed south of Maxwell (CH2MHILL, 2016a; RD 108, 2008) and could negatively impact agricultural applications. Elevated concentrations of boron within Colusa County have already impacted agricultural practices (GCID, 1995). In contrast, boron concentrations measured in select groundwater wells within Glenn County have not exceeded the United States Environmental Protection Agency (USEPA) agricultural water quality goal for boron of 750 micrograms per liter (µg/L) (USEPA, 1986; USGS, 2018). Elevated salinity levels throughout much of Colusa County, nitrates near Orland and Willows, arsenic near Grimes, and iron and manganese near Williams and Colusa are of concern with respect to drinking water MCLs (CH2MHILL, 2016a). Arsenic, especially, has been a constituent of concern for Grimes, Colusa, and the surrounding area. Local agencies have been working to mitigate arsenic contamination in groundwater in this area. Drinking water supply wells near Willows, Glenn County, have experienced high concentrations of hexavalent chromium (California Water Service, 2016).

There are also several active groundwater contamination cleanup sites in the Subbasin. These primarily include leaky storage tanks and unauthorized releases of contaminants such as petroleum hydrocarbons, nitrate, pesticides and herbicides including dicamba, and solvents. Most of these cleanup sites impact the unconfined portion of the principal aquifer, but there is a risk that the contamination could migrate into

the deeper, more heavily pumped portions of the aquifer. The largest contamination site is the Orland Dry Cleaner site, a tetrachloroethylene (PCE) plume that extends approximately two miles southeast of the source location in Orland, Glenn County (Department of Toxic Substances Control [DTSC], 2020; SWRCB, 2020b). In 2007, PCE contamination was recorded at depths of 127 feet bgs (DTSC, 2020).

More detail regarding existing and historical groundwater quality issues and trends is provided in Section 3.2 of this GSP.

3.1.11 Groundwater Inflows and Outflows

Groundwater inflows and outflows between the Subbasin and neighboring groundwater subbasins depend on fixed aquifer hydraulic properties and the prevailing groundwater gradients, which are influenced by time-dependent natural recharge and discharge patterns, aquifer interactions with streams, the effects of pumping, and the effects of managed and unmanaged recharge. These inflows and outflows are discussed further in the following subsections.

3.1.11.1 Groundwater Underflow

Groundwater underflow occurs as outflow across the boundary of the Colusa and Yolo Subbasins under the influence of the generally southeasterly to southerly groundwater flow gradient. The boundary between the Colusa and Yolo Subbasins is jurisdictional and has no influence on the flow of groundwater. Groundwater underflow as inflow occurs along the boundary of the Colusa and Corning Subbasins, along Stony Creek. Groundwater underflow may occur as either outflow or inflow across the eastern hydrologic border of the Subbasin, where the Subbasin is bound by either the Sacramento River or the jurisdictional boundary of R.D. 1004. How groundwater levels impact interconnected surface waters is discussed in Section 3.2.7.

The magnitude of these underflows is not currently quantified but is anticipated to be a relatively small component of the water budget for the Subbasin and neighboring groundwater subbasins. Significant influences on these inflows and outflows include groundwater gradients across subbasin boundaries, stream stage in the Sacramento River, Stony Creek and Butte Creek, and the timing, location, and magnitude of groundwater pumping, managed recharge, and unmanaged recharge, which includes recharge due to agricultural practices and precipitation.

Underflow across the western boundary of the Subbasin is negligible due to the low permeability of the Coast Range rocks.

3.1.11.2 Groundwater Recharge Areas

The primary sources of groundwater recharge in the Subbasin are deep percolation – the movement of water from land surface to the aquifer – of precipitation and applied water. Other volumetrically less important sources include deep percolation resulting from domestic and municipal uses.

3.1.11.2.1 Agricultural Recharge

Much of the Subbasin is devoted to agriculture; many of the agricultural fields are irrigated with surface water supplies from the Tehama-Colusa Canal, the Glenn-Colusa Canal, and other irrigation water supply systems, which provide Sacramento River water from outside of the subbasin boundaries (Figure 3-6). Water applied to agricultural lands has a significant contribution to groundwater recharge.

3.1.11.2.2 Soil Suitability for Groundwater Recharge

Recharge occurs throughout the Subbasin, but at variable rates depending on topography, soil properties and the underlying geology, as introduced in Sections 3.1.4, 3.1.6, and 3.1.7, respectively. Figure 3-18 shows potential recharge areas based on the Soil Agricultural Groundwater Banking Index (SAGBI) (O'Geen et. al., 2015). SAGBI was developed to provide a measure of soil suitability for recharge on agricultural lands while maintaining the viability of soils and crops, and groundwater quality. The index was developed considering five major factors (O'Geen et. al., 2015):

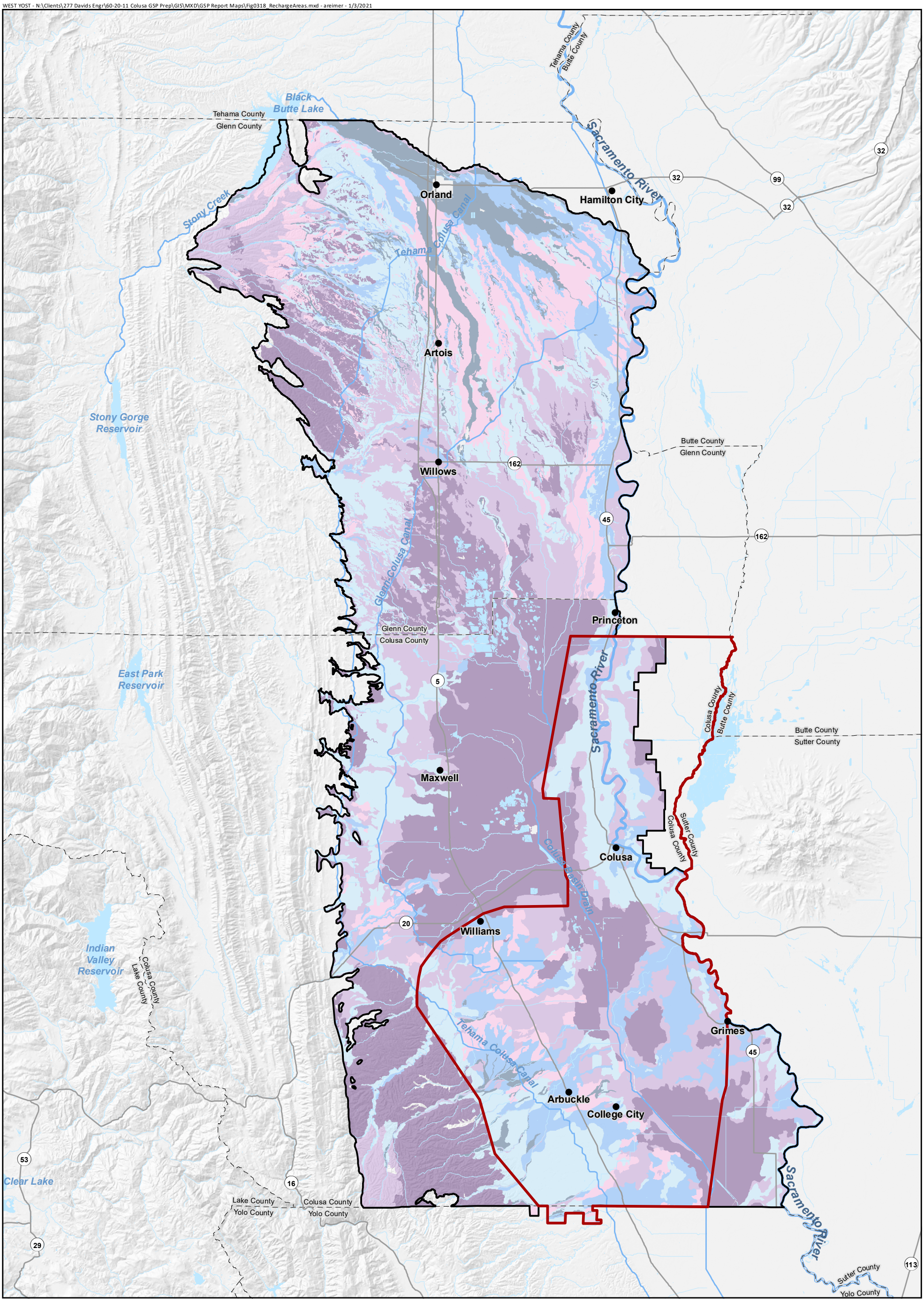
1. Deep percolation;
2. Root zone residence time;
3. Topography;
4. Chemical limitations; and
5. Soil surface conditions.

As depicted on Figure 3-18, the index also includes the assumption that soils with restrictive layers would be made more permeable through deep tillage. The index ranges from very poor to excellent over the Subbasin.

Soils with indices in the moderately good to excellent range correspond to hydrologic soil groups A through C, as discussed in Section 3.1.6, and are mostly located over younger alluvial fan and stream channel deposits, including those of Stony Creek and other small streams draining the Coast Ranges, and younger stream channel deposits located along the Sacramento River (Figure 3-9 and Figure 3-10).

3.1.11.2.3 On-Farm Multi-Benefit Managed Aquifer Recharge and Shorebird Habitat Program

In 2018, CGA in cooperation with The Nature Conservancy (TNC) implemented a pilot managed aquifer recharge program. During this program, farmers worked with TNC to create temporary wetlands using existing water conveyance infrastructure and available flows during fall and winter migration periods. The program sought to increase groundwater recharge in severely disadvantaged communities while providing habitat for migratory birds. Various factors including water availability, soil suitability, and farming practices were evaluated for participating farmers. The pilot project areas are delineated on Figure 3-18.



Source: O'Geen, A.T. et. al., 2015, Soil Suitability Index Identifies Potential Areas for Groundwater Banking on Agricultural Lands: California Agriculture, Volume 69, Number 2, pages 75-84, April 2015, GIS files provided November 2017.

Horizontal Datum: North American Datum of 1983, California State Plane Zone II, feet.

Note:
1. Modified Soil Agricultural Groundwater Banking Index (SAGBI) suitability groups assume that soils with restrictive soil layers have been modified by deep tillage.

Colusa Subbasin

Colusa Multi-Benefit Groundwater Recharge Project Area (2020)

Soil Agricultural Groundwater Banking Index with Assumed Deep Tillage Modification

- Excellent
- Good
- Moderately Good
- Moderately Poor
- Poor
- Very Poor

N

0 2.5 5

Scale in Miles

Figure 3-18

Locations of Potential Recharge

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

3.1.11.3 Groundwater Discharge Areas

Groundwater discharges in the Subbasin include:

- Discharges to streams, drains, seeps and springs;
- Losses to the atmosphere through uptake and consumption by wetland or riparian vegetation (phreatophytes), deeply rooted crops, and bare soil evaporation under shallow water table conditions; and
- Groundwater pumping.

Figure 3-19 and Figure 3-20 show depth to groundwater during the spring of 2006 (prior to the multiple year droughts of 2007-2009 and 2012-2015) and the spring of 2017 (after the multiple year droughts), respectively.

Areas with depth to groundwater close to land surface may indicate potential zones of groundwater discharge that can be expressed as flowing artesian wells, or through discharge to ponds, springs, wetlands, streams and canals. Discharges can also occur through evapotranspiration from riparian or phreatophytic vegetation, and from bare soil evaporation.

Approximately 25 springs can be identified from historical USGS topographic maps of the subbasin. Most of these springs are unnamed and located in the Subbasin occur near the western boundary. Location indicates that the springs historically discharged from the Tehama, Riverbank, or Modesto Formations and stream channel alluvium. A number of these springs have been developed for agricultural use by landowners locally (apparent on satellite imagery). Data regarding discharge and water quality was not found for incorporation into this GSP.

In the spring of 2006, the largest of these potential discharge zones was in a low elevation area of the Subbasin aligned along a north-northwesterly trend extending from the Colusa-Yolo County line into the southern half of Glenn County (Figure 3-19). The axis of the southerly part of this zone was aligned with the Colusa Drain, which is an indication that the Colusa Drain received groundwater discharge in spring 2006. Shallow depths to water in spring of 2006 also were evident along the Sacramento River, indicating that some reaches of the Sacramento River may have received groundwater discharges in spring 2006. The extent of potential groundwater discharge areas in the spring of 2017 was similar but more limited.

Comparison of the depth to groundwater contours to land use shows that many areas with shallow depths to groundwater correspond to the areas of rice cultivation and wildlife refuges. Ponded agricultural fields tend to be in areas that contain a high percentage of silts and clays, which restrict, yet do not negate the vertical flow of water into or out of the groundwater system. A portion of the groundwater would therefore discharge into the ponded water and a portion would discharge into unlined irrigation canals, drains, or ephemeral stream channels.

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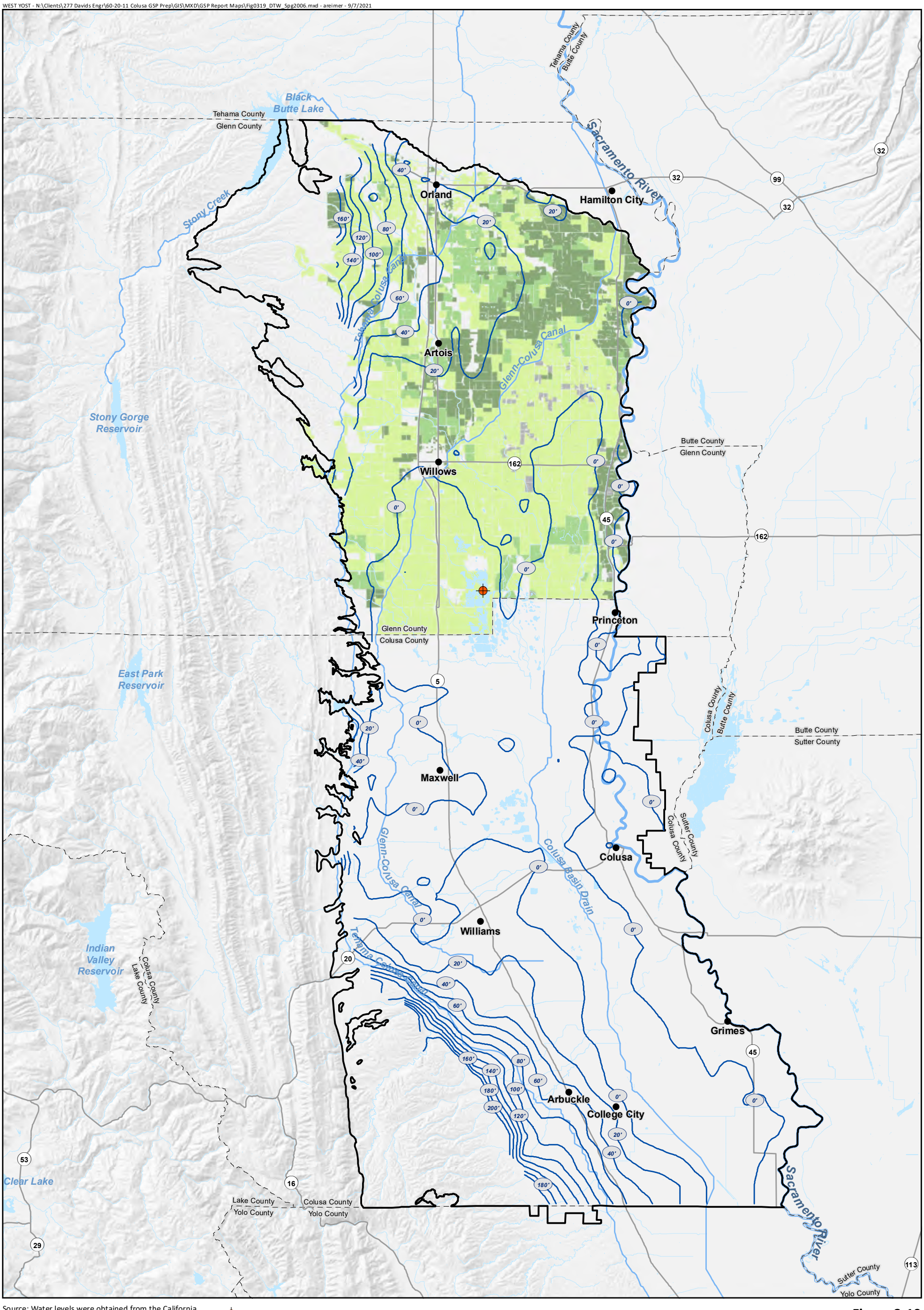


Source: Water levels were obtained from the California Department of Water Resources Water Data Library. Water source information was obtained from DWR Land Use Survey. Water source data for Glenn County was surveyed in 2003. Colusa County was surveyed in 2003 for land use but not water use.

Horizontal Datum: North American Datum of 1983, California State Plane Zone II, feet.

Note: Colusa County was not surveyed for water use within 3 years of 2006 for comparison to the spring 2006 groundwater level contours.

Well 18N02W18D001-004M

Spring 2006 Depth to Water Contours (feet, 20-foot Interval)

Colusa Subbasin

Water Source (2003)

Surface Water

Groundwater

Mixed Surface and Groundwater

Unknown

N

0 2.5 5

Scale in Miles

Figure 3-19

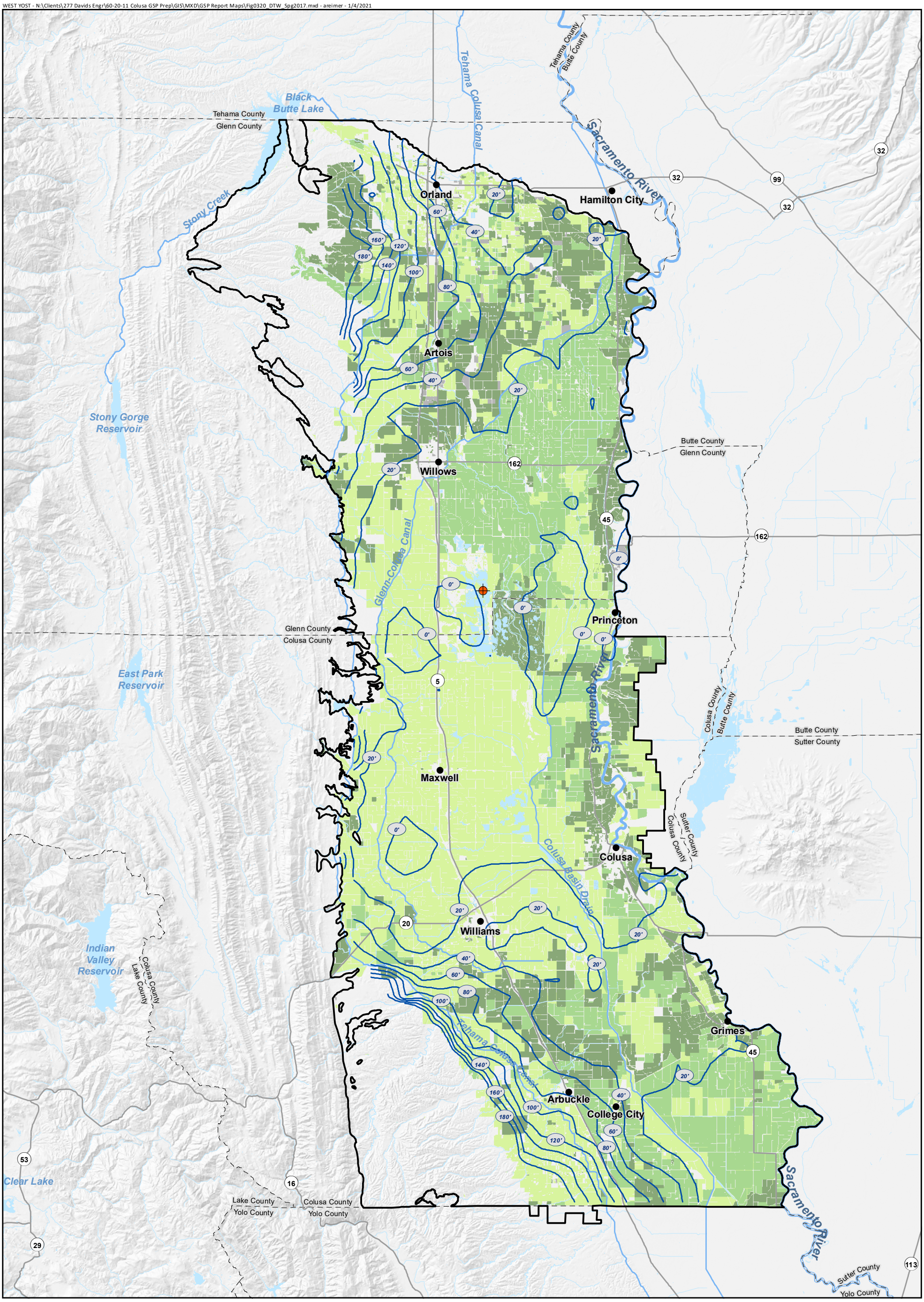
Depth to Groundwater Contours Spring 2006

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

WEST YOST - N:\Clients\277 Davids Engr\60-20-11 Colusa GSP Prep\GIS\MXD\GSP Report Maps\Fig0320_DTW_Spg2017.mxd - areimer - 1/4/2021



Source: Water levels were obtained from the California Department of Water Resources Water Data Library. Water source information was obtained from DWR Land Use Survey. Water source data for Glenn and Colusa Counties were marked as provisional, 2014.

Horizontal Datum: North American Datum of 1983, California State Plane Zone II, feet.

Well 18N02W18D001-004M

Spring 2017 Depth to Water Contours (feet, 20-foot Interval)

Colusa Subbasin

Water Source (2014)

- Surface Water
- Groundwater
- Mixed Surface and Groundwater
- Unknown

N

0 2.5 5

Scale in Miles

Figure 3-20

Depth to Groundwater Contours Spring 2017

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

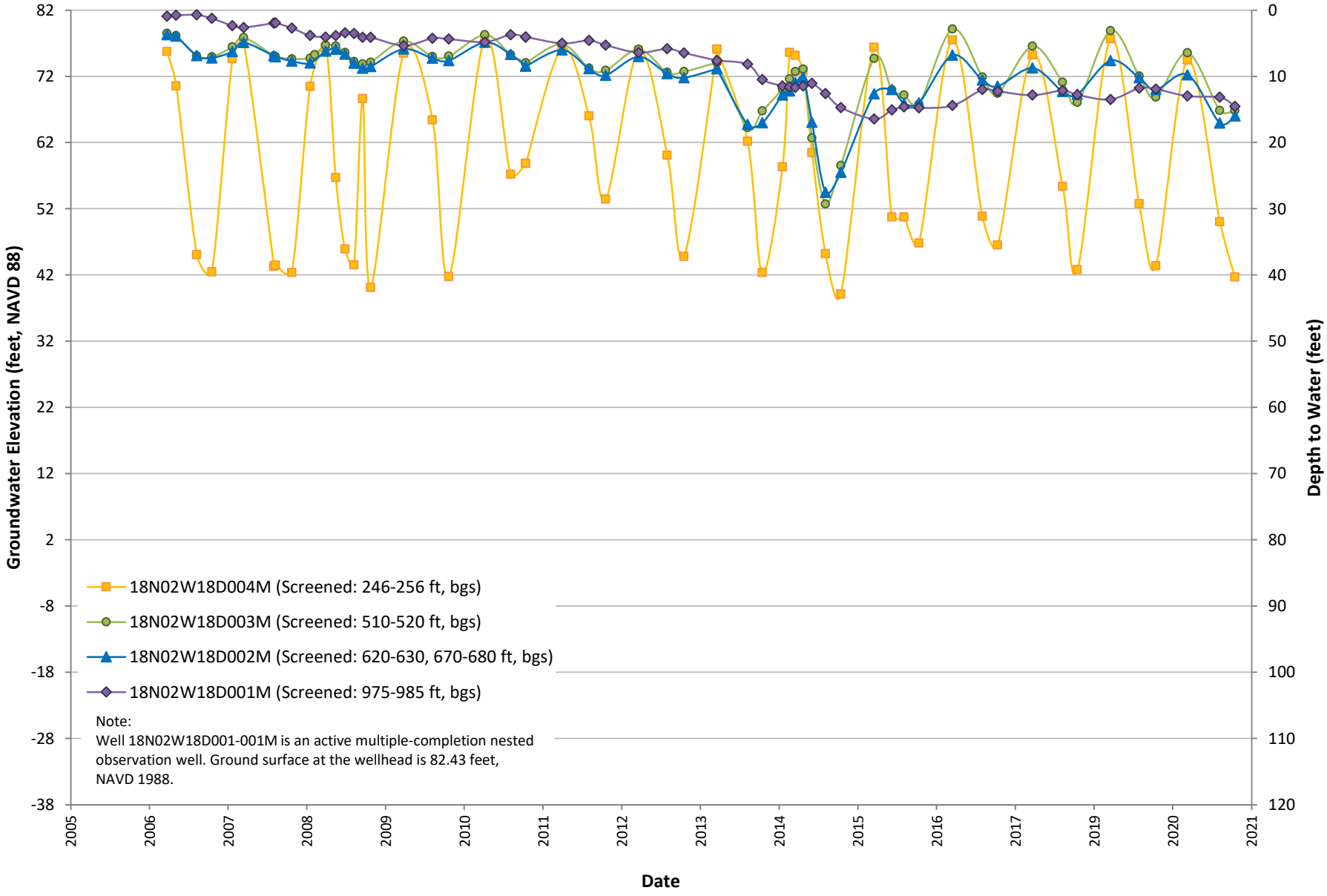
Groundwater Sustainability Plan

The potential for flowing artesian conditions is evident in the historical groundwater level measurements for some monitoring wells in the Subbasin. Figure 3-21 is a hydrograph for a multiple completion well located north of the Sacramento National Wildlife Refuge, west of Princeton. As seen on the hydrograph, the groundwater within the deep completion (18N02W18D001) historically has a higher potentiometric head than the groundwater within the shallower completions. This indicates a potential for upward flow of groundwater from the deeper confined water-bearing units to the shallower confined water-bearing units. Starting in 2014 and continuing through the first half of 2020, however, the depth to groundwater within the deepest completion has decreased significantly, indicating a reversal in the vertical flow direction. This period corresponds to the multiple year droughts of 2007 to 2009 and 2012 to 2016. Although the overall depths to groundwater were greater in the latter half of 2020, the vertical flow direction quickly reverted back to pre-2014 conditions. Generally speaking, groundwater pumping increases during periods of drought, when surface water deliveries are diminished. This causes a lowering of groundwater levels and may result in cones of depression surrounding the groundwater extraction wells. When sufficient surface water supplies exist, pumping decreases, and the groundwater levels revert to their previous vertical gradient regime, as evidenced in the hydrographs. Groundwater levels can take much longer to recover than the vertical gradient regime.

Groundwater pumping within the subbasin serves municipal, domestic, irrigation, commercial, and environmental needs. Figure 3-19 and Figure 3-20 show the irrigation districts, reclamation districts, municipal water agencies, and wildlife refuges within the Subbasin and the water supply source identified by DWR in 2014 (DWR, 2014b). DWR surveys of groundwater extraction for the Subbasin reported approximately 310,000 af for agricultural applications, 14,000 af for municipal and industrial consumption, and 22,000 af for environmental wetland use (DWR, 2006a). There are also many unmetered domestic and small agricultural wells located throughout the Subbasin. Colusa County estimates approximately 1,200 af of groundwater extraction from domestic wells (Wood Rodgers, 2008) across the entire County. A more detailed discussion of the water budget is discussed in Section 3.3 of this GSP. For GSP development, groundwater pumping by rural residential wells was estimated using the C2VSimFG-Colusa model, and was calculated based on residential demand after accounting for any other available water supplies and separately accounting for agricultural demand (see Appendix 3D for additional information). More detailed discussion of the GSP water budget and groundwater pumping estimates is provided in Section 3.3 of this GSP.

While the municipalities rely on groundwater to serve their residents, much of the agricultural lands within the Subbasin divert surface water supplies for irrigation. Some of the farmlands use a mix of surface water supplies and groundwater (Figure 3-19 and Figure 3-20). The primary groundwater pumping areas for irrigation correspond to farmlands that do not receive surface water supplies. An example of this includes farmlands that are not part of an existing irrigation district.

Figure 3-21. Hydrograph for Well 18N02W18D001-004M



3.1.12 Data Gaps, Uncertainty, and Recommended Actions

BMPs for the HCM (DWR, 2016a) state that "the HCM should be developed and periodically updated as part of an iterative process as data gaps are addressed and new information becomes available". The different components of the HCM were evaluated for data gaps, uncertainty, and unresolved discrepancies identified through comparison with the C2VSimFG. These topics and recommended future actions are discussed in more detail in the following subsections. More information regarding C2VSimFG and how it was used for the Subbasin can be found in Appendix 3D.

The data gaps in the HCM and some recommended actions to address the data gaps are discussed in the following sections. The following data gaps have been identified:

- Lateral and vertical extent of geologic units and the principal aquifer, specifically with regard to the Tehama-Tuscan transition zone, volcanic and plutonic formations related to the Colusa Done and Sutter Buttes, Turlock Lake Formation or similar highly compressible clayey deposits, and thickness of the Tehama Formation in the upland areas of western Colusa Subbasin and near the Zamora Syncline.
- Vertical extent of the base of fresh water.
- Hydraulic parameters of the principal aquifer.
- Groundwater quality of the principal aquifer, specifically with regard to the source and vertical migration of contaminated waters.
- Groundwater levels within the principal aquifer, specifically pertaining to the western margins of the Subbasin where there is a lack of monitoring locations and the unconfined shallow water table (e.g., near Orland where an increase of drying shallow domestic wells is currently occurring).
- Location and discharge of springs.

3.1.12.1 Extent of Geologic Units, Principal Aquifer, and Base of Fresh Water

Uncertainties in the thickness and extent of the principal aquifer, geologic formations, and base of fresh water have been identified in the following areas of the subbasin:

1. Tehama-Tuscan Transition Zone;
2. West and south of the Sutter Buttes;
3. Northwestern upland area, west of Orland;
4. Southwestern upland area, west of Arbuckle; and
5. Near the Zamora Syncline, east of Williams and College City.

There is uncertainty regarding the extent and depths of the Tehama and Tuscan Formations within the Tehama-Tuscan Transition Zone. Previous geologic mapping shown on the cross sections (Figure 3-11 through Figure 3-13) and Figure 3-15 depict thick depositions of Tehama and Tuscan within the Transition Zone, but the borehole data delineating the thickness and extent of units and the degree to which Tehama and Tuscan Formation sediments are intermixed is limited.

Springhorn (2008) identified the lands west and south of the Sutter Buttes, along the Sacramento River and surrounding area, as an area with gaps in information regarding subsurface lithologic extent and how it impacts groundwater quality, primarily arsenic. The investigations conducted for this GSP agree that the area is a data gap.

Additionally, there is some concern regarding the extent and thickness of the Turlock Lake Formation or a similar diatomaceous clay layer within or near the Subbasin. The compressible Turlock Lake Formation sediments may lead to land subsidence and reduction in aquifer storage. The Turlock Lake Formation and a similar diatomaceous clay layer is present in boreholes east and south of the Sutter Buttes and was encountered in a borehole near Zamora in Yolo County. Additional subsurface investigations in the areas west and south of the Sutter Buttes is recommended to better understand the extent of these sediments.

The base elevation of the uppermost three C2VsimFG model layers is overlain on the cross sections (Figure 3-11 through Figure 3-13). The modeled layers for C2VSimFG are based on groundwater conditions and pumping, not geologic units, but can be compared with the extent of the geologic units comprising the principal aquifer. The principal aquifer is also characterized by the extent and thickness of the freshwater-bearing geologic formations within the subbasin. Therefore, the extent of the geologic formations, principal aquifer, mapped base of freshwater and extent of the model layers are all related. Discrepancies between these datasets highlight uncertainty in the underlying datasets, the methods used to interpolate the base of fresh water, and the methods used to interpolate the thicknesses of geologic formations between locations with known data. Available information in the northwest uplands indicate that the Tehama Formation in that area is relatively thin compared to the rest of the subbasin and has low groundwater yield. The geologic mapping and cross section B-B' shown on Figure 3-10 and Figure 3-11 support this theory. The modeled base of fresh water, however, shows the principal aquifer as approximately 1,000 feet thick. This contradicts the available geologic data and verbal reports from residents of the area. Olmsted and Davis (1961) did not map the base of fresh water in this area. Table 3-5 provides a comparison of the four model layers with the principal aquifer and geologic formations.

Table 3-5. Comparison of Modeled Layers with Principal Aquifer and Geologic Units

C2VSimFG Model Layer Number	C2VSimFG Model Layer Description	Principal Aquifer	Geologic Formation
1	Unconfined Freshwater Aquifer Zone with Pumping	Unconfined Zone	Holocene Basin Fill and Stream Channel Deposits Modesto Formation Riverbank Formation Tehama Formation (minimal)
2	Confined Freshwater Aquifer Zone with Pumping	Confined Zone	Tehama Formation Tuscan Formation
3	Confined Freshwater Aquifer Zone with Little Pumping	Confined Zone	Tehama Formation Tuscan Formation Upper Princeton Valley Fill (partial)
4	Confined Saline Aquifer	--	Upper Princeton Valley Fill (partial) Ione Formation Lower Princeton Valley Fill

Uncertainty is even greater in the southwestern upland area than the northwest upland area. In addition to minimal available well logs, there are no mapped isolated outcrops of older Cretaceous-aged rocks within the southern uplands to indicate uplift of older bedrock formations. Cross sections D-D' and G-G', which cut through the southwestern upland area, show the reverse discrepancy along the west margin of the Subbasin (Figure 3-12). Cross sections D-D' and G-G' show the modeled base of the aquifer to be much shallower than the mapped freshwater-bearing geologic units.

The Tehama Formation thickens near the Zamora Syncline, however available data that identifies the base of the Tehama Formation in this area is scarce. The modeled based of fresh water from C2VSimFG and the mapped base of fresh water from Olmsted and Davis (1961) both indicate that fresh water exists at depths greater than those shown on cross section G-G' (Figure 3-12).

Other locations where the modeled or mapped base of fresh water does not coincide with the freshwater-bearing formations can be seen on the cross sections (Figure 3-11 through Figure 3-13). For example, near the Corning Fault on cross section B-B', near Sacramento River on cross section D-D', or between Cortina Creek and the Tehama-Colusa Canal on cross section F-F'. Additionally, input from residents and additional groundwater quality studies support that the base of fresh water is shallower than reported along fault zones (e.g., Willows Fault) and near the Sutter Buttes, where the freshwater-bearing geologic formations are thinner and shallower.

Additional subsurface data will be collected to help delineate the base of the geologic formations in the aforementioned areas. The vertical extents of these geologic units will be updated through evaluation of DWR's forthcoming texture model developed as part of the Sacramento Valley Simulation Model (SVSim); inspection of geophysical logs from oil and gas wells; aeromagnetic surveys; passive seismic or other geophysical investigation surveys, such as controlled source audio-frequency magnetotellurics (CSAMT); in-depth evaluation of available well completion reports (most of which may not be deep enough to characterize the base of the Tehama and Tuscan Formations, but may be sufficient to better define the Tehama-Tuscan Transition Zone); information from new boreholes; and/or other methods or data sources that may characterize the subsurface stratigraphy.

Different agencies have chosen different TDS concentration thresholds to define the base of fresh water. These different threshold concentrations used to classify fresh water versus saline water is a contributing factor in the discrepancy between all of the mapped depth to base of fresh water. Olmsted and Davis (1961) used a threshold of approximately 2,000 mg/L while C2VSimFG assumes a threshold of 3,000 ppm (approximately 3,000 mg/L of TDS, DWR, 2020a), and DWR is preparing an updated analysis of the base of freshwater within the Central Valley, which will be based on a TDS concentration of 1,000 mg/L, the MCL for TDS (DWR, 2016a). The new DWR analysis will be used to update the HCM and the freshwater threshold concentration used by that analysis will supersede all previous mapped thresholds.

Once additional, more recent information is evaluated the geologic and base of freshwater extents in the HCM can be updated and the relevant C2VSimFG model inputs can be adjusted to better represent the principal aquifer in these areas. Further improvements to the HCM can be conducted using oil and gas well logs, the proposed future DWR airborne electromagnetic survey data (AEM), and any new theses or studies regarding hydrogeology or geochemistry in the greater Colusa Subbasin area.

3.1.12.2 Hydraulic Parameters

Hydraulic parameter estimates will be updated and refined by performing additional pumping tests, and reanalyzing existing test data in cases in which parameter estimates are outside of expected ranges. Pumping tests will use pumping wells and dedicated monitoring wells discretely screened in either the

unconfined or confined portion of the principal aquifer in order to better quantify hydraulic parameters per the principal aquifer's unconfined or confined condition.

The hydraulic properties of Tuscan Formation Unit C will be further investigated to verify the high hydraulic conductivities reported for Unit C and their applicability in the Subbasin.

3.1.12.3 Groundwater Quality

23 CCR §354.14(b)(4)(D) states that "general water quality of the principal aquifers" shall be included in the HCM. Future groundwater quality characterization efforts will utilize wells with known construction. The wells used to characterize groundwater quality discussed in this plan are all drilled within the principal aquifer but have not been identified as representing the unconfined or confined conditions. Identifying well depths and construction information would be beneficial in order to better understand groundwater quality and the potential spatial trends and movement of contaminants within the principal aquifer. GSAs should keep in mind the Human Right to Water and how it could be managed via water quality degradation projects implemented under the Colusa Subbasin GSP.

Coordination with local agencies, public water systems and domestic pumpers west and south of the Sutter Buttes and near Williams is encouraged to better understand the extent and potential movement of arsenic and salinity concentrations. Further investigation regarding the potential for mobilization of brackish waters or naturally occurring constituents of concern is recommended. The proposed DWR AEM survey is anticipated to be able to characterize shallow freshwater-saline water interface(s).

3.1.12.4 Groundwater Level Measurements

Groundwater elevation contours shown on Figure 3-19 and Figure 3-20 imply that the faulting could be impacting the localized groundwater flow regime. Additional water level measurements collected from the greater Artois area and westward would allow better evaluation of groundwater conditions in the area. More data could shed light on if the localized groundwater lows are due to the fault zone or some other factor such as localized pumping. The same applies to the Willows Fault near Colusa and the Sutter Buttes, where uncertainty exists regarding how the fault zone could impact migration of deep brackish to saline water into the freshwater aquifer system.

Most of the wells monitored for groundwater elevations are greater than 100 feet deep. This presents a data gap in understanding the shallow, unconfined groundwater elevations that many domestic and agricultural irrigation supply wells extract from. Recent conversations with domestic pumpers near the greater Orland area have indicated that many domestic wells have gone and are going dry as a result of the ongoing drought. DWR has recently started mapping and recording reports of drying wells and more published data is being made available. Glenn County and Colusa County are also recording reports of wells that have gone dry or have other issues. Maps of reported wells in Glenn County are regularly updated and available to the public at: https://arcg.is/10nmyT2. Coordination between the GSAs, public monitoring agencies, public water systems, domestic pumpers, and other stakeholders that depend on shallow groundwater wells has already started and evaluation of shallow water levels is currently ongoing. Regular monitoring of shallow wells and recording of drying wells will provide information to better characterize the extent and magnitude of groundwater lowering within the shallow portion of the principal aquifer.

3.1.12.5 Springs

According to historical USGS topographical maps, springs exists throughout the western margin of the Subbasin. However, their location, if they still exist, and their characteristics such as source waters, use, and flow discharge and frequency are not well reported. Better understanding the spring flows from the

Coast Range foothills will help shed light on the shallow groundwater regime of the western area of the Subbasin, as well as provide insight into the ephemeral and intermittent streams and potentially help delineation of groundwater dependent ecosystems and habitats. Additional evaluation, potentially including field survey of the spring locations, communication with local residents and stakeholders, and monitoring of surface discharge is recommended.

3.2 EXISTING AND HISTORICAL GROUNDWATER CONDITIONS

This section describes the existing and historical groundwater conditions of the Subbasin to support development and implementation of the GSP pursuant to the requirements of SGMA. This plan section was prepared through a coordinated effort between the GSAs responsible for managing the Subbasin.

3.2.1 Regulatory Requirements

Title 23 Section 354.16 of the California Code of Regulations (23 CCR §354.16) requires that the GSP "*shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information*" and shall include descriptions for conditions related to the six undesirable results listed under SGMA:

- Groundwater elevations (Section 3.2.2)
- Groundwater storage (Section 3.2.3)
- Seawater intrusion (Section 3.2.4)
- Groundwater quality issues (Section 3.2.5)
- Land subsidence (Section 3.2.6)
- Interconnected surface water systems (Section 3.2.7)
- Groundwater-dependent ecosystems (Section 3.2.8)

This section addresses these requirements using currently available data and information in accordance with the information provided by DWR and listed in the California Code of Regulations.

3.2.2 Groundwater Elevations

Appendix 3A contains the location map and historical hydrographs for the 50 wells within the Subbasin. The hydrograph wells contain a mix of active water supply wells and dedicated observation wells. The hydrograph wells are constructed to different depths within the principal aquifer and represent conditions within the unconfined to confined zones. Appendix 3B contains historical groundwater elevation contour maps for spring and fall of calendar years 2006 (wet conditions), 2015 (critical conditions), 2017 (wet conditions), and 2020 (dry conditions). Most of the wells used in contouring are screened at depths greater than 100 feet and represent groundwater levels in the semiconfined to confined part of the principal aquifer. This presents a data gap in mapping shallow groundwater elevations that would impact domestic and agricultural irrigation supply wells, discussed in Section 3.1.12, and would potentially impact environmental water users.

3.2.2.1 Temporal and Spatial Trends

Figure 3A-1 of Appendix 3A shows the locations of historical monitoring wells within the subbasin. A hydrograph representative of typical historical and seasonal groundwater level trends within the Subbasin is shown on Figure 3-22. Historical water levels, measured between approximately 1975 and 2005, were overall increasing or stable from year to year. Since about 2007, however, there has been a general decline in water levels. Many wells with historical measurements (Appendix 3A) recovered to pre-2006 conditions after the 2012 to 2016 multiple-year drought but are still below their historical average. With the current ongoing dry years, it is expected that water levels will continue to decline.

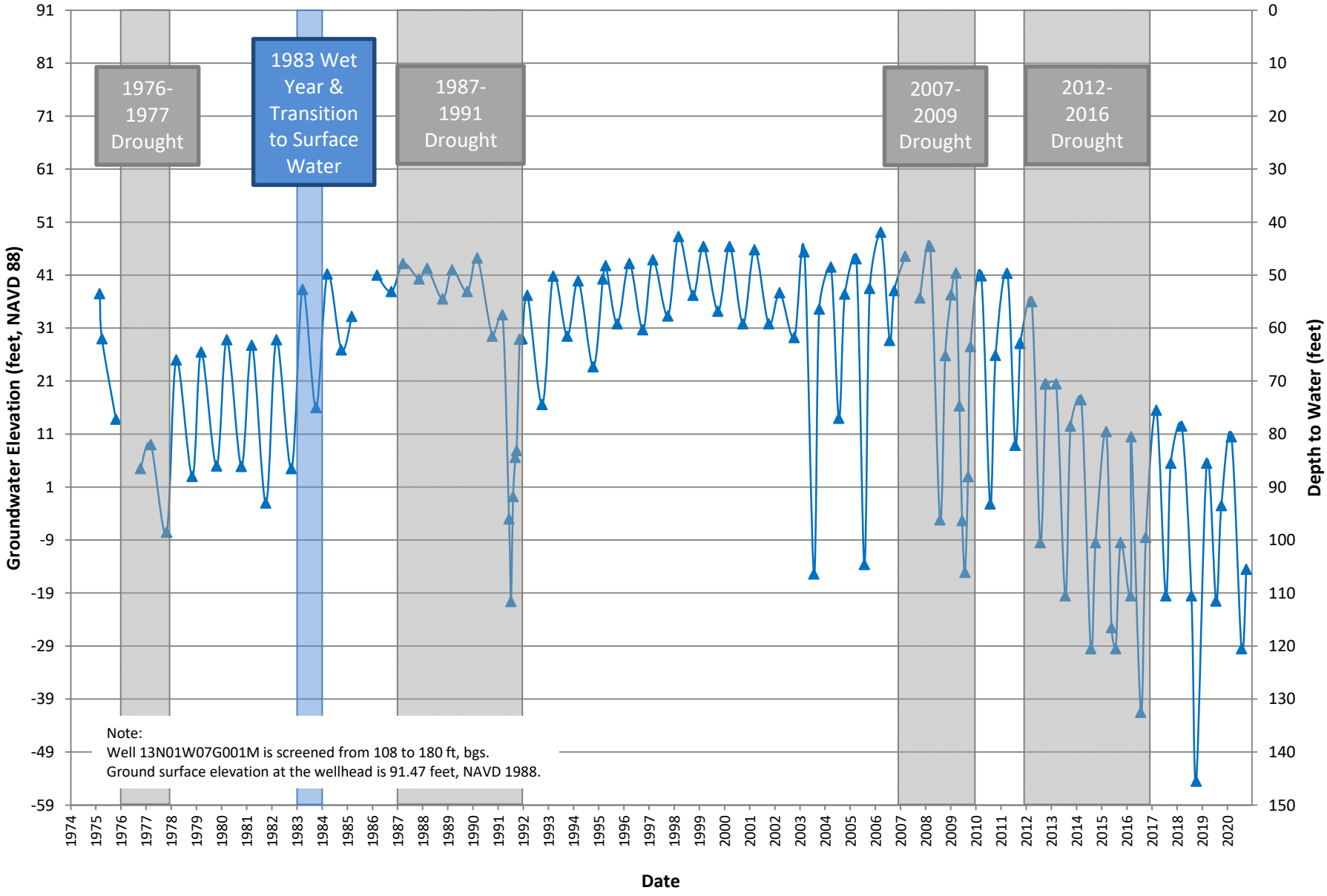
The Subbasin has a Mediterranean-type climate with wet winters and dry summers. Seasonal trends in groundwater elevations reflect these seasonal climatic changes. During the dry season when there is an increase in groundwater pumping, depth to groundwater increases, and during the rainy season when there is a decrease in demand and groundwater recharge rates are higher, depth to groundwater decreases. These seasonal fluctuations in groundwater elevations can be seen in the hydrograph on Figure 3-22 as the "peaks" and "valleys", respectively, of the water level line. The magnitude of the seasonal drawdown and recovery depends on hydrologic conditions (e.g., dry or wet years) and human influence such as demand and available water supply sources.

Well 13N01W07G001M (Figure 3-22) is screened in the unconfined to semi-confined portion of the principal aquifer. Groundwater levels declined during the droughts of 1976 to 1977, 1987 to 1991, 2007 to 2009, and 2012 to 2016 and either stabilized or recovered after these dry years. The most notable recovery periods occurred around 1983, which was both a wet year and when water users added more surface water to their supply portfolios, and after the 1987 to 1991 drought. Groundwater recharge increased after the introduction of surface waters due to a decrease in groundwater pumping and the addition of applied surface waters for agricultural use. Event signatures such as these are less notable in shallow wells located near surface waters, where flows in perennial streams or irrigation canals may smooth out impacts to groundwater levels.

Regional groundwater flow within the Subbasin is generally eastward from the margins of the Sacramento Valley toward the Sacramento River and southward towards the Sacramento-San Joaquin Delta. The regional groundwater flow trends are typified by groundwater conditions in 2006. Figures 3B-1 and 3B-2 of Appendix 3B shows the groundwater elevations in spring and fall of 2006, before the onset of the multiple-year droughts of 2007 to 2009 and 2012 to 2016. For most of the subbasin, the groundwater flows in a southeasterly direction, consistent with typical regional trends. South of Arbuckle, however, groundwater flows northeast down from the uplands before turning southeast and down the valley. This flow pattern is repeated in spring and fall 2015, which represent conditions during a multiple-year drought period (Figure 3B-3 of Appendix 3B).

Groundwater pumping has resulted in localized cones of depression that disrupt the regional groundwater flow trends. Changes in land use and multiple-year droughts have led to increased groundwater pumping. These changes in groundwater pumping have created new cones of depression and enlarged existing cones of depression. The regional groundwater gradient and direction were affected by cones of depression in areas of heavy groundwater pumping, which can be seen on the spring and fall 2015 contour maps (Figures 3B-3 and 3B-4 of Appendix 3B).

Figure 3-22. Hydrograph for Well 13N01W07G001M



Groundwater elevations throughout the Subbasin declined over the prolonged dry period after 2006 but recovered in 2017. Figure 3-23 is a groundwater elevation change map that compares spring 2006 (pre-drought) to spring 2017 (post-drought) conditions. Negative changes in groundwater elevations indicate decreases in the spring groundwater elevations from 2006 to 2017, which highlights areas that had not fully recovered from the multiple-year drought between 2007 and 2016. The primary areas with groundwater declines were in the northwestern part of the Subbasin near, and west of, the Glenn County communities of Orland and Artois, and in the southern part of the Subbasin near the Colusa County communities of Williams, Arbuckle, and College City.

Current groundwater elevations are shown on Figure 3-24 and Figure 3-25 for spring and fall 2020, respectively. Current groundwater levels are similar to those measured in 2017, indicating that regional groundwater levels have been relatively stable since the end of the previous multiple-year drought. However, since the end of the previous multiple-year drought, the Subbasin has experienced alternating years of average or dry conditions. These climatic patterns are starting to have an impact on groundwater levels. Shallow groundwater levels are of particular concern. Many shallow domestic and agricultural irrigation wells in Glenn County have been going dry. Monitoring of shallow wells and coordination with public water systems, domestic pumpers and monitoring agencies is in-progress to characterize the magnitude and rate of shallow groundwater level decline. Data gaps and recommendations are discussed in Section 3.1.12.

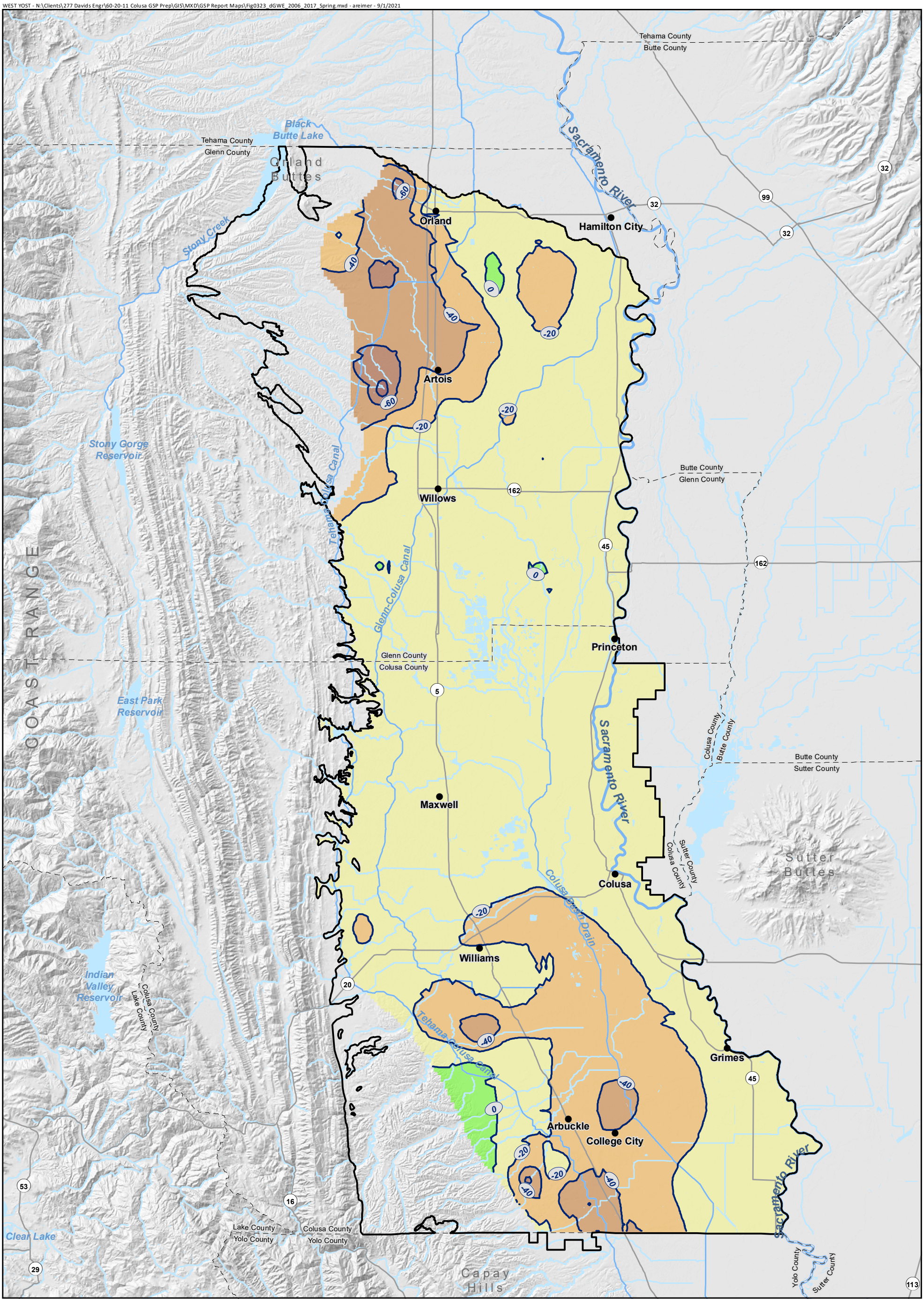
3.2.2.2 Lateral and Vertical Flow Gradients

The lateral groundwater gradient has historically been relatively stable over time and typically increases with increasing terrain slope. Typical lateral flow gradients within the Subbasin are approximately 0.001 in the valley and approximately 0.01 in the uplands. Impacts due to pumping are the exception to the typical gradients and disrupt both local and regional gradients. Changes in hydraulic parameters due to reduction in storage or compression of aquifer materials to land subsidence can result in long-term impacts to the lateral and vertical hydraulic gradients.

The vertical groundwater gradients within the principal aquifer provide insight into pumping stresses within the aquifer. Vertical groundwater gradient also helps in the identification and assessment of areas where groundwater discharge and recharge may occur and supports the understanding of interconnections between the surface water features and the groundwater system. Figure 3-26, Figure 3-27, and Figure 3-28 contain hydrographs for multiple-completion nested monitoring wells in order from north to south. The well locations are shown on Figure 3A-1 of Appendix 3A. Well 22N03W24E001-003M is located just south of Stony Creek near the Tehama-Colusa Canal. A downward vertical gradient has consistently been observed at 22N03W24E001-003M (Figure 3-26), indicating that there is potential groundwater recharge from surface sources. This is consistent with other multiple-completion wells in the area.

Well 18N02W18D001-004M, shown on Figure 3-27, is located just north of the Glenn and Colusa County border. Before 2014, the well exhibited an upward flow gradient, with potential for upward groundwater from the deeper confined aquifer zone towards a shallower semi-confined aquifer zone. After 2014, in the midst of the prolonged dry period, the gradient began to transition. The vertical gradients in 18N02W18D001-004M after 2014 show potential for downward flow during the rainy season and upward flow during the dry season.

WEST YOST - N:\Clients\277 Davids Engr\60-20-11 Colusa GSP Prep\GIS\MXD\GSP Report Maps\Fig0323_dGWE_2006_2017_Spring.mxd - areimer - 9/1/2021



Change in Groundwater Elevation Contour (20-Foot Interval)

Colusa Subbasin

Change in Groundwater Elevation: Spring 2006 to Spring 2017

< -80 | -60 to -40 | -20 to 0

-80 to -60 | -40 to -20 | > 0

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Notes:

1. Negative change in groundwater elevation indicates a decrease in the spring groundwater elevation and an increase in the seasonal depth to water, from 2006 to 2017.

N

0 2.5 5

Scale in Miles

Figure 3-23

Change in Groundwater Elevation Spring 2006 to Spring 2017

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

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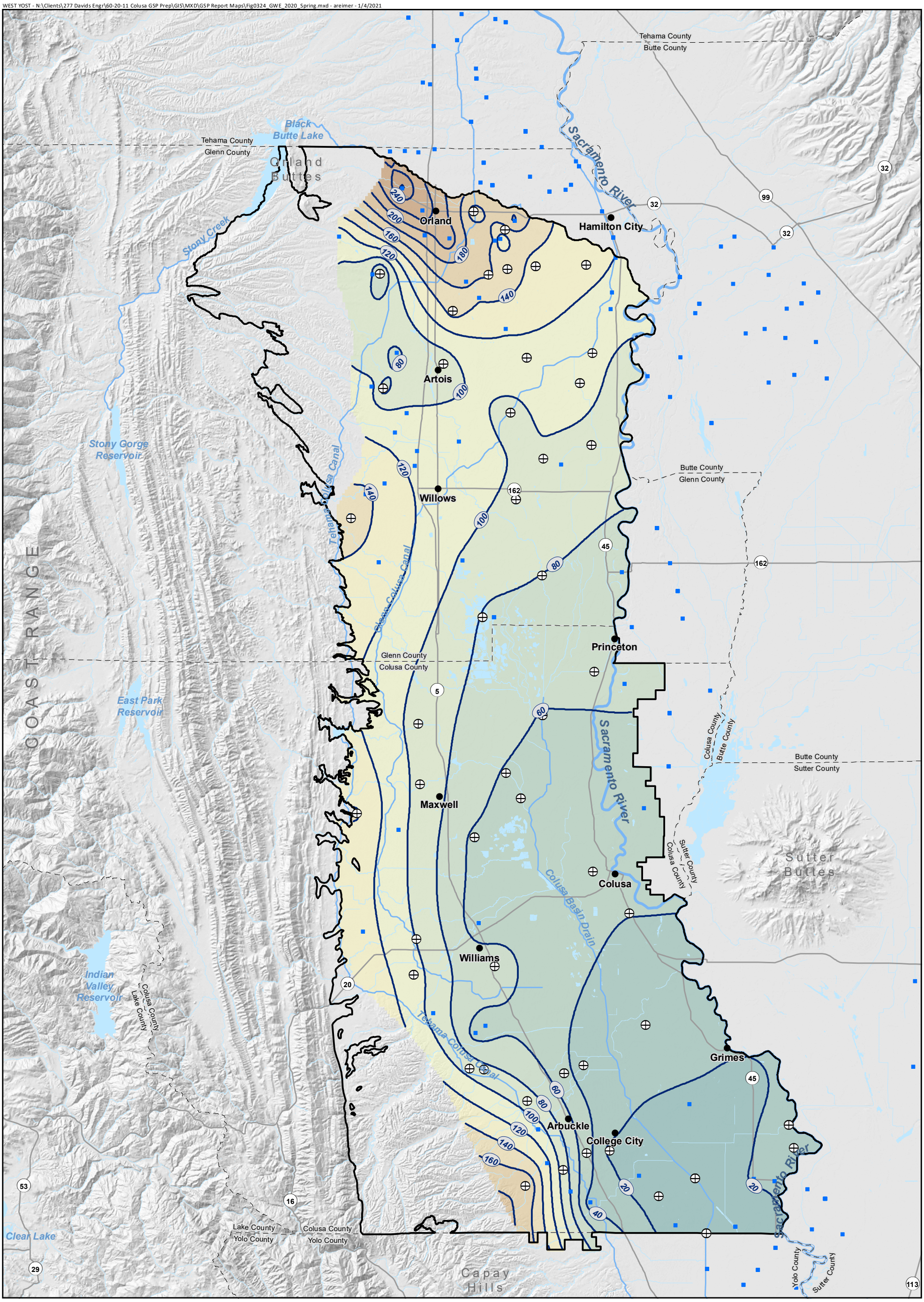


Groundwater Elevation (ft)

260 - 280	140 - 160	20 - 40
240 - 260	120 - 140	0 - 20
220 - 240	100 - 120	-20 - 0
200 - 220	80 - 100	-40 - -20
180 - 200	60 - 80	
160 - 180	40 - 60	

- Well Used for Contouring
- Monitoring Network Wells
- Groundwater Elevation Contour (20-Foot Interval)
- Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Vertical Datum: North American Vertical Datum of 1988, feet (NAVD 88).

N

0 2.5 5

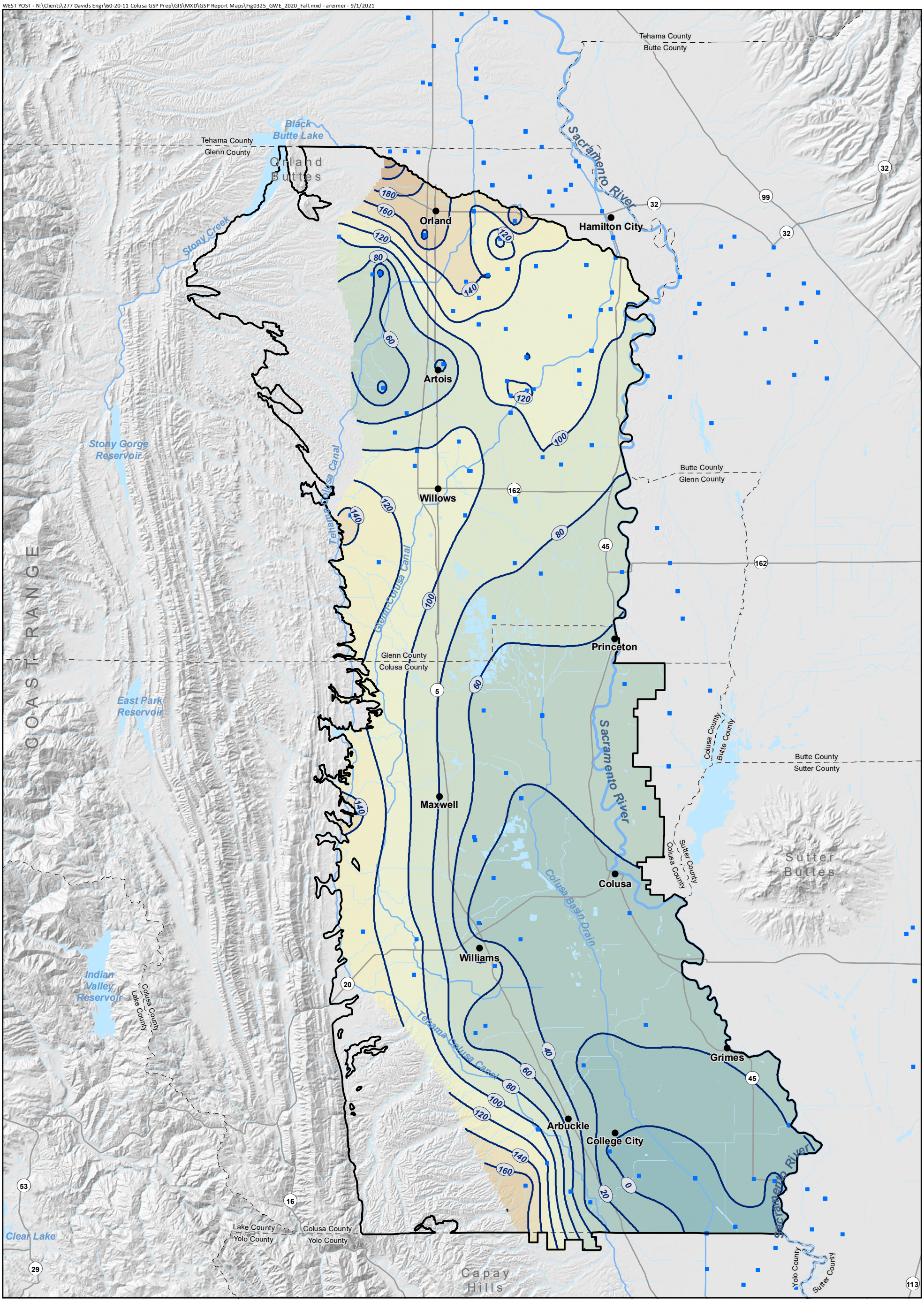
Scale in Miles

Figure 3-24

Groundwater Elevation Contours Spring 2020

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

WEST YOST - N:\Clients\277 Davids Engr\60-20-11 Colusa GSP Prep\GIS\MXD\GSP Report Maps\Fig0325_GWE_2020_Fall.mxd - areimer - 9/1/2021



Groundwater Elevation (ft)

260 - 280	140 - 160	20 - 40
240 - 260	120 - 140	0 - 20
220 - 240	100 - 120	-20 - 0
200 - 220	80 - 100	-40 - -20
180 - 200	60 - 80	
160 - 180	40 - 60	

Well Used for Contouring

Groundwater Elevation Contour (20-Foot Interval)

Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Vertical Datum: North American Vertical Datum of 1988, feet (NAVD 88).

N

0 2.5 5

Scale in Miles

Figure 3-25

Groundwater Elevation Contours Fall 2020

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

Figure 3-26. Hydrograph for Well 22N03W24E001-003M

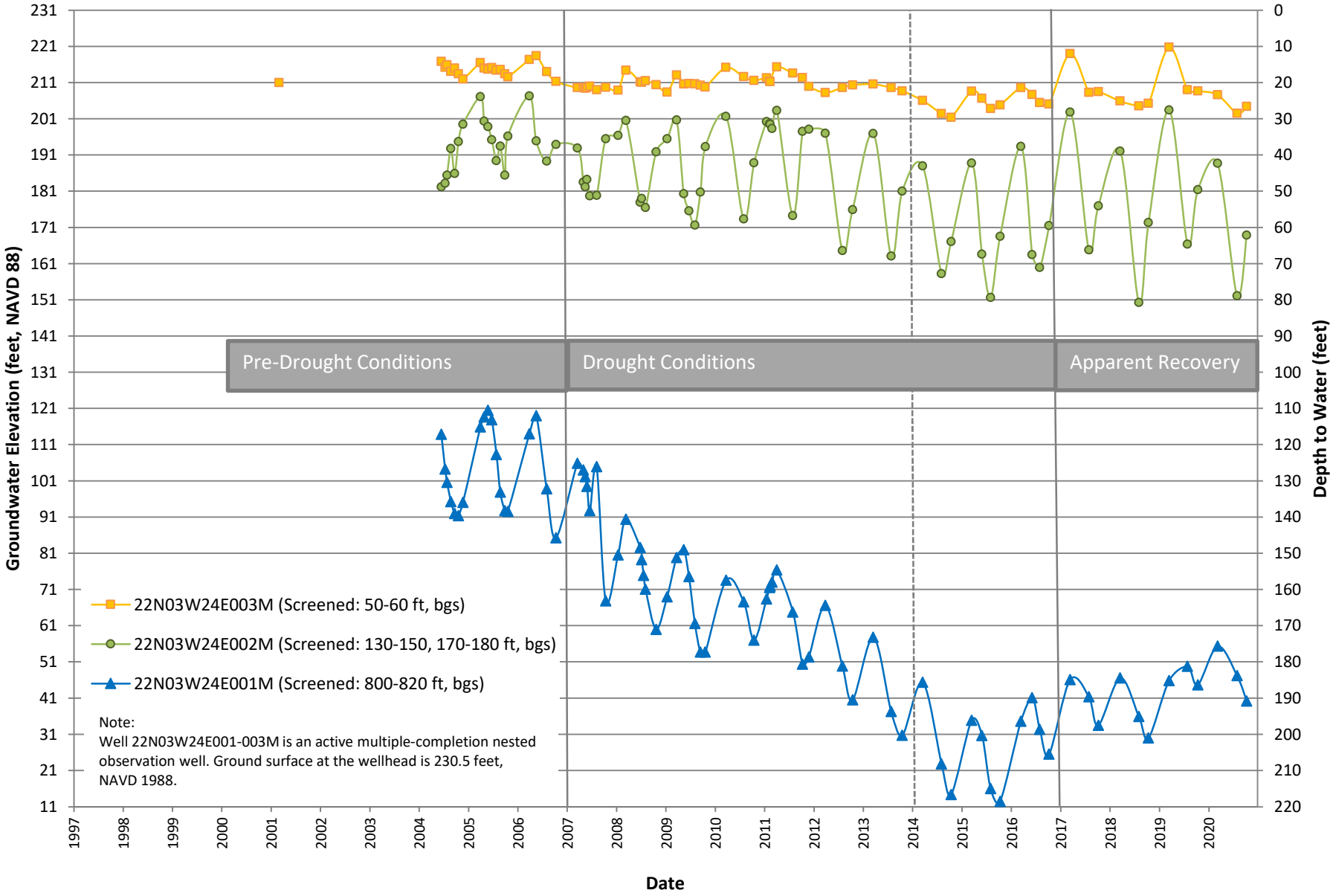


Figure 3-27. Hydrograph for Well 18N02W18D001-004M

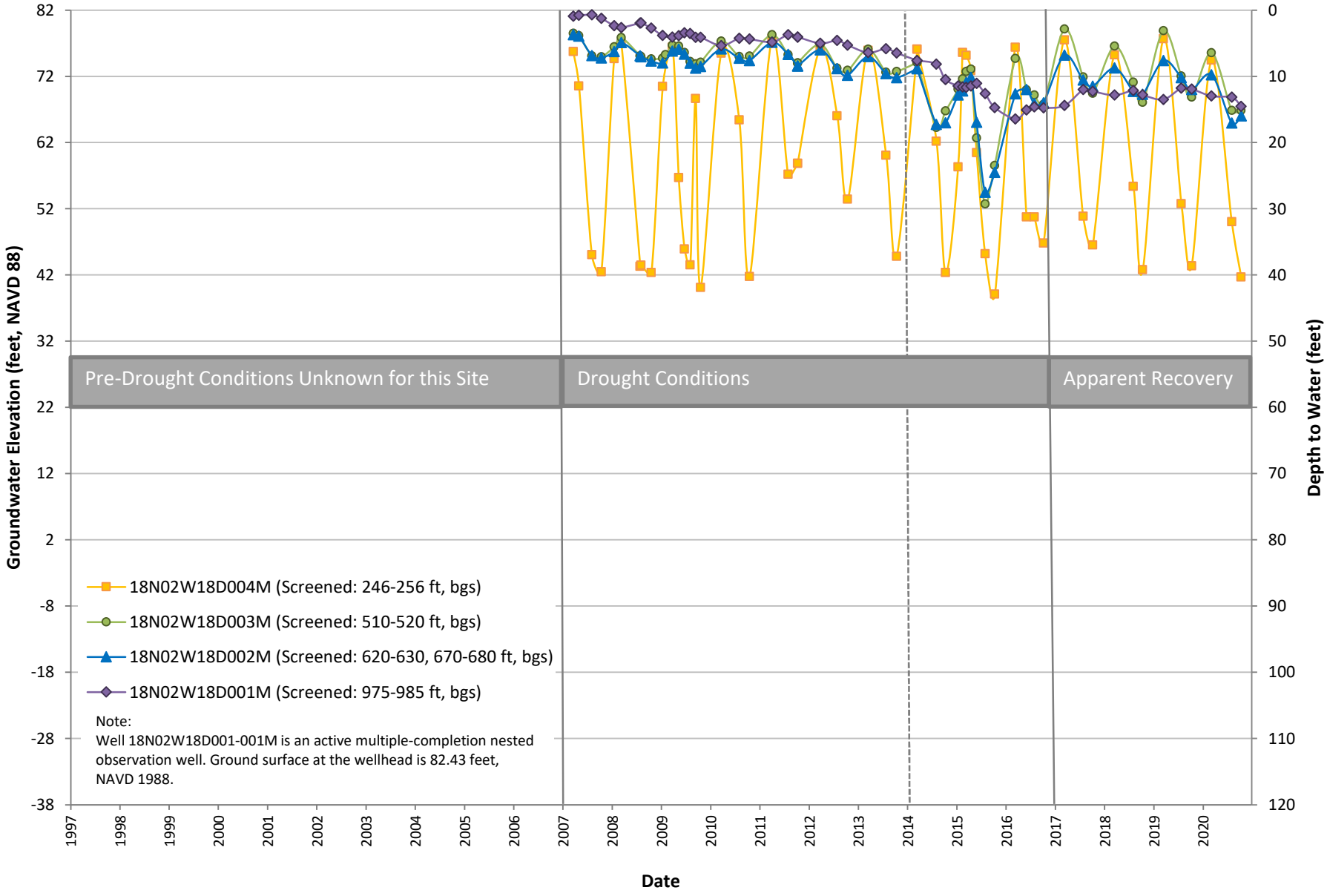
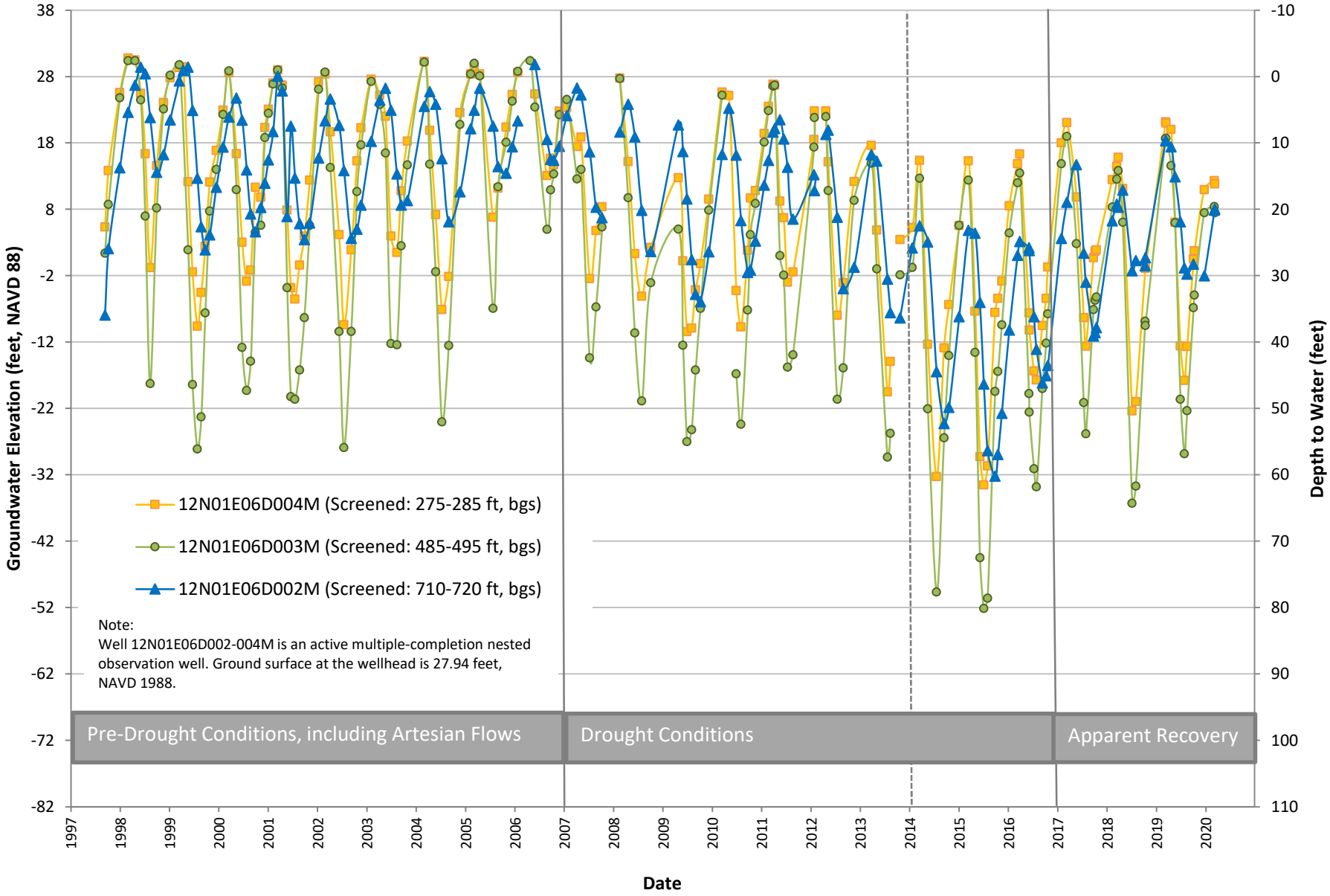


Figure 3-28. Hydrograph for Well 12N01E06D002-004M



Variable vertical gradients also occurred in well 12N01E06D002-004M (Figure 3-28), located on the Colusa and Yolo County line. Prior to the prolonged dry period between 2007 and 2016, the vertical gradients and groundwater elevations measured in the well showed potential for seasonal flowing artesian conditions. The potentiometric head of the confined aquifer system rose above land surface during the wet season. During the start of the multiple-year drought, the vertical gradient was upward from the deep zone and downward from the shallow zone towards the middle zone. This may have been due to the majority of groundwater pumping occurring at depths similar to the middle completion of the monitoring well. During the latter half of the multiple-year drought, the vertical gradient reversed during the wet season, with vertical gradients showing potential for flow from the shallow towards the deeper zones. After 2016, the vertical gradients returned to pre-drought conditions, but at generally lower groundwater elevations.

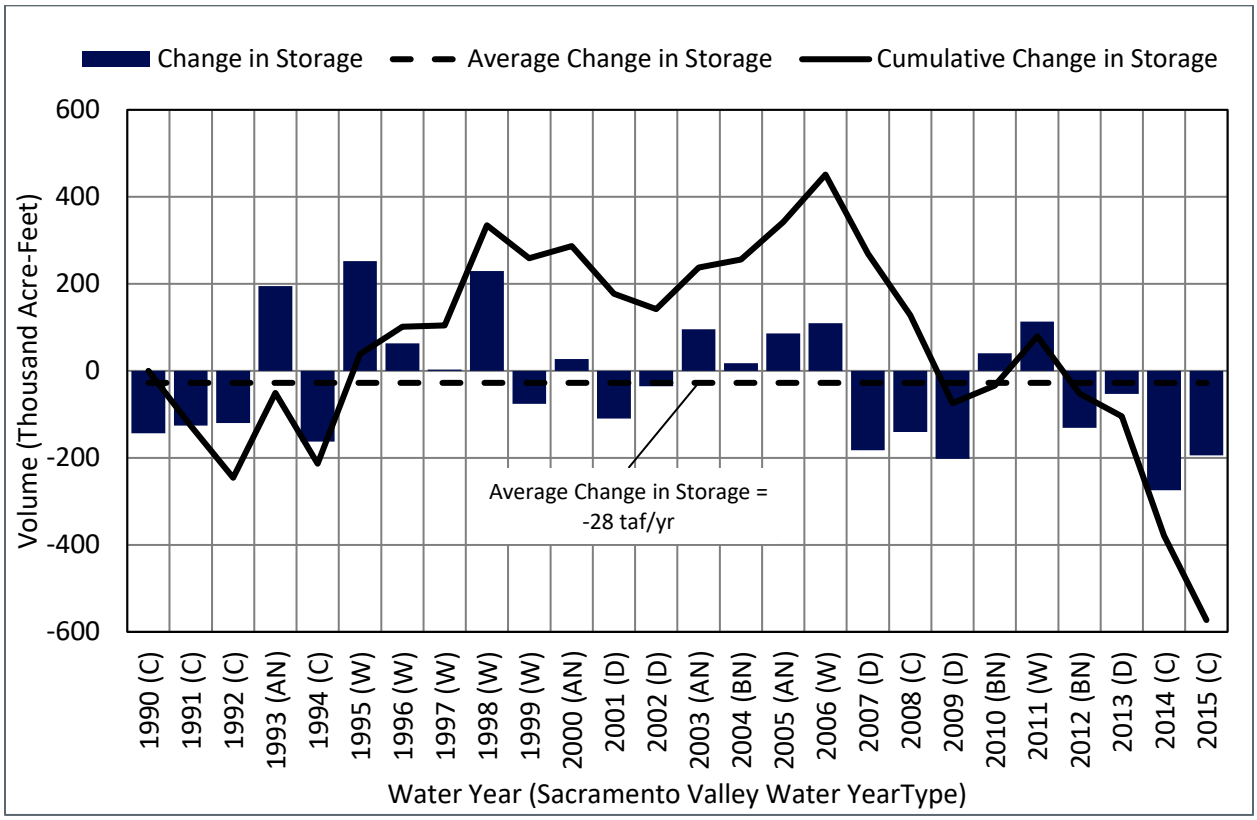
3.2.3 Estimate of Groundwater Storage

The current groundwater storage volume within the Subbasin, above the crystalline basement rocks and base of freshwater, is estimated to be between about 26 million acre-feet (maf) and 140 maf based on an analysis using contouring of Spring 2020 groundwater levels, an average saturated thickness, and an assumed average specific yield range of 0.034 to 0.185, taken from Olmsted and Davis (1961). This range in groundwater storage volume reported in this GSP is low due the lack of groundwater elevation data within the upland areas of the subbasin and uncertainty regarding the depth to the base of freshwater. Recent groundwater modeling conducted to support development of this GSP suggests average specific yield values for the full saturated thickness in the subbasin (i.e., from the regional water table to the base of fresh water) fit within the range provided by Olmsted and Davis (1961).

Prior to the groundwater basin boundary modification process concluded by DWR in 2019, DWR Bulletin 118 estimated the aquifer storage capacity within the upper 200 feet of the Subbasin to be approximately 13 maf (DWR, 2006a). The Subbasin at the time was bounded by Stony Creek to the north, Sacramento River to the east, Cache Creek to the south, and the uplands of Dunnigan Hills and the foothills of the Coast Ranges to the west. Currently, the Subbasin excludes the areas south of the Colusa-Yolo County boundary and includes a portion of the former West Butte Subbasin east of the Sacramento River within Colusa County. Taking into account the area of the current Subbasin extent and a specific yield estimate of 0.071 within the unconfined zone, as reported in Bulletin 118 (2006a), approximately 10.3 maf of storage capacity is estimated within the upper 200 feet of the current subbasin extent.

The average annual change in storage was -28 thousand acre-feet per year (taf/yr) over the historical water budget period of 1990 to 2015. This indicates that, on average, more groundwater has left the Subbasin than entered, resulting in an average net reduction in groundwater stored in the Subbasin. Figure 3-29 summarizes the annual change in storage and the cumulative change in storage in the Subbasin aquifer system over the historical water budget period. A decrease in groundwater storage occurred during critically dry (C), dry (D), and below normal (BN) water years. This is most evident between 2007 and 2015, when the region experienced a series of consecutive, multiple-year droughts. While critically dry, dry, and below normal water years almost always correspond with a decrease in storage, above normal (AN) and wet (W) water years do not always result in an increase in groundwater storage. On average, the Subbasin's storage volume is influenced more by dry years than wet years. This is likely due to both a greater reliance on groundwater supply during dry years when surface water is less readily available and the relatively slow nature of deep percolation to recharge the groundwater system during wet years. Most of the groundwater inflows and outflows within the Subbasin are exchanged directly with the land and surface water system overlying the Subbasin groundwater system. More information regarding the groundwater storage calculations can be found in the water budget section of this GSP

(Section 3.3) and the model development and calibration Technical Memorandum prepared by Woodard & Curran and Davids Engineering (2021) (Appendix 3D).



Reference: Woodard & Curran and Davids Engineering. 2021. C2VSimFG-Colusa Model Development and Calibration Technical Memorandum: (Appendix 3D).

Figure 3-29. Change in Groundwater Storage

3.2.4 Seawater Intrusion

The Subbasin is located approximately 30 miles from the legal Sacramento-San Joaquin River Delta boundary, and even farther from the brackish delta estuaries. Additionally, the 2019 Basin Prioritization study by DWR found that the Subbasin has not exhibited any impacts of seawater intrusion within the past 20 years (DWR, 2020b). Seawater intrusion is neither occurring nor anticipated to occur in the subbasin over the planning horizon and thus further discussion of seawater intrusion is not included in this GSP.

3.2.5 Groundwater Quality

Groundwaters within the subbasin are mixed calcium, magnesium, and sodium bicarbonate waters (DWR, 2004a, 2006a, 2006b). The northern portion of the subbasin is dominated by calcium bicarbonate water, while increased sodium content has been observed near the Sutter Buttes and west towards Williams, resulting in localized occurrences of mixed sodium and magnesium bicarbonate waters south of Princeton, near Williams, Colusa, Grimes, and Arbuckle, and south towards Yolo County (DWR, 2006a).

Groundwater quality concerns within the Subbasin include locally elevated levels of salinity, TDS, adjusted sodium absorption ratio, arsenic, boron, hexavalent chromium, iron, manganese, and nitrate (DWR, 2006a; Wood Rodgers, 2008; California Water Service, 2016; SWRCB, 2020a). The following subsections discuss the occurrence of these constituents of concern within the subbasin.

Monitoring and regulatory programs exist for the major constituents of concern within the Subbasin. These include programs managed by the U.S. Geological Survey, State of California Department of Water Resources and the State Water Resources Control Board, Central Valley Salinity Coalition, and Central Valley Regional Water Quality Control Board. This section summarizes groundwater quality information from these existing programs. The California Safe Drinking Water Act addresses the regulation and control of public water systems in the State of California, including enforcing provisions of the federal Safe Drinking Water Act. The federal government first granted primary enforcement responsibility to the State in 1978. The State Water Resources Control Board Division of Drinking Water (DDW) is the agency responsible for enforcement in Colusa and Glenn Counties, including the entire Subbasin.

Chapter 4 describes the proposed monitoring network for monitoring the potential mobilization of brackish or saline water from below the freshwater aquifer or along faults in the vicinity of the Sutter Buttes.

3.2.5.1 Major Naturally Occurring Constituents

All groundwater contains dissolved constituents that are products of natural processes of the hydrologic cycle. Rainfall contains only small concentrations of dissolved constituents. Upon reaching the land surface, dissolution of minerals contributes dissolved ions to the water. Calcium, magnesium, and sodium are the major cations (positively charged ions) typically found in groundwater, and sulfate and chloride, which, along with bicarbonate, are the major anions (negatively charged ions). The bicarbonate ion is formed by dissolution of carbon dioxide from the atmosphere and released by organic processes in the soil. Dissolved carbon dioxide contributes to the dissolution of minerals as water is recharged. The quantity of dissolved salts depends on the specific surface area of the aquifer material, the solubility of the minerals present, the pH and oxidation-reduction potential (Eh) of the system, and the residence time of the water in the subsurface aquifer.

3.2.5.1.1 Salinity

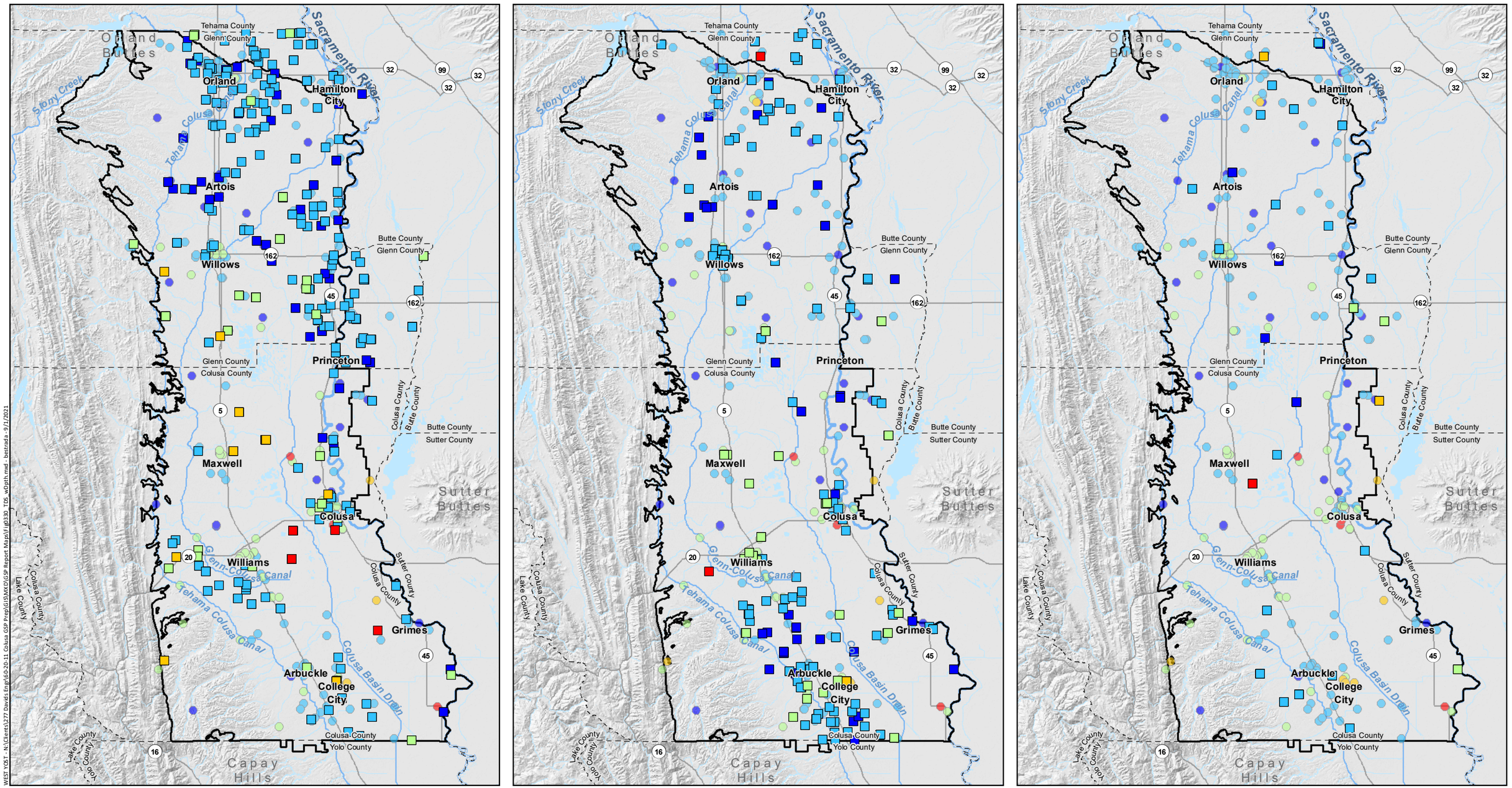
Salinity of groundwater can be characterized by the measured TDS concentration and/or the electrical conductivity (EC) value, which is easily measured in the field and can be used as a proxy for TDS. TDS has three secondary drinking water MCLs, which are established for aesthetic consumer acceptance: recommended limit (500 mg/L), upper limit (1,000 mg/L), and short-term limit (1,500 mg/L). The recommended MCL is the threshold for a “higher degree of consumer acceptance”, the upper MCL indicates the limit for which it is reasonable to provide an alternate water source, and the short-term MCL water is “acceptable only for existing community water systems on a temporary basis pending construction of treatment facilities or development of acceptable new water sources” (22 CCR §64449).

TDS concentrations throughout the subbasin range from less than 100 mg/L to more than 1,500 mg/L, the short-term secondary MCL defined by Title 22 California Code of Regulations (SWRCB, 2018b). Figure 3-30 shows TDS concentrations detected in wells of varying depths. Wells with unknown depth and construction information are shown on all three panels of Figure 3-30. TDS concentrations of more than 500 mg/L, the recommended secondary MCL, have been detected in wells throughout the subbasin, but mostly in wells south of Artois. The highest concentrations of TDS have been measured in the area surrounding the cities of Maxwell, Colusa, and Williams.

Wells Less Than 200 ft Deep

Wells 200 to 700 ft Deep

Wells Greater Than 700 ft Deep



Source: Total dissolved solid (TDS) concentration and well depth information was downloaded from GeoTracker Groundwater Ambient Monitoring and Assessment Program (GAMA) and U.S. Geological Survey (USGS) National Water Information System (NWIS), 2020.

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Note:
1. TDS concentrations shown are the maximum detected at that location.
2. The drinking water standards (2018) secondary maximum contaminant level for TDS is 500 mg/L (recommended), 1,000 mg/L (upper limit), and 1,500 mg/L (short term).

Colusa Subbasin

Maximum TDS Concentration (mg/L) in Wells with Known Depth
- < 250
- 250 - 500
- 500 - 1,000
- 1,000 - 1,500
- > 1,500

Maximum TDS Concentration (mg/L) in Wells with Unknown Depth
- < 250
- 250 - 500
- 500 - 1,000
- 1,000 - 1,500
- > 1,500

N

0 4 8

Scale in Miles

Figure 3-30

Historical Concentrations Total Dissolved Solids

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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Wells screened in the unconfined to semi-confined zone of the aquifer (i.e., in wells less than 200 feet deep) in the central and southern portion of the Subbasin had the highest number of wells with elevated TDS concentrations. TDS concentrations in the shallow wells southwest of Colusa have consistently been greater than 2,000 mg/L over a 20-year period. The wells southwest of Colusa with unknown depth have historically had TDS concentrations between 649 mg/L and 1,820 mg/L between 1957 and 2011. The wells northeast of Maxwell have consistently had TDS concentrations above 1,000 mg/L over a 20-year period.

Wells with depths greater than 200 feet near Maxwell, Colusa, and Williams have historically had TDS concentrations less than 1,000 mg/L, with the exception of the deep well southeast of Maxwell. This well is a multiple-completion nested monitoring well with completions set at 378 feet, 775 feet, 1,236 feet, and 1,481 feet deep. In 2011, TDS concentrations in the deepest completion had the lowest TDS concentration (approximately 260 mg/L) while the second-deepest completion well had the highest TDS detection (approximately 930 mg/L). The two shallowest completions in the well had TDS concentrations of approximately 520 mg/L. In 2016, the second-shallowest completion well had the highest TDS concentration (approximately 1,640 mg/L), while the shallowest completion well had the lowest concentration (approximately 530 mg/L). The deepest completion was not measured in 2016.

The shallow well west of Grimes shown in Figure 3-30 is shown with an elevated TDS symbol because of a single TDS measurement of 2,040 mg/L taken in 1975. This older measurement may not be representative of current conditions in the area. Similarly, the wells near College City and other locations with TDS detections greater than 1,000 mg/L tend to be wells with a single measurement and may not represent current or consistent TDS concentrations for those locations.

Many of the wells located in or near urban areas exhibit TDS concentrations above the 500-mg/L recommended secondary MCL. This includes wells with unknown depths in the areas of Williams, Maxwell, Williams, Colusa, Arbuckle, and College City. Public supply wells deeper than 200 feet near Williams and Willows exhibited an increasing trend in TDS concentrations (Dupuy, et. al., 2019; Jurgens, et. al., 2020).

3.2.5.1.2 Major Cations and Anions

The primary cations within the Subbasin are calcium, magnesium, and sodium. The highest calcium concentrations within the Subbasin have been measured in wells between Colusa and Williams, where concentrations have been recorded above 100 mg/L. Elevated sodium concentrations have been detected in wells throughout the Subbasin but tend to be higher in the area surrounding Williams and Colusa. In Colusa, sodium concentration levels are often an order of magnitude greater that of magnesium or calcium. Magnesium concentrations are typically between 10 and 30 mg/L. Wells near Willows, Williams, and Arbuckle have shown an increasing trend in magnesium concentrations over the past decade (DWR, 2021b; SWRCB, 2020a; USGS, 2020).

The ratio of calcium to sodium is much higher in the northern part of the subbasin compared to the southern part of the subbasin. This aligns with the spatial trend in water type, with calcium bicarbonate waters being characteristic of northern Glenn County and sodium bicarbonate waters generally characterizing Colusa County.

As a general rule, the ratio of sodium to calcium and magnesium concentrations in groundwater increases with residence time. This is due to cation exchange, which can be thought of as a natural water softening process that occurs when groundwater containing calcium and magnesium comes in contact with clay containing exchangeable sodium. The longer the water is in contact with the aquifer, the higher the ratio of sodium to calcium and magnesium, and the softer the water. This relationship may be obscured by

other factors, including geologic heterogeneities that may cause variation in the sodium concentrations, independent of the residence time of the groundwater, and saline water intrusion. These factors, notwithstanding the relative concentrations of sodium, calcium and magnesium in the wells, may also help to delineate recharge and discharge zones, and potential mobilization of brackish or saline water.

The subbasin waters are mixed bicarbonate waters. Other major anions distributed throughout the subbasin include chloride and sulfate. The spatial distribution of the high concentrations of chloride and sulfate is similar to that of elevated concentrations of TDS and sodium, with the highest concentrations detected in the general Maxwell-Colusa-Williams area and south towards Arbuckle (Figure 3-30). Sulfate concentrations in this area have been measured above the 250-mg/L recommended secondary MCL, with the southern wells showing a long-term increasing trend in sulfate concentrations (SWRCB, 2020a). Groundwater samples in the past decade have generally contained chloride concentrations below the 250-mg/L recommended secondary MCL throughout the Subbasin (DWR, 2021b; SWRCB, 2020a). Anthropogenic sources of chloride and sulfate include wastewater effluent, septic discharge, industrial use, landfill leachate, and agricultural runoff.

3.2.5.2 Other Naturally Occurring Constituents

Naturally occurring constituents that could constrain the use of groundwater within the Subbasin for potable supply, and which have been detected in wells regionally throughout the Sacramento Valley, include arsenic, boron, iron, manganese, and hexavalent chromium. Boron can also be detrimental to plants.

3.2.5.2.1 Arsenic

Arsenic is a naturally occurring constituent in groundwater and commonly occurs at concentrations ranging from 10 to 50 µg/L in the western United States, where it is typically associated with alluvial-lacustrine basin-fill deposits and volcanic rocks and sediments (Welch, et. al., 1988). The primary MCL for arsenic in drinking water is 10 µg/L (SWRCB, 2018a).

Grimes and Princeton have had violations of the 10 µg/L drinking water MCL, which is both the State of California and federal standard. Arsenic has been detected near Grimes at concentrations as high as about 28 µg/L (measured in 2012). A federal program was initiated to install filters on water connections and reduce the arsenic concentration (Glenn County, 2005). Recent concentrations of arsenic in wells near Grimes have been less than 20 µg/L, however, there have been detections of high levels of arsenic in wells near the Sutter Buttes. The elevated arsenic concentrations near Grimes were determined to be due to natural conditions (Glenn County, 2005), potentially including proximity to the Sacramento River stream channel, Sutter Buttes, Willows Fault, and the Colusa Dome.

3.2.5.2.2 Boron

Boron is a naturally occurring element that is associated with the marine deposits of the Coast Ranges. Anthropogenic sources of boron include industrial waste discharges, municipal wastewater, and agricultural practices (SWRCB, 2017). Fire retardant manufacturing, storage, and use throughout Glenn and Colusa Counties could be an anthropogenic source of boron in the aquifer system. Boron in groundwater is most likely in the form of boric acid. Boron is a necessary component to plant growth in small amounts, but some plants are sensitive to the presence of boric acid in waters and may exhibit adverse effects if exposed to boron concentrations higher than the plant's tolerance.

Elevated concentrations of boron reported by GCID within Colusa County have impacted agricultural practices (GCID, 1995). According to GCID (1995), groundwater underlying the northern portion of the GCID service area has boron concentrations suitable for irrigation. Additionally, boron measured in select groundwater wells within Glenn County has not exceeded the USEPA agricultural water quality goal for boron of 750 µg/L (USEPA, 1986; USGS, 2020). In contrast, elevated levels of boron have been detected in the southern portion of the GCID service area (GCID, 1995).

3.2.5.2.3 Iron and Manganese

Iron and manganese in groundwater are naturally occurring via weathering from subterranean sediment. Anthropogenic sources include landfill leachate, sewage discharge, and industrial effluent. Iron concentrations exceeding the 300-µg/L secondary MCL have been reported in water supply wells near Orland, Willows, Delevan, Williams, Colusa, and Arbuckle within the past decade (DWR, 2021b; SWRCB, 2020a). Williams and Colusa have experienced long-term increasing trends in iron concentrations, although the most recent concentrations have been lower than during previous years (USEPA, 2020; CH2MHILL, 2016a).

Elevated manganese concentrations above the 50-µg/L secondary MCL have been reported near the cities of Williams and Colusa, and northeast of Artois, near the Sacramento River (USEPA, 2020). According to the Northern Sacramento Valley (Four Valley) Drinking Water Strategy Document (Glenn County, 2005), there have been customer complaints near Williams and Colusa related to iron and manganese in drinking water.

3.2.5.2.4 Hexavalent Chromium

Chromium typically occurs in in the trivalent state, which is nearly insoluble. Geochemical conditions in recharge zones or the aquifer can oxidize trivalent chromium to hexavalent chromium, which is soluble, mobile in groundwater, and a carcinogen. Naturally occurring chromium minerals are associated with serpentinite and other Coast Range rocks. Over geologic time, these rocks have been eroded, transported by streams, and incorporated in the basin fill sediments of the Subbasin. Anthropogenic sources of hexavalent chromium are mostly related to industrial use and waste.

There is currently no MCL for hexavalent chromium. The SWRCB implemented a 10-µg/L primary MCL for hexavalent chromium on July 1, 2016. On May 31, 2017, the Sacramento Superior Court ruled that the SWRCB must withdraw the 10-µg/L hexavalent chromium MCL and develop a new MCL after assessing the economic feasibility of compliance, especially for smaller public water systems. The 10-µg/L hexavalent chromium MCL was withdrawn on September 11, 2017. The SWRCB has not published a timeline for issuing the new MCL, but the new MCL is anticipated to be announced in late 2021.

Drinking water supply wells near Willows have experienced high concentrations of hexavalent chromium (California Water Service, 2016). Hexavalent chromium in a well west of Willows has not been detected at concentrations below 20 µg/L since 2016 and was detected at 40.1 µg/L in July 2020 (SWRCB, 2020a). Hexavalent chromium concentrations greater than 20 µg/L have also been detected in wells midway between Williams and Arbuckle, and near Colusa, within the past decade (DWR, 2021b; SWRCB, 2020a).

3.2.5.3 Non-Point Sources of Groundwater Pollution

Non-point sources of groundwater pollution are diffuse discharges that occur over a wide area. The major non-point source groundwater constituent of concern in the Subbasin is nitrate.

3.2.5.3.1 Nitrate

Nitrate is a naturally occurring compound that forms when nitrogen and oxygen combine in the soil. Nitrate occurs naturally in groundwater or can be introduced through a variety of land uses, including row crop agriculture, irrigated agriculture, and various waste disposal practices. Typical waste materials resulting in nitrate pollution include animal manures from commercial poultry, dairy, hog and beef operations; wastewater treatment plant effluent applied to land; household wastes disposed of in septic systems; and landfill leachate.

Small amounts of nitrate in groundwater are normal, but larger concentrations can result in serious health problems. The 45-mg/L MCL for nitrate (quantified as nitrate) is considered by the State and Federal governments to be the maximum concentration that can be safely consumed from a public water system. Excessive nitrate consumption can lead to health problems, including irritation of gastrointestinal tract and bladder, and methemoglobinemia, or blue baby syndrome, so named because affected infants take on a bluish tinge. Blue baby syndrome is caused when nitrate is converted to nitrite by bacterial activity in the stomach. Typically, in adults, these bacteria are destroyed by stomach acid. The stomachs of infants (especially less than 3 months of age in humans) are not fully developed and do not produce strong acids. This allows the bacteria to survive, leading to the buildup of nitrite in the blood. The nitrite oxidizes the ferrous iron in the blood to ferric iron, thereby limiting its ability to carry oxygen to the cells. The syndrome is readily treated if diagnosed.

Nitrate detections are widespread in the Subbasin but are mostly low concentrations, typically meeting drinking water standards, with the exception of the northern portion of Glenn County and the area near Willows (CH2MHILL, 2016a; Wood Rodgers, 2008). According to the Sacramento Valley Water Quality Coalition Groundwater Quality Report (CH2MHILL, 2016a), only 2 percent of the 359 total wells analyzed within Glenn and Colusa Counties had nitrate concentrations above the 45-mg/L MCL and the average nitrate concentration was 8.3 mg/L.

3.2.5.4 Point Sources of Groundwater Pollution

Point sources of groundwater pollution are discrete discharges that occur at a single identified location. Discharges from point sources can be either a single discharge event or have occurred continuously over a period of time. Point sources of groundwater pollution often require monitoring and cleanup programs.

There are several active groundwater contaminant cleanup sites in the Subbasin. These mostly include leaky storage tanks and unauthorized releases of contaminants such as petroleum hydrocarbons, nitrate, pesticides and herbicides. The largest contamination site is the Orland Dry Cleaner site, a perchloroethylene (PCE) plume within the Subbasin that extends approximately two miles southeast of the source location in Orland (DTSC, 2020; URS Corporation Americas, 2020). PCE is a dense non-aqueous phase liquid, meaning it is denser than water, with a moderate to high mobility rating (SWRCB, 2017). Long-term temporal trends of PCE concentrations in most of the monitoring wells show concentrations stabilizing or decreasing since the start of sampling in 2003 (URS Corporation Americas, 2020).

3.2.6 Land Subsidence

Differential land subsidence and associated earth fissuring resulting from groundwater withdrawal have had significant consequences in several California groundwater basins. Land subsidence can cause structural damage to wells, foundations, roads, bridges, and other infrastructure, as well as impacting surface water flows by reducing conveyance capacity and potentially changing flow gradients within canals, natural streams, and floodplains. Inelastic land subsidence may also negatively impact groundwater storage capacity. Land subsidence has been measured within the Subbasin, however, it is yet to be determined if the subsidence measured within the Subbasin has measurably impacted storage capacity.

The 1976-1977 drought was the first time that more groundwater than surface water was used for agricultural irrigation in the Sacramento Valley. Drilling and pump contractors reported that in the summer of 1977 many wells were discovered to have broken casings, and the demand for new and replacement wells could barely be met (Borchers, et. al., 1998).

The risk of significant land subsidence impacts depends on a complex array of variables including: the degree of new groundwater development, especially in areas or at depths not previously exploited; changing land use, which could bring to light an effect that would otherwise go unnoticed; and the mineral composition and consolidation history of the aquifer skeleton.

Land subsidence due to groundwater withdrawal is triggered by decreases in pore pressure in a confined aquifer system containing clay layers (typically, montmorillonite clay). The decrease in pore pressure increases the effective stress on the aquifer skeleton. If this effective stress exceeds the maximum stress to which the aquifer skeleton has been subjected in the past, the clay layers will undergo permanent compaction. Highly compressible clays, such as montmorillonite, have not been reported within Subbasin boreholes. They have, however, been encountered in boreholes south of the Sutter Buttes (see discussion regarding lacustrine deposits and the Turlock Lake Formation in Section 3.1.7.1). Additionally, a borehole drilled near the Colusa Drain, near Zamora in Yolo County (south of the Subbasin), at 12N1E34Q1 contained a silty, diatomaceous, kaolinitic clay with a compression index of 1.22 and coefficient of consolidation of 4.98 square feet per year. These values are comparable to samples of diatomaceous clay from the Corcoran Clay of the San Joaquin Valley, and indicate a high susceptibility to compaction (Page, 1998). The core sample was collected at a depth of 534 to 544 feet.

Figure 3-31 shows the measured land surface displacement from resurvey of Sacramento Valley benchmarks between 2008 and 2017 (DWR, 2018a). Figure 3-32 includes the annual rate of subsidence from 2018 to 2019, as calculated from interferometric synthetic aperture radar (InSAR) imagery surveys (TRE ALTAMiRA, 2020). Appendix 3C contains the location map and ground surface displacement charts measured in five extensometers located within the counties of Colusa and Glenn.

Land subsidence has been reported and measured in the Arbuckle area of Colusa County. A 2015 NASA report based on InSAR survey evaluation showed isolated land subsidence of up to approximately 0.5 feet west of Arbuckle (Farr et. al., 2015). Data from a repeat survey of the Sacramento Valley Height-Modernization Project benchmarks also indicates a decrease in land surface elevation by as much as 2 feet between 2008 and 2016 near Arbuckle (Ehorn, 2016). A resurvey of those benchmarks conducted in 2017 showed a total displacement of 2.14 feet since 2008. This equates to approximately 0.24 feet, or approximately 3 inches, of subsidence per year between 2008 and 2017, on average. Subsidence calculated by TRE ALTAMiRA from InSAR imagery showed up to more than 2 inches of subsidence occurring between 2018 and 2019 within the greater Arbuckle area (Figure 3-32).

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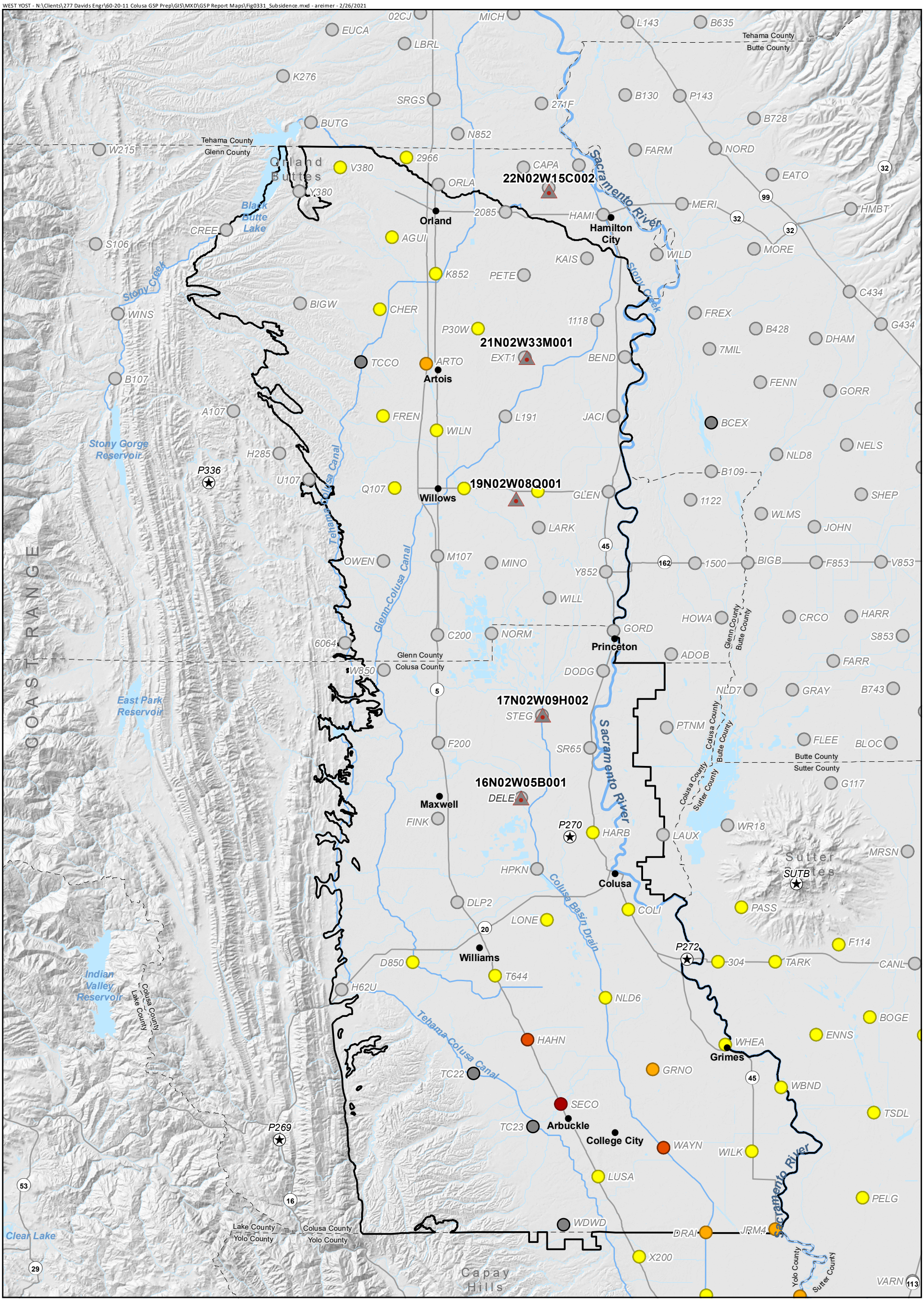

Source: Extensometers and continuous GPS stations were obtained from DWR and USGS. Benchmarks and displacement data were obtained from a resurvey report puublished by DWR (2020).

Datums: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Extensometer

Continuous GPS Station

Colusa Subbasin

Sacramento Valley Benchmark Subsidence Measured Between 2008 and 2017

- > 2 ft
- 1 - 2 ft
- 0.5 - 1 ft
- 2 inches - 0.5 ft
- < 2 inches
- New Benchmark or Not Surveyed

N

0 2.5 5

Scale in Miles

Figure 3-31

Measured Subsidence 2008 to 2017

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

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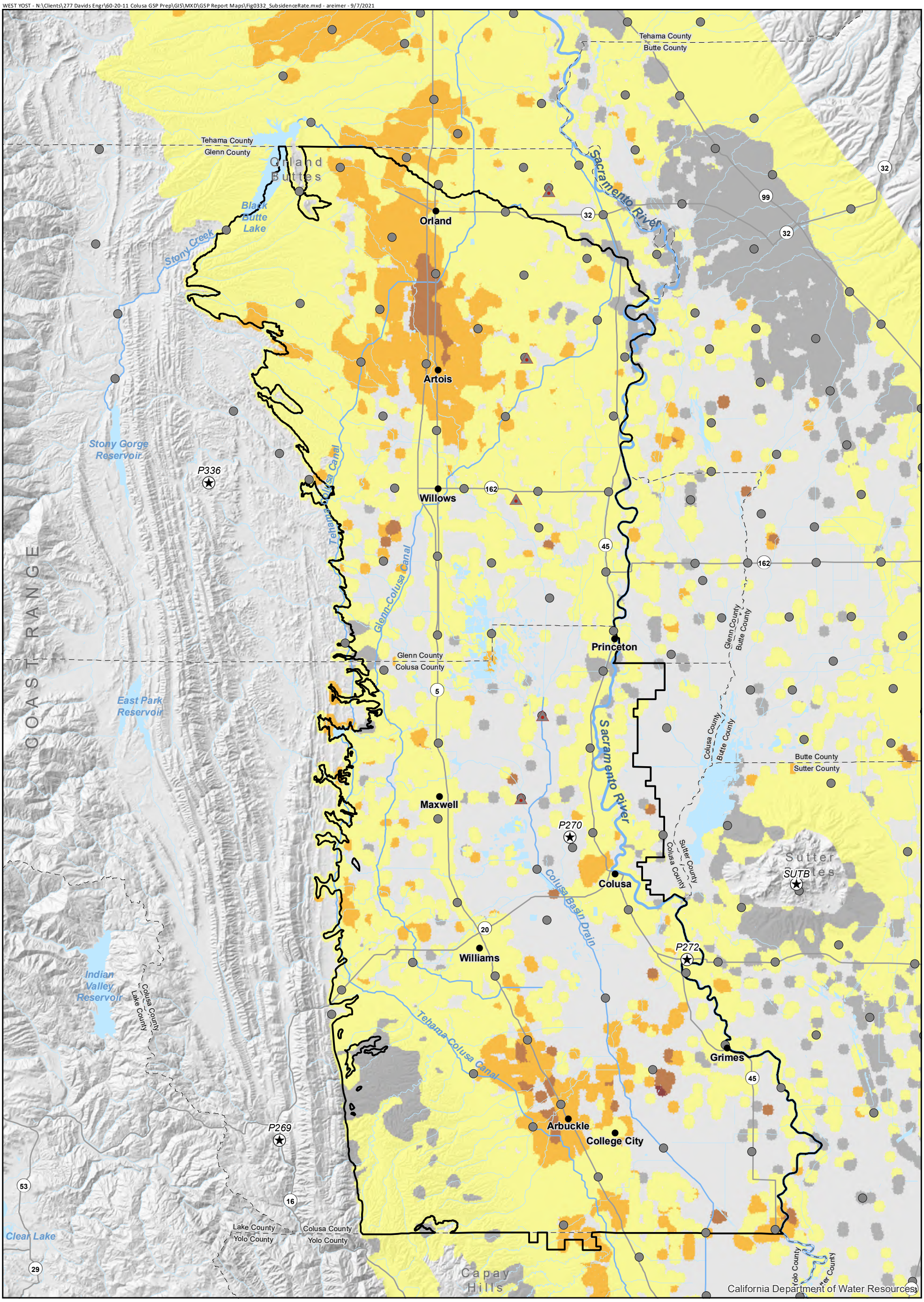


Source: TRE ALTAMiRA, 2020, InSAR Land Surveying and Mapping Services in Support of the DWR SGMA Program, Vertical Displacement v2019 Annual Rate 2018-09-01 to 2019-09-01, March 2020.

Datums: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

- Extensometer
- Continuous GPS Station
- Sacramento Valley Subsidence Benchmark
- Colusa Subbasin

Annual Subsidence Rate (inches per year) Between September 2018 and September 2019

- > 2
- 1 - 2
- 0.5 - 1
- 0 - 0.5
- Uplift or No Subsidence

N

0 2.5 5

Scale in Miles

Figure 3-32

Annual Subsidence Rate 2018 to 2019

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

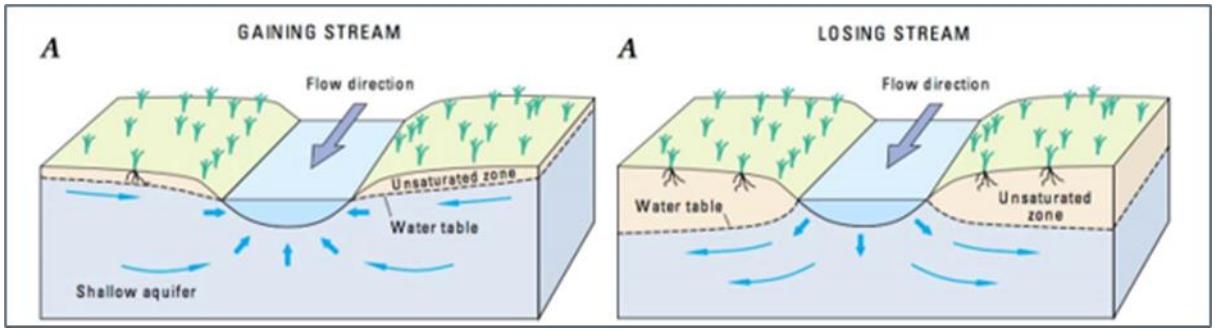
Land subsidence is not exclusive to the Colusa County portion of the subbasin; repeat surveys of benchmarks in Glenn County showed small amounts of land subsidence southwest of Orland occurring between 2008 and 2017 (Ehorn, 2016; DWR, 2018a). One benchmark located near Artois had a measured displacement of 0.59 feet, or approximately 7 inches. InSAR imagery from 2018 to 2019 showed approximately 1.5 inches of subsidence occurring between Orland and Artois.

Extensometer measurements have also recorded ground displacement in the Subbasin. Appendix 3C contains a map of the extensometer locations (Figure 3C-1 of Appendix 3C) and ground displacement measured within extensometers in or near the subbasin. Seasonal displacements of ±0.3 inches have been recorded in these extensometers. Most of the subsidence measured in the extensometers has been elastic, meaning the aquifer materials are not permanently compressed. Potential inelastic displacement may have occurred in extensometers 21N02W33M001M, northeast of Artois, and 16N02W05B001M, east of Maxwell, during the multiple-year droughts (Figure 3C-5 and Figure 3C-2 of Appendix 3C, respectively). Potential inelastic subsidence occurred in 21N02W33M001M between 2007 and 2010, and between 2008 and 2016 in 16N02W05B001M. Measured seasonal fluctuations in displacement within both of these boreholes have since stabilized.

3.2.7 Interconnected Surface Waters

Traditionally, water resource managers have tended to address surface water and groundwater systems as distinct and separate. However, most surface water bodies (e.g., rivers, streams, drains and lakes) are connected to the groundwater system to some degree so that changes to surface water bodies (either gains or losses) can affect flows in aquifer systems, and vice versa. Additionally, changes in land use, irrigation methods, and management of surface water storage and conveyance infrastructure can impact surface water and groundwater systems.

Figure 3-33 illustrates the typical range of groundwater-surface water interactions in the absence of groundwater pumping. Streams interact with groundwater in three basic ways: streams gain water from inflow of groundwater through the streambed (gaining stream); they lose water to groundwater by outflow through the streambed (losing stream); or they do both, gaining in some reaches and losing in other reaches (Winter, et. al., 1998). Also, whether a given reach is gaining or losing can vary with time in response to changing hydrological conditions. The upper, high elevation reaches of a stream may tend to be losing while the lower reaches may tend to be gaining. If the stream is connected to the groundwater system, meaning that it is physical contact with the groundwater system, then the gains and losses depend on the stage of the stream, the groundwater level, and the streambed conductance. If the stream is disconnected from the groundwater system, meaning that the stream is separated from the groundwater system by an unsaturated zone, then the gains and losses are independent of the groundwater level.



Reference: U.S. Geological Survey. 2021.

Figure 3-33. Conceptual Example of Gaining and Losing Streams

Groundwater pumping can lead to streamflow depletion, potentially reducing supplies for human and ecosystem water uses (USGS, 2012). When groundwater is pumped, the water table near the well declines, forming a cone of depression. Initially the decline is accounted for by a change in aquifer storage surrounding the well. As pumping continues, the cone of depression expands, and begins to capture groundwater that would have otherwise discharged to the stream. The pumping may lower groundwater levels enough to cause induced infiltration from the stream, changing the once gaining reach of the stream to a losing reach. The streamflow depletion is the sum of the captured groundwater discharge that would otherwise have reached the stream, plus the induced infiltration caused by the groundwater pumping (Barlow and Leake, 2012).

After pumping is stopped, groundwater levels will not recover immediately. Instead, groundwater will flow towards the cone of depression at a rate dictated by the hydraulic properties of the aquifer and the hydraulic gradient directed radially inward towards the well. The rate will gradually decline with the hydraulic gradient. The existence of residual drawdown in the aquifer after pumping ceases means that streamflow depletion can continue after pumping stops.

The duration of streamflow depletions caused by pumping depends on the spatial scale: the greater the distance between groundwater pumping and affected stream, the longer the timescale. As a consequence, the ultimate effects of pumping can occur significantly after pumping starts, or even after pumping has ceased. The timescales involved in aquifer responses to pumping and other stresses can be on the order of decades, making it difficult to associate cause with effect. Monitoring for potential impacts may be ineffective because, by the time effects are observed, it may be too late to take in action, and the effects may persist for decades. In general, the longer the timeframe for effects to be observed at a given monitoring point, the longer those effects will persist, if the pumping resulting in the effects is halted immediately. Also, the effects of pumping on stream depletions are cumulative, with the effects of each pumping cycle in each well imposed on the next.

3.2.7.1 Simulated Stream Gains and Losses

The Subbasin integrated hydrologic model, C2VSimFG-Colusa, was used to analyze historical stream gains (water that enters the stream from the groundwater system) and losses (water that enters the groundwater system from the stream; also referred to as seepage) in waterways that flow within or along the boundaries of the Subbasin. The modeled streams include the Sacramento River, Stony Creek, and the Colusa Drain.

Table 3-6 includes the breakdown of the modeled net stream gain (stream gains minus stream losses) for each stream by water year type. Table 3-7 includes stream gain and loss statistics for the modeled streams. Simulated Sacramento River conditions were mostly net gaining, with the exception of 1998, where the Sacramento River experienced net loss of approximately 13 taf. The median net gain along the Sacramento River was approximately 72 taf/yr. The net stream gain in the Sacramento River was lower during wet years, when there would be more surface flow, and higher in the dry years, when surface waters would be in short supply. Simulated conditions in the Colusa Drain indicate net stream gain of approximately 115 taf/yr on average between 1990 and 2015, with net gains occurring in all years including critically dry years. Contrary to simulated Sacramento River conditions, net stream gain in the Colusa Drain were higher during wet years than during dry conditions. Stony Creek always experienced annual net losses between 1990 and 2015. Stream losses were greatest during critically dry and dry years.

A detailed assessment of projected stream gains and losses is presented in Appendix 3G. The analysis considers the Sacramento River, Stony Creek, and the Colusa Drain individually and collectively, and

evaluates temporal patterns of gain and loss over the 50-year projected (future) water budget period (described in Section 3.3, below). Under projected future conditions without climate change, average net stream gains (stream gains minus stream losses) are projected to be approximately 125 taf/yr in aggregate for the Sacramento River, Stony Creek, and the Colusa Drain combined. With the potential effects of climate change[1], net stream gains are projected to remain positive but to decrease by about 48 taf/yr, or by 38 percent, with respect to the projected future conditions without climate change. However, viewed in the relation to the average Sacramento River flow above the Feather River confluence of approximately 11,700 taf/yr the projected change is roughly one half of one percent. These simulated net stream gains are less than the typical ±2.5% accuracy of annual volume measurements when calculated from current meter-based stage-discharge functions (Clemmens and Wahlin, 2006). Consequently, these simulated net stream gains are not significantly different than the uncertainty of average annual streamflows along these waterways, and cannot be measured directly from stream gage measurements with certainty. This will continue to be evaluated and addressed as part of continued work to fill data gaps and part of ongoing monitoring to be reported in annual reports.

Table 3-6. Modeled Net Stream Gain 1990-2015 by Water Year Type

Water Year Type	Number of Years Evaluated	Net Stream Gain, taf		
		Colusa Drain	Stony Creek	Sacramento River
Critical Dry	7	109	-38	91
Dry	5	109	-30	86
Below Normal	3	104	-31	57
Above Normal	4	121	-33	47
Wet	7	127	-28	26

Note: Total gains, losses and net stream gains will not exactly match values reported elsewhere in this GSP due to different methods of extracting data from C2VSimFG-Colusa.

Table 3-7. Modeled Net Stream Gain 1990-2015 Statistics

	Colusa Drain		Stony Creek		Sacramento River	
	Net Stream Gain, taf	Year	Net Stream Gain, taf	Year	Net Stream Gain, taf	Year
Minimum	82	2010	-55	1992	-13	1998
Maximum	152	1999	-21	2006	117	2007
Median	115	1997	-31	2011	72	2000
Average	115	--	-32	--	62	--

Note: Total gains, losses and net stream gains will not exactly match values reported elsewhere in this GSP due to different methods of extracting data from C2VSimFG-Colusa.

[1] Results are from the C2VSimFG-Colusa model "Projected Future Conditions with 2070 Climate Change and without Projects" scenario, in which projected precipitation, evapotranspiration, and surface water supplies are adjusted to reflect the estimated effects of climate change based on the 2070 Central Tendency climate change datasets provided by DWR to support GSP development. Climatological, hydrological, and water operations datasets, change factors, and the DWR Climate Change Resource Guide are available at: https://data.cnra.ca.gov/dataset/sgma-climate-change-resources.

3.2.7.2 Stony Creek Thalweg Analysis

A thalweg analysis was conducted for Stony Creek, where local historical water level measurements were compared to streambed elevation of Stony Creek's thalweg to evaluate for stream-aquifer connectivity and to compare those results with results of the *Interconnected Surface Water in California's Central Valley* (ICONS) study (TNC, 2021). Shallow wells less than 200 feet deep and within 5 miles of surface water features are the criteria used to identify representative groundwater level wells to be used as a proxy for surface water depletion and stream-aquifer interaction monitoring, discussed in Chapter 4 and Chapter 5. Figure 3-34 shows a cross section, A-A', that follows the thalweg of Stony Creek. Superimposed onto the cross section are the spring and fall 2006, 2015, and 2020 groundwater level measurements from 31 shallow wells (less than 200 feet deep) within 5 miles of the creek. Also shown in the cross section are the ICONS datasets:

- Minimum groundwater elevation measured between 2011 and 2018: depicted as a light blue interpolated potentiometric water surface.
- Maximum groundwater elevations measured between 2011 and 2018: depicted as a medium blue interpolated potentiometric water surface.
- Stream likelihood of connectivity based on the average groundwater elevations measured between 2011 and 2018: depicted as a graded rainbow-colored horizontal line above land surface where red indicates disconnected stream reaches, yellow are reaches with uncertain connectivity, green indicates connected and potentially losing reaches, and dark blue are connected and potentially gaining stream reaches.

The measured groundwater levels roughly match the interpolated surface of the ICONS minimum and maximum groundwater elevation datasets. The most notable discrepancies occur just southeast of Orland, where measured groundwater levels appear deeper than the interpolated minimum groundwater elevation, and just northwest of Orland, where measured groundwater levels appear shallower than the maximum interpolated groundwater elevation. None of the measured groundwater levels are at higher elevation than the streambed land surface which suggests that no part of Stony Creek is gaining. This, however, could be due to the spatial density of the shallow groundwater wells. Additionally, there is no active stream gage on Stony Creek below Black Butte Lake.

Further evaluation of locations, quantity and timing of stream depletions through additional monitoring and/or construction of additional shallow or multiple-completion monitoring wells near surface waters (e.g., Stony Creek, Sacramento River, and the Colusa Drain) comparing observed groundwater levels with stream discharge or river stage information would provide more insight into stream-aquifer interactions and a subsequent detailed analysis of potential impacts to beneficial users and uses.

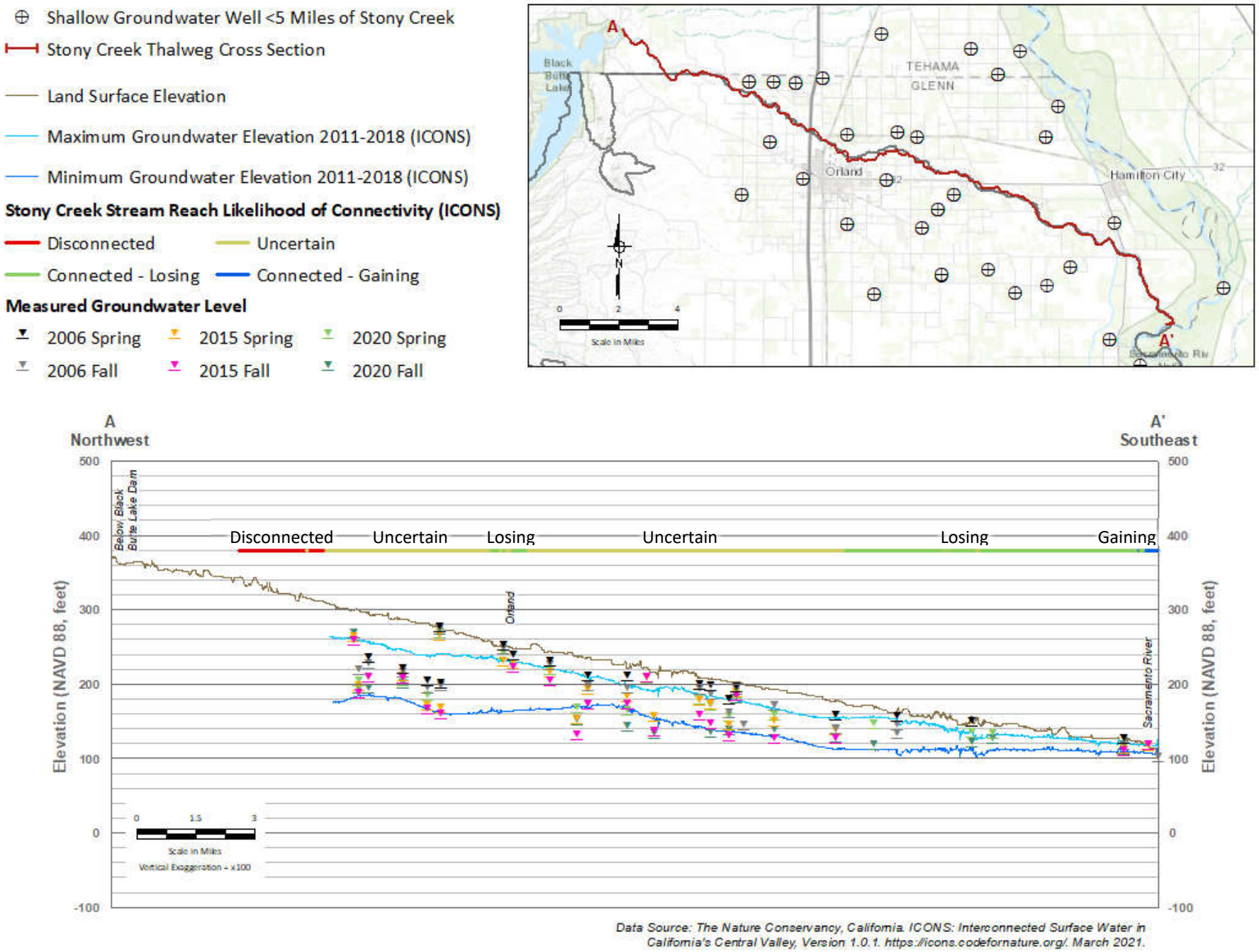


Figure 3-34. Thalweg Analysis

3.2.8 Groundwater Dependent Ecosystems

GDEs are defined as "ecological communities of species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (23 CCR § 351(m)). As described in TNC's guidance for GDE analysis (Rohde et al. 2018), a GDE's dependence on groundwater refers to reliance of GDE species and/or communities on groundwater for all or a portion of their water needs. TNC has identified hundreds of freshwater species that are located in the Subbasin, based on analysis of the California Freshwater Species Database version 2.0.9 within the Subbasin boundary (Appendix 2B-2). While there are data gaps in understanding how many of these species utilize or depend on groundwater, the GSAs conducted an initial evaluation of potential GDEs in the Subbasin using the best available information at the time of GSP development. As described in Chapter 7 of this GSP, the GSAs have also planned several studies that will expand monitoring of GDEs and help to increase understanding of the potential impacts of land use planning and well permitting on GDEs in the Subbasin.

Natural communities commonly associated with groundwater (NCCAG) within the State of California were mapped by TNC (2018b) and Klausmeyer, et. al. (2018). The NCCAG mapping provided an initial indication of the location, habitat type, and impacted vegetation for potential GDE areas within the Subbasin. The majority of the potential GDE vegetation areas include cottonwood (31 percent), bulrush (21 percent), willow (15 percent), and oak (13 percent) habitat areas. Arundo, or giant reed, accounts for four percent of NCCAGs initially identified within the Subbasin.

Preliminary screening of the potential GDEs within the Subbasin was conducted to help prioritize areas for further mapping, evaluation, and monitoring of GDEs during implementation of the Colusa Subbasin GSP. The preliminary screening supported the assessment of data gaps, evaluation of existing monitoring networks, which could potentially be used for GDE monitoring, and development of PMAs.

The GSAs will seek to work with resource agencies, stakeholders, beneficial users and the public to refine the understanding of GDEs in the Subbasin, fill data gaps, and develop PMAs with consideration of GDEs.

Under the preliminary screening, a score of 1 (less likely to be a GDE) to 4 (more likely to be a GDE) was applied to the NCCAG areas based on depth to groundwater, proximity to surface waters, and proximity to irrigated croplands. Figure 3-35 shows the relationship between the score and ranking criteria.

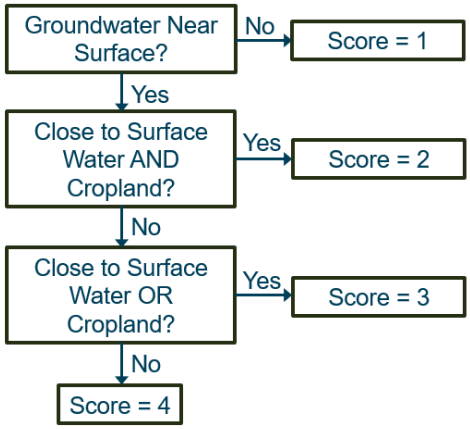


Figure 3-35. GDE Scoring Criteria

Average spring groundwater level data from 2014 to 2018 indicates that shallow groundwater levels (i.e., within 30 feet of ground surface) exists throughout most of the subbasin. A depth to water (DTW) of 30 feet based on the average DTW for 2014 to 2018 was used as one of the primary criteria in the initial

screening of potential GDEs. The use of a 30-foot DTW criterion to screen potential GDEs is based on reported maximum rooting depths of California phreatophytes and is consistent with guidance provided by TNC (Rohde et al., 2018) for identifying GDEs. The use of shallow groundwater data over the 5-year 2014 to 2018 time period was deemed appropriate because it provided a more conservative (i.e., more inclusive) indicator of potential GDEs than the use of a data from a single year. The 30-foot DTW contour is shown on Figure 3-36. Depths to shallow groundwater east of the contour are less than 30 feet. Based on the scoring criteria presented in Figure 3-35, east of the 30-foot contour line is shallow groundwater and so will be evaluated using the next criteria while land west of the contour line receives a score 1 (less likely to be a GDE) and is not evaluated with additional criteria.

Areas within 150 feet of surface waters, including canals, ditches, and perennial streams, were considered to have access to surface waters. Additionally, areas within 150 feet of irrigated rice paddies and 50 feet of other irrigated croplands were considered to have access to surface waters. The leftmost and middle panels of Figure 3-36 include the areas within 150 feet of surface waters, 150 feet of rice croplands, and 50 feet of other irrigated croplands. Vegetation within these areas is assumed to have access to surface water and/or agricultural runoff and percolation and therefore receive a score of 2 if they are close to both surface water and agricultural lands (i.e., they are more likely to be a GDE than lands without shallow groundwater, but still not very likely) or a score of 3 if they are close to either surface waters or agricultural lands (i.e., they only have one source of water from surface practices or natural flows). GDEs include vegetation and habitat that are wholly dependent on groundwater. Closer proximity to available surface waters decreases the likelihood that a vegetated wetland or potential GDE habitat area is a GDE. The exception to this could be locations where surface waters gain a significant amount of water from groundwater. The Sacramento River and the Colusa Drain are both under net-gaining conditions, where surface waters annually gain water from the aquifer system (Section 3.2.7). These net-gaining conditions along surface water corridors could increase the likelihood of GDEs regardless of the scoring exercise results presented here.

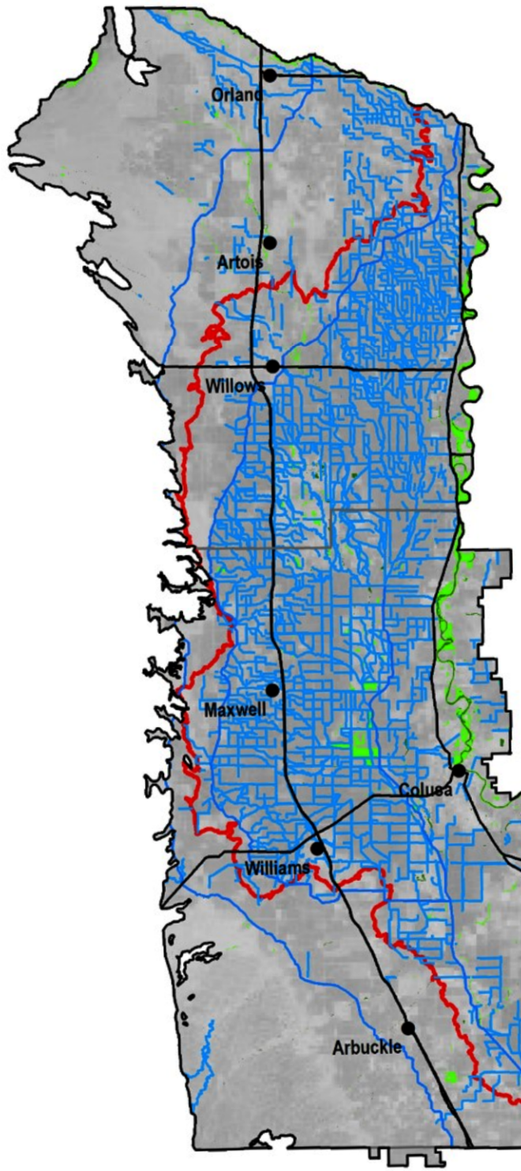
Vegetated lands that have access to shallow groundwater and not near either surface waters or irrigated agricultural lands receive a score of 4 (i.e., the only water source available for vegetation consumption is groundwater).

The rightmost panel of Figure 3-36 shows the scores for the potential GDE areas within the Subbasin. Table 3-8 includes the acreages per GDE score. Most of the NCCAG lands within the Subbasin were designated a score of 2, which is on the lower end of likelihood of being classified as a GDE due to proximity to both surface waters and irrigated croplands. The majority of the high scores (i.e., score of 3 or 4, or a high likelihood of being a GDE) occur along the Sacramento River corridor, within the wildlife refuges, and in non-agricultural lands surrounding some of the streams, such as along Willows Creek and south of Delevan Wildlife Refuge. Groundwater level data is lacking in the uplands west of Orland and west of Arbuckle. There is potential for GDEs to be present in these areas, especially near seeps and springs, but the data is lacking in order to determine their existence. This data gap is discussed in Section 3.1.12

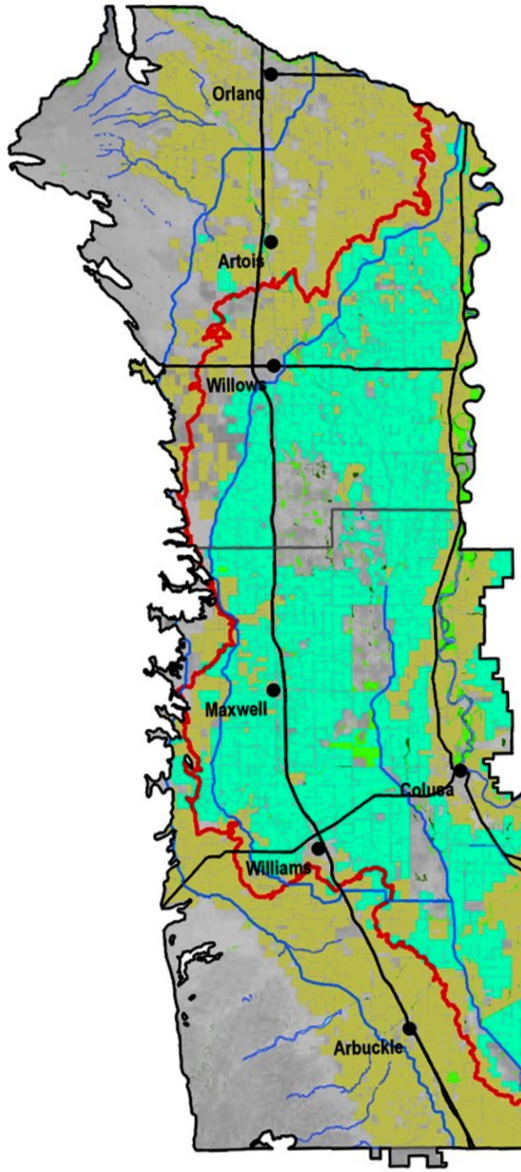
Table 3-8. GDE Likelihood Scores

Score	Score Description	Approximate Acreage
1	Less Likely	2,540
2	--	8,710
3	--	5,580
4	More Likely	920

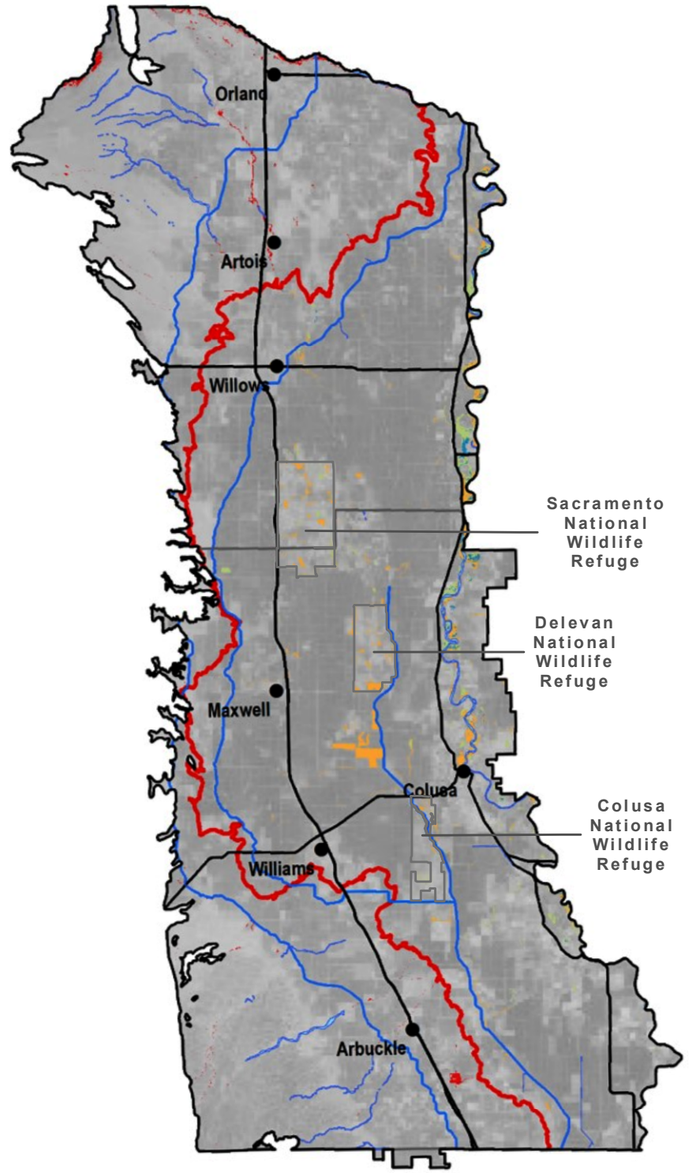
Within 150 ft of Surface Waters



Within 150 ft of Rice and 50 ft of Other Irrigated Croplands



GDE Liklihood Scores



WEST YOST - N:\Clients\277 Davids Engr\60-20-11 Colusa GSP Prep\GIS\MXD\GSP Report Maps\Fig0336_GDEs.mxd - areimer - 9/1/2021

Source: Wetland and vegetation areas are from the Natural Communities Naturally Associated with Groundwater (NCCAG) datasets and associated reports prepared by The Nature Conservancy (2018).

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Note:
1. GDE liklihood scores were obtained via comparison of NCCAG ares with proximity to surface waters and irrigated croplands.

- Colusa Subbasin
- Spring Depth to Water 30 ft Contour
- Proximity to Surface Waters (Within 150 ft)
- Proximity to Irrigated Rice Croplands (Within 150 ft)
- Proximity to Other Irrigated Croplands (Within 50 ft)
- NCCAG Vegetation and Wetlands

GDE Liklihood Score

- 4 (High Liklihood)
- 3
- 2
- 1 (Low Liklihood)

N

0 4 8

Scale in Miles

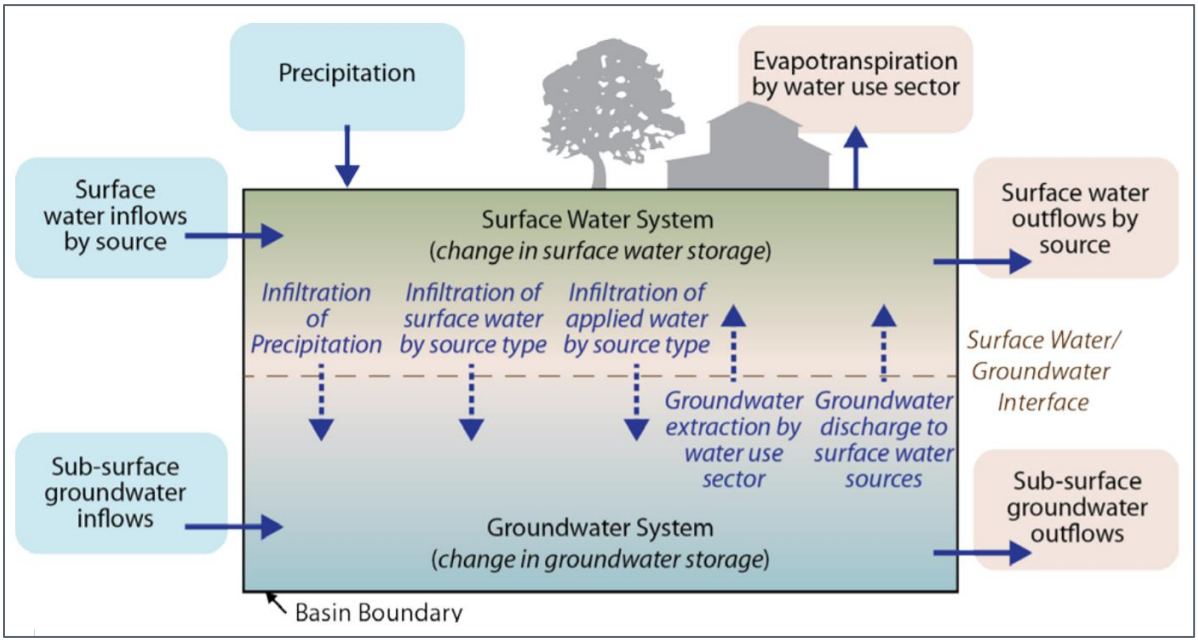
Figure 3-36

Groundwater Dependent Ecosystems

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

3.3 WATER BUDGET INFORMATION

This section describes historical, current, and projected water budgets developed for the Subbasin in accordance with §354.18 of the GSP Emergency Regulations. According to §354.18, the water budgets were prepared using the best available information and best available science to quantify and provide an understanding of historical and projected hydrology, water demands, water supplies, land use, population, climate change, groundwater and surface water interaction, and subsurface groundwater flow. The water budgets support GSP development in a number of ways, including assessing the sustainable yield of the subbasin, development of sustainable management criteria, and evaluating the need for projects and management actions to ensure sustainable operation of the Subbasin. Components of the water budgets are depicted in Figure 3-37.



Notes: Boundary fluxes are shown as solid blue arrows, with inflows and outflows indicated by blue and red captions, respectively. Internal fluxes are indicated by dashed blue arrows. The two primary storage mechanisms are the surface water storage and groundwater storage systems.

Figure 3-37. Water Budget Components (DWR 2016)

Water budgets were developed considering hydrology, water demand, water supply, land use, population, climate change, surface water - groundwater interaction, and subsurface groundwater inflows and outflows to and from neighboring groundwater basins. Water budget results are reported on a water year basis spanning from October 1 of the prior year to September 30 of the current year. All water budget values are expressed in average annual volumes, with annual volumes presented in tabular form in Appendix 3E (for the entire Subbasin) and in Appendix 3F (for 32 subareas within the Subbasin).

3.3.1 Selection of Hydrologic Periods

The GSP Emergency Regulations require evaluation of water budgets over a minimum of 10 years for the historical water budget, using the most recent hydrology for the current water budget, and 50 years of hydrology for the projected water budget. Hydrologic periods were selected for each water budget category listed below based on consideration of the best available information and science to support water budget development and consideration of the ability of the selected periods to provide a representative range of wet and dry conditions:

- **Historical** – The 26-year period from water years[2] 1990 to 2015 was selected based on the level of confidence in historical input data and information to support water budget development considering land use, surface water availability, hydrology, and other factors.
- **Current Conditions** – Historical water budget information for 2015 represents the most recent hydrology developed for GSP analysis (i.e., precipitation, evapotranspiration, stream inflows). To provide a broader basis for understanding current water budget conditions, a water budget scenario combining most recently available land use (2013 and 2015, representing non-curtailment [Shasta Non-Critical] and curtailment [Shasta Critical] years[3], respectively) and urban demands (average of 2006-2015) over 50 years of historical hydrology was developed. The period selected was 1966 to 2015. An advantage of evaluating the current conditions water budget over a representative 50-year period is that the results provide a baseline for evaluation of the projected water budgets.
- **Future Conditions** – Consistent with the current conditions water budget, the hydrologic period selected as the basis for the projected water budgets was 1966 to 2015.

Selection of the 50-year hydrologic period for the current and projected water budget scenarios was based primarily on three considerations:

- C2VSimFG, the primary tool used to develop the water budgets, has hydrologic information from water years 1922 to 2015.
- The average Sacramento Valley Water Year Index[4] values for the 50-year period from 1966 to 2015 and the 104-year period from 1906 to 2019 (1906 is the first year for which the index is available) are both 8.1. This indicates that the selected 50-year period is similar on average to the entire period of record for the Sacramento Valley watershed. (Figure 3-38). This is important because the major source of surface water in the Subbasin is the Sacramento River.

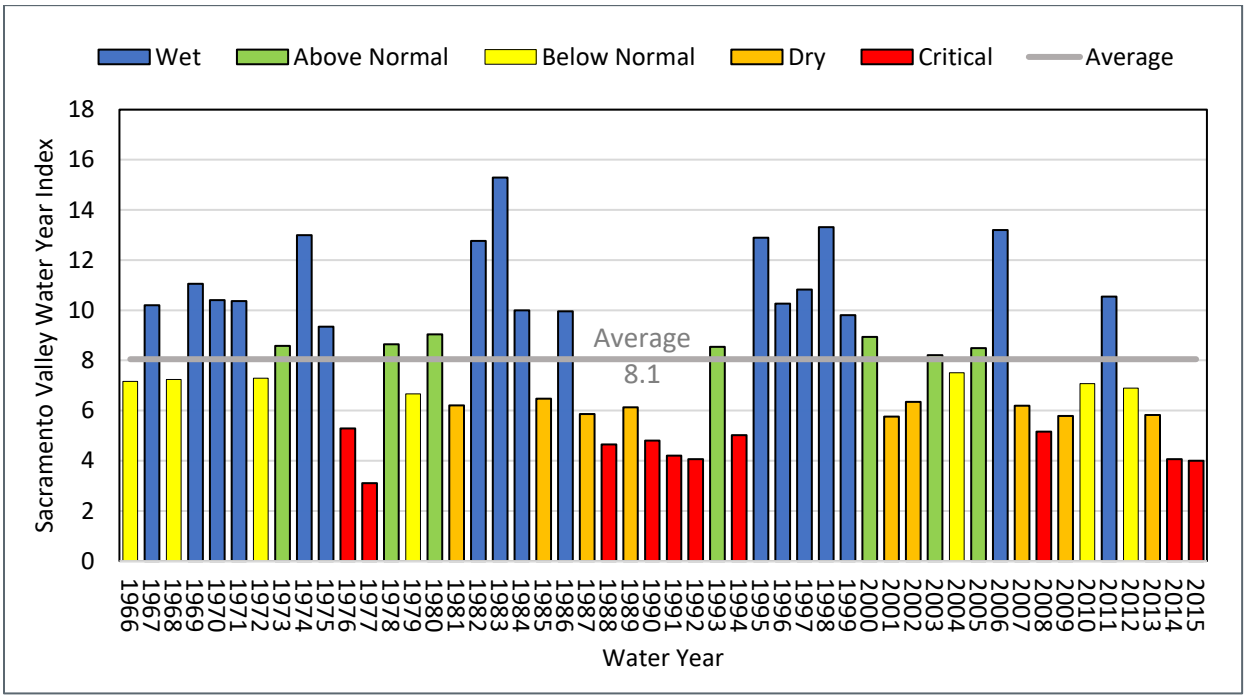
[2] A water year is defined as the period from October 1 of the prior year to September 30 of the current year. For example, water year 2000 refers to the period from October 1, 1999, to September 30, 2000.

[3] In general, Shasta Critical conditions are declared when the forecast inflow to Lake Shasta for a particular water year is equal to or less than 3.2 million acre-feet. In Shasta Critical years, the Sacramento River Settlement Contractors in the Colusa Subbasin (and elsewhere in the Sacramento Valley) are subject to 25% water supply reductions, significantly reducing surface water supplies available to the subbasin in those years. In turn, the reduction of surface water supplies results in a reduction of cropped farmland.

[4] The Sacramento Valley Water Year Index classifies water years as wet, above normal, below normal, dry, or critical based on Sacramento River unimpaired flows. Additional details describing the Sacramento Valley Water Year Index are available from the California Data Exchange Center .

- The selected period includes a combination of wet and dry cycles, including relatively wet periods in the early 1970's, mid 1980's, and late 1990's and dry periods in the late 1970's, early 1990's, and from approximately 2007 to 2015.

Additionally, annual precipitation for the 1966 to 2015 period averaged approximately 19.4 inches per year, as compared to 18.0 inches for the 1906 to 2018 period indicating slightly wetter conditions than the entire period of record for the Sacramento Valley Index.



Notes: The average index is 8.1, which is the same as the average for the entire period of record from 1906 through 2019.

Figure 3-38. Sacramento Valley Water Year Index and Water Year Types for a 50-year Period from 1966 to 2015

3.3.2 Use of the C2VSimFG Integrated Hydrologic Model

Development of the Integrated Water Flow Model (IWFM) began under the direction and funding of the DWR in 2001. The fine-grid application of IWFM, the California Central Valley Groundwater-Surface Water Simulation Model (C2VSimFG), became publicly available in 2012. The model has been updated over time to simulate historical conditions through water year 2015. The model performs calculations on a monthly time step with monthly input data (i.e., precipitation, stream inflow, surface water diversions) and some annual input data (i.e., land use). Refinements to the model over time include additional crop types to better represent ponded crops (i.e., rice and wetlands), recalibrated soil parameters, and elemental land use. Development and calibration of the C2VSimFG-Colusa[5] model used for water budget analyses in the Subbasin are described in more detail in Appendix 3D.

[5] Version BETA2 of C2VSimFG was used for C2VSimFG-Colusa.

To prepare water budgets for this GSP, historical C2VSimFG-Colusa results for water years 1990 to 2015 have been relied upon, and four additional baseline scenarios have been developed to represent current and projected (future) conditions utilizing 50 years of hydrology (described previously). Specific assumptions associated with these scenarios are described in the following section.

3.3.3 Water Budget Assumptions

Assumptions utilized to develop the historical, current, and projected water budgets are described below and summarized in Table 3-9. Assumptions are listed for the analysis period, hydrology (including stream inflows and precipitation), land use, and water supplies (including surface water diversions and water demands).

In the historical simulation, surface water supplies implicitly reflect historical surface water transfers and any effects of transfers on groundwater pumping. In the current conditions and future conditions scenarios, possible future water transfers (unrelated to GSP projects) were considered but not simulated, as they were considered to be highly speculative. GSP implementation will follow the principle of adaptive management, with continued monitoring and refinement of the basin setting, and with implementation of projects and/or management actions in response to changes in Subbasin conditions that may occur depending on future water transfers and other factors potentially affecting surface water supplies and groundwater pumping.

Table 3-9. Summary of Water Budget Assumptions Used for Historical, Current Conditions, Future Conditions, and Future Conditions with Climate Change at Two Times in the Future (i.e., 2030 and 2070)

Water Budget	Analysis Period	Hydrology	Land Use	Water Supplies
Historical Simulation	1990-2015	Historical	Historical	Historical
Current Conditions Baseline	2016-2065	Historical (1966-2015)	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively, for water diversions; 2006-2015 average for urban demands
Future Conditions, No Climate Change Baseline	2016-2065	Historical (1966-2015)	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively, for water diversions; 2006-2015 average for urban demands
Future Conditions, 2030 Climate Change Baseline	2016-2065	Historical (1966-2015), adjusted based on 2030 climate change with central tendency	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Same as Current (see above), adjusted for 2030 climate change

Table 3-9. Summary of Water Budget Assumptions Used for Historical, Current Conditions, Future Conditions, and Future Conditions with Climate Change at Two Times in the Future (i.e., 2030 and 2070)

Water Budget	Analysis Period	Hydrology	Land Use	Water Supplies
Future Conditions, 2070 Climate Change Baseline	2016-2065	Historical (1966-2015), adjusted based on 2070 climate change with central tendency	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Same as Current (see above), adjusted for 2070 climate change

3.3.3.1 Historical

A historical water budget was developed to support understanding of past aquifer conditions, considering surface water and groundwater supplies utilized to meet demands. The historical water budget was developed using C2VSimFG-Colusa and incorporates the best available science and information. Historical water supplies and aquifer response have been characterized by water year type based on DWR's Sacramento Valley Water Year Index.

As described previously, water years 1990 to 2015 were selected to provide a minimum of ten years across a range of hydrologic conditions. This period includes relatively wet years in 1995, 1998, 2006, and 2011 as well as dry conditions between 1990 and 1992, in 1994, between 2007 and 2009, and between 2013 and 2015.

Development of the historical water budget is described in greater detail in Appendix 3E. Model inputs and historical water budget results were summarized for 32 distinct subareas within the Subbasin. These subareas, described in Appendix 3F, approximately represent regions of the subbasin that share a common water supplier (e.g., an irrigation or water district service area), a common governing agency (e.g., a county or city), and a common primary water supply source (e.g., areas with access to surface water or areas with access to only groundwater, i.e., "groundwater" areas). Subareas were delineated within the C2VSimFG-Colusa model to support development of model inputs and to support quality control and calibration of model outputs. Specific data and information used to create model inputs are summarized in Appendix 3D.

Information utilized to develop the historical water budget includes:

- **Analysis Period** – Water years 1990 to 2015
- **Stream Flows** – Data from C2VSimFG-Colusa were used as best-estimates for inflows and outflows from rivers, streams, and other waterways traversing the Subbasin or along the boundary. The Sacramento River is the major surface water inflow to the subbasin. Stony Creek also provides inflow to the region along the northern boundary. Flows were estimated using C2VSimFG-Colusa which simulates the Sacramento River, Stony Creek, and Colusa Drain in the Subbasin.

- **Land Use** – Land use characteristics for agricultural, native, and urban (including rural residential) lands were estimated annually based on a combination of DWR land use surveys and county agricultural commissioner cropping reports. DWR land use data were available for 1993, 1998, 2003, 2009, and 2014. Urban land use areas were also verified against urban spheres of influence identified from city and county planning documents.
- **Agricultural Water Demand** – Agricultural irrigation demands were estimated using C2VSimFG-Colusa, which simulates crop growth and water use on a monthly basis, considering crop type, evapotranspiration, root depth, soil characteristics, and irrigation practices. For ponded land uses (rice and managed wetlands), pond depths and pond drainage are also considered to simulate demands.
- **Urban and Industrial Water Demand** – Urban and industrial demands and per capita water use over time were estimated based on a combination of pumping data provided by the State Water Resource Control Board (Small Supplier Conservation Reports) and Urban Water Management Plans (UWMPs). Estimates of population were based on data from the Department of Finance and from UWMPs.
- **Surface Water Diversions** – Surface water diversions were estimated based on a combination of reported diversions by water suppliers and Bureau of Reclamation records. In some cases, agricultural water demand was estimated for areas known to receive surface water but for which reported diversion data were not available. Deliveries of surface water supplies were configured to simulate actual surface water deliveries, to the extent possible with available data, and thus implicitly reflect historical surface water transfers and any effects of transfers on groundwater pumping.
- **Groundwater Pumping** – For urban water suppliers, historical pumping was estimated from reported pumping volumes over time. Pumping for large irrigation districts was developed from reported data and private pumping for landowners was calculated automatically within the model by first estimating the total demand and then subtracting surface water deliveries to calculate estimated groundwater pumping required to meet the remaining demand.

3.3.3.2 Current Conditions

The current conditions water budget was developed as a baseline to evaluate projected water budgets considering future conditions and is based on 50 years of hydrology along with the most recent information describing land use, urban demands, and surface water supplies. The 50-year hydrologic period was selected rather than the most recent year for which historical water budget information is available to allow for direct comparison of potential future conditions to current conditions. The use of a representative hydrologic period containing wet and dry cycles supports the understanding of variability and uncertainty in groundwater conditions over time, establishment of sustainable management criteria, and development of projects and management actions to avoid undesirable results.

The current water budget estimates current inflows, outflows, and change in storage for the subbasin using 50 years of representative hydrology and the most recent water supply, water demand, and land use information.

Information utilized to develop the current conditions baseline water budget include:

- **Analysis Period** – The 2016-2065 analysis period was simulated based on 50 years of historical hydrology representing the period from 1966 to 2015. Table 3-10 identifies the projected water years and corresponding historical water years and water year types that

were assigned for mapping historical hydrologic data to the current conditions scenario. Hydrologic model inputs for years 2016-2065 were based on these historical water year assignments to achieve a future hydrologic period of that is representative and consistent with historical hydrology over the 1965-2015 period.

- **Stream Inflows** – Inflows of surface water into the subbasin were estimated utilizing the same information as for the historical water budget.
- **Land Use** – Land use for agricultural, native, and urban (including rural residential) lands was estimated annually using the most recent land use information. Specifically, 2013 and 2015 land use were mapped to the 50-year analysis period, with 2015 land use applied to critically dry years corresponding to Shasta Critical years and 2013 land use applied to all other years. Shasta Critical years were identified based on annual inflow to Shasta Lake. Annual inflow to Shasta Lake is a reasonable indicator of surface water supplies and associated changes in diversion curtailments within the subbasin, which are primarily from the Sacramento River.
- **Agricultural Water Demand** – Agricultural irrigation demands were estimated using C2VSimFG-Colusa, in the same manner as the historical water budget. The same general assumptions used for simulating all crops (including rice and managed wetlands) in the historical water budget were also used in the current conditions baseline water budget.
- **Urban and Industrial Water Demand** – Urban and industrial demands were estimated based on recent per capita water use and projected 2050 population. Specifically, average per capita water use for recent years (2006 to 2015) was reduced based on projected 2050 values in the Willows UWMP.
- **Surface Water Diversions** – For the current conditions scenario, historical diversions were applied to the future, with 2015 diversions used in Shasta Critical years and 2013 diversion used in Shasta Non-Critical years. Shasta Critical Conditions were simulated for the following five years throughout the 50-year simulation period: 2026, 2027, 2041, 2064, and 2065. Simulated diversions in the Subbasin in those Shasta Critical years were on average approximately 30 percent less than the simulated diversions in Shasta Non-Critical years.
- **Groundwater Pumping** – Pumping to meet urban demands was estimated based on an average of recent years, as described above. Pumping to meet agricultural and managed wetlands demands was estimated using C2VSimFG-Colusa as described previously for the historical water budget.

Table 3-10. Summary of Projected Water Years and Assigned Historical Water Year

Projected Water Year	Assigned Historical Water Year	Sacramento Valley Water Year Type	Projected Water Year	Assigned Historical Water Year	Sacramento Valley Water Year Type
2016	1966	BN	2041	1991	C
2017	1967	W	2042	1992	C
2018	1968	BN	2043	1993	AN
2019	1969	W	2044	1994	C
2020	1970	W	2045	1995	W
2021	1971	W	2046	1996	W
2022	1972	BN	2047	1997	W
2023	1973	AN	2048	1998	W
2024	1974	W	2049	1999	W
2025	1975	W	2050	2000	AN
2026	1976	C	2051	2001	D
2027	1977	C	2052	2002	D
2028	1978	AN	2053	2003	AN
2029	1979	BN	2054	2004	BN
2030	1980	AN	2055	2005	AN
2031	1981	D	2056	2006	W
2032	1982	W	2057	2007	D
2033	1983	W	2058	2008	C
2034	1984	W	2059	2009	D
2035	1985	D	2060	2010	BN
2036	1986	W	2061	2011	W
2037	1987	D	2062	2012	BN
2038	1988	C	2063	2013	D
2039	1989	D	2064	2014	C
2040	1990	C	2065	2015	C

Note: Sacramento Valley Water Year Type is based on the Sacramento Valley Water Year Index and is classified into five types: Wet (W), Above Normal (AN), Below Normal (BN), Dry (D), and Critical (C).

3.3.3.3 Future Conditions Scenarios

Three projected (future conditions) baseline water budgets were developed considering a range of future conditions that may occur. The scenarios consider future planned land use changes (i.e., development), along with changes in climate, including precipitation, surface water inflows, and evapotranspiration. These baselines provide information regarding changes in subbasin conditions (e.g., groundwater storage) that may occur in the future over a series of wet and dry cycles.

The projected water budget estimates potential future inflows, outflows, and change in storage for the subbasin using 50 years of representative hydrology (including modifications based on climate change projections), the most recent water supply and water demand, and planned future land use information.

Information utilized to develop the future conditions baseline water budgets include:

- **Analysis Period** – The 2016-2065 analysis period was simulated based on 50 years of historical hydrology representing the period from 1966 to 2015. Table 3-10 identifies the projected water years and corresponding historical water years and water year types that were assigned for mapping historical hydrologic data to the future conditions scenarios. Hydrologic model inputs for years 2016-2065 were based on these historical water year assignments to achieve a future hydrologic period of that is representative and consistent with historical hydrology over the 1965-2015 period.
- **Stream Inflows**
  - Future Conditions, No Climate Change – Inflows of surface water into the subbasin were estimated utilizing the same information as for the historical water budget.
  - Future Conditions, 2030 Climate Change – Precipitation, evapotranspiration, and surface water supplies were adjusted to reflect climate change based on the 2030 Central Tendency climate change datasets provided by DWR to support GSP development.
    - For precipitation and evapotranspiration, monthly change factors were applied to historical values to estimate potential future conditions.
    - For stream flows, DWR estimates of stream inflows were utilized where available; for streams without direct estimates of inflows, inflows were estimated using streamflow change factors applied at the watershed scale.
  - Future Conditions, 2070 Climate Change – Precipitation, evapotranspiration, and surface water supplies were adjusted to reflect climate change based on the 2070 Central Tendency climate change datasets provided by DWR to support GSP development.
    - For precipitation and evapotranspiration, monthly change factors were applied to historical values to estimate potential future conditions.
    - For stream flows, DWR estimates of stream inflows were utilized where available; for streams without direct estimates of inflows, inflows were estimated using streamflow change factors applied at the watershed scale.
- **Land Use** – Land use for agricultural, native, and urban (including rural residential) lands was estimated annually using the most recent land use information and modified based on planned development according to County General Plan documents.
  - Future Conditions, No Climate Change – Land use was assumed to be similar to the current conditions water budget scenario.
  - Future Conditions, 2030 Climate Change – 2013 and 2015 land use data were mapped to the 50-year analysis period considering 2030 central tendency climate change projections. 2015 land use was applied to extreme dry years and 2013 land use applied to all other years. 2013 and 2015 land use data were modified to reflect planned development, generally resulting in an increase in urban land through development of previously undeveloped (i.e., native) lands.
- **Future Conditions, 2070 Climate Change** – 2013 and 2015 land use data were mapped to the 50-year analysis period considering 2070 central tendency climate change projections. 2015 land use was applied to Shasta Critical years and 2013 land use applied to all other (Shasta Non-Critical) years. 2013 and 2015 land use data were modified to reflect planned development, generally resulting in an increase in urban land through development of previously undeveloped (i.e., native) lands.

- **Agricultural Water Demand** – Agricultural irrigation demands were estimated using C2VSimFG-Colusa and modified from the current conditions scenario as described below.
  - Future Conditions, No Climate Change – Agricultural water demand was assumed to be similar to the current conditions water budget scenario.
  - Future Conditions, 2030 Climate Change – Agricultural water demand was increased from current conditions based on 2030 central tendency climate change projections.
  - Future Conditions, 2070 Climate Change – Agricultural water demand was increased from current conditions based on 2070 central tendency climate change projections.
  - Besides these modifications, the same general assumptions used for simulating all crops (including rice and managed wetlands) in the historical water budget were also used in the future conditions water budgets.
- **Urban and Industrial Water Demand** – Urban and industrial demands were estimated based on projected urban demands. Specifically, future urban demands were estimated based on preliminary draft demands for 2050 provided as part of the 2020 Urban Water Management Plan (UWMP) for Willows. Estimates for other urban demand areas were based on population growth rates and per capita water use similar to Willows.
- **Surface Water Diversions** – Climate change estimates are based on current diversions with reduced diversions in some years to simulate drought periods. For both the 2030 and 2070 central tendency scenarios, reductions occurred in eight years within the 50-year simulation period: 2016, 2026, 2027, 2028, 2041, 2042, 2064, 2065. Diversions were on average about 25 percent less than full supply years.
- **Groundwater Pumping** – Pumping to meet urban demand was estimated based on draft projections from UWMPs currently under development, as described above. Pumping to meet agricultural and managed wetlands demand was estimated using C2VSimFG-Colusa as described previously for the historical water budget.

3.3.4 Water Budget Estimates

As described previously, water budget estimates were developed using the C2VSimFG-Colusa model. Primary components of the land and surface water system water budget include the following:

- **Inflows**
  - Surface Water Inflows – Inflows at the land surface through rivers, streams, canals, or other waterways, including Sacramento River diversions, Stony Creek diversions, Sacramento River inflows, and inflows from boundary streams. These inflows may also include overland flow from upslope areas outside of the Subbasin. Note that although interactions with streams along the boundary of the subbasin (i.e., diversions and stream-aquifer interaction) are accounted for, the flow in the stream is not considered an inflow to the Subbasin. Inflows from streams that traverse the Subbasin, primarily the Sacramento River near the eastern edge of the subbasin where the river is within the subbasin, are accounted for explicitly. All surface water that enters the Subbasin that does not flow out of the Subbasin or evaporate may be used or available for use for groundwater recharge or in-lieu use, whether through seepage or deep percolation to the groundwater system, or irrigation or other consumptive use that offsets groundwater demand.

- Precipitation – Rainfall on the land surface within the Subbasin boundary.
- Groundwater pumping – Extraction of groundwater to meet agricultural, urban and industrial, managed wetlands, or other beneficial uses.
- Stream Gains from Groundwater (Accretions) – Gains in streamflow from shallow groundwater occurring when the water level in the aquifer adjacent to the stream is greater than the water level in the stream.

- **Outflows**
  - Evapotranspiration – Consumptive use of water including both evaporation and transpiration components occurring on agricultural, urban, industrial, managed wetland, native vegetation lands, and evaporation from canals and other water surfaces. Native vegetation includes riparian corridors along streams and rivers.
  - Deep Percolation – Recharge of the groundwater system through the vertical movement of precipitation and applied irrigation water (surface water and groundwater) below the root zone.
  - Seepage (also referred to as losses or leakage) – Recharge of the groundwater system from streams, canals, drains or other water bodies.
  - Surface Water Outflows – Outflows at the land surface through rivers, streams, canals, or other waterways, including runoff or precipitation, runoff of surface water and groundwater applied for irrigation, and outflows from the Sacramento River, Colusa Drain, the Colusa Weir (to the Sutter Bypass) and other boundary streams. These outflows may also include overland flow to downslope areas outside of the subbasin.
- **Change in Storage** – Changes in soil moisture storage within the upper several feet of soil in the root zone, as well as changes in storage in surface water bodies within the subbasin, calculated as Total Inflow minus Total Outflow. These changes vary over the course of a year based on precipitation and irrigation patterns and other factors, but are generally negligible on an annual basis.

Primary components of the groundwater system water budget include the following:

- **Inflows**
  - Subsurface Water Inflows – Groundwater inflows from adjacent subbasins or from the Coast Range foothills on the west side of the subbasin.
  - Deep Percolation (from the overlying land surface and surface water system) – Described above.
  - Seepage (from streams, canals, and drains) – Described above.
- **Outflows**
  - Groundwater Pumping – Described above.
  - Subsurface Outflows – Groundwater outflows to adjacent basins.
  - Accretions – Described above.
- **Change in Storage** – Changes in water storage in the aquifer system, calculated as Total Inflow minus Total Outflow. These changes tend to be large compared to changes in root zone soil moisture storage and can vary substantially from year to year.

Many components of the water budget can be estimated based on measured data (e.g., precipitation, diversions, evapotranspiration, etc.) and are used to develop inputs to C2VSimFG-Colusa to support water budget development. Other components are more difficult to measure or do not have measured values readily available (e.g., deep percolation, subsurface flows, groundwater pumping, surface water-groundwater interaction, etc.) and are estimated using C2VSimFG-Colusa. Additional detail describing the C2VSimFG is available in DWR Technical Memorandum entitled Integrated Water Flow Model: IWFM-2015 Theoretical Documentation[6].

Average annual water budget estimates for the historical water budgets and for the current and projected water budget scenarios are summarized in Table 3-11 for the land and surface water system and in Table 3-12 for the groundwater system. Additional information and discussion regarding the water budgets is provided in the following subsections. It is anticipated that the water budgets will be refined and updated over time as part of GSP implementation in the subbasin.

Table 3-11. Average Annual Land and Surface Water System Inflows, Outflows, and Changes in Storage in taf/yr for the Water Budget Analysis Periods Listed in Table 3-9

Component	Historical Simulation	Current Conditions Baseline	Future Conditions, No Climate Change Baseline	Future Conditions, 2030 Climate Change Baseline[(a)]	Future Conditions, 2070 Climate Change Baseline[(a)]
Inflows					
Surface Water Inflows	11,747	12,556	12,556	12,597	12,715
Sacramento River Diversions[(b)]	1,076	1,192	1,196	1,196	1,196
Stony Creek Diversions[(b)]	92	95	91	91	91
Sacramento River Inflows[(c)]	10,500	11,188	11,188	11,228	11,335
Other Inflows from Boundary Streams	78	81	81	81	92
Precipitation	1,210	1,183	1,183	1,198	1,258
Groundwater Pumping	502	499	499	525	559
Agricultural	463	458	458	484	516
Urban and Industrial	11	11	10	10	10
Managed Wetlands	28	30	30	31	32
Stream Gains from Groundwater (Stream Accretions)	366	349	349	337	323
Total Inflow	**13,824**	**14,587**	**14,586**	**14,658**	**14,853**

[6] https://data.cnra.ca.gov/dataset/5c4b82c9-d219-4d71-a6cc-7ea6ccbaa54b/resource/a94dda67-4d90-418d-8c10-f403626b0f8d/download/iwfm-2015.0.1129_theoreticaldocumentation.pdf

Table 3-11. Average Annual Land and Surface Water System Inflows, Outflows, and Changes in Storage in taf/yr for the Water Budget Analysis Periods Listed in Table 3-9

Component	Historical Simulation	Current Conditions Baseline	Future Conditions, No Climate Change Baseline	Future Conditions, 2030 Climate Change Baseline[(a)]	Future Conditions, 2070 Climate Change Baseline[(a)]
Outflows					
Evapotranspiration	1,740	1,790	1,790	1,841	1,901
Agricultural	1,430	1,494	1,494	1,542	1,596
Urban and Industrial	22	28	28	28	28
Managed Wetlands	69	69	69	70	73
Native Vegetation	180	163	163	165	167
Canal Evaporation	40	36	36	36	36
Deep Percolation	441	416	415	415	411
Precipitation	174	162	162	160	156
Applied Surface Water	196	162	162	161	158
Applied Groundwater	72	92	91	94	97
Seepage	345	379	379	387	401
Streams	206	231	231	239	253
Canals and Drains	139	148	148	148	148
Surface Water Outflows	11,302	12,002	12,003	12,015	12,141
Precipitation Runoff	55	51	51	52	60
Applied Surface Water Return Flows	96	93	93	92	90
Applied Groundwater Return Flows	22	19	18	19	20
Sacramento River	9,371	11,049	11,050	11,086	11,187
Colusa Drain	709	759	759	742	774
Colusa Weir to Sutter Bypass	994	0	0	0	0
Other Outflows to Boundary Streams	56	32	32	23	10
Total Outflow	**13,828**	**14,587**	**14,587**	**14,658**	**14,853**
Change in Storage (Inflow - Outflow)	**-3**	**0**	**0**	**0**	**0**

(a) Central Tendency Climate Change Projections
(b) Sacramento River Diversions and Stony Creek Diversions are diversions from boundary streams outside the subbasin. About 20 percent of the total diversions come from streams within the subbasin and are included in the Sacramento River Inflow.
(c) Sacramento River Inflows include flows along the Sacramento River and the Colusa Drain that enter the Subbasin.

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Table 3-12. Average Annual Groundwater System Inflows, Outflows, and Changes in Storage in taf/yr for the Water Budget Analysis Periods Listed in Table 3-9

Component	Historical Simulation	Current Conditions Baseline	Future Conditions, No Climate Change Baseline	Future Conditions, 2030 Climate Change Baseline[a]	Future Conditions, 2070 Climate Change Baseline[a]
Inflows[b]					
Subsurface Water Inflows	200	203	203	205	209
Deep Percolation	441	416	415	415	411
Precipitation	174	162	162	160	156
Applied Surface Water	196	162	162	161	158
Applied Groundwater	72	92	91	94	97
Seepage	345	379	379	387	401
Streams	206	231	231	239	253
Canals and Drains	139	148	148	148	148
Total Inflow	**986**	**997**	**997**	**1,008**	**1,021**
Outflows					
Subsurface Water Outflows	146	149	149	148	147
Groundwater Pumping	502	499	499	525	559
Agricultural	463	458	458	484	516
Urban and Industrial	11	11	10	10	10
Managed Wetlands	28	30	30	31	32
Stream Gains from Groundwater (Stream Accretions)	366	349	349	337	323
Total Outflow	**1,014**	**997**	**996**	**1,011**	**1,028**
Change in Storage (Inflow - Outflow)	**-28**	**1**	**1**	**-3**	**-7**

(a) Central Tendency Climate Change Projections
(b) Sacramento River Diversions and Stony Creek Diversions are diversions from boundary streams outside the Subbasin. About 20 percent of the total diversions come from streams within the Subbasin and are included in the Sacramento River Inflow.

3.3.4.1 Historical Simulation

The historical water budget provides a foundation for understanding how the subbasin has behaved, including insight into historical groundwater conditions (e.g., observed water levels). Also, in accordance with the GSP Emergency Regulations, the historical water budget covers a period of at least ten years (26-year period from 1990 to 2015). The historical water budget is used to evaluate the availability and reliability of historical surface water supplies and provides insight into the ability to operate the subbasin sustainably. Note that the historical analysis period experienced slightly more precipitation than the long-term average and included historic drought conditions from approximately 2007 to 2015.

Average annual inflows to and outflows from the Subbasin for the historical land and surface water system water budget were estimated to be 13,825 taf/yr (13.8 maf/yr). Average annual values were presented previously in Table 3-11 and are shown graphically in Figure 3-39.

Primary inflows to the land and surface water system include surface water inflows (11,747 taf/yr), precipitation (1,210 taf/yr), groundwater pumping (502 taf/yr), and stream gains from groundwater[7] (366 taf/yr). Surface water inflows include the Sacramento River, other inflows from boundary streams including Stony Creek, as well as overland runoff of precipitation and applied water from upslope lands. Additionally, diversions from the Sacramento River and from Stony Creek are major sources of surface water inflows.

Primary outflows from the land and surface water system include evapotranspiration (1,740 taf/yr), deep percolation (441 taf/yr), seepage (345 taf/yr), and surface water outflows (11,302 taf/yr). Evapotranspiration is primarily from agricultural lands but also from managed wetlands, canal evaporation, native vegetation, and urban and industrial lands. Deep percolation is primarily from precipitation, but also from applied water. Seepage includes a combination of stream seepage and seepage from canals and drains.

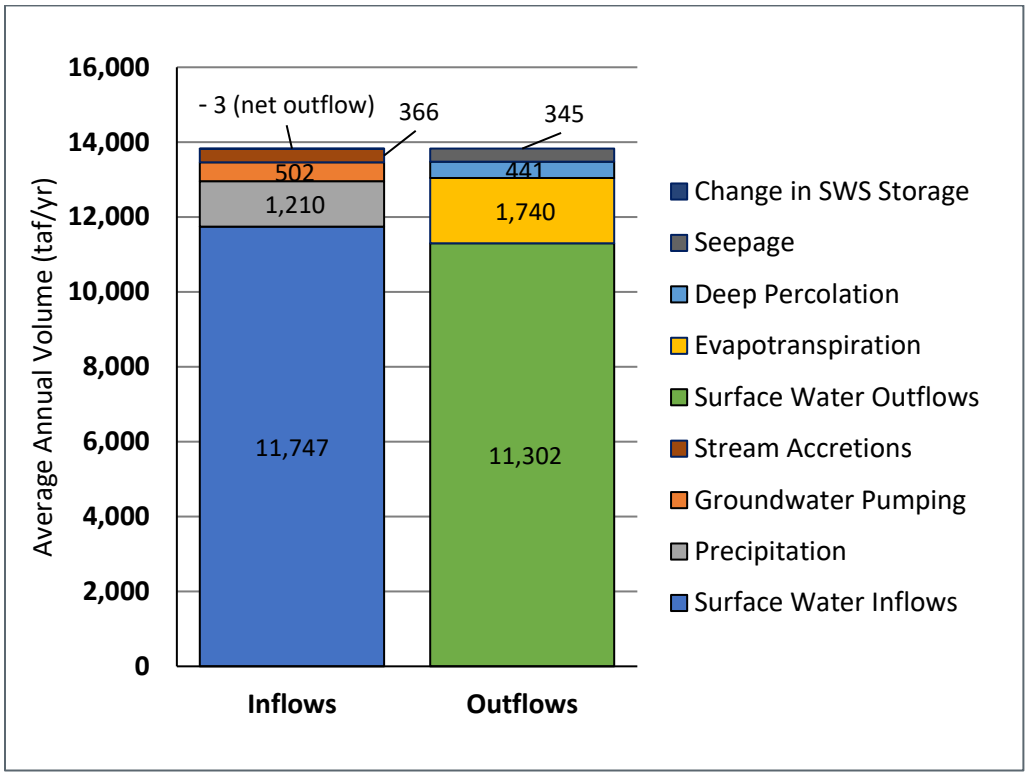


Figure 3-39. Average Annual Historical Land and Surface Water System Water Budget Summary (1990-2015, rounded to nearest taf/yr)

The average annual change in storage in the land and surface water system (3 taf/yr) is negligible due to similar soil moisture content in the root zone, on average, across water years.

Annual historical land and surface water system water budgets for 1990 to 2015 are provided in Table 3E-1 of Appendix 3E for the entire Subbasin.

[7] i.e., stream accretions

Average annual historical inflows to and outflows from the groundwater system were estimated to be 986 taf and 1,014 taf, respectively. Average annual values were presented previously in Table 3-12 are shown graphically in Figure 3-40 Inflows to the groundwater system include deep percolation (441 taf/yr), subsurface inflows from the Corning, Butte, Sutter, and Yolo Subbasins (200 taf/yr), seepage (345 taf/yr), and changes in groundwater storage (28 taf/yr). Outflows from the groundwater system include groundwater pumping (502 taf/yr), subsurface outflows to the Corning, Butte, Sutter, and Yolo Subbasins (146 taf/yr), and stream gains from groundwater (366 taf/yr).

Annual historical groundwater system water budgets for 1990 to 2015 are provided in Table 3E-2 of Appendix 3E for the entire Subbasin.

Historical water budget values are also presented in Appendix 3F for 32 distinct subareas defined within the Subbasin. Each subarea approximately represents a region of the Subbasin that shares a common water supplier (e.g., an irrigation or water district service area), a common governing agency (e.g., county or city), and a common primary water supply source (e.g., areas with access to surface water or areas with access to only groundwater, i.e., "groundwater" areas).

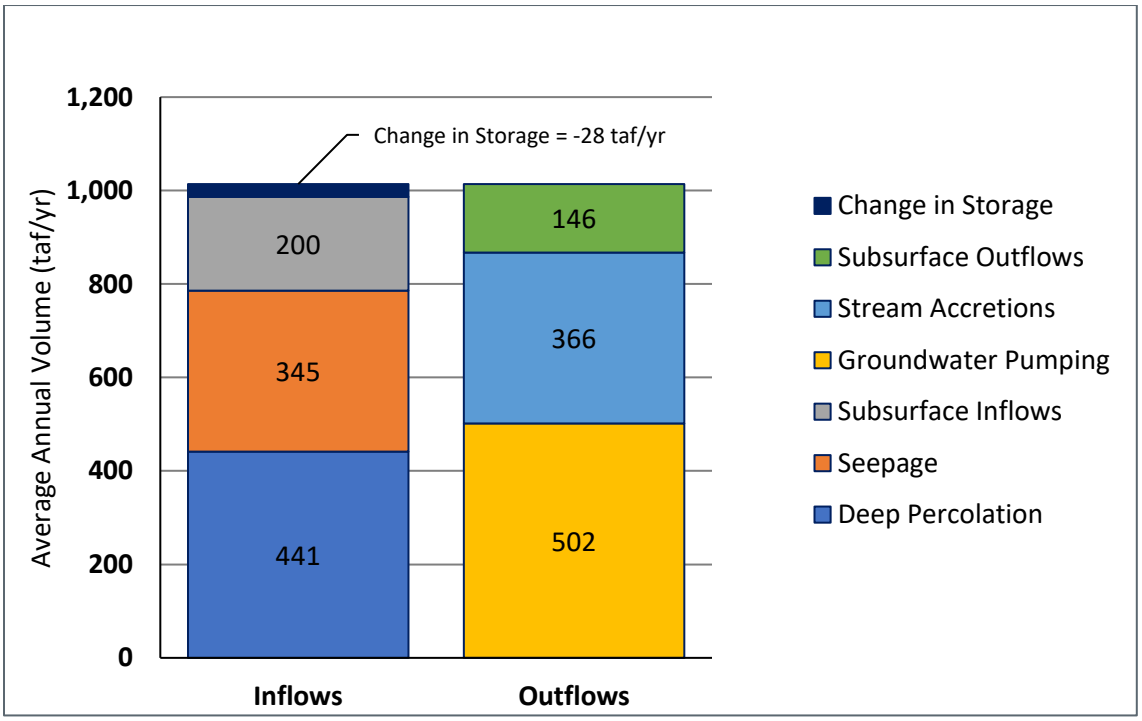


Figure 3-40. Average Annual Historical Groundwater System Water Budget Summary (1990-2015, rounded to nearest taf/yr)

Historical water supplies and change in groundwater storage are summarized by water year type in Table 3-13 based on the Sacramento Valley Water Year Index. Between 1990 and 2015, there were seven wet years, four above normal years, three below normal years, five dry years, and seven critical years. Historical surface water deliveries were greatest in dry years, when agricultural demands tend to be relatively high and surface water supplies tend to be available, and least in critical years, when surface water supplies tend to be constrained despite relatively high agricultural demands. Groundwater pumping was greatest in dry years and least in wet years. Historically, groundwater storage in the subbasin has tended to increase in wet and above normal years and to decrease in below normal, dry, and critical years,

with reductions in storage in below normal years less than reductions in dry and critical years. The average annual change in storage over the 1990-2015 historical period was -28 taf.

Table 3-13. Historical Water Supplies and Change in Groundwater Storage by Hydrologic Water Year Type, taf/yr (1990-2015)

Water Year Type	Surface Water Deliveries[(a)]	Groundwater Pumping	Total Supply	Change in Groundwater Storage
Wet	1,381	435	1,814	99
Above Normal	1,474	435	1,909	101
Below Normal	1,592	546	2,138	-24
Dry	1,598	570	2,168	-116
Critical	1,228	540	1,768	-166
Average	**1,420**	**502**	**1,922**	**-28**

(a) Surface Water Deliveries represents the volume of water delivered to agricultural and urban lands. It is an internal flow path and is different than Surface Water Inflow in the Subbasin boundary balance summarized in Table 3-11.

3.3.4.1.1 Availability or Reliability of Historical Surface Water Supplies

As indicated in Table 3-13, historical surface water supplies for delivery to agricultural land vary based on water year type. The primary sources of surface water in the subbasin are the Sacramento River and Stony Creek Diversions. Surface water supplies are relatively reliable in the Subbasin and represent approximately 70-percent of the total water supplies (Sacramento River and Stony Creek diversions plus Groundwater Pumping). This average percentage reflects all of the supply curtailments or shortages experienced by the surface water suppliers in the subbasin over the 1990-2015 historical period, including the 25 percent curtailments to Sacramento River settlement contractors in Shasta Critical years, less than 100 percent allocations to Tehama-Colusa Canal CVP contractors in certain years, and Stony Creek water shortages experienced by the Orland Unit Water Users Association. Under 2030 and 2070 climate change conditions there may be an increase in the availability of surface water for irrigation in the Subbasin due to increased precipitation from climate change effects. Potential effects of these changes are evaluated as part of the projected water budgets in the following sections.

Under diversion agreements between Sacramento River Settlement Contractors and the State, Sacramento River diversions can be reduced under the following conditions:

- DWR forecasted annual inflow into Lake Shasta is less than 3,200 taf[8], or
- There is a cumulative deficit of inflows below 4,000 taf of greater than 800 taf for any year or consecutive series of years.

Another source of uncertainty in the availability or reliability of historical surface water supplies is Phase 2 of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary Water Quality Control Plan (Bay-Delta Water Quality Control Plan). Standards within the Bay-Delta Water Quality Control Plan are being updated by the State Water Resources Control Board in two phases. Phase 2 of this effort will include a

[8] The final, official forecast must be made by April 10 of each year.

comprehensive update to the plan, creating new inflow requirements for the Sacramento River and its tributaries. While Phase 2 is not yet complete, the requirements proposed in this phase have the potential to constrain the volume and/or timing of surface water diversions by water users along the Sacramento River and its tributaries. GSP annual reports and periodic evaluations will address specific impacts of the Bay-Delta Water Quality Control Plan, when known.

3.3.4.1.2 Suitability of Tools and Methods for Planning

The water budgets presented herein have been developed using the best available information and best available science and structured in a manner consistent with the hydrogeologic conceptual model of the Subbasin. The IWFM application C2VSimFG-Colusa, which is used to organize information for the water budgets, develop water budget scenarios, and perform water budget calculations, is currently the best available tool and is suitable for GSP development for the subbasin. The IWFM has been developed over the past several decades and updated over time to use updated model code, updated datasets, and updated input parameters through a series of efforts by DWR. Refinements to C2VSimFG specific to the Subbasin are described Appendix 3D.

The water budgets developed using C2VSimFG-Colusa support the development of sustainable management criteria, evaluation of the monitoring network, and development of projects and management actions as part of GSP development. It is anticipated that the C2VSimFG-Colusa will continue to be updated and refined in the future as part of GSP implementation. Additional information describing C2VSimFG is available in DWR's Theoretical Documentation and User's Manual[9].

3.3.4.1.3 Ability to Operate the Subbasin within the Sustainable Yield

Sustainable yield refers to the maximum quantity of water, calculated over a base period representative of long-term conditions in the Subbasin, and including any temporary surplus that can be withdrawn annually from a groundwater supply without causing an undesirable result. As a result, determination of sustainable yield requires consideration of SGMA's six sustainability indicators. Historical water budget estimates indicate an average annual decrease in storage of 28 taf/yr for the period from water year 1990 to 2015. Operation of the subbasin within the sustainable yield will likely require implementation of projects and management actions over the 20-year SGMA planning and implementation horizon. Projects and management actions are discussed in Chapter 6. The estimated sustainable yield of the subbasin is described in greater detail in Section 3.3.7.

3.3.4.2 Current Conditions Baseline

The current conditions baseline water budget provides a foundation to understand the behavior of the subbasin considering current land use and urban demands over a broad range of hydrologic conditions as well as a basis for evaluating how groundwater conditions may change in the future based on comparison of water budget results to projected water budgets presented in the following section. A 50-year hydrologic period was selected, rather than a single, recent year to improve the basis for estimation of sustainable yield under current conditions (along with consideration of other sustainability parameters).

[9] https://data.cnra.ca.gov/dataset/c2vsimfg_beta2

Average annual inflows to and outflows from the subbasin for the current conditions land and surface water system baseline water budget were estimated to be 14,587 taf/yr. Average annual values were presented previously in Table 3-11 and are shown graphically in Figure 3-41.

Primary inflows to the land and surface water system include surface water inflows (12,556 taf/yr), precipitation (1,183 taf/yr), groundwater pumping (499 taf/yr), and stream gains from groundwater (349 taf/yr). Surface water inflows include the Sacramento River, other inflows from boundary streams including Stony Creek, as well as overland runoff of precipitation and applied water from upslope lands. Additionally, diversions from the Sacramento River and from Stony Creek are primary sources of surface water inflows.

Primary outflows from the land and surface water system include surface water outflows (12,002 taf/yr), evapotranspiration (1,790 taf/yr), deep percolation (416 taf/yr), and seepage (379 taf/yr). Surface water outflows include outflows through Sacramento River, Colusa Drain, Colusa Weir to Sutter Slough, and outflows to boundary streams including Stony Creek, as well as overland runoff of precipitation and applied water to downslope lands. Evapotranspiration is primarily from agricultural lands but also from managed wetlands, canal evaporation, native vegetation, and urban and industrial lands. Deep percolation is primarily from precipitation, but also from applied water. Seepage includes a combination of stream seepage and seepage from canals and drains.

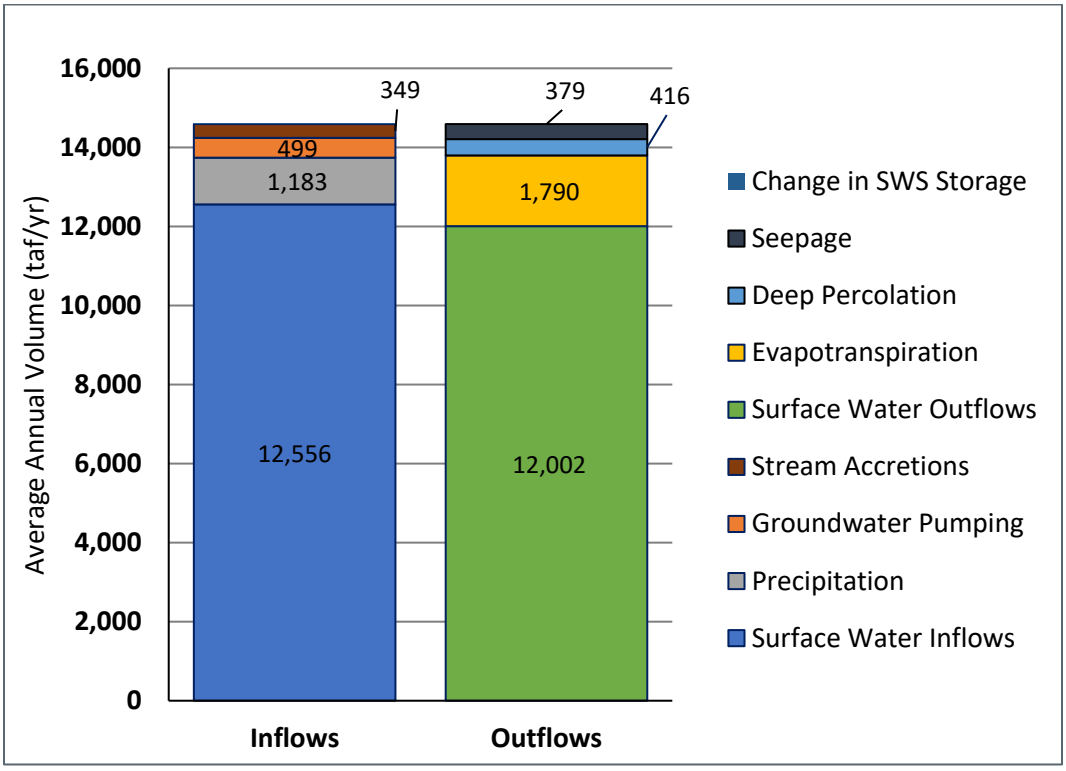


Figure 3-41. Average Annual Current Conditions Baseline Land and Surface Water System Water Budget Summary (2016-2065, rounded to nearest taf/yr)

The average annual change in storage in the land and surface water system (0.1 taf/yr) is negligible due to similar soil moisture content in the root zone, on average, across water years.

Average annual inflows to and outflows from the groundwater system were estimated to be 997 taf/yr during the current conditions baseline simulation period. Average annual values were presented previously in Table 3-12 and are shown graphically in Figure 3-42.

Inflows to the groundwater system include deep percolation (416 taf/yr), seepage (379 taf/yr), and subsurface inflows from the Corning, Butte, Sutter, and Yolo Subbasins (203 taf/yr). Outflows from the groundwater system include groundwater pumping (499 taf/yr), stream gains from groundwater (349 taf/yr), subsurface outflows to Corning, Butte, Sutter, and Yolo Subbasins (149 taf/yr), and change in groundwater storage (1 taf/yr).

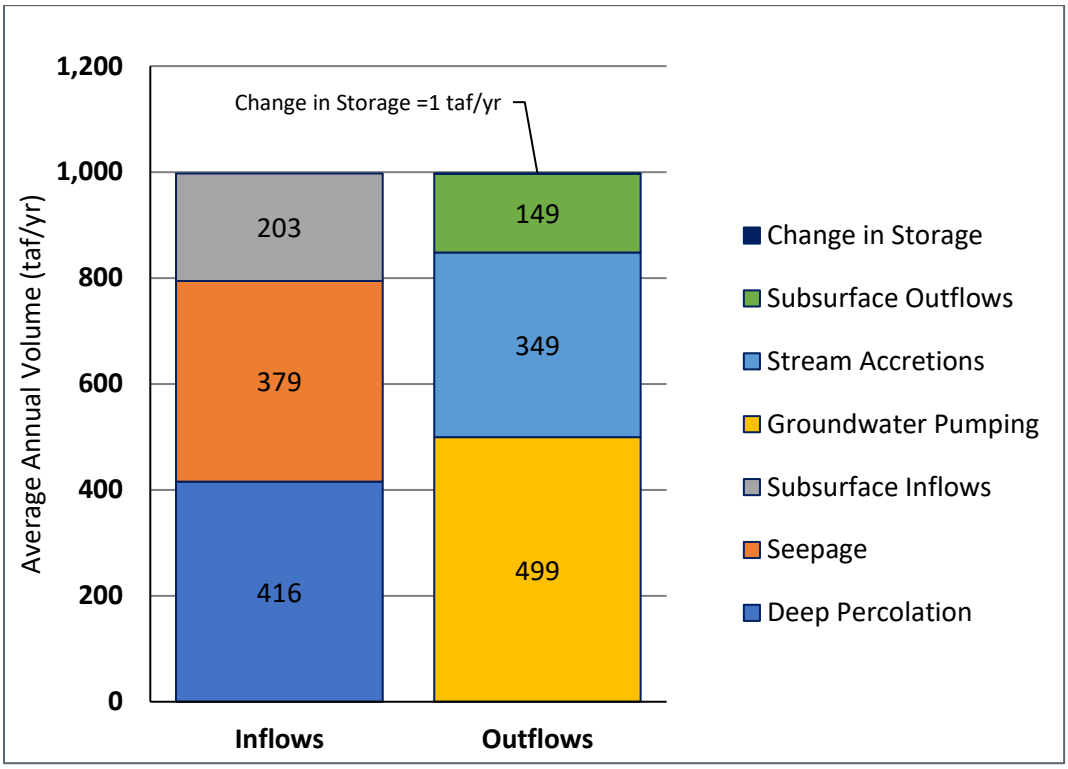


Figure 3-42. Average Annual Current Conditions Baseline Groundwater System Water Budget Summary (2016-2065, rounded to nearest taf/yr)

3.3.4.3 Future Conditions Scenarios

Three projected water budgets were developed for the subbasin to provide baseline scenarios representing potential future conditions considering planned development under the Colusa County 2030 General Plan and climate change centered around 2030 and 2070 based on central tendency climate change datasets provided by DWR. The projected water budget scenarios provide a foundation to understand the behavior of the subbasin considering potential future land use and urban demands over a broad range of hydrologic conditions, modified based on climate change projections. Use of a 50-year hydrologic period provides a basis for estimation of sustainable yield under potential future conditions.

3.3.4.3.1 Future Conditions, No Climate Change Baseline

Average annual inflows to and outflows from the subbasin for the future conditions without climate change projected land and surface water system baseline water budget were estimated to be 14,587 taf/yr. Average annual values were presented previously in Table 3-11 and are shown graphically in Figure 3-43.

Primary inflows to the land and surface water system include surface water inflows (12,556 taf/yr), precipitation (1,183 taf/yr), groundwater pumping (499 taf/yr), and stream gains from groundwater (349 taf/yr). Surface water inflows include the Sacramento River, other inflows from boundary streams including Stony Creek, as well as overland runoff of precipitation and applied water from upslope lands. Additionally, diversions from the Sacramento River and from Stony Creek are a primary source of surface water inflows. Surface water inflows include the Sacramento River, other inflows from boundary streams including Stony Creek, as well as overland runoff of precipitation and applied water from upslope lands. Additionally, diversions from the Sacramento River and from Stony Creek are a key source of surface water inflows.

Primary outflows from the land and surface water system include surface water outflows (12,003 taf/yr), evapotranspiration (1,790 taf/yr), deep percolation (415 taf/yr), and seepage (379 taf/yr). Surface water outflows include outflows through Sacramento River, Colusa Drain, Colusa Weir to Sutter Slough, and outflows to boundary streams including Stony Creek, as well as overland runoff of precipitation and applied water to downslope lands. Evapotranspiration is primarily from agricultural lands but also from managed wetlands, canal evaporation, native vegetation, and urban and industrial lands. Deep percolation is primarily from precipitation, but also from applied water. Seepage includes a combination of stream seepage and seepage from canals and drains.

The average annual change in storage in the land and surface water system (0.1 taf/yr) is negligible due to similar soil moisture content in the root zone, on average, across water years.

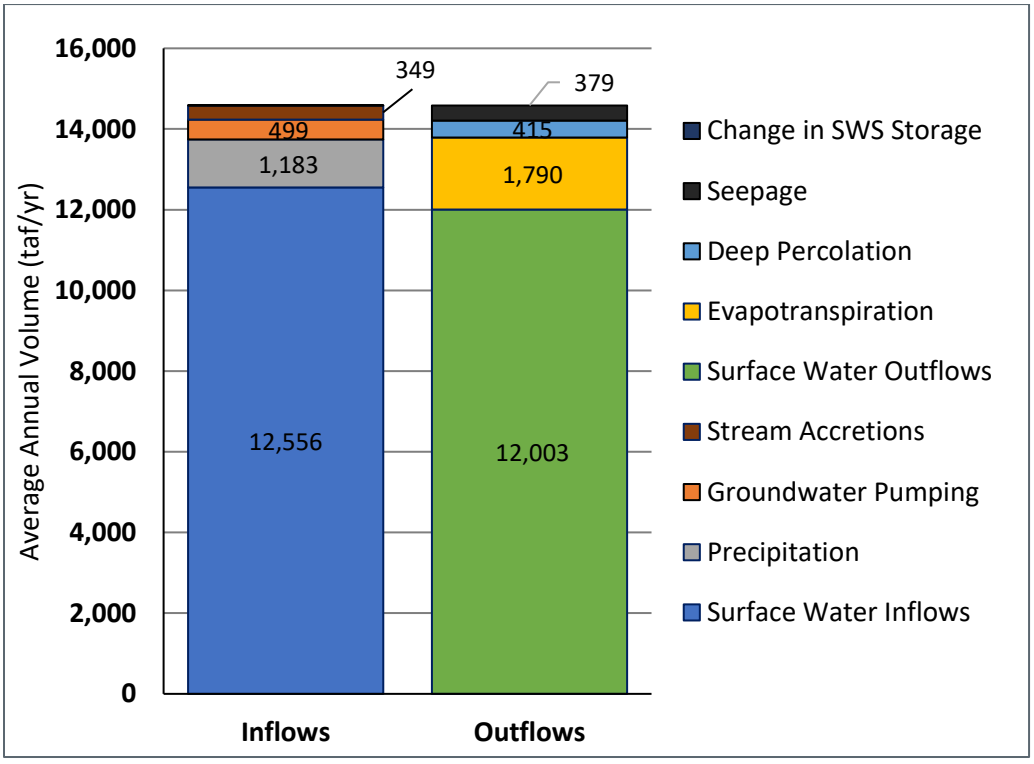


Figure 3-43. Average Annual Future Conditions, No Climate Change Baseline Land and Surface Water System Water Budget Summary (2016-2065, rounded to nearest taf/yr)

Average annual inflows to and outflows from the groundwater system were estimated to be 997 taf/yr for the future conditions without climate change simulation. Average annual values were presented previously in Table 3-12 are shown graphically in Figure 3-44**.**

Inflows to the groundwater system include deep percolation (415 taf/yr), seepage (379 taf/yr), and subsurface inflows from the Corning, Butte, Sutter, and Yolo Subbasins (203 taf/yr). Outflows from the groundwater system include groundwater pumping (499 taf/yr), stream gains from groundwater (349 taf/yr), and subsurface outflows to the Corning, Butte, Sutter, and Yolo Subbasins (149 taf/yr).

There is negligible change (+1 taf/yr) in groundwater storage under the future condition, no climate change baseline water budget.

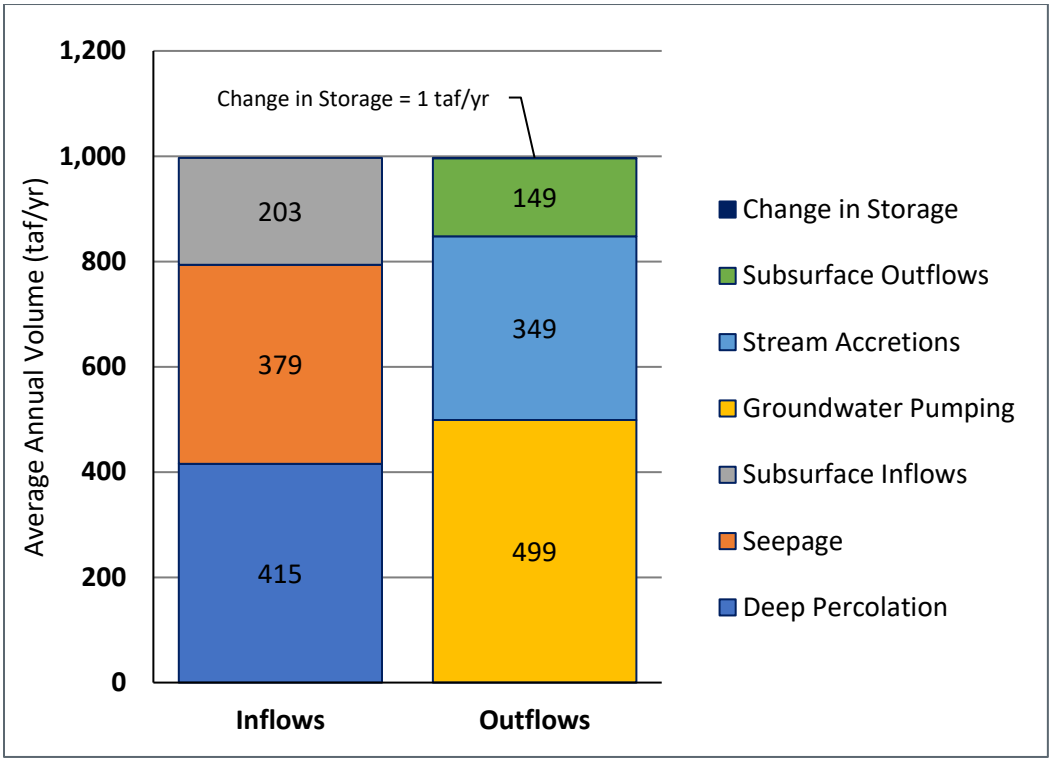


Figure 3-44. Average Annual Future Conditions, No Climate Change Baseline Groundwater System Water Budget Summary (2016-2065, rounded to nearest taf/yr)

3.3.4.3.2 Future Conditions, 2030 Climate Change Baseline

Average annual inflows to and outflows from the subbasin for the future conditions with 2030 climate change projected land and surface water system baseline water budget were estimated to be 14,657 taf/yr. Average annual values were presented previously in Table 3-11 and are shown graphically in Figure 3-45.

Primary inflows to the land and surface water system include surface water inflows (12,597 taf/yr), precipitation (1,198 taf/yr), groundwater pumping (525 taf/yr), and stream gains from groundwater (337 taf/yr). Surface water inflows include the Sacramento River, other inflows from boundary streams including Stony Creek, as well as overland runoff of precipitation and applied water from upslope lands.

Additionally, diversions from the Sacramento River and from Stony Creek are a key source of surface water inflows.

Primary outflows from the land and surface water system include surface water outflows (12,015 taf/yr), evapotranspiration (1,841 taf/yr), deep percolation (415 taf/yr), and seepage (387 taf/yr). Surface water outflows include outflows through Sacramento River, Colusa Drain, Colusa Weir to Sutter Slough, and outflows to boundary streams including Stony Creek, as well as overland runoff of precipitation and applied water to downslope lands. Evapotranspiration is primarily from agricultural lands but also from managed wetlands, canal evaporation, native vegetation, and urban and industrial lands. Deep percolation is primarily from precipitation, but also from applied water. Seepage includes a combination of stream seepage and seepage from canals and drains.

The average annual change in storage in the land and surface water system (0.1 taf/yr) is negligible due to similar soil moisture content in the root zone, on average, across water years.

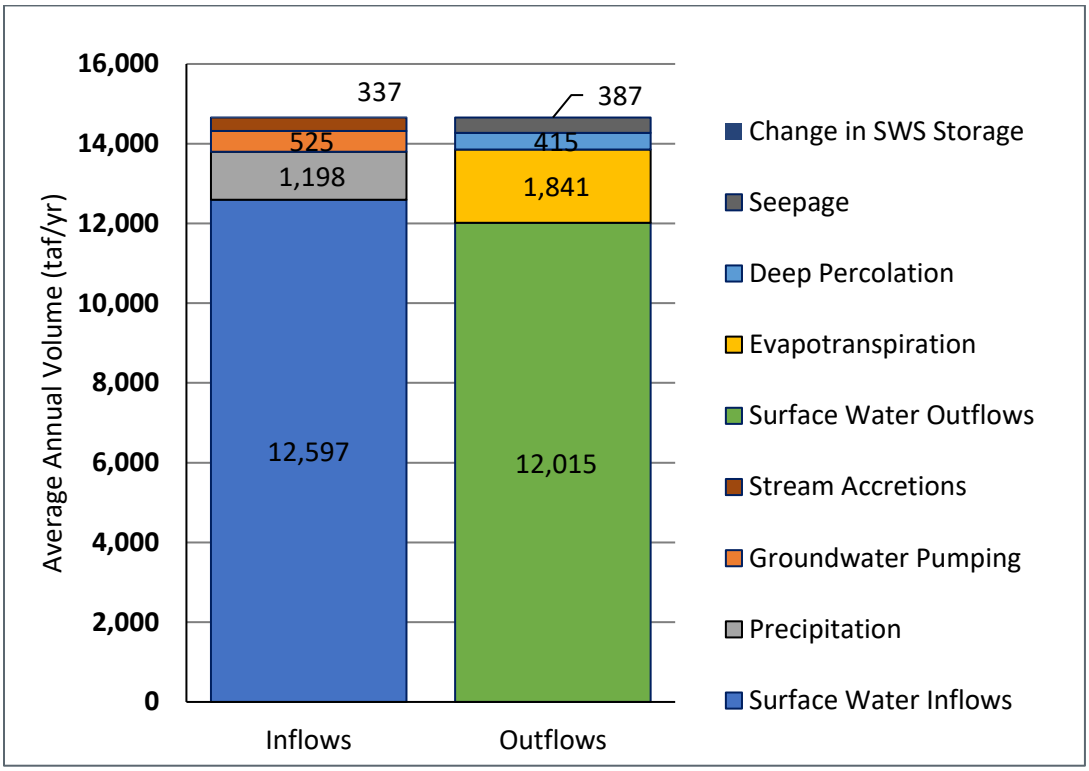


Figure 3-45.Average Annual Future Conditions, 2030 Climate Change Baseline Land and Surface Water System Water Budget Summary (2016-2065, rounded to nearest taf/yr)

Average annual future conditions 2030 climate change baseline groundwater system inflows and outflows were estimated to be 1,010 taf/yr during the 50-year simulation period. Average annual values were presented previously in Table 3-12 are shown graphically in Figure 3-46.

Inflows to the groundwater system include deep percolation (415 taf/yr), seepage (387 taf/yr), subsurface inflows from the Corning, Butte, Sutter, and Yolo Subbasins (205 taf/yr), and change in storage (3 taf/yr). Outflows from the groundwater system include groundwater pumping (525 taf/yr), stream gains from

groundwater (337 taf/yr), and subsurface outflows to the Corning, Butte, Sutter, and Yolo Subbasins (148 taf/yr).

There is a very small (-3 taf/yr) change in groundwater storage under the Future Condition, 2030 Climate Change water budget.

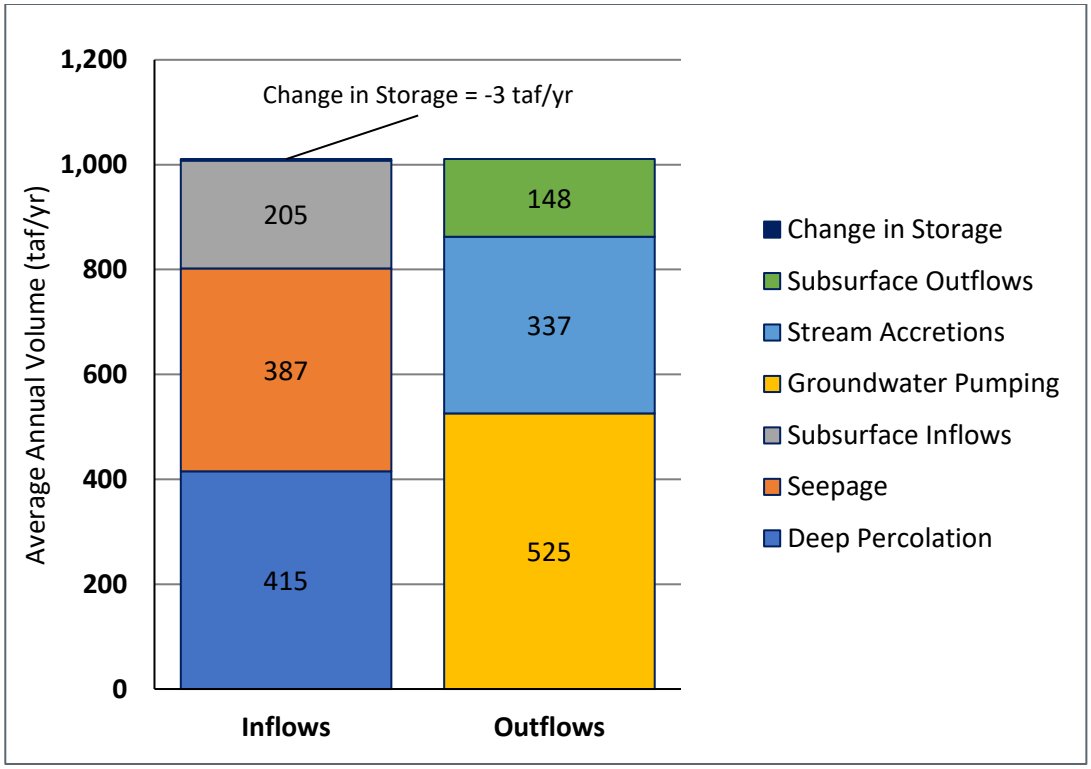


Figure 3-46. Average Annual Future Conditions, 2030 Climate Change Baseline Groundwater System Water Budget Summary (2016-2065, rounded to nearest taf/yr)

3.3.4.3.3 Future Conditions, 2070 Climate Change Baseline

Average annual inflows to and outflows from the Subbasin for the future conditions with 2070 climate change projected land and surface water system baseline water budget were estimated to be approximately 14,855 taf/yr. Average annual values were presented previously in Table 3-11 and are shown graphically in Figure 3-47.

Primary inflows to the land and surface water system include surface water inflows (12,715 taf/yr), precipitation (1,258 taf/yr), groundwater pumping (559 taf/yr), and stream gains from groundwater (323 taf/yr). Surface water inflows include the Sacramento River, other inflows from boundary streams including Stony Creek, as well as overland runoff of precipitation and applied water from upslope lands. Additionally, diversions from the Sacramento River and from Stony Creek are a key source of surface water inflows.

Primary outflows from the land and surface water system include surface water outflows (12,141 taf/yr), evapotranspiration (1,901 taf/yr), deep percolation (411 taf/yr), and seepage (401 taf/yr). Surface water outflows include outflows through Sacramento River, Colusa Drain, Colusa Weir to Sutter Slough, and

outflows to boundary streams including Stony Creek, as well as overland runoff of precipitation and applied water to downslope lands. Evapotranspiration is primarily from agricultural lands but also from managed wetlands, canal evaporation, native vegetation, and urban and industrial lands. Deep percolation is primarily from precipitation, but also from applied water. Seepage includes a combination of stream seepage and seepage from canals and drains.

The average annual change in storage in the land and surface water system (0.1 taf/yr) is negligible due to similar soil moisture content in the root zone, on average, across water years.

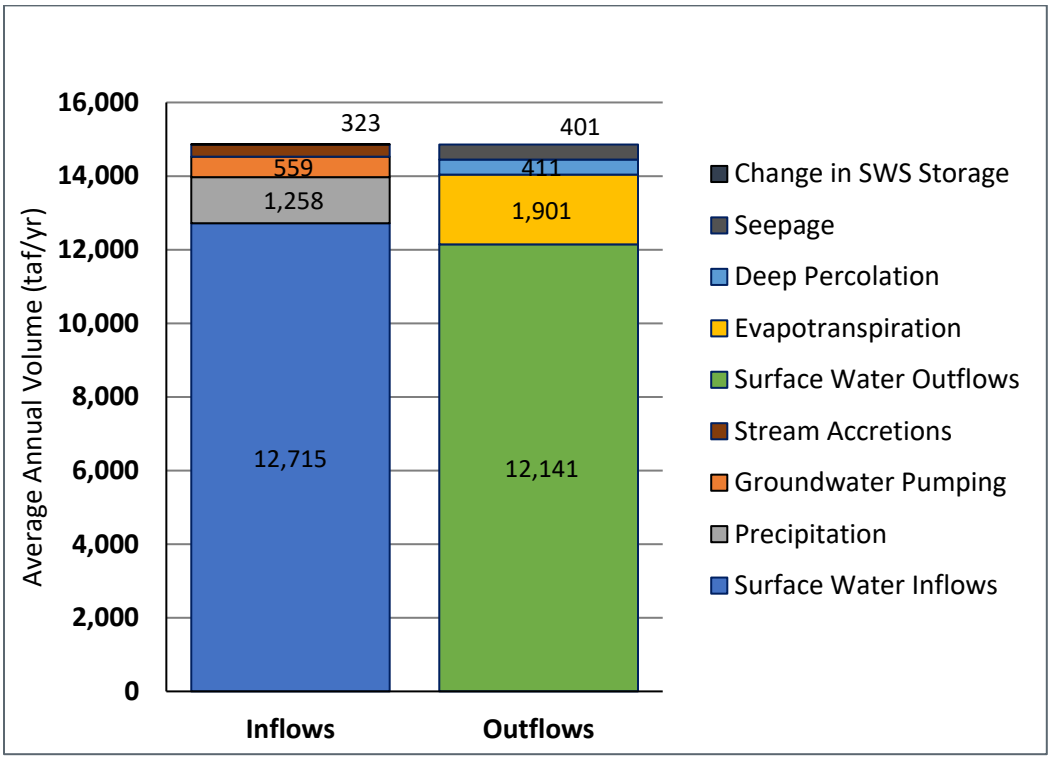


Figure 3-47. Average Annual Future Conditions, 2070 Climate Change Baseline Land and Surface Water System Water Budget Summary (2016-2065, rounded to nearest taf/yr)

Average annual inflows to and outflows from the groundwater system were estimated to be approximately 1,020 to 1,030 taf/yr during the 50-year simulation period. Average annual values were presented previously in Table 3-12 are shown graphically in Figure 3-48.

Inflows to the groundwater system include deep percolation (411 taf/yr), seepage (401 taf/yr), subsurface inflows from the Corning, Butte, Sutter, and Yolo Subbasins (209 taf/yr), and change in groundwater storage (-7 taf/yr). Outflows from the groundwater system include groundwater pumping (559 taf/yr), stream gains from groundwater (323 taf/yr), and subsurface outflows to the Corning, Butte, Sutter, and Yolo Subbasins (147 taf/yr).

There is a very small (-7 taf/yr) change in groundwater storage under the Future Condition, 2070 Climate Change water budget.

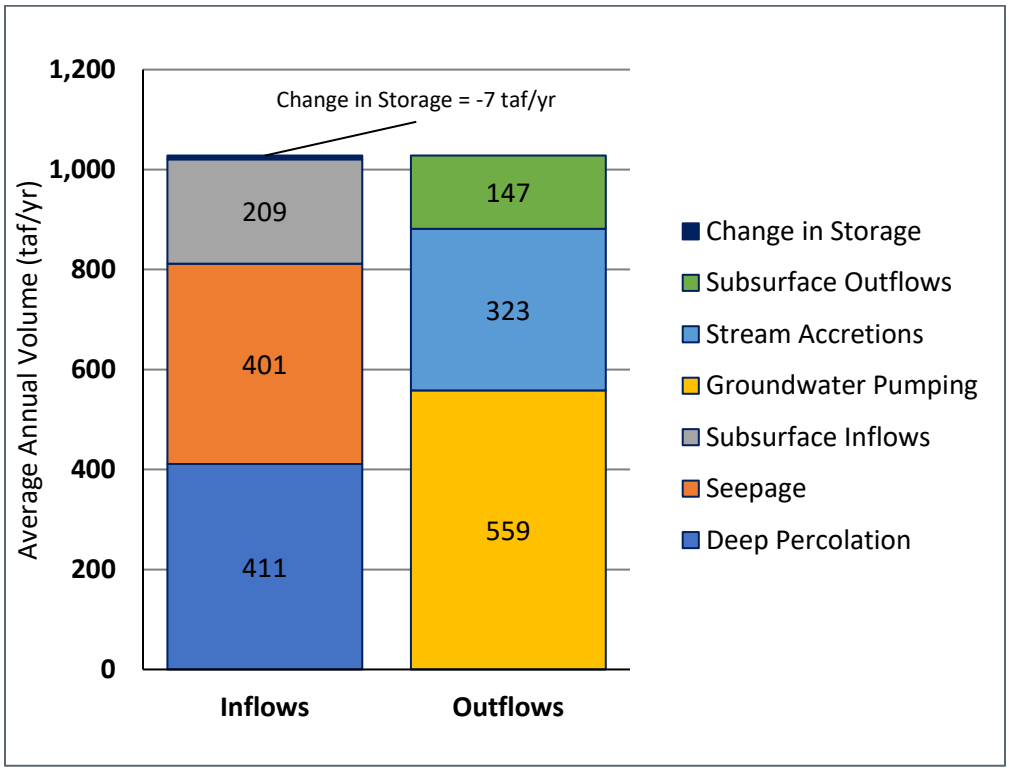


Figure 3-48. Average Annual Future Conditions, 2070 Climate Change Baseline Groundwater System Water Budget Summary (2016-2065, rounded to nearest taf/yr)

3.3.4.3.4 Comparison of Water Budget Scenarios

A figure depicting cumulative change in storage for the current conditions and three future conditions baseline scenarios is provided on the following page (Figure 3-49). In the figure, the cumulative change in groundwater storage is shown for the 50-year hydrologic period. The x-axis (horizontal axis) is labeled with the historical reference year along with the corresponding water year type based on the Sacramento Valley Water Year Index. Years are identified as wet (W), above normal (AN), below normal (BN), dry (D), or critical (C).

Estimated changes in storage are practically zero for the current conditions and future conditions without climate change scenarios. Current conditions and future conditions with no climate change are identical, except for minor urban growth represented in the future scenario without climate change. For the two future with climate change scenarios, there are small decreases in groundwater storage over the 50-year period, due primarily to increased groundwater pumping needed to meet increasing agricultural water demands resulting from climate change. For all scenarios, the changes in groundwater storage are substantial across wet and dry cycles, with the total range in storage change for all scenarios exceeding 800 taf over the 50-year period.

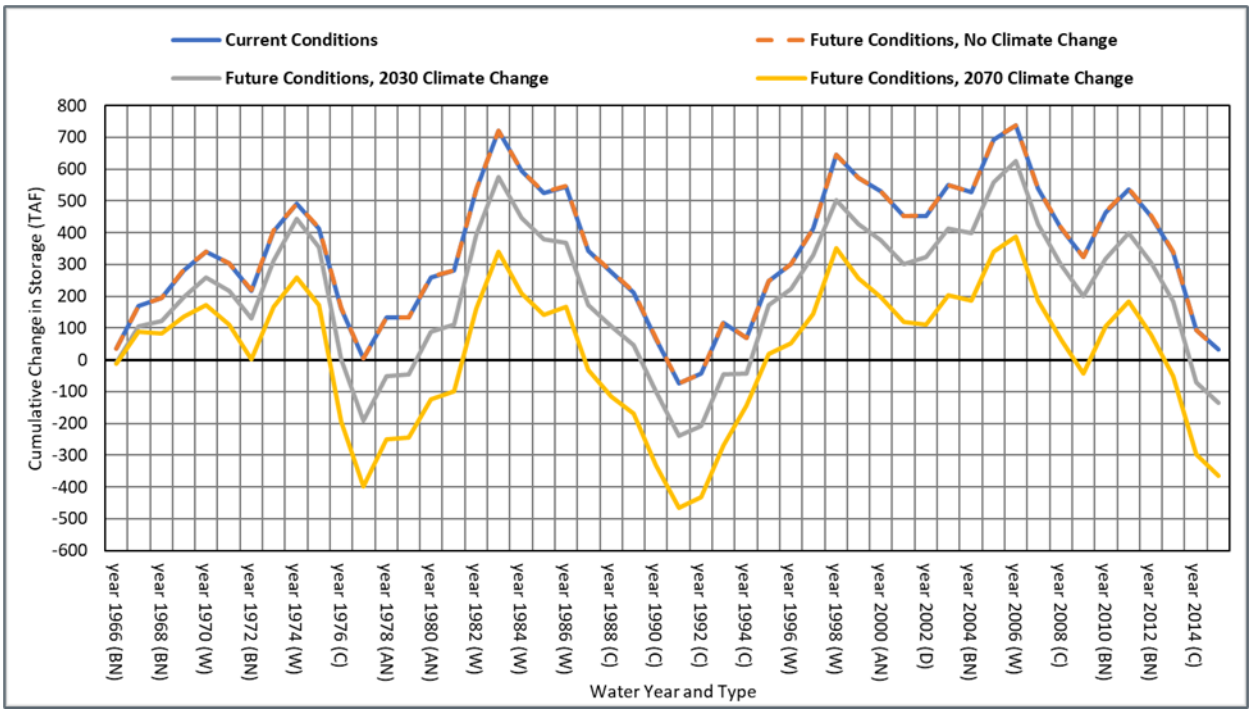


Figure 3-49. Cumulative Change in Groundwater Storage for Current and Future Conditions Baseline Scenarios

3.3.5 Water Budget Uncertainty

Water budget uncertainty refers to a lack of understanding of the subbasin setting that significantly affects an Agency's ability to develop sustainable management criteria and appropriate projects and management actions in a GSP, or to evaluate the efficacy of plan implementation, and therefore may limit the ability to assess whether a subbasin is being sustainably managed. Substantial uncertainty exists in all components of each water budget component. Substantial uncertainty also exits in the assumptions used to project potential future conditions related to planned development and associated urban demands, as well as projections of climate change. Consequently, the estimated negligible or very small changes in groundwater storage for current and future water budgets, calculated as total subbasin inflows minus outflows, are highly uncertain. It is anticipated that confidence in model results will be increased over time through additional monitoring and data collection, refinements to C2VSimFG-Colusa input, and coordination with neighboring subbasins.

However, the uncertainties that currently exist do not substantially limit the ability to develop and implement a GSP for the subbasin including the ability to develop sustainable management criteria and appropriate projects and management actions, including improved monitoring, nor the ability to assess whether the subbasin is being sustainably managed over time. GSPs are by nature iterative, and each opportunity will allow for improvements that will (1) lower uncertainty and (2) facilitate more refined analyses of sustainable management criteria and projects and management actions, and (3) refine the GSP implementation.

3.3.6 Overdraft Conditions

Overdraft refers to a negative average annual change in storage for the groundwater system over time. Based on the current conditions and future conditions with no climate change scenarios, which represent long-term average conditions in the subbasin, overdraft is expected to be negligible or very small in the Subbasin. An average annual change in storage of approximately 0.6 taf/yr is expected, as presented in Table 3-11 previously and Table 3-14 in the following section. However, based on the future condition scenarios with climate change, modest overdraft is expected to occur. Average annual overdraft is approximately 2.7 taf/yr in the 2030 scenario and 7.3 taf/yr in the 2070 scenario, corresponding to cumulative overdraft volumes of 135 taf and 365 taf, respectively, over the 50-year simulation of future conditions.

3.3.7 Sustainable Yield Estimate

As described previously, sustainable yield refers to the maximum quantity of water, calculated over a base period representative of long-term conditions in the subbasin, and including any temporary surplus that can be withdrawn annually from a groundwater supply without causing an undesirable result. Provisional estimates of sustainable yield have been calculated from water budget parameters for each scenario as the long-term annual average groundwater pumping, minus the average annual decrease in groundwater storage, as summarized in Table 3-14**.** Sustainable subbasin operation is expected to be achievable in current and future conditions scenarios, but modest overdraft is expected in future conditions with 2030 climate change and future conditions with 2070 climate change. Ultimately, it is anticipated that other factors will be considered in refining these sustainable yield estimates as part of development of sustainable management criteria for the subbasin, and as monitoring is improved and operational experience is gained during GSP implementation.

Table 3-14. Estimated Groundwater Pumping, Change in Groundwater Storage, and Sustainable Yield by Baseline Scenario, in taf/yr for the Water Budget Analysis Periods Listed in Table 3-9

Baseline Scenario	Groundwater Pumping	Change in Groundwater Storage	Sustainable Yield
Current	499	1	500
Future, No Climate Change	499	1	500
Future, 2030 Climate Change	525	-3	522
Future, 2070 Climate Change	559	-7	552
Future, 2070 Climate Change with Simulated Projects and Management Actions[(a)]	510	0	510

(a) Simulated projects and management actions are described in Appendix 6D.

3.4 MANAGEMENT AREAS

The GSP emergency regulations (at §354.20) provide that GSAs "may define one or more management areas with a basin if the Agency has determined that creation of management areas will facilitate implementation of the Plan". Both the CGA and the GGA boards considered defining management areas for purposes of developing and implementing the initial GSP. Both boards reached the conclusion that defining management areas is premature at this time because clear, compelling advantages could not be identified. However, both boards are receptive to the concept of management areas and will give them further consideration during GSP implementation.

CHAPTER 4
Monitoring Networks

Monitoring networks are required to better understand and evaluate changing conditions within the groundwater, surface water, and land surface systems. To optimize data collection and analysis, the network should be easily accessible, spatially and temporally relatable to other monitoring networks, sufficient for demonstrating spatial and temporal trends, and representative of actual conditions. The following sections discuss the Subbasin monitoring network objectives, requirements, monitoring protocols, network sites, data gaps, and proposed actions.

4.1 MONITORING NETWORK OBJECTIVES

Title 23 Section §354.34b of the California Code of Regulations (23 CCR §354.34(b)) states that the monitoring network objectives shall be implemented to:

> *(1) "Demonstrate progress toward achieving measurable objectives described in the [Groundwater Sustainability] Plan.*
>
> *(2) Monitor impacts to the beneficial uses or users of groundwater.*
>
> *(3) Monitor changes in groundwater conditions relative to measurable objectives and minimum thresholds.*
>
> *(4) Quantify annual changes in water budget components."*

Monitoring network objectives for the Subbasin were designed to address the requirements of five sustainability indicators (not including seawater intrusion, which is neither occurring nor anticipated to occur in the subbasin over the planning horizon) in support of the future measurable objectives and minimum thresholds. The overarching goals of the monitoring networks are to: (1) characterize current and historical conditions within the groundwater, surface water, and land surface systems, and (2) evaluate future conditions within the groundwater, surface water, and land surface systems due to water management practices, climatic influence, and GSP implementation within the Subbasin.

The monitoring network objectives are to characterize:

- Groundwater levels, availability, and flow characteristics, including impacts to groundwater storage;
- Surface water availability and interactions with groundwater, including impacts to native riparian land and groundwater dependent ecosystems (GDEs);
- Quality of groundwater; and,
- Extent and rate of land subsidence.

4.2 MONITORING NETWORKS

The following sections describe the monitoring sites included in the Subbasin groundwater level, groundwater quality, land subsidence, and surface water monitoring networks. Most of the networks consist of existing monitoring and reporting programs and are reliant on data collected and provided by other agencies. The Subbasin GSAs will continue to coordinate and collaborate with the other agencies regarding their monitoring programs, including changes to monitoring sites, monitoring protocols or frequencies, and management actions. Data acquisition is not anticipated to be an issue. If necessary, the

GSAs will consider implementing their own monitoring programs to address concerns over undesirable results, data gaps in the monitoring networks, or GSP project needs.

4.2.1 Groundwater Level Monitoring

Groundwater levels are and will continue to be monitored to evaluate groundwater elevations (GWE), reduction in groundwater storage, and stream-aquifer interactions throughout the subbasin. The GSP groundwater level monitoring network is based on the pre-existing groundwater monitoring networks of Colusa and Glenn Counties.

4.2.1.1 Requirements

The groundwater monitoring network should have sufficient density to represent spatial and temporal trends through the Subbasin:

- Spatial densities should sufficiently represent both lateral and vertical extents of the groundwater subbasin.
  - The quantity and density of groundwater monitoring wells should be sufficient to evaluate overall static groundwater conditions for each principal aquifer and sufficiently support evaluation of impacts from GSP implementation and water and land management practices.
  - The quantity and density of groundwater monitoring wells shall be sufficient to evaluate groundwater conditions for the subbasin (23 CCR §354.34(d)).
- Groundwater monitoring network shall be designed such that the sustainability indicators are adequately covered, not just over the entire groundwater basin, but also within any specific GSP-defined management areas (23 CCR §354.34(d)), of which there are none currently defined within the Subbasin. The sustainability indicators supported by the groundwater level monitoring network include:
  - **Chronic lowering of groundwater levels**
    - 23 CCR §354.34(c)(1) specifies that the groundwater monitoring network shall be sufficient to represent the seasonal occurrence, flow direction, and hydraulic gradients of groundwater within and between the principal aquifer and surface waters.
    - The representative groundwater level monitoring network is discussed in Section 4.2.5.1.
  - **Reduction in groundwater storage**
    - Data from the groundwater monitoring network shall be sufficient to enable calculations of annual changes in groundwater storage over time (Monitoring Network Best Management Practice [BMP], California Department of Water Resources [DWR], 2016b).
    - The representative groundwater quality monitoring network is discussed in Section 4.2.5.
  - **Depletion of interconnected surface water**
    - The groundwater monitoring network shall be sufficient to represent the seasonal occurrence, flow direction, and hydraulic gradients of groundwater between the principal aquifer and surface waters (23 CCR §354.34(c)(6)). Per the Monitoring Network BMP (DWR, 2016b), shallow groundwater monitoring wells should be appropriately located with respect to connected streams to enable characterization

of the groundwater levels adjacent to connected stream channels. The groundwater monitoring network should extend away from and along the stream course at appropriate intervals and be monitored on a frequency to capture seasonal pumping conditions (DWR, 2016b).

- The representative groundwater quality monitoring network is discussed in Section 4.2.5 and the surface water monitoring network is discussed in Section 4.2.4.

The Monitoring Network BMP states that the groundwater monitoring network should be able to provide data sufficient to:

- Represent the unconfined and confined parts of the principal aquifer.
- Support evaluation of groundwater level data to support evaluation of stream-aquifer interactions, impacts to GDEs, declining GWE, reduction in groundwater storage, and impacts to land subsidence.
- Support delineation of areas with declining GWE, recharge areas, and conditions at subbasin boundaries.
- Groundwater level monitoring frequencies shall be capable of representing:
  - Short-term, seasonal, and long-term trends (i.e., minimum of twice-annually to represent seasonal high and low groundwater conditions) per 23 CCR §354.34(c)(1)(b)).
  - Groundwater conditions, as necessary, to evaluate the progress of GSP implementation (23 CCR §354.34(a)).

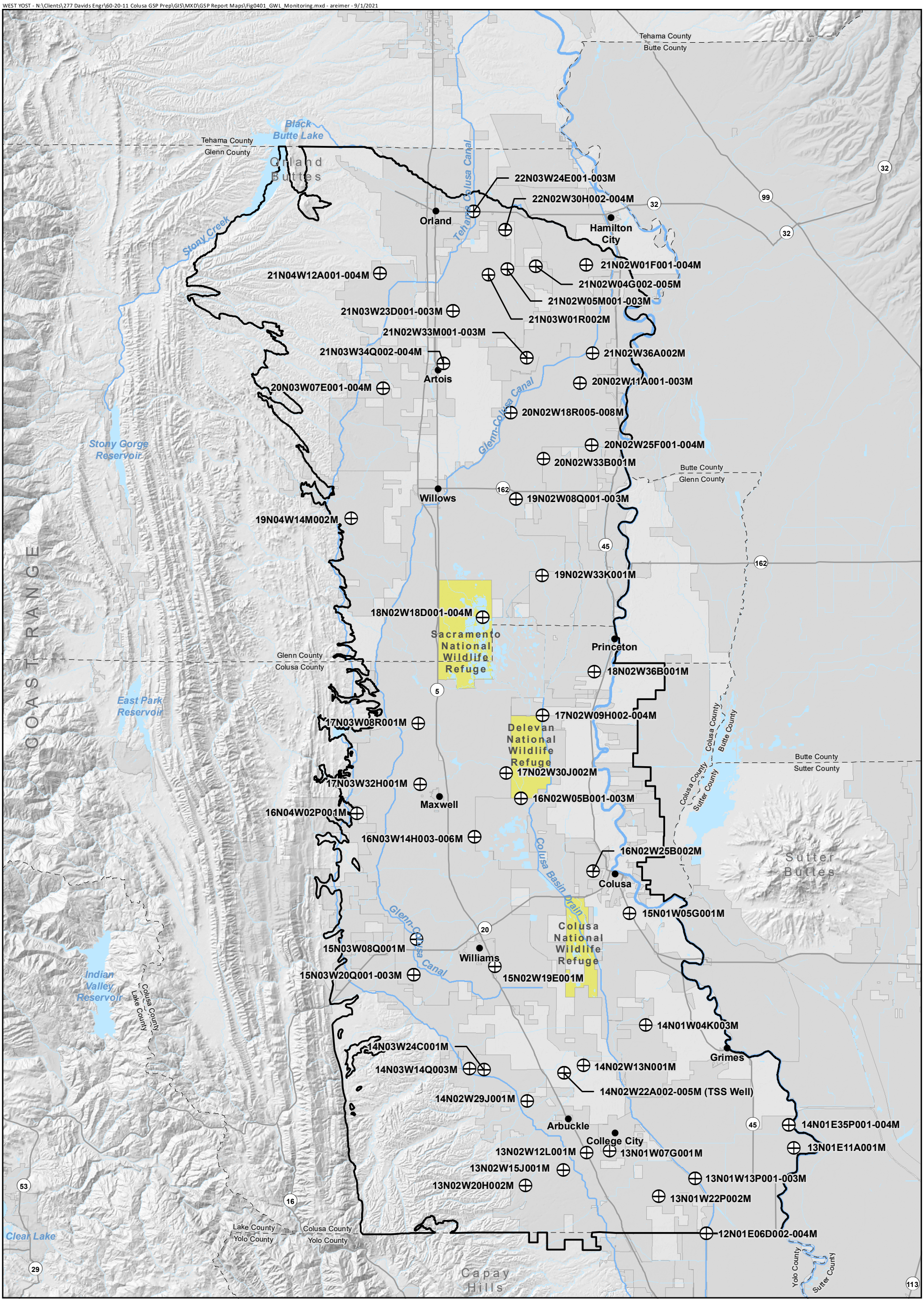
The Subbasin groundwater level monitoring network meets these requirements. Data gaps in the network are discussed in Section 4.2.1.4.

4.2.1.2 Groundwater Level Monitoring Network

The Subbasin groundwater monitoring network wells shown on Figure 4-1 are a combination of pre-SGMA Colusa County groundwater monitoring wells and pre-SGMA Glenn County dedicated groundwater monitoring wells (Glenn County wells that are dedicated observation wells and not used for supply). For the Glenn County wells, these exclude the Basin Management Objective (BMO) water supply wells and the wells included in the Glenn County annual water quality monitoring program discussed in Section 2.2. The Colusa County groundwater monitoring network includes active water supply wells as part of the County's groundwater level monitoring program.

All of the wells originally used for monitoring purposes by Colusa and Glenn Counties were assessed for their suitability as a groundwater monitoring network well. Table 4-1 lists the criteria used for evaluating the groundwater monitoring wells in the Subbasin groundwater monitoring network. These criteria were identified based on the groundwater monitoring network requirements discussed in the Monitoring Network BMP and 23 CCR §354.34.

There are 104 completions in 48 wells in the Subbasin groundwater level monitoring network. All of these wells are currently included in the California Statewide Groundwater Elevation Monitoring Program (CASGEM) database and monitored by DWR. Table 4-2 contains the entire current groundwater monitoring network with State Well Numbers (SWNs), CASGEM IDs, well completion report IDs, well status and use, location information, reference point information, construction, principal aquifer designations, and quality assessment categories. Well completion reports for the current Subbasin groundwater monitoring network wells, if available, are included in Appendix 4A.



Groundwater Monitoring Network Well

Colusa Subbasin

Water Agencies

U.S. Fish and Wildlife Refuge

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

N

0 2.5 5

Scale in Miles

Figure 4-1

Groundwater Monitoring Network Wells

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

Table 4-1. Assessment Categories of the Groundwater Monitoring Network Wells

Characteristic	Importance
Known Construction Characteristics	Known well construction characteristics will enable evaluation of groundwater conditions at specific depths within the principal aquifer. Examples of construction characteristics include borehole depth, screened intervals, and the presence of seals within the annular fill.
Nested Multiple Completion Wells	Nested, multiple completion wells allow the measurement of water levels at discrete depths within the aquifer system. The degree of confinement of the aquifer increases with depth. Multiple completion wells can provide insight into how the aquifer system is connected and allow estimates of vertical gradients and vertical hydraulic conductivity to be made.
Non-Dedicated Monitoring Wells	Pumping causes cones of depression that impact the water levels at and near the pumping well. Pumping water levels are not indicative of the static condition of the aquifer system and can skew estimates of groundwater storage. Pumping wells included in the groundwater monitoring network should be verified as inactive when measurements are made.
Proximity to Streams and Interconnected Surface Waters	Wells, including multiple completion wells, near streams or interconnected surface waters are useful for evaluating interaction between the aquifer and interconnected streams and surface waters. Vertical hydraulic gradients measured in wells near stream gages can provide insight regarding the direction of flow into or away from the surface water feature.
Lateral and Vertical Density	To characterize groundwater levels throughout the Subbasin, accessible monitoring sites should be spatially distributed throughout the area of interest. Not only should the monitoring sites be distributed laterally, but their screened intervals should also be set at representative depths within the principal aquifer.
Accessibility and Usability	The monitoring sites need to be easily accessible by field staff. Additionally, well completions should be clear down-hole to allow access of water level measuring equipment.

Known Construction. Construction details are known for all but one of the groundwater monitoring wells (Table 4-2 and Figure 4-1). Colusa County monitoring well 13N02W12L001 is a U.S. Bureau of Reclamation (USBR) well without well construction information. This well is listed in Table 4-2 and shown on Figure 4-1 because there is historical groundwater level data available for the well.

Nested Multiple Completion Wells. Of the 48 groundwater monitoring sites (104 separate completions) shown on Figure 4-1 and listed in Table 4-2, over 20 are nested multiple completion wells. These nested wells are screened at discrete depths up to a maximum depth of 1,180 feet below ground surface. The nested wells enable measurement of vertical head gradients within the principal aquifer. Additionally, the nested wells support monitoring of the groundwater system and interconnected surface waters. The current groundwater monitoring network contains wells that provide a lateral and vertical density sufficient to enable characterization of groundwater within the principal aquifer.

Non-Dedicated Monitoring Wells. The majority of the active domestic, irrigation, and stock water wells included in the current groundwater monitoring network are located in Colusa County. The Monitoring Network BMP allows the temporary inclusion of water supply wells in the groundwater monitoring network if the wells are screened within a single water-bearing unit. Of these wells, three were identified to be perforated across broad depth intervals, potentially with different degrees of confinement, but all still zoned within the principal aquifer. These three wells are 18N02W36B001 (near Princeton), 15N03W08Q001 (west of Williams), and 14N02W13N001 (north of Arbuckle).

Proximity to Streams and Interconnected Surface Waters. The subbasin is bounded and traversed by irrigation canals and drains, as well as perennial, ephemeral, and intermittent streams. Many of the surface waters are near wells included in the current groundwater monitoring network, except for surface waters in the following areas:

- Within the Colusa National Wildlife Refuge, east of Williams (Figure 4-1). There are no network groundwater monitoring wells near the Colusa National Wildlife Refuge.
- North and northwest of Orland near Stony Creek.
- Northwest of Artois along the middle reaches of Walker Creek.
- Northwest of Willows along the middle reaches of Willow Creek.

Lateral and Vertical Density. The groundwater monitoring network has a lateral density of approximately 9.2 completions per 100 square miles and 4.2 well boreholes per 100 square miles in the principal aquifer, averaged over the entire subbasin. These well densities are sufficient to evaluate groundwater level trends throughout the subbasin, in accordance with the recommendations listed in the Monitoring Network BMP (DWR, 2016b). Additionally, there are sufficient depth-specific wells located throughout the subbasin to evaluate groundwater elevation trends, groundwater storage, surface water connectivity, and aquifer characteristics with depth.

Accessibility and Usability. Five completions within three wells included in the Glenn County or Colusa County monitoring networks were determined to be unusable due to damaged casings. These include 13N02W04G001, -003, -004, 16N03W35N002, and 22N03W28P002 (shown on Figure 4-2). These wells are not included in the Subbasin groundwater level monitoring network but are shown on Figure 4-2 along with one suggested replacement well. The suggested replacement well is an existing well with known construction. All of the Subbasin groundwater monitoring network wells listed in Table 4-2 are accessible for field investigations. However, the accessibility of these sites should be verified via site visits.

Table 4-2. Groundwater Monitoring Network Wells

No.	County	State Well Number	CASGEM[a] Station ID	Well Completion Report ID	Latitude, decimal degrees	Longitude, decimal degrees	Datum	Well Use	Well Status	Well Completion Type (single or nested)	Ground Surface Elevation, feet	Reference Point Elevation, feet	Reference Point Description	Borehole Depth, feet, bgs[b]	Completed Well Depth, feet, bgs	Screen Intervals, feet, bgs	Total Length of Screen, feet	Casing Diameter, inches	Representative GWL Site[c]	Representative ISW Site[d]	Primary Geologic Formation	Assessment Category						Notes
																						Existing Monitoring Network	Known Construction	Non-Pumping Well	Nested Well	Proximity to Surface Water[e]	Accessible and Usable	
1	Colusa	12N01E06D002	16330	DWR, 2001[f]	38.92490	-121.91400	NAD 83[g]	Observation	active	nested	27.94	26.76	top of casing	1020	729	710-720	10	2			Tehama	x	x	x	x	x	x	Local Well LCB-4 Deep.
2	Colusa	12N01E06D003	33886	DWR, 2001	38.92490	-121.91400	NAD 83	Observation	active	nested	27.94	30.32	top of casing	1020	505	485-495	10	2			Tehama	x	x	x	x	x	x	Local Well LCB-4 Middle.
3	Colusa	12N01E06D004	16331	DWR, 2001	38.92490	-121.91400	NAD 83	Observation	active	nested	27.94	30.72	top of casing	1020	298	275-285	10	2	x		Tehama	x	x	x	x	x	x	Local Well LCB-4 Shallow.
4	Colusa	13N01E11A001	18534	2865	38.99371	-121.82401	NAD 83	Domestic	active	single	31.8	32.8	top of casing	158	145	136-158	22	8	x	x	Alluvium	x	x			x	x	Approximate screen or open hole 136-158 feet (Roy Hull, DWR, 2017)[h].
5	Colusa	13N01W07G001	36246	2868	38.99161	-122.01411	NAD 83	Irrigation	active	single	90.47	90.47	plug at top of casing, west side	180	180	108-180	72	12	x	x	Alluvium	x	x				x	
6	Colusa	13N01W13P001	18549	DWR, 2001	38.96935	-121.92587	NAD 83	Observation	active	nested	32.23	33.52	top of casing	1000	885	865-875	10	2			Tehama	x	x	x	x	x	x	Local Well LCB-1 Deep.
7	Colusa	13N01W13P002	25159	DWR, 2001	38.96935	-121.92587	NAD 83	Observation	active	nested	32.23	34.58	top of casing	1000	480	410-420 450-456	16	2			Tehama	x	x	x	x	x	x	Local Well LCB-1 Middle.
8	Colusa	13N01W13P003	36248	DWR, 2001	38.96935	-121.92587	NAD 83	Observation	active	nested	32.23	35.49	top of casing	1000	355	271-278	7	2	x		Tehama	x	x	x	x	x	x	Local Well LCB-1 Shallow.
9	Colusa	13N01W22P002	16357	40376	38.95531	-121.96311	NAD 83	Irrigation	active	single	60.46	61.16	not provided	236	236	196-236	40	12	x		Tehama	x	x				x	USBR[i] well.
10	Colusa	13N02W12L001	31899	115408	38.98981	-122.03751	NAD 83	Irrigation	active	single	135.49	135.99	not provided	778	NA[j]	NA	NA	NA	x		Tehama						x	USBR well.
11	Colusa	13N02W15J001	39884	77457	38.97631	-122.06161	NAD 83	Domestic	active	single	212.52	213.02	hole in plate	362	362	270-362	92	8	x		Tehama	x	x				x	
12	Colusa	13N02W20H002	25005	423344	38.96341	-122.10091	NAD 83	Domestic	active	single	342.58	343.58	not provided	320	320	200-260 300-320	80	5	x		Tehama	x	x				x	
13	Colusa	14N01E35P001	38718	E0109311A	39.01241	-121.82906	NAD 83	Observation	active	nested	46.88	48.74	not provided	1540	1039	985-995	10	2.5			Tehama	x	x	x	x	x	x	
14	Colusa	14N01E35P002	24655	E0109311B	39.01241	-121.82906	NAD 83	Observation	active	nested	46.88	48.36	not provided	1540	736	545-555 610-620 695-705	30	2.5			Tehama	x	x	x	x	x	x	
15	Colusa	14N01E35P003	24656	E0109311C	39.01241	-121.82906	NAD 83	Observation	active	nested	46.88	48	not provided	1540	275	135-145 215-225	20	2.5	x		Alluvium, Tehama	x	x	x	x	x	x	
16	Colusa	14N01E35P004	24657	E0109311D	39.01241	-121.82906	NAD 83	Observation	active	nested	46.88	47.62	not provided	1540	71	50-60	10	2.5			Alluvium	x	x	x	x	x	x	
17	Colusa	14N01W04K003	18554	USGS[k] Well Log	39.09301	-121.97671	NAD 83	Irrigation	inactive	single	37.43	37.43	top of casing, under pump base, northwest side	73	73	46-70	24	16	x	x	Alluvium	x	x				x	USBR well.
18	Colusa	14N02W13N001	18563	3027	39.06021	-122.04111	NAD 83	Irrigation	active	single	62.45	62.45	not provided	392	392	104-392	288	14	x		Alluvium, Tehama	x	x			x	x	USBR well.
19	Colusa	14N02W22A002	54756	WCR2020_003773	39.05398	-122.06067	NAD 83	Observation	active	nested	84	87.055	top of tallest casing	1200	1050	1020-1030	10	2	x		Tehama		x	x	x		x	
20	Colusa	14N02W22A003	54757	WCR2020_003773	39.05398	-122.06067	NAD 83	Observation	active	nested	84.38	86.9	top of 2nd tallest casing	1200	950	860-870 920-930	20	2			Tehama		x	x	x		x	
21	Colusa	14N02W22A004	54758	WCR2020_003773	39.05398	-122.06067	NAD 83	Observation	active	nested	84	86.825	top of 2nd shortest casing	1200	610	580-590	10	2			Tehama		x	x	x		x	
22	Colusa	14N02W22A005	54758	WCR2020_003773	39.05398	-122.06067	NAD 83	Observation	active	nested	84	86.69	top of shortest casing	1200	320	290-300	10	2			Alluvium, Tehama		x	x	x		x	
23	Colusa	14N02W29J001	18566	44455	39.03171	-122.09911	NAD 83	Irrigation	active	single	162.5	162.5	not provided	924	412	119-143 152-158 176-182 198-208 215-239 264-276 307.5-319.5 334.5-349.5	109	12	x		Tehama	x	x			x	x	
24	Colusa	14N03W14Q003	32324	20032	39.05761	-122.15861	NAD 83	Irrigation	active	single	172.52	172.52	open hole in pump base	704	685	390-480 500-590 614-685	251	16	x		Tehama	x	x			x	x	
25	Colusa	14N03W24C001	16691	72290	39.05691	-122.14351	NAD 83	Domestic	active	single	172.51	172.81	not provided	320	312	292-312	20	8	x		Tehama		x				x	USBR well. Records indicate the well is 160 feet deep (Roy Hull, DWR, 2017).
26	Colusa	15N01W05G001	14309	12982	39.18261	-121.99351	NAD 83	Domestic	active	single	47.42	48.82	not provided	140	140	75-140	65	8	x	x	Alluvium	x	x				x	Well is either screened or open hole after 75 feet.
27	Colusa	15N02W19E001	14319	71038	39.14011	-122.13251	NAD 83	Irrigation	inactive	single	87.46	88.11	top of casing	334	334	162-182 198-206 262-274 290-294 310-334	72	14	x		Alluvium, Tehama	x	x	x			x	Irrigation well with no pump installed.
28	Colusa	15N03W08Q001	NA	492125	39.16139	-122.21378	NAD 83	Irrigation	NA	single	NA	NA	NA	360	350	30-130 250-350	200	10.75 16	x		Alluvium, Tehama	x	x		x	x	x	
29	Colusa	15N03W20Q001	38293	802508C	39.13302	-122.21647	NAD 83	Observation	active	nested	128.56	130.32	top of short casing	620	424	370-410	40	2.5			Tehama	x	x	x	x	x	x	
30	Colusa	15N03W20Q002	24470	802508B	39.13302	-122.21647	NAD 83	Observation	active	nested	128.56	130.66	top of middle casing	620	170	130-160	30	2.5	x		Tehama	x	x	x	x	x	x	

Table 4-2. Groundwater Monitoring Network Wells

No.	County	State Well Number	CASGEM[a] Station ID	Well Completion Report ID	Latitude, decimal degrees	Longitude, decimal degrees	Datum	Well Use	Well Status	Well Completion Type (single or nested)	Ground Surface Elevation, feet	Reference Point Elevation, feet	Reference Point Description	Borehole Depth, feet, bgs[b]	Completed Well Depth, feet, bgs	Screen Intervals, feet, bgs	Total Length of Screen, feet	Casing Diameter, inches	Representative GWL Site[c]	Representative ISW Site[d]	Primary Geologic Formation	Assessment Category						Notes
																						Existing Monitoring Network	Known Construction	Non-Pumping Well	Nested Well	Proximity to Surface Water[e]	Accessible and Usable	
31	Colusa	15N03W20Q003	38294	802508A	39.13302	-122.21647	NAD 83	Observation	active	nested	128.56	131	top of tall casing	620	82	30-80	50	2.5			Alluvium	x	x	x	x	x	x	
32	Colusa	16N02W05B001	25511	726832C	39.27527	-122.10568	NAD 83	Observation	active	nested	65	66.91	top of casing	986	797	730-750	20	4			Tehama	x	x	x	x	x	x	
33	Colusa	16N02W05B002	25512	726832B	39.27527	-122.10568	NAD 83	Observation	active	nested	65	65.55	not provided	986	535	462-472	10	2.5			Tehama	x	x	x	x	x	x	
34	Colusa	16N02W05B003	38669	726832A	39.27527	-122.10568	NAD 83	Observation	active	nested	65	66.34	not provided	986	301	174-184 246-256	20	2.5	x		Tehama	x	x	x	x	x	x	
35	Colusa	16N02W25B002	33868	Owner's Log	39.21651	-122.03121	NAD 83	Domestic	active	single	55.42	55.42	not provided	274	274	254-274	20	8	x		Tehama	x	x			x	x	Construction and lithology information provided by owner.
36	Colusa	16N03W14H003	24683	E0116237D	39.24391	-122.15401	NAD 83	Observation	active	nested	65.7	68.5	top of tallest	1500	1481	1370-1380 1410-1420	20	2.5			Tehama	x	x	x	x	x	x	Artesian flowing well.
37	Colusa	16N03W14H004	24684	E0116237C	39.24391	-122.15401	NAD 83	Observation	active	nested	65.7	68.21	top of second tallest	1500	1236	1140-1150 1170-1180	20	2.5			Tehama	x	x	x	x	x	x	
38	Colusa	16N03W14H005	37673	E0116237B	39.24391	-122.15401	NAD 83	Observation	active	nested	65.7	67.91	top of second shortest	1500	775	720-730	10	2.5			Tehama	x	x	x	x	x	x	
39	Colusa	16N03W14H006	24685	E0116237A	39.24391	-122.15401	NAD 83	Observation	active	nested	65.7	67.68	top of shortest	1500	378	295-305	10	2.5	x		Tehama	x	x	x	x	x	x	
40	Colusa	16N04W02P001	16308	77484	39.26291	-122.27541	NAD 83	Stock	active	single	162.53	163.03	not provided	203	203	112-203	91	8.625	x		Tehama	x	x			x	x	
41	Colusa	17N02W09H002	25514	726866A	39.34170	-122.08377	NAD 83	Observation	active	nested	67	69.36	top of casing	940	806	779-800	21	4			Tehama	x	x	x	x	x	x	
42	Colusa	17N02W09H003	25761	726866B	39.34170	-122.08377	NAD 83	Observation	active	nested	67	68.54	top of southernmost casing	940	578	460-470 510-520	20	2.5			Tehama	x	x	x	x	x	x	
43	Colusa	17N02W09H004	25515	726866C	39.34170	-122.08377	NAD 83	Observation	active	nested	67	68.78	top of northernmost casing	940	302	250-260	10	2.5	x		Tehama	x	x	x	x	x	x	
44	Colusa	17N02W30J002	16960	57983	39.29541	-122.12121	NAD 83	Domestic	active	single	63.43	63.43	not provided	182	159	157-159	2	6	x	x	Tehama	x	x				x	
45	Colusa	17N03W08R001	39127	49451	39.33521	-122.21241	NAD 83	Domestic	active	single	107.46	108.46	not provided	151	130	125-130	5	6	x		Alluvium	x	x			x	x	
46	Colusa	17N03W32H001	35475	93568	39.28610	-122.21046	NAD 83	Domestic	active	single	100.47	102.47	not provided	140	112	68-72 104-112	12	6.625	x		Alluvium	x	x				x	
47	Colusa	18N02W36B001	16914	177869	39.37721	-122.02981	NAD 83	Irrigation	unknown	single	75.4	76	square hole in disk blade atop well	455	410	88-128 195-225 240-340	170	18 18 16	x		Alluvium, Tehama	x	x			x	x	
48	Glenn	18N02W18D001	24953	E045412	39.42083	-122.14578	NAD 83	Observation	active	nested	82.43	83.03	top of shortest PVC	1200	1000	975-985	10	2.5			Tuscan A	x	x	x	x	x	x	
49	Glenn	18N02W18D002	38201	E045412	39.42083	-122.14578	NAD 83	Observation	active	nested	83.43	83.43	top of second shortest PVC	1200	700	620-630 670-680	20	2.5			Tuscan C		x	x	x	x	x	
50	Glenn	18N02W18D003	24992	E045412	39.42083	-122.14578	NAD 83	Observation	active	nested	84.43	84.03	top of second tallest PVC	1200	530	510-520	10	2.5			Tehama		x	x	x	x	x	
51	Glenn	18N02W18D004	38358	E045412	39.42083	-122.14578	NAD 83	Observation	active	nested	85.43	84.43	top of tallest PVC	1200	266	246-256	10	2.5	x		Tehama		x	x	x	x	x	
52	Glenn	19N02W08Q001	25762	726952	39.51596	-122.11143	NAD 83	Observation	active	nested	108.36	120	top of casing	1000	939.7	856.6-876.6	20	2.5			Tehama	x	x	x	x	x	x	
53	Glenn	19N02W08Q002	25763	726952	39.51595	-122.11143	NAD 83	Observation	active	nested	108.36	109.38	westernmost piezometer	1000	228	208-218	10	2.5	x		Tehama	x	x	x	x	x	x	
54	Glenn	19N02W08Q003	25764	726952	39.51596	-122.11143	NAD 83	Observation	active	nested	108.36	109.56	easternmost piezometer	1000	97	77-87	10	2.5			Tehama	x	x	x	x	x	x	
55	Glenn	19N02W33K001	19793	581475	39.45469	-122.08402	NAD 83	Irrigation	active	single	87.41	87.11	top of western sounding pipe	300	260	160-260	100	16	x		Tehama		x				x	
56	Glenn	19N04W14M002	25787	816220	39.50037	-122.28269	NAD 83	Observation	active	single	185.83	187.83	top of casing	366	65	45-55	10	2.5	x		Alluvium	x	x	x			x	Local Well GCAB303-1.
57	Glenn	20N02W11A001	17170	3669	39.60922	-122.04491	NAD 83	Observation	active	nested	125.40	125.90	top of board on northernmost piezometer	700	90	70-90	20	1.5	x	x	Modesto	x	x	x	x		x	
58	Glenn	20N02W11A002	17171	3669	39.60922	-122.04491	NAD 83	Observation	active	nested	125.40	125.90	top of board on southernmost piezometer	700	160	140-160	20	1.5			Tehama	x	x	x	x		x	
59	Glenn	20N02W11A003	35614	3669	39.60922	-122.04491	NAD 83	Observation	active	nested	125.40	125.90	top of board on middle piezometer	700	510	490-510	20	1.5			Tehama	x	x	x	x		x	
60	Glenn	20N02W18R005	23986	801448	39.58552	-122.11701	NAD 83	Observation	active	nested	131.38	132.45	top of lowest casing	1020	1000	920-930 970-980	20	2			Tuscan AB	x	x	x	x	x	x	
61	Glenn	20N02W18R006	23987	801448	39.58552	-122.11701	NAD 83	Observation	active	nested	131.38	132.98	top of second lowest casing	1020	675	635-655	20	2			Tehama	x	x	x	x	x	x	
62	Glenn	20N02W18R007	24259	801448	39.58552	-122.11701	NAD 83	Observation	active	nested	131.38	133.43	top of second highest casing	1020	545	450-460 515-526	20	2			Tehama	x	x	x	x	x	x	
63	Glenn	20N02W18R008	23988	801448	39.58552	-122.11701	NAD 83	Observation	active	nested	131.38	133.97	top of highest casing	1020	201	140-150 170-180	20	2	x		Modesto	x	x	x	x	x	x	
64	Glenn	20N02W25F001	23989	782025	39.55949	-122.03263	NAD 83	Observation	active	nested	102.20	105.56	top of lowest casing	1000	980	940-960	20	2			Tehama	x	x	x	x		x	Artesian flowing well; Data logger installed August 2016.

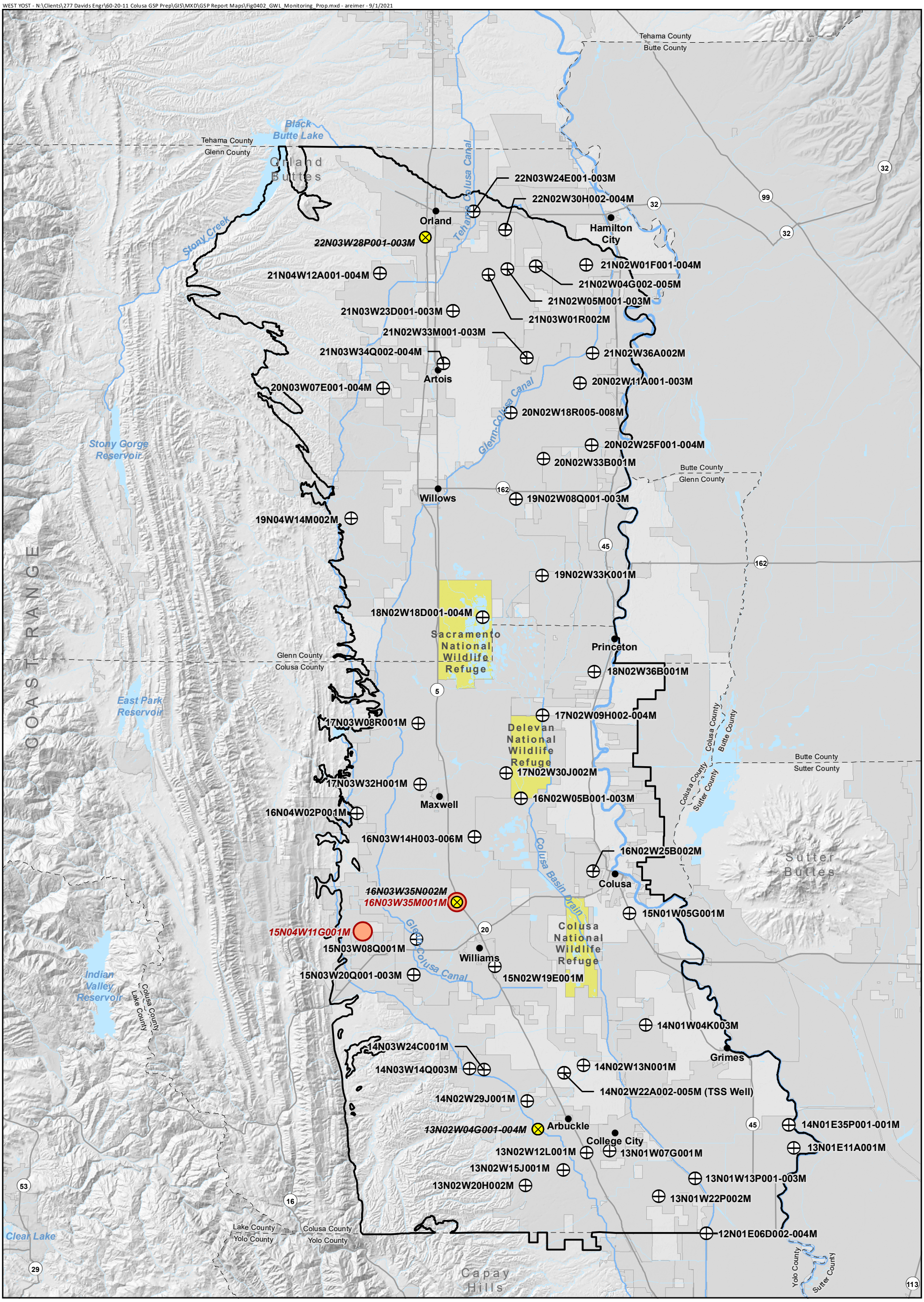
Table 4-2. Groundwater Monitoring Network Wells

No.	County	State Well Number	CASGEM[a] Station ID	Well Completion Report ID	Latitude, decimal degrees	Longitude, decimal degrees	Datum	Well Use	Well Status	Well Completion Type (single or nested)	Ground Surface Elevation, feet	Reference Point Elevation, feet	Reference Point Description	Borehole Depth, feet, bgs[b]	Completed Well Depth, feet, bgs	Screen Intervals, feet, bgs	Total Length of Screen, feet	Casing Diameter, inches	Representative GWL Site[c]	Representative ISW Site[d]	Primary Geologic Formation	Assessment Category						Notes
																						Existing Monitoring Network	Known Construction	Non-Pumping Well	Nested Well	Proximity to Surface Water[e]	Accessible and Usable	
65	Glenn	20N02W25F002	23990	782025	39.55949	-122.03263	NAD 83	Observation	active	nested	102.20	105.86	top of second lowest casing	1000	490	420-430 460-470	20	2			Tehama	x	x	x	x		x	Artesian flowing well.
66	Glenn	20N02W25F003	25519	782025	39.55950	-122.03263	NAD 83	Observation	active	nested	102.20	104.58	top of second highest casing	1000	280	190-200 250-260	20	2			Tehama	x	x	x	x		x	
67	Glenn	20N02W25F004	23991	782025	39.55949	-122.03263	NAD 83	Observation	active	nested	102.20	105.10	top of highest casing	1000	85	55-65	10	2	x	x	Tehama	x	x	x	x		x	
68	Glenn	20N02W33B001	17174	3686	39.54846	-122.08307	NAD 83	Observation	active	single	105.41	107.01	bottom of box	326	320	100-120 200-320	20 120	6	x		Tehama	x	x	x		x	x	
69	Glenn	20N03W07E001	37860	E057712D	39.60475	-122.24962	NAD 83	Observation	active	nested	179.17	180.83	top of lowest casing	1400	1030	984-1014	30	2			Tehama	x	x	x	x	x	x	
70	Glenn	20N03W07E002	24329	E057712C	39.60476	-122.24962	NAD 83	Observation	active	nested	179.17	181.06	top of second lowest casing	1400	656	616-636	20	2			Tehama	x	x	x	x	x	x	
71	Glenn	20N03W07E003	24330	E057712B	39.60475	-122.24962	NAD 83	Observation	active	nested	179.17	181.47	top of second highest casing	1400	505	380-410 465-485	50	2			Tehama	x	x	x	x	x	x	
72	Glenn	20N03W07E004	37861	E057712A	39.60475	-122.24962	NAD 83	Observation	active	nested	179.17	181.75	top of highest casing	1400	138	118-128	10	2	x		Tehama	x	x	x	x	x	x	
73	Glenn	21N02W01F001	38535	726740	39.70439	-122.03830	NAD 83	Observation	active	nested	160.88	162.13	top of lowest casing	600	578	547-557	10	2			Tuscan C	x	x	x	x		x	
74	Glenn	21N02W01F002	24205	726740A	39.70439	-122.03830	NAD 83	Observation	active	nested	160.83	162.28	top of highest casing	600	318	297-307	10	2			Tehama	x	x	x	x		x	
75	Glenn	21N02W01F003	39954	726741	39.70439	-122.03830	NAD 83	Observation	active	nested	161.84	162.84	top of lowest casing	125	124	109-119	10	2	x		Modesto	x	x	x	x		x	
76	Glenn	21N02W01F004	40029	726741	39.70439	-122.03830	NAD 83	Observation	active	nested	161.92	163.22	top of highest casing	125	75	55-65	10	2		x	Modesto	x	x	x	x		x	
77	Glenn	21N02W04G002	24993	E044112	39.70333	-122.09103	NAD 83	Observation	active	nested	178.41	180.21	top of shortest casing	1200	948	928-938	10	2			Tuscan B	x	x	x	x	x	x	
78	Glenn	21N02W04G003	24994	E044112	39.70333	-122.09103	NAD 83	Observation	active	nested	178.41	180.51	top of second shortest casing	1200	713	673.5-683.5 693.5-703.5	20	2			Tuscan C	x	x	x	x	x	x	
79	Glenn	21N02W04G004	38359	E044112	39.70333	-122.09102	NAD 83	Observation	active	nested	178.41	180.31	top of second tallest casing	1200	289	165-175 269-279	20	2	x		Tehama	x	x	x	x	x	x	
80	Glenn	21N02W04G005	24995	E044112	39.70333	-122.09102	NAD 83	Observation	active	nested	178.41	181.16	top of tallest casing	1200	77	57-67	10	2			Modesto	x	x	x	x	x	x	
81	Glenn	21N02W05M001	39676	801406	39.70082	-122.12076	NAD 83	Observation	active	nested	188.93	190.43	top of shortest casing	520	473	442-452	10	2			Tehama	x	x	x	x		x	
82	Glenn	21N02W05M002	36588	801406	39.70082	-122.12076	NAD 83	Observation	active	nested	188.93	190.91	top of middle casing	520	153	122-132	10	2	x		Tehama, Modesto	x	x	x	x		x	
83	Glenn	21N02W05M003	23996	801406	39.70082	-122.12076	NAD 83	Observation	active	nested	188.93	191.33	top of tallest casing	520	75	44-54	10	2		x	Modesto	x	x	x	x		x	
84	Glenn	21N02W33M001	38536	726724	39.62970	-122.10045	NAD 83	Observation	active	nested	149	151.60	top of 4" casing	1020	974.2	869-890	21	4			Tuscan AB	x	x	x	x		x	
85	Glenn	21N02W33M002	24206	726724	39.62970	-122.10045	NAD 83	Observation	active	nested	149	151.26	top of shortest 2" casing	1020	571.1	540-550	10	2			Tuscan C	x	x	x	x		x	
86	Glenn	21N02W33M003	24207	726724	39.62970	-122.10045	NAD 83	Observation	active	nested	149	151.49	top of tallest 2" casing	1020	171.1	140-150	10	2	x		Tehama	x	x	x	x		x	
87	Glenn	21N02W36A002	21239	315494	39.63341	-122.03194	NAD 83	Observation	active	single	135.39	136.29	top of chip board inside casing	155	145	120-140	20	6	x	x	Tehama	x	x	x			x	
88	Glenn	21N03W01R002	25232	726894	39.69624	-122.14048	NAD 83	Observation	active	single	203.32	206.77	bottom of hole cut in casing	1530	255	235-245	10	2	x		Tehama	x	x	x			x	Local Well OAWD-Mon Well.
89	Glenn	21N03W23D001	23992	801404	39.66720	-122.17735	NAD 83	Observation	active	nested	204.76	205.89	top of shortest casing	420	393.5	363-373	10	2			Tehama	x	x	x	x		x	
90	Glenn	21N03W23D002	25233	801404	39.66720	-122.17734	NAD 83	Observation	active	nested	204.76	206.43	top of middle casing	420	191.5	142-152 160-170	20	2	x		Modesto	x	x	x	x		x	
91	Glenn	21N03W23D003	23993	801404	39.66720	-122.17735	NAD 83	Observation	active	nested	204.76	206.93	top of tallest casing	420	93.5	42-72	30	2			Modesto	x	x	x	x		x	
92	Glenn	21N03W34Q002	25789	816224	39.62472	-122.18714	NAD 83	Observation	active	nested	166.65	167.07	top of shortest casing	1020	980	930-960	30	2			Tehama	x	x	x	x		x	
93	Glenn	21N03W34Q003	25234	816224	39.62472	-122.18714	NAD 83	Observation	active	nested	166.65	167.38	top of middle casing	1020	710	620-630 650-660 680-690	30	2			Tehama	x	x	x	x		x	
94	Glenn	21N03W34Q004	25790	816224	39.62472	-122.18714	NAD 83	Observation	active	nested	166.65	167.63	top of tallest casing	1020	80	60-70	10	2	x		Alluvium	x	x	x	x		x	
95	Glenn	21N04W12A003	38716	E0103388	39.69716	-122.25330	NAD 83	Observation	active	nested	247.50	250.12	top of tallest casing	1080	1070	955-975 1030-1050	40	2			Tehama	x	x	x	x	x	x	
96	Glenn	21N04W12A004	24650	E0103388	39.69717	-122.25330	NAD 83	Observation	active	nested	247.50	249.62	top of shortest casing	1080	660	520-530 590-600 630-640	30	2			Tehama	x	x	x	x	x	x	
97	Glenn	21N04W12A001	24000	726739	39.69717	-122.25330	NAD 83	Observation	unknown	nested	247.88	249.38	top of piezometer	640	629	598-608	10	2			Tehama	x	x	x	x	x	x	Local Well Big W-Deep.
98	Glenn	21N04W12A002	25725	726739	39.69716	-122.25330	NAD 83	Observation	active	nested	247.88	249.88	top of tallest casing	640	278	247-257	10	2	x		Tehama	x	x	x	x	x	x	
99	Glenn	22N02W30H002	25726	726922	39.73252	-122.12306	NAD 83	Observation	active	nested	204.43	205.22	top of shortest casing	920	900	850-880	30	2			Tuscan C	x	x	x	x	x	x	
100	Glenn	22N02W30H003	25727	726922	39.73252	-122.12304	NAD 83	Observation	active	nested	204.43	205.77	top of middle casing	920	275	130-140 150-160 250-260	30	2	x		Tehama, Modesto	x	x	x	x	x	x	

Table 4-2. Groundwater Monitoring Network Wells

No.	County	State Well Number	CASGEM[a] Station ID	Well Completion Report ID	Latitude, decimal degrees	Longitude, decimal degrees	Datum	Well Use	Well Status	Well Completion Type (single or nested)	Ground Surface Elevation, feet	Reference Point Elevation, feet	Reference Point Description	Borehole Depth, feet, bgs[b]	Completed Well Depth, feet, bgs	Screen Intervals, feet, bgs	Total Length of Screen, feet	Casing Diameter, inches	Representative GWL Site[c]	Representative ISW Site[d]	Primary Geologic Formation	Assessment Category						Notes
																						Existing Monitoring Network	Known Construction	Non-Pumping Well	Nested Well	Proximity to Surface Water[e]	Accessible and Usable	
101	Glenn	22N02W30H004	38609	726922	39.73253	-122.12304	NAD 83	Observation	active	nested	204.43	206.43	top of tallest casing	920	80	45-55 60-70	20	2		x	Tehama, Modesto	x	x	x	x	x	x	
102	Glenn	22N03W24E001	25236	726923A	39.74717	-122.15597	NAD 83	Observation	active	nested	230.51	231.70	top of shortest casing	860	840	800-820	20	2			Tehama	x	x	x	x	x	x	
103	Glenn	22N03W24E002	38667	726923B	39.74717	-122.15597	NAD 83	Observation	active	nested	230.51	231.93	top of middle casing	860	195	130-150 170-180	30	2	x		Modesto	x	x	x	x	x	x	
104	Glenn	22N03W24E003	25758	726923C	39.74717	-122.15597	NAD 83	Observation	active	nested	230.51	232.41	top of tallest casing	860	70	50-60	10	2		x	Modesto	x	x	x	x	x	x	

(a) California's Statewide Groundwater Elevation Monitoring Program (CASGEM).
(b) Below ground surface (bgs).
(c) Representative Groundwater Level (GWL) Monitoring Network Site.
(d) Representative Interconnected Surface Water (ISW) Monitoring Site.
(e) Monitoring sites located within 200 feet of an existing water channel or water body.
(f) California Department of Water Resources (DWR), 2001, Lower Colusa Basin Conjunctive Use Investigation: Monitoring Network Completion Report, June 1999. (DWR, 2001)
(g) Latitude and longitude values are in North American Datum of 1983 (NAD 83), decimal degrees.
(h) Email correspondence from Roy Hull, DWR North Region Office, received November 16, 2017. (Roy Hull, DWR, 2017)
(i) U.S. Bureau of Reclamation (USBR).
(j) NA denotes field where data was not unknown or unavailable.
(k) U.S. Geological Survey (USGS).



Groundwater Monitoring Network Well

Well Removed from Groundwater Monitoring Network due to Damage or Destruction

Existing Well to Potentially Add to the Groundwater Monitoring Network

Colusa Subbasin

Water Agencies

U.S. Fish and Wildlife Refuge

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

N

0 2.5 5

Scale in Miles

Figure 4-2

Proposed Groundwater Monitoring Network Wells

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

4.2.1.3 Monitoring Protocols

Data will either be obtained from the agencies that are responsible for managing the monitoring sites within the groundwater quality monitoring network or downloaded from dataset host websites. The Subbasin GSAs will continue to coordinate and collaborate with other agencies regarding their monitoring programs and data acquisition. Issues with obtaining data is not anticipated to occur and the GSAs will consider implementing their own monitoring programs, if necessary. Water levels measured in the Subbasin groundwater monitoring network wells can be found in multiple online state websites including:

- CASGEM website: https://www.casgem.water.ca.gov
- DWR Water Data Library (WDL) website: https://wdlbeta.water.ca.gov/Map.aspx
- California Natural Resources Agency (CNRA) website: https://data.cnra.ca.gov/dataset/periodic-groundwater-level-measurements

Since all of the wells identified as part of the Subbasin groundwater monitoring network are included in existing DWR monitoring programs, water levels being collected comply with existing regulatory protocols. These protocols also comply with those required in the Monitoring Protocols BMP (DWR, 2016c), which are summarized below for both methodology and frequency.

4.2.1.3.1 Methodology

The Monitoring Protocols, Standards, and Sites Best Management Practices (Monitoring Protocols BMP, DWR, 2016c) recommends the following monitoring conditions:

- Groundwater levels should be measured from a pre-established and recorded reference point.
- Groundwater levels should be measured using approved measurement equipment. Equipment should be operated, calibrated, maintained in accordance with the manufacturer's instructions.
- When well caps are removed, signs of pressure release should be noted. If pressure release is noted, an appropriate time should be allowed for the water surface to equilibrate to aquifer conditions. Multiple measurements may be taken to assess whether equilibration has been reached.
- Questionable measurements should be appropriately noted at time of monitoring.
- All salient conditions should be recorded at time of monitoring.
- Water levels shall be measured to the nearest 0.1 foot, at a minimum (23 CCR §352.4(a)(3)).
- Water level equipment should be decontaminated after each use.
- Measurements should be collected from all monitoring sites within as short a time period as possible; in general, one to two weeks is acceptable. All data should be entered into the data management system as soon as possible.

In addition to manual measurements, pressure transducers connected to data loggers may be used to monitor groundwater levels (DWR, 2016). Pressure transducers should be installed in conjunction with manual depth to water measurements; it is recommended that GWE be calculated after data have been downloaded to prolong the battery life of the unit. The Monitoring Protocols BMP identifies the following requirements when using data loggers:

- All transducers should be installed, operated, and maintained in accordance with the manufacturer's specifications.
- Unvented pressure transducers should be corrected for barometric pressure with continuous data from a barometric transducer.
- Groundwater levels should be recorded to the nearest 0.1 foot, at a minimum.
- The pressure transducers should be assessed to determine if the unit is capable of recording data to an appropriate precision and accuracy. Instrument drift due to groundwater conditions, battery life, and storage capacity should be taken into consideration when GWE are being calculated.
- Manual groundwater levels should be measured to maintain data logger integrity.

4.2.1.3.2 Frequency

Manual water level measurements shall be collected twice annually, at a minimum, to ensure seasonal trends are well accounted for (23 CCR §354.34(c)(1)(B)). Manual measurements for all network wells should be collected in the spring and fall, at a minimum, unless more frequent measurements are required to characterize changes in groundwater levels.

4.2.1.4 Data Gaps in Groundwater Level Monitoring Network

23 CCR §354.38(b) defines data gaps as occurring where there is an insufficient number of monitoring sites, insufficient monitoring frequency, or unreliable monitoring sites. Data gaps can also occur when collected data are of insufficient quality or quantity to support evaluation of the sustainability indicators (Monitoring Network BMP, 2016b).

The groundwater monitoring network was assessed based on requirements listed in the Monitoring Network BMP and 23 CCR §354.34. Spatial or temporal density and quality of monitoring sites were then assessed to identify potential data gaps. Data gaps within the groundwater monitoring network were evaluated for all criteria and categorized as follows:

- Usability of the monitoring site due to:
  - Wells screened across multiple water-bearing units and principal aquifers
- Spatial distribution of monitoring sites with regard to:
  - Presence near a surface water body
  - Full lateral and vertical extent of coverage
  - Areas and depths with known groundwater level decline (e.g., near Orland where an increase of drying shallow domestic wells is currently occurring).

Many of the surface waters are near wells included in the current groundwater monitoring network, except for surface waters in the following areas:

- Within the Colusa National Wildlife Refuge, east of Williams (Figure 4-1). There are no network groundwater monitoring wells near the Colusa National Wildlife Refuge.
- North and northwest of Orland near Stony Creek.
- Northwest of Artois along the middle reaches of Walker Creek.
- Northwest of Willows along the middle reaches of Willow Creek.

4.2.1.5 Proposed Actions to Address Data Gaps

Figure 4-2 shows the Subbasin groundwater monitoring network and recommended revisions. The recommended revisions include:

- Potential "replacement" wells that would replace historical monitoring wells that have been removed from the groundwater monitoring network due to well destruction or damage. The "replacement" wells are existing wells that could be added to the Subbasin groundwater monitoring network.
- Potential existing wells to add to the Subbasin groundwater monitoring network to address data gaps in spatial coverage.

Existing wells proposed to be added to the groundwater monitoring network and the rationale for selection are listed in Table 4-3.

Table 4-3. Existing Wells Proposed to be Added to the Groundwater Monitoring Network

State Well Number	Location	Existing Groundwater Monitoring Network	Rationale for Selection
15N04W11G001	Colusa County	DWR CASGEM/WDL[(a)]	Expand lateral monitoring network coverage towards the subbasin's western margin.
16N03W35M001	Colusa County	DWR CASGEM/WDL	Replacement for 16N03W35N002M, an inaccessible caved-in well. Similar location and construction characteristics.

(a) California Department of Water Resources (DWR) California Statewide Groundwater Elevation Monitoring (CASGEM) and/or Water Data Library (WDL).

It is recommended that a field survey be conducted of all current groundwater monitoring network sites to verify latitude and longitude coordinates, well depths, ground surface elevations, reference point elevations, and descriptions in accordance with the requirements described in 23 CCR §352.4(a) through (c). Monitoring frequencies should also be verified for compliance with requirements set forth in 23 CCR §354.34(c)(1)(B).

Additional monitoring sites are recommended for urban areas, near surface waters, and within areas with reported occurrences of drying shallow domestic wells. New monitoring sites would require a well siting study or public survey, as well as continued coordination with local stakeholders and DWR, to determine existing wells to include as monitoring sites or determine land suitable for the construction of new

monitoring wells. Evaluation of the shallow unconfined portion of the principal aquifer is ongoing by DWR and the Colusa Subbasin GSAs and will impact scope of work to address this data gap.

Annual reports and future revisions to the GSP will provide updates on actions taken to address data gaps over the reporting period.

4.2.2 Groundwater Quality Monitoring

The primary groundwater quality constituent of concern within the Subbasin is salinity, specifically the upwelling of brackish connate water into the principal aquifer. There are many existing programs that monitor for and manage salinity (e.g., total dissolved solids or electrical conductivity) in groundwater. In lieu of managing and monitoring a groundwater quality monitoring program of its own, the Colusa Subbasin GSAs will utilize data collected via existing groundwater quality monitoring programs. The GSAs will continue to coordinate and collaborate with other agencies regarding their monitoring programs, including changes to monitoring sites, monitoring protocols or frequencies, and management actions. Data acquisition is not anticipated to be an issue. If necessary, the GSAs will consider implementing their own monitoring programs to address concerns over undesirable results, data gaps in the monitoring networks, or GSP project needs. A discussion of recommendations to address any data gaps within the existing monitoring networks is provided in this section.

4.2.2.1 Requirements

In accordance with the Monitoring Network BMP (DWR, 2016b), the groundwater quality monitoring network shall be designed such that the sustainability indicators are adequately covered not just over the entire subbasin, but also within any specific GSP-defined Management Areas, of which there are none defined within the Subbasin. The groundwater quality monitoring network shall be designed to collect sufficient spatial and temporal data from the principal aquifer to enable determination of groundwater quality trends and to address known water quality issues (23 CCR §354.34(c)(4)).

Data collected from the groundwater quality monitoring network should be sufficient to:

- Enable definition of the three-dimensional extent of impacts;
- Enable mapping of transient water quality degradation;
- Facilitate assessment of groundwater quality impacts to beneficial uses and users;
- Enable evaluation of management practice impacts to groundwater quality degradation;
- Support evaluation of movement and concentration of brackish or saline waters.

The Subbasin groundwater quality monitoring network mostly meets these requirements. Data gaps within the groundwater quality monitoring network are mostly regarding mapping of three-dimensional impacts and migration of poor-quality waters. Data gaps in the network are discussed in Section 4.2.2.4.

4.2.2.2 Groundwater Quality Monitoring Network

Groundwater quality monitoring network locations for the Subbasin include wells identified and currently being monitored for salinity under existing regulatory programs. These include groundwater monitoring conducted by coalitions formed under Irrigated Lands Regulatory Program (ILRP) and public drinking water supply communities regulated by the State Water Resources Control Board (SWRCB) Division of Drinking Water. The Subbasin representative groundwater quality monitoring network includes 54 monitoring sites. Table 4-4 includes the Subbasin groundwater quality monitoring network programs. The

wells included in those programs as of 2020 are listed in Appendix 4B. Their locations are shown on Figure 4-3.

Table 4-4. Groundwater Quality Monitoring Network

Monitoring Program	Responsible Agency	Number of Wells in the Colusa Subbasin
SWRCB DDW[a,b]	Del Oro Water Company – Black Butte District	1
SWRCB DDW	Black Butte Mobile Home Park	1
SWRCB DDW	City of Orland	6
SWRCB DDW	Country Leisure Mobile Estates	1
SWRCB DDW	Orland Estates Mobile Home Park	2
SWRCB DDW	Orland Mobile Home Park	1
SWRCB DDW	Orland Oaks Mobile Home Park	1
SWRCB DDW	Shady Oaks Trailer Park	1
SWRCB DDW	Voyles Trailer Park	1
SWRCB DDW	Willows Mobile Home Community & RV Park	1
SWRCB DDW	Artois Community Service District	2
SWRCB DDW	Cal-Water Service Company - Willows	5
SWRCB DDW	Colusa County Water Works District #2 – Princeton	2
SWRCB DDW	Maxwell Public Utility District	1
SWRCB DDW	City of Colusa	5
SWRCB DDW	City of Williams	3
SWRCB DDW	Colusa County Water Works District #1 – Grimes	1
SWRCB DDW	Arbuckle Public Utility District	4
SWRCB DDW	Del Oro Water Company – Arbuckle District	1
ILRP[c]	California Rice Commission[d]	10
ILRP	Sacramento Valley Water Quality Coalition[e]	4

(a) SWRCB DDW = State Water Resources Control Board Division of Drinking Water.
(b) Representative groundwater quality monitoring wells were selected from the bolded agencies' monitoring well network.
(c) ILRP = Irrigated Lands Regulatory Program.
(d) Central Valley Regional Water Quality Control Board. 2016.
(e) Luhdorff and Scalmanini. 2019.

Active community water system wells regulated under SWRCB Division of Drinking Water from each municipal or community water system within the Subbasin were selected for the Subbasin groundwater quality monitoring network. Community water systems are defined as "public water systems that serve at least 15 service connections used by yearlong residents or regularly serves at least 25 yearlong residents of the area served by the system" and may include municipalities, community services districts, and mobile home and trailer parks. These public supply wells are constructed at varying depths throughout the subbasin and are sampled and monitored by their respective water supply agency. As of the issuance of this Colusa Subbasin GSP, there are 40 active wells being monitored by 19 public water supply agencies included in the SWRCB Division of Drinking Water.

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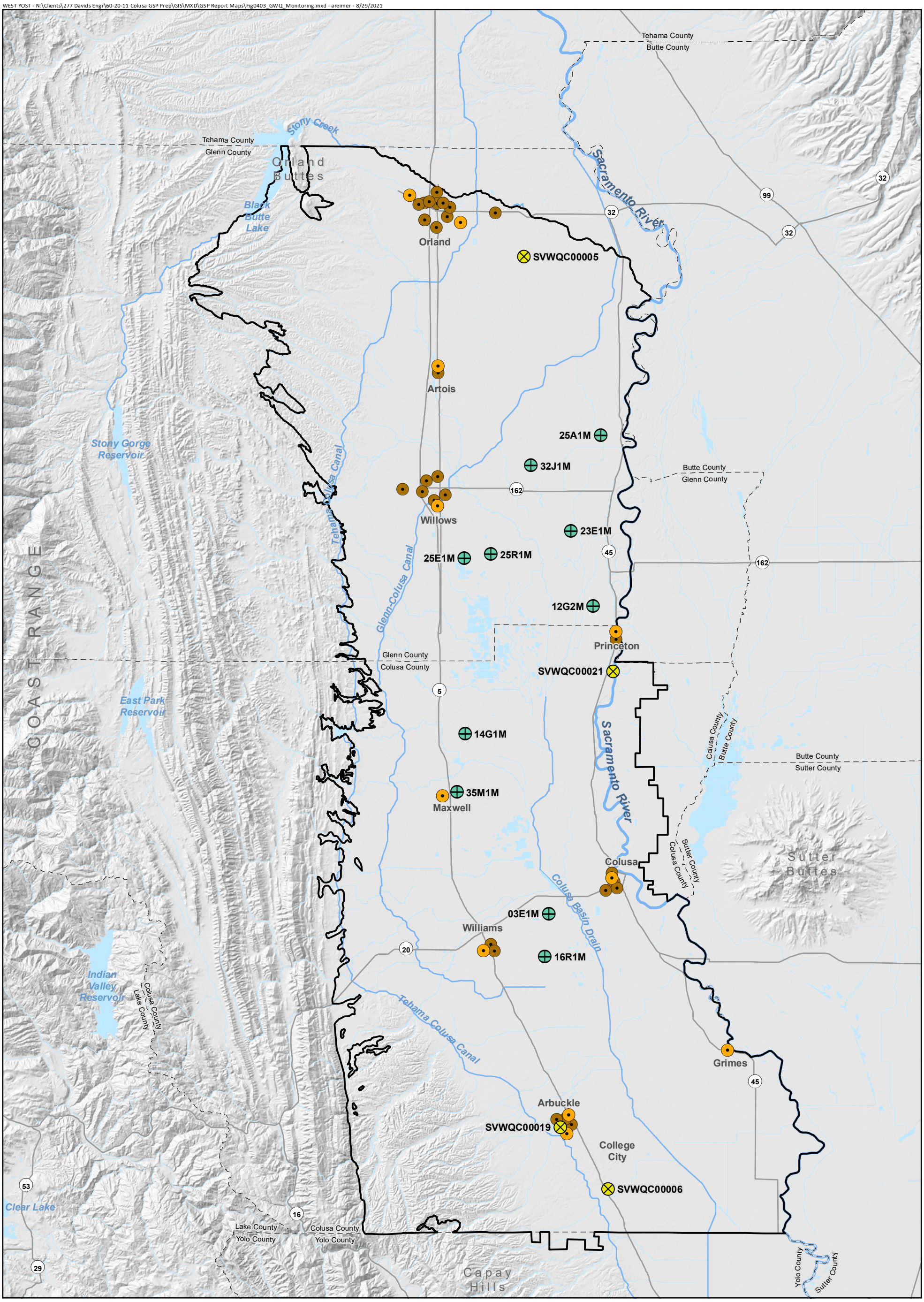

Colusa Subbasin

Representative California Rice Commission Groundwater Monitoring Well

Representative Sacramento Valley Water Quality Coalition Groundwater Monitoring Well

Representative Public Water Supply Well

Other Active Public Water Supply Well

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

N

0 2.5 5

Scale in Miles

Figure 4-3

Groundwater Quality Monitoring Network Wells

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

The California Rice Commission ILRP groundwater quality trend network includes USGS-managed wells within and surrounding the California Rice Commission management area (CH2MHILL, 2016a). Ten of these wells are within the Subbasin (CVRWQCB, 2016) and are included in the Subbasin groundwater quality monitoring network. All ten of the wells are relatively shallow (less than 40 feet deep) and located near rice ponds, irrigation canals, and other agricultural fields and infrastructure. Water chemistry within these wells will provide information regarding shallow instances of increased salinity within agricultural areas.

The Sacramento Valley Water Quality Coalition Groundwater Quality (SVWQC) Trend Monitoring Program, formed under ILRP, includes four wells within the Subbasin (Luhdorff and Scalmanini, 2019). One well is in Glenn County, just south of Stony Creek, one well is near the intersection of the Sacramento River and the Glenn-Colusa County boundary line, and the other two are near Arbuckle, Colusa County. The SVWQC wells are public or domestic water supply wells of moderate depths (100 to 300 feet deep). SVWQC's monitoring program started in 2020 and is relatively new. As such, there is not much information available for these wells as of the writing of this GSP.

The groundwater quality monitoring network will be re-evaluated and updated in annual reports and future revisions of the Subbasin, as necessary to address the needs and concerns of the GSAs and local stakeholders. The Colusa Subbasin GSAs will continue to coordinate with the existing monitoring agencies to account for any changes in well status or sampling frequencies. Additionally, water quality data from wells included in other groundwater quality monitoring programs discussed in Chapter 2, but not yet included in the Subbasin groundwater quality monitoring network, will be evaluated during future groundwater condition investigations for the Subbasin.

4.2.2.3 Monitoring Protocols

Data will either be obtained from the agencies that are responsible for managing the monitoring sites within the groundwater quality monitoring network or downloaded from dataset host websites. A listing of the websites is provided below:

- SWRCB Division of Drinking Water wells:
  - SWRCB Drinking Water Watch website: https://sdwis.waterboards.ca.gov/PDWW/
  - CNRA website: https://data.cnra.ca.gov/dataset/ground-water-water-quality-results
- California Rice Commission (CRC) wells:
  - California Rice Commission contact: https://calrice.org/
  - USGS National Water Information System (NWIS) website: https://waterdata.usgs.gov/nwis
  - GeoTracker Groundwater Ambient Monitoring & Assessment Program (GAMA) website: http://geotracker.waterboards.ca.gov/gama/
- Sacramento Valley Water Quality Coalition wells:
  - SVWQC contact: https://www.svwqc.org/
  - GeoTracker ESI website: https://geotracker.waterboards.ca.gov/

Most recent data will be more easily obtained directly from the responsible agency instead of via the alternate host websites. The GSAs will continue to coordinate and collaborate with other agencies regarding their monitoring programs, including changes to monitoring sites, monitoring protocols or frequencies, and management actions. Data acquisition is not anticipated to be an issue. If necessary, the GSAs will consider implementing their own monitoring programs to address concerns over undesirable

results, data gaps in the monitoring networks, or GSP project needs. A discussion of recommendations to address any data gaps within the existing monitoring networks is provided later in this section.

Since all of the wells identified as part of the Subbasin groundwater quality monitoring network are included in existing monitoring programs, water quality samples being collected must comply with existing regulatory sampling and testing protocols. Water quality samples collected from public drinking water wells and reported to SWRCB comply with SWRCB sampling and testing protocols for drinking water. Water quality samples collected from the California Rice Commission and SVWQC wells comply with sampling and testing protocols required by the Regional Water Quality Board for compliance under ILRP and CV-SALTS. These protocols also comply with those required in the Monitoring Protocols BMP (DWR, 2016c), which are summarized below:

- All water quality analyses should be performed by a State Environmental Laboratory Accreditation Program certified laboratory.
- Groundwater quality sampling protocols should follow USGS National Field Manual for the Collection of Water Quality Data (Wilde, 2005 or more recent).
- Groundwater sampling protocols should ensure that salient data are recorded and all data are handled such that integrity is maintained.
- Samples from pumping wells should be collected near the wellhead.
- All sampling equipment and ports should be free of contaminants and decontaminated between sampling locations.
- Wells not equipped with low-flow sampling taps should be purged prior to sampling to ensure sampling is of ambient groundwater conditions and not borehole storage conditions. Typically, three casing volumes purged is adequate.
- If purging or pumping causes a well to be evacuated, allow 90 percent recovery prior to sampling.
- Samples should be collected under laminar flow conditions.
- Samples should be collected according to appropriate standards. The sample collection procedure should reflect the type of analysis being performed.
- Samples should be preserved at the time of sampling. Samples should be filtered, as appropriate.
- Samples should be chilled after collection to prevent degradation.
- Chain of custody forms should be used to track procession of the samples.
- Analytical laboratories should utilize reporting limits that are equal to or less than the regional water quality objectives and screening levels.

4.2.2.4 Data Gaps in Groundwater Quality Monitoring Network

Potential data gaps have been identified within the proposed groundwater quality monitoring network:

- The current California Rice Commission groundwater monitoring plan to collect groundwater quality samples every two years and the varying sampling frequency of public water supply wells may not be sufficient to satisfy the requirements set forth in the Monitoring Network BMP (DWR, 2016b) or to satisfy the Colusa Subbasin GSAs' goal of tracking salinity concentrations.

- The existing groundwater quality monitoring network does not provide full monitoring coverage in areas with salinity concerns. Specifically, sites may not be sufficient to monitor the movement of brackish or saline waters in the area west and south of the Sutter Buttes and near the City of Williams.
- It is possible that the existing groundwater quality monitoring networks may not be sufficient to adequately allow differentiation between upwelling or intrusion of deeper brackish/connate waters or percolation recharge of waters with elevated salinity into the freshwater aquifer system.
- Existing monitoring networks are managed by other agencies. Monitoring locations and frequencies are subject to change based on the needs of the existing monitoring programs.

4.2.2.5 Proposed Actions to Address Data Gaps

Groundwater quality data collected under existing regulatory programs may not be sufficient for SGMA compliance. The Colusa Subbasin GSAs will consider coordinating with the SVWQC, Northern California Water Association (NCWA), and the California Rice Commission in the establishment and ongoing evaluation of these groundwater quality monitoring network sites with the goal of using data collected under the ILRP for SGMA compliance.

The wells included in the groundwater level monitoring network (discussed in Section 4.2.1) provide ample spatial coverage throughout the Subbasin. These wells, shown on Figure 4-1, would be good potential sites to add to the groundwater quality monitoring network in areas with identified salinity and upwelling concerns. The wells could be sampled regularly, at varying frequencies, in accordance with the needs of the Colusa Subbasin GSAs and local stakeholders.

The SWRCB GeoTracker and GeoTracker GAMA databases include information from a variety of monitoring and public wells, including domestic and agricultural irrigation wells. The GeoTracker sites are continuously being updated with new data and should be evaluated for all future Subbasin water quality projects and studies.

Annual reports and future revisions to the GSP will provide updates on actions taken to address data gaps over the reporting period.

4.2.3 Land Subsidence Monitoring

Land subsidence has been measured within the Subbasin. There are several existing programs in place to monitor and measure ongoing land subsidence. Many of these existing programs are included in the Subbasin land subsidence monitoring network so that the GSAs and local stakeholders can best determine the rate and extent of subsidence within the subbasin boundaries.

4.2.3.1 Requirements

In accordance with the Monitoring Network BMP (DWR, 2016b), the land subsidence network shall be designed such that the sustainability indicators are adequately covered, not just over the entire subbasin, but also within any specific GSP-defined Management Areas, of which there are none defined within the Subbasin. The land subsidence monitoring network shall be designed to enable the characterization of the rate and extent of subsidence by providing consistent, accurate, and reproducible results (23 CCR §354.34(c)(5); DWR, 2016).

Monitoring sites shall be compliant with requirements listed in 23 CCR §352.4(a) through (b).

The Subbasin land subsidence monitoring network meets these requirements. Data gaps in the network are discussed in Section 4.2.3.4.

4.2.3.2 Land Subsidence Monitoring Network

The Subbasin land subsidence monitoring network is comprised of survey benchmarks, benchmarks, continuous GPS stations, extensometers, and remote sensing data. Table 4-5 lists the benchmarks, continuous GPS stations, and extensometers included in the land subsidence monitoring network. Figure 4-4 shows these locations relative to the subbasin. All of the land subsidence monitoring network sites and remote sensing programs are managed and monitored through the following agencies and programs.

California DWR Ground Surface Displacement - Land Subsidence Monitoring

Extensometers are land surface displacement sensors that are installed inside of groundwater monitoring wells. A cable or pipe attached to the bottom of the well is connected to a sensor at the top of the well. Subsidence or land displacement due to compaction of sediment between the bottom of the well and the top can be detected to the nearest 0.01 foot by installed extensometers.

DWR monitors eleven extensometers within the Sacramento Valley, four of which are installed in wells within the Subbasin. One extensometer is within the Glenn County portion of the Corning Subbasin, just north of Stony Creek. All five of the extensometers within Glenn and Colusa Counties are included in the Subbasin land subsidence monitoring network.

UNAVCO Plate Boundary Observatory GPS/GNSS Network

The University of California Agriculture and Natural Resources (UNAVCO) Plate Boundary Observatory (PBO) network of continuously operating global positioning system (CGPS) stations was developed for measuring vertical and horizontal deformation of the North American and Pacific tectonic plates in the western United States. The data collected with the CPGS stations, however, can be used for near-real-time measurements of land subsidence.

There are two CPGS stations within the Subbasin, both in Colusa County west of the Sutter Buttes. Two additional stations are located out of the Subbasin in the Coast Range foothills west of Willows and west of Arbuckle. One station is located in the Sutter Buttes. The stations are measured on 15-second intervals and data is evaluated to provide a daily displacement record.

Sacramento Valley Height Modernization Project

The Sacramento Valley benchmark network is managed by DWR in cooperation with USBR and local agencies to both monitor land subsidence and extend the high-accuracy geodetic control of USBR facilities. As of 2017, the network contained 305 benchmarks within the Sacramento Valley, of which 63 benchmarks are located within the Subbasin and 76 benchmarks are included in the Subbasin land subsidence monitoring network. The benchmarks are surveyed by field crews on an as-needed or as-requested basis.

Table 4-5. Land Subsidence Monitoring Network Extensometers and Benchmarks

Groundwater Subbasin	County	Station ID	Latitude[a]	Longitude	Frequency	Monitoring Agency	Site Type
Colusa	Colusa	16N02W05B001	39.27527	-122.10568	Daily	DWR[b]	Extensometer[c]
Colusa	Colusa	17N02W09H002	39.34170	-122.08377	Daily	DWR	Extensometer
Colusa	Glenn	19N02W08Q001	39.51596	-122.11143	Daily	DWR	Extensometer
Colusa	Glenn	21N02W33M001	39.62970	-122.10045	Daily	DWR	Extensometer
Colusa	Colusa	P270	39.24377	-122.05520	Daily	UNAVCO[d]	Continuous GPS Benchmark[e]
Colusa	Colusa	P272	39.14548	-121.93406	Daily	UNAVCO	Continuous GPS Benchmark
Colusa[f]	**Colusa**	**COLI**	**39.18514**	**-121.99461**	**TBD[g]**	**DWR**	**Benchmark[h]**
Colusa	**Colusa**	**D850**	**39.14268**	**-122.21725**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**DELE**	**39.27528**	**-122.10558**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**DLP2**	**39.19113**	**-122.17126**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**DODG**	**39.37739**	**-122.02070**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**DRAI**	**38.92529**	**-121.91457**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**F200**	**39.31920**	**-122.19154**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**FINK**	**39.25828**	**-122.19148**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**GORD**	**39.40956**	**-122.00997**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**GRNO**	**39.05664**	**-121.96914**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**H62U**	**39.12059**	**-122.29094**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**HAHN**	**39.08068**	**-122.09838**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**HARB**	**39.24734**	**-122.03128**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**HPKN**	**39.21772**	**-122.08883**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**JRM4**	**38.92774**	**-121.84330**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**LAUX**	**39.24547**	**-121.95867**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**LONE**	**39.17702**	**-122.07852**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**LUSA**	**38.97056**	**-122.02556**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**NLD6**	**39.11442**	**-122.01828**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**SECO**	**39.02883**	**-122.06393**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**SR65**	**39.31529**	**-122.03400**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**STEG**	**39.34150**	**-122.08425**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**T644**	**39.13183**	**-122.13209**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**TC22**	**39.05341**	**-122.15435**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**TC23**	**39.01061**	**-122.09302**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**W850**	**39.37778**	**-122.24806**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**WAYN**	**38.99358**	**-121.95819**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**WBND**	**39.04187**	**-121.83686**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**WDWD**	**38.93141**	**-122.06109**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**WHEA**	**39.07662**	**-121.89427**	**TBD**	**DWR**	**Benchmark**
Colusa	**Colusa**	**WILK**	**38.99058**	**-121.86709**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**1118**	**39.65967**	**-122.02694**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**2085**	**39.74664**	**-122.12269**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**6064**	**39.39964**	**-122.28803**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**AGUI**	**39.72608**	**-122.24058**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**ARTO**	**39.62432**	**-122.20473**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**BEND**	**39.62986**	**-121.99831**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**BIGW**	**39.67254**	**-122.33616**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**C200**	**39.40630**	**-122.19228**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**CHER**	**39.66815**	**-122.25317**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**CREE**	**39.73149**	**-122.41332**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**EXT1**	**39.62967**	**-122.10220**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**FREN**	**39.58243**	**-122.24968**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**GLEN**	**39.52165**	**-122.01480**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**JACI**	**39.58242**	**-122.01000**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**K852**	**39.69694**	**-122.19524**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**KAIS**	**39.70917**	**-122.03745**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**L191**	**39.58203**	**-122.12229**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**LARK**	**39.49276**	**-122.08760**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**M107**	**39.46981**	**-122.19286**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**MINO**	**39.46442**	**-122.13664**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**NORM**	**39.40751**	**-122.13629**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**OWEN**	**39.46565**	**-122.24895**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**P30W**	**39.65274**	**-122.15119**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**PETE**	**39.69582**	**-122.10299**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**PROV**	**39.52184**	**-122.08860**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**Q107**	**39.52422**	**-122.23729**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**TCCO**	**39.62555**	**-122.27261**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**V380**	**39.78232**	**-122.29498**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**WALK**	**39.52420**	**-122.16497**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**WILL**	**39.43593**	**-122.07612**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**WILN**	**39.57084**	**-122.19379**	**TBD**	**DWR**	**Benchmark**
Colusa	**Glenn**	**Y852**	**39.45718**	**-122.01761**	**TBD**	**DWR**	**Benchmark**
Butte	Butte	7MIL	39.63631	-121.90997	TBD	DWR	Benchmark
Butte	Butte	B109	39.53803	-121.90831	TBD	DWR	Benchmark
Butte	Butte	BCEX	39.57706	-121.90831	TBD	DWR	Benchmark
Butte	Butte	FREX	39.66553	-121.92506	TBD	DWR	Benchmark
Butte	Butte	NLD7	39.36214	-121.86808	TBD	DWR	Benchmark
Butte	Colusa	PTNM	39.33181	-121.95453	TBD	DWR	Benchmark
Butte	Glenn	1122	39.51501	-121.93004	TBD	DWR	Benchmark
Butte	Glenn	1127	39.45017	-121.91706	TBD	DWR	Benchmark
Butte	Glenn	1500	39.46406	-121.92539	TBD	DWR	Benchmark
Butte	Glenn	ADOB	39.39075	-121.95015	TBD	DWR	Benchmark
Butte	Glenn	HOWA	39.42011	-121.89788	TBD	DWR	Benchmark
Corning	Glenn	22N02W15C002	39.76352	-122.07727	Daily	DWR	Extensometer
Corning	Glenn	2966	39.79034	-122.22586	TBD	DWR	Benchmark
Corning	Glenn	CAPA	39.78244	-122.10402	TBD	DWR	Benchmark
Corning	Glenn	HAMI	39.74437	-122.02057	TBD	DWR	Benchmark
Corning	Glenn	ORLA	39.76848	-122.19233	TBD	DWR	Benchmark
Corning	Glenn	PMPR	39.78431	-122.04597	TBD	DWR	Benchmark
Corning	Glenn	VIOL	39.76637	-122.07760	TBD	DWR	Benchmark
Corning	Glenn	WILD	39.71269	-121.96469	TBD	DWR	Benchmark
Corning	Tehama	BUTG	39.81825	-122.32561	TBD	DWR	Benchmark
Corning	Tehama	K276	39.85558	-122.35492	TBD	DWR	Benchmark
Corning	Tehama	N852	39.80959	-122.17255	TBD	DWR	Benchmark
Corning	Tehama	SRGS	39.83700	-122.19756	TBD	DWR	Benchmark
Sutter	Sutter	0304	39.14328	-121.90174	TBD	DWR	Benchmark
Sutter	Sutter	ENNS	39.08444	-121.80039	TBD	DWR	Benchmark
Sutter	Sutter	PASS	39.18694	-121.87767	TBD	DWR	Benchmark
Sutter	Sutter	PELG	38.95292	-121.75322	TBD	DWR	Benchmark
Sutter	Sutter	TARK	39.14319	-121.84265	TBD	DWR	Benchmark
Sutter	Sutter	TSDL	39.02147	-121.74125	TBD	DWR	Benchmark
Sutter	Sutter	WR18	39.25300	-121.89167	TBD	DWR	Benchmark
Vina	Butte	MERI	39.75321	-121.93846	TBD	DWR	Benchmark
Yolo	Yolo	BIRD	38.84854	-122.04374	TBD	DWR	Benchmark
Yolo	Yolo	HERS	38.87468	-121.91444	TBD	DWR	Benchmark
Yolo	Yolo	TYND	38.87394	-121.81773	TBD	DWR	Benchmark
Yolo	Yolo	X200	38.90576	-121.98328	TBD	DWR	Benchmark
None	Colusa	P269	38.99953	-122.35455	Daily	UNAVCO	Continuous GPS Benchmark
None	Colusa	P208	39.10097	-122.30108	TBD	DWR	Benchmark
None	Glenn	P336	39.52808	-122.43047	Daily	UNAVCO	Continuous GPS Benchmark
None	Glenn	A107	39.58564	-122.40492	TBD	DWR	Benchmark
None	Glenn	H285	39.55203	-122.35723	TBD	DWR	Benchmark
None	Glenn	U107	39.53084	-122.32621	TBD	DWR	Benchmark
None	Glenn	WINS	39.66351	-122.52596	TBD	DWR	Benchmark
None	Glenn	Y380	39.76272	-122.33738	TBD	DWR	Benchmark
None	Sutter	SUTB	39.20583	-121.82058	Daily	UNAVCO	Continuous GPS Benchmark

(a) Latitude and longitude values are in North American Datum of 1983 (NAD 83), decimal degrees.
(b) Extensometers are maintained and managed by California DWR under their Ground Surface Displacement-Land Subsidence Monitoring program.
(c) Extensometers include those that are within or near the Colusa Subbasin. Extensometers are installed at depths of approximately 700-800 ft.
(d) Continuous global positioning system (GPS) benchmark data is received, cleaned, and managed by UNAVO's Geodetic Facility for the advancement of Geoscience (GAGE) Facility with support from the National Science Foundation and NASA.
(e) Continuous global positioning system (GPS) benchmark.
(f) Bolded benchmarks are included in the representative land subsidence monitoring network and were used to determine the sustainability thresholds discussed in Chapter 5.
(g) Frequency to be determined (TBD). Benchmarks have historically been re-surveyed irregularly, on an as-needed/as-requested basis, by DWR staff in coordination with local agencies.
(h) Benchmarks are those listed for the Sacramento Valley Height Modernization Project within 5 miles of the Colusa Subbasin.

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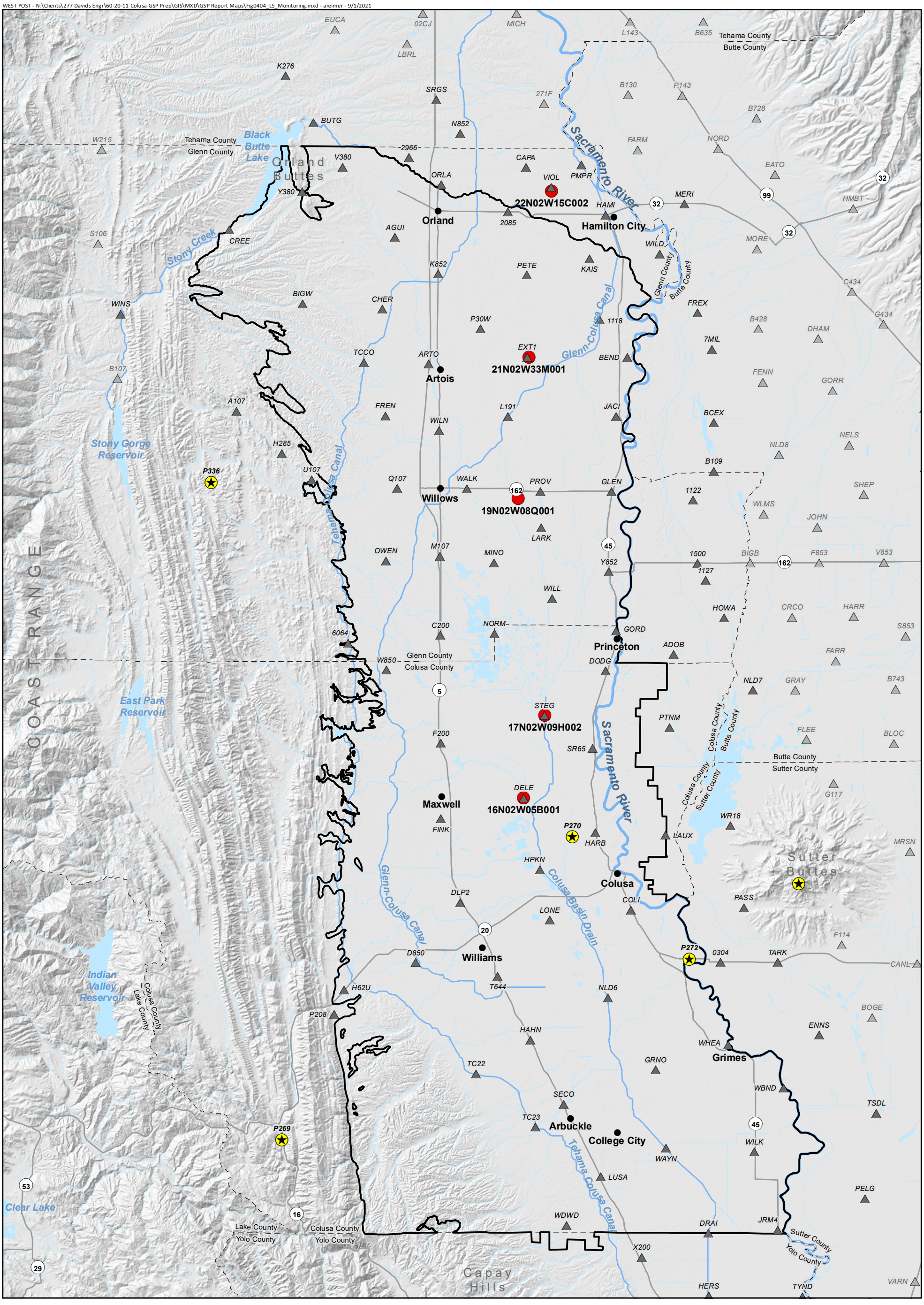

Extensometer

Continuous GPS Station

Sacramento Valley Benchmark Included in the Monitoring Network

Sacramento Valley Benchmark Not Included in the Monitoring Network

Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

N

0 2.5 5

Scale in Miles

Figure 4-4

Land Subsidence Monitoring Network

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

InSAR Remote Sensing

The land subsidence monitoring network is mostly comprised of discrete monitoring point locations. The exception to this are remote sensing datasets. Interferometric Synthetic Aperture Radar (InSAR) is a remote sensing technique that uses satellites to scan the earth's surface and measure displacement. The technology is used for studies regarding land subsidence, tectonic movement, earthquake and volcano activity, and public safety due to earth hazards.

As part of DWR's effort to provide relevant and up-to-date data to assist with SGMA-related projects and compliance, InSAR data was collected and analyzed for vertical land displacement across the State's groundwater basins (TRE ALTAMiRA, 2020). This data was used to assess existing land subsidence conditions within the Subbasin in Chapter 3. Future InSAR surveys and other remote sensing datasets contracted for local, state, or federal agency projects will be used to monitor land subsidence within the Subbasin as they become available, and so are included in the Subbasin land subsidence monitoring network.

4.2.3.3 Monitoring Protocols

Data will either be obtained from the agencies that are responsible for managing the monitoring sites within the land subsidence monitoring network or downloaded from dataset host websites. If necessary, the Colusa Subbasin GSAs will request resurvey of the Sacramento Valley benchmarks. The relevant websites are:

- California DWR Ground Surface Displacement – Land Subsidence Monitoring:
  - CNRA website: https://data.cnra.ca.gov/dataset/wdl-ground-surface-displacement
  - UNAVCO Plate Boundary Observatory GPS/GNSS Network:
  - UNAVCO website: https://www.unavco.org/data/data.html
- Sacramento Valley Height Modernization Project:
  - California DWR Northern Region Office: No website available
- InSAR remote sensing:
  - CNRA database: https://data.cnra.ca.gov/dataset/tre-altamira-insar-subsidence
  - UNAVCO website: https://www.unavco.org/data/data.html

Since all of the land subsidence monitoring locations identified as part of the Subbasin land subsidence monitoring network are included in existing state or federal monitoring programs, collection of displacement data complies with existing regulatory monitoring protocols.

The following land subsidence monitoring protocols have been established by DWR (DWR, 2016c):

- Levelling surveys should follow standards defined in the California Department of Transportation's (Caltrans) Surveys Manual (Caltrans, assorted dates).
- Continuous GPS surveys should follow standards defined in the Caltrans Surveys Manual.
- Extensometer instruments should be installed, calibrated, and maintained per the manufacturer's instructions.
- InSAR surveys should be obtained via interpretative reports for specific regions. Raw data files may be obtained and processed instead, if needed.

4.2.3.4 Data Gaps in Land Subsidence Monitoring Network

Land subsidence has been measured in the greater Arbuckle and southern Colusa County area (Section 3.2.6). The benchmarks must be manually surveyed in order to determine the magnitude of displacement. This is currently done on an irregular frequency and does not provide short-term insight regarding ongoing land subsidence. The installation of a CGPS station or extensometer would allow near real-time monitoring of subsidence in the Arbuckle area without relying on the irregular re-survey frequency of the Sacramento Valley benchmarks.

4.2.3.5 Proposed Actions to Address Data Gaps

No additional benchmarks are recommended at this time. However, a new CGPS station or extensometer near Arbuckle, where subsidence has been occurring, is recommended. A new near real-time monitoring site located in a location with known of subsidence would provide a better understanding of the rate and magnitude of subsidence.

Additionally, all future Sacramento Valley benchmark survey reports and results will be evaluated as they are made available. The Sacramento Valley benchmarks provide a good spatial distribution of vertical displacement measurements over time. Ongoing studies using InSAR data to determine vertical displacement should also be evaluated as they are published and data is made available.

Annual reports and future revisions to the GSP will provide updates on actions taken to address data gaps over the reporting period.

4.2.4 Surface Water Monitoring

Surface water monitoring is conducive for evaluating stream-aquifer relations. Comparing stream flows and stages with groundwater levels from specific monitoring wells can provide insight into how the surface waters are interconnected with the groundwater system. The surface water monitoring network includes stream gages placed on rivers, streams, and canals. All of the stream gages included in the surface water monitoring network are managed and monitored via existing federal and state programs. The representative surface water depletion monitoring network includes shallow groundwater level monitoring wells from which water levels will be used as a proxy for evaluating surface water depletions. The representative surface water depletion monitoring network is discussed in Section 4.2.5.3.

4.2.4.1 Requirements

In accordance with the Monitoring Network BMP (DWR, 2016b), the surface water monitoring network should be designed such that the sustainability indicators are adequately covered not just over the entire subbasin, but also within any specific GSP-defined Management Areas, of which there are none defined within the Subbasin. The surface water monitoring network shall be designed to characterize spatial and temporal changes between interconnected waters such that depletions from surface waters caused by groundwater extraction can be calculated (23 CCR §354.34(c)(6); DWR, 2016b).

Data collected from the surface water monitoring network shall be sufficient to:

- Characterize flow conditions including surface water discharge, stage, and baseflows.
- Identify locations and flow periods of ephemeral and intermittent stream channels, if any. The Monitoring Network BMPs state that monitoring of ephemeral or intermittent streams should be conducted annually or as appropriate to characterize flow changes (DWR, 2016b).
- Identify temporal trends due to localized, regional, and seasonal surface water discharge and groundwater extraction impacts.
- Identify and collect information necessary to evaluate adverse effects to the beneficial use of surface water.
- Support evaluation of stream-aquifer interactions, including impacts to surface water supplies due to changes in groundwater levels and impacts to native riparian land or GDEs.

Stream gages should be located along stream reaches with known groundwater connection, per the Monitoring Network BMP (DWR, 2016b). Locations should account for surface water diversions and return flows, if necessary. Per the Monitoring Network BMP (DWR, 2016b), surface water discharge monitoring should be accompanied by groundwater level monitoring within shallow wells.

The Subbasin surface water monitoring network has been established using the best available data and science to identify, assess, and select existing monitor wells and stream gages meeting these requirements. However, significant data gaps exist, which need to be addressed during implementation of this GSP. Data gaps in the network are discussed in Section 4.2.4.4.

4.2.4.2 Surface Water Monitoring Network

Table 4-6 lists the surface water monitoring network, their locations, and monitoring frequency. These station locations are shown on Figure 4-5 and include all of the active stream gages and monitoring sites managed state and federal agencies both within and upstream of the Subbasin. The surface water monitoring sites are managed and maintained by WDL, California Data Exchange Center (CDEC), and USGS NWIS.

There are 15 active stream gages within the Subbasin surface water monitoring network.

Table 4-6. Surface Water Monitoring Network Stream Gages

County	Station ID	Station Name	Latitude[a]	Longitude	Site Type	Frequency	Source
Colusa	BSO; A02967	Butte Slough at Outfall Gates near Colusa	39.195161	121.936567	Discharge [c]	Hourly	CDEC[b]; WDL[d]
Colusa	CDR; A02976	Colusa Drain at Highway 20	39.195512	122.060517	Discharge	Hourly	CDEC; WDL
Colusa	CLW; A02981	Sacramento River at Colusa Weir	39.23682	121.99476	Discharge	Hourly	CDEC; WDL
Colusa	A00647	Freshwater Creek at Leesville Road near Williams	39.129339	122.30993	Discharge	Daily	WDL
Sutter	MPS	Meridian Pumps	39.148	121.918	Discharge	Hourly	CDEC
Colusa	MLW; A02986	Sacramento River at Moulton Weir	39.33821	122.022627	Discharge	Hourly	CDEC; WDL
Glenn	BTC; A02500	Sacramento River at Butte City	39.45784	121.99416	Discharge	Hourly	CDEC; WDL
Colusa	11389500	Sacramento River at Colusa	39.214057	122.000251	Discharge	Daily	USGS
Glenn	HMC; A02630	Sacramento River at Hamilton City	39.750925	121.997877	Discharge	Hourly	CDEC; WDL
Glenn	ORD; A02570	Sacramento River at Ord Ferry	39.628132	121.993182	Discharge	Hourly	CDEC; WDL
Sutter	TIS	Sacramento River at Tisdale Weir	39.02644	121.822083	Discharge	Hourly	CDEC
Colusa	11390500	Sacramento River below Wilkins Slough near Grimes	39.009974	121.823398	Discharge	Daily	USGS
Glenn	WCF	South Fork Willow Creek near Fruto	39.541538	122.390045	Stage	Hourly	CDEC
Tehama	BBQ	Stony Creek below Black Butte Dam	39.8186	122.3239	Stage	Event	CDEC
Glenn	SCG	Stony Creek near Grizzly Flat (County Road 200A)	39.73181	122.413997	Discharge	Hourly	CDEC

(a) Latitude and longitude are reported in North American Datum of 1983 (NAD 83), decimal degrees.
(b) California Data Exchange Center (CDEC).
(c) The term "Discharge" means that stream flows are reported. If no flows are reported but stream stage is, then the term "Stage" is used.
(d) California Department of Water Resources (DWR) Water Data Library (WDL).

1

2

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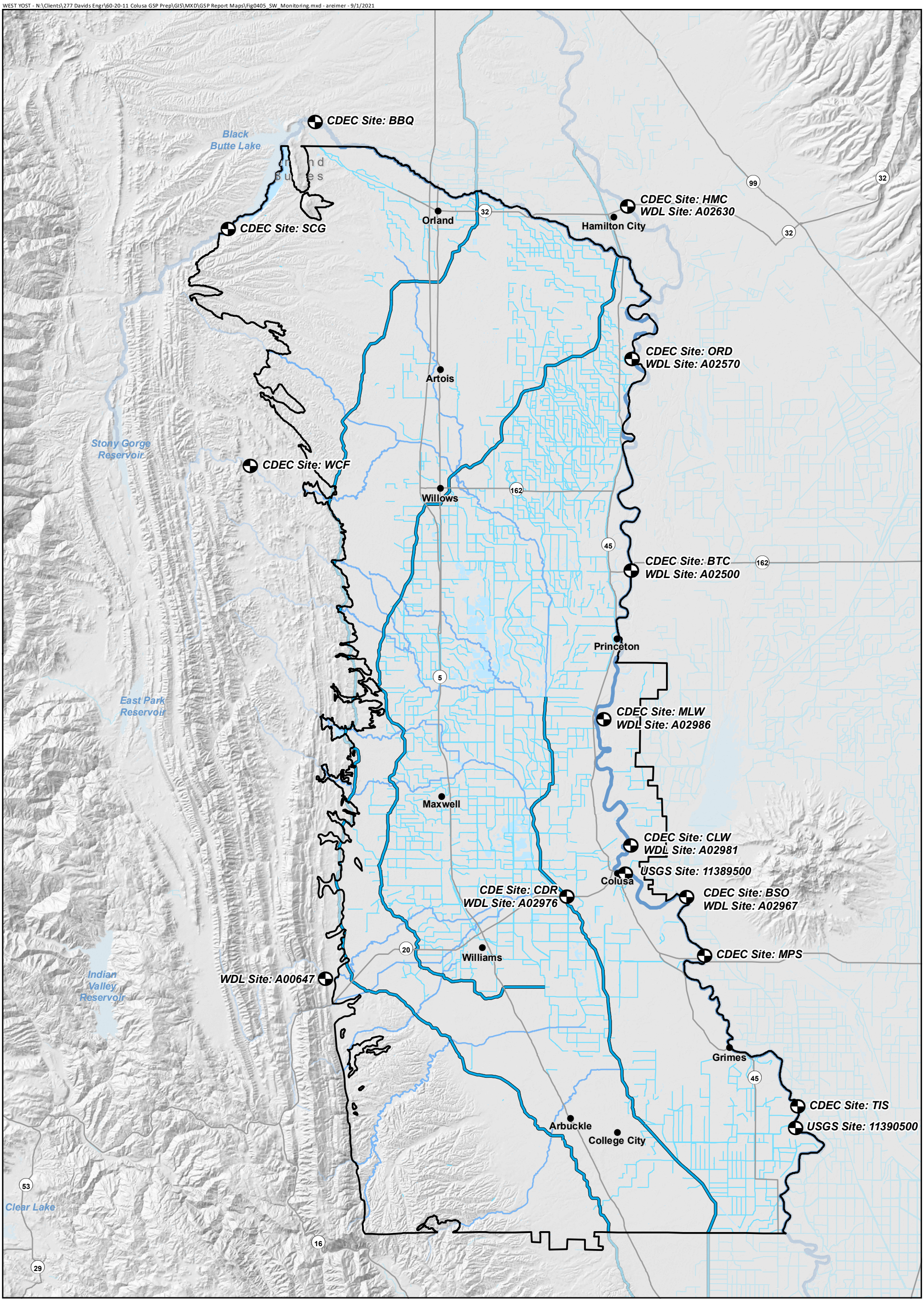

Surface Water Monitoring Stream Gage

Major Waterways

Minor Waterways

Major Conveyance Infrastructure

Other Conveyance Infrastructure

Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

N

0 2.5 5

Scale in Miles

Figure 4-5

Surface Water Monitoring Network

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

4.2.4.3 Monitoring Protocols

Data will either be obtained from the agencies that are responsible for managing the monitoring stream gages within the surface water monitoring network or downloaded from dataset host websites.

- California DWR WDL: https://wdlbeta.water.ca.gov/Map.aspx
- CDEC: https://cdec.water.ca.gov/
- USGS NWIS: https://waterdata.usgs.gov/nwis

Since all of the stream gages identified as part of the Subbasin surface water monitoring network are included in existing state or federal monitoring programs, collection of discharge and river stage measurements comply with existing regulatory monitoring protocols.

Per the Monitoring Protocols BMP (DWR, 2016c), streamflow measurements should be collected, analyzed, and reported in accordance with procedures defined in the USGS Water Supply Paper 2175, volumes 1 and 2 (Rantz, 1982). This methodology is currently being used for both DWR and USGS surface water monitoring networks within the Subbasin.

4.2.4.4 Data Gaps in Surface Water Monitoring Network

Data gaps in the surface water monitoring network include the following:

- The temporal changes in ephemeral and intermittent stream stage and flow within the subbasin may not be sufficiently addressed by the existing surface water monitoring network to the extent required by 23 CCR §354.34(c).
- Colusa Basin Drainage Canal System (Colusa Drain) outflows from the Subbasin are not currently monitored, and historical monitoring records for Colusa Drain outflows from the Subbasin are not available within the CDEC, NWIS, and WDL databases.
- With the exception of the Black Butte Lake stream gages, there is currently no active stream gage on Stony Creek. A stream gage on Stony Creek that measured both discharge and river stage would benefit evaluating potential surface water depletions and help characterize the stream-aquifer relationship.

4.2.4.5 Proposed Actions to Address Data Gaps

The perennial streams (Stony Creek and the Sacramento River) that bound or intersect the Subbasin and adjacent subbasins are shown on Figure 4-4. Surface water monitoring, particularly as related to streamflow depletion, should be coordinated across subbasins. The Colusa Subbasin GSAs are participating in a surface water monitoring network data gap assessment and fulfillment in cooperation with neighboring GSAs.

Additionally, existing stream and drainage reports will be evaluated for additional information on the timing, stage, and magnitude of flows in ephemeral and intermittent streams in the subbasin, if necessary, to fill data gaps or support projects and management actions during GSP implementation. Willow or Walker Creek, two of the more prominent and long-ranging creeks in the Subbasin, could provide data representative of the subbasin's other ephemeral or intermittent creeks. If necessary, site-specific studies will be conducted to fill data gaps or address requirements for monitoring of ephemeral and intermittent streams, per 23 CCR §354.34(c)(6).

DWR is reportedly in the process of evaluating the adequacy of existing stream gages to support SGMA implementation. As a result of this effort, it is anticipated that DWR will identify data gaps and develop recommendations regarding the existing stream gage networks. There is one inactive USGS stream gage on Stony Creek (Station 11388500) near Hamilton City that may be identified as adequate to re-equip. Some of the ephemeral or intermittent streams within Subbasin have inactive stream gages that could also provide important information if re-equipped. Actions proposed by DWR, if any, will be taken into consideration by the Colusa Subbasin GSAs.

The need for additional monitoring wells to assist in the monitoring of stream-aquifer interactions will be assessed during implementation of this GSP. Evaluation of the new groundwater level data from the representative monitoring network described in the following section will be an important first step in determining the need for additional monitoring wells.

Annual reports and future revisions to the GSP will provide updates on actions taken to address data gaps over the reporting period.

4.2.5 Representative Monitoring Sites

Per 23 CCR §354.36, "*Each Agency may designate a subset of monitoring sites as representative of conditions in the basin or an area of the basin…*" to evaluate or monitor for sustainability indicators. Representative monitoring locations were designated to evaluate undesirable results due to lowering of groundwater levels, reduction of groundwater storage, groundwater quality degradation, inelastic land subsidence, and surface water depletions. The purpose and composition of the representative monitoring networks are discussed below. Undesirable results and sustainability thresholds determined by the representative monitoring networks are discussed in Chapter 5 (Sustainable Management Criteria).

4.2.5.1 Representative Groundwater Level Monitoring Network

The representative groundwater level monitoring network includes one completion from each of the 48 wells in the groundwater monitoring network. The representative groundwater level monitoring sites are indicated in Table 4-2 and shown on Figure 4-6. Each single completion well is a representative groundwater level monitoring site. For multiple completion wells in the representative monitoring network, the completion depth was selected based on the median depth of domestic wells within the Thiessen polygon bounding each multiple completion monitoring well.

Additional information regarding the selection of these representative groundwater level monitoring sites and how they were used to determine sustainability thresholds can be found in Chapter 5 and Appendix 5B.

4.2.5.2 Representative Groundwater Quality Monitoring Network

The Subbasin representative groundwater quality monitoring network includes 25 monitoring sites to monitor for groundwater quality degradation due to increasing salinity concentrations, either via migration of deep brackish to saline waters into the freshwater aquifer system or recharge from agricultural runoff. The representative groundwater quality monitoring sites are indicated in Appendix 4B and shown on Figure 4-7.

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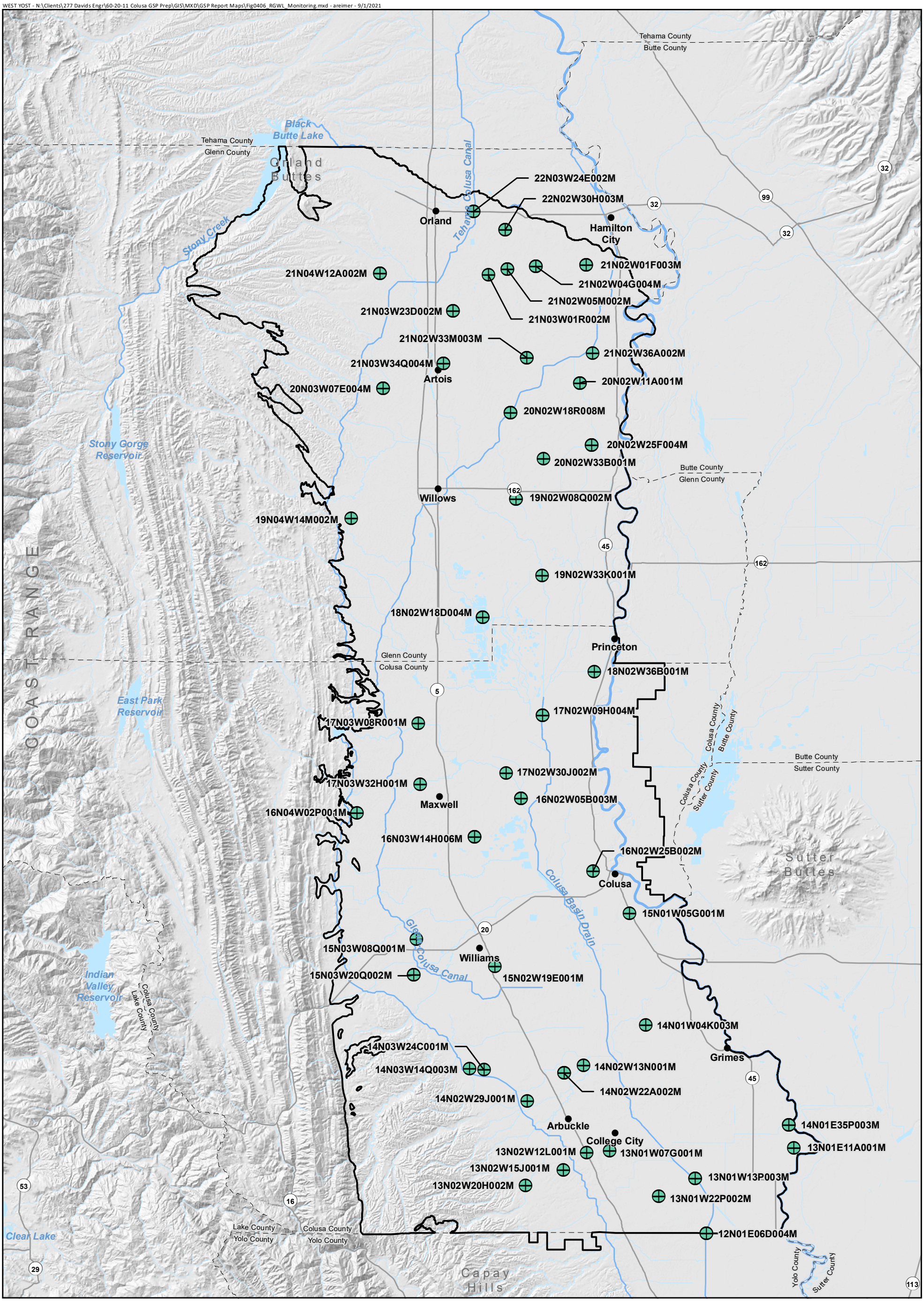

Representative Groundwater Level Monitoring Network Site

Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

N

0 2.5 5

Scale in Miles

Figure 4-6

Representative Groundwater Level Monitoring Network

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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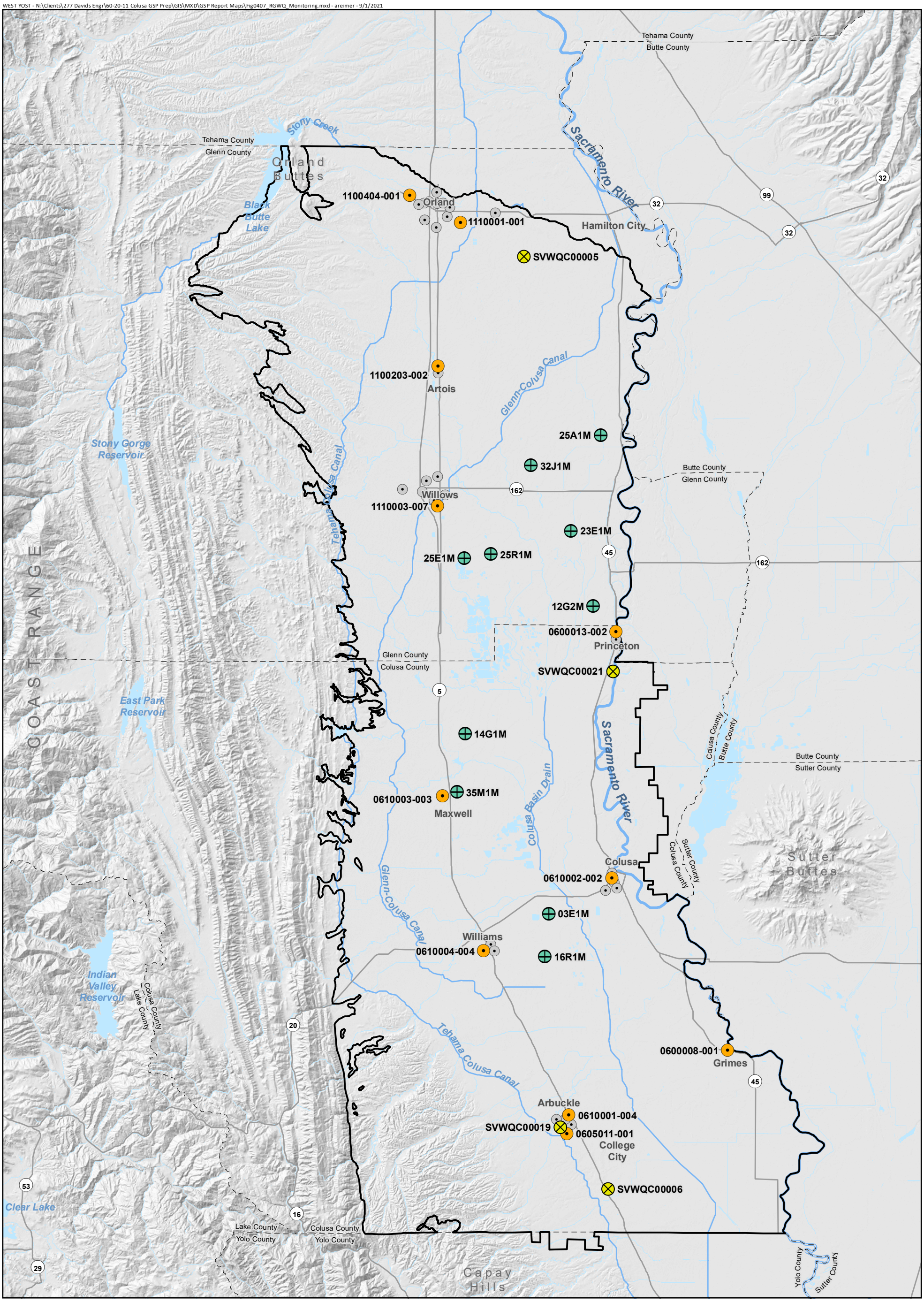


Colusa Subbasin

Active Public Water Supply Well

Representative Groundwater Quality Monitoring Network Well

Representative Public Water Supply Well

Representative California Rice Commission Groundwater Monitoring Well

Representative Sacramento Valley Water Quality Coalition Groundwater Monitoring Well

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

N

0 2.5 5

Scale in Miles

Figure 4-7

Representative Groundwater Quality Monitoring Network

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

Ten California Rice Commission wells were selected as representative monitoring sites due to their shallow construction (less than 30 feet deep) to monitor recharge waters, proximity to irrigated agricultural lands, proximity to areas with known salinity concerns, inclusion in an existing groundwater quality monitoring program with a focus on salinity, and dedicated observation well status. Four Sacramento Valley Water Quality Coalition wells were selected as representative groundwater quality monitoring sites due to their locations near irrigated agricultural lands and surface waters, proximity to areas with high domestic and agricultural wells, relatively deeper constructed depth than the California Rice Commission wells, and inclusion in an existing groundwater quality monitoring program with a focus on salinity. One well from each community-level public water system was selected as a representative groundwater quality monitoring site based on their proximity to urban areas, status, level of use, and conversations with water agency operational staff. The groundwater quality monitoring network includes 11 public drinking water wells.

Additional information regarding the selection of these representative groundwater quality monitoring sites and how they were used to determine sustainability thresholds can be found in Chapter 5.

4.2.5.3 Representative Land Subsidence Monitoring Network

Sixty-three (63) benchmarks within the Subbasin are included in the representative land subsidence monitoring network to determine sustainability thresholds and evaluate the occurrence of undesirable results. The benchmarks are shown on Figure 4-4 and bolded in Table 4-5. None of the CGPS stations, extensometers, or benchmarks outside of the Subbasin are included in the representative monitoring network. The benchmarks are evenly distributed throughout the Subbasin, including through the areas with current land subsidence occurrence, and are easily re-surveyed to measure for vertical displacement.

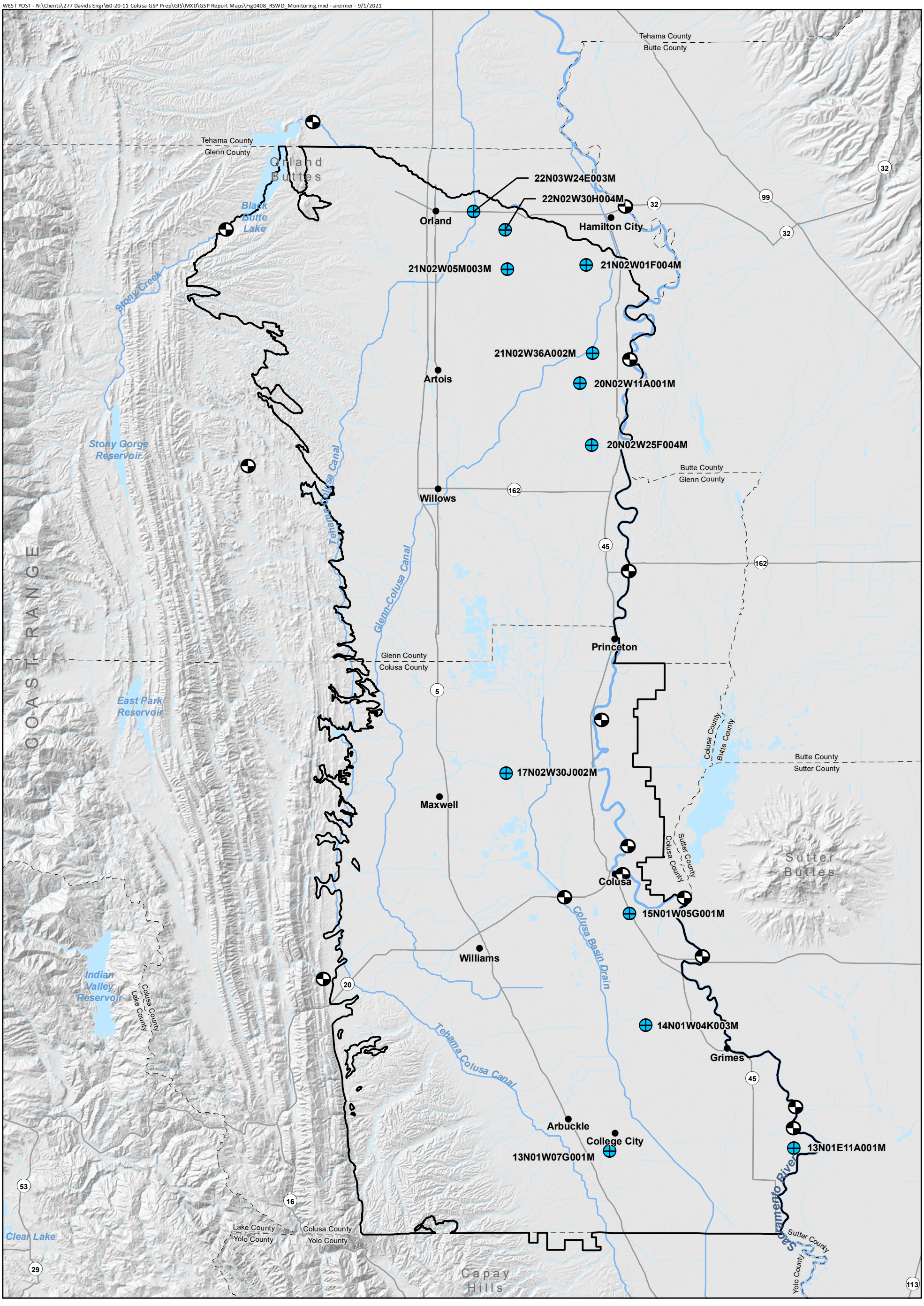
Additional information regarding the representative land subsidence monitoring sites and how they were used to determine sustainability thresholds can be found in Chapter 5.

4.2.5.4 Representative Surface Water Depletion Monitoring Network

Groundwater levels in shallow wells are being used as a proxy to monitor for surface water depletions and interconnected surface waters. The rationale and methodology for this is explained in Chapter 5 and Appendix 5B. The criteria for inclusion in the representative surface water depletion monitoring network was that the site must be:

- Less than 200 feet deep, and
- More than 2,000 feet and less than 5 miles from the surface water feature of concern.

Twelve (12) shallow wells from the groundwater level monitoring network qualified as representative monitoring sites. These wells may also be useful as monitoring sites for GDEs, although a dedicated network of shallow monitoring wells will be developed specifically for GDE monitoring during implementation of the GSP. The representative surface water depletion monitoring sites are indicated in Table 4-2 and shown on Figure 4-8. Additional information regarding the selection of these representative surface water depletion monitoring sites and how they were used to determine sustainability thresholds can be found in Chapter 5 and Appendix 5B.



Surface Water Monitoring Stream Gage

Representative Surface Water Depletion Monitoring Site

Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

N

0 2.5 5

Scale in Miles

Figure 4-8

Representative Surface Water Depletion Monitoring Network

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

CHAPTER 5
Sustainable Management Criteria

This chapter describes the sustainable management criteria (SMC) for each applicable sustainability indicator for the Subbasin (Subbasin). These sustainable management criteria are used by the CGA and GGA to gauge progress towards achieving the Sustainability Goal during GSP implementation. This chapter also describes undesirable results for each applicable sustainability indicator and how undesirable results are detected.

5.1 SUSTAINABILITY TERMINOLOGY

This section defines key terminology used is discussing groundwater sustainability in the Subbasin.

- **Sustainability goal**: The sustainability goal qualitatively describes the overall objectives of the GSP and desired conditions for the Subbasin.
- **Undesirable results**: Undesirable results statements describe the Subbasin conditions at which each applicable sustainability indicator would have significant and unreasonable effects on the beneficial uses and users of groundwater in the Subbasin.
- **Minimum thresholds**: Minimum thresholds are quantitative values established for each applicable sustainability indicator that, when exceeded, indicate that undesirable results could occur.
- **Measurable objectives**: Measurable objectives are quantitative goals for the maintenance or improvement of specified groundwater conditions, reflecting desired Subbasin conditions and providing a benchmark to achieve and maintain the Subbasin sustainability goal.
- **Interim milestones**: Interim milestones are target values representing measurable groundwater conditions, in increments of five years, set by the GSAs to provide a glidepath toward sustainability over the GSP implementation horizon, ultimately leading to the measurable objectives and achievement and maintenance of the Subbasin sustainability goal.
- **Sustainable management criteria**: Sustainable management criteria refer to the criteria by which the GSAs define conditions in the GSP that constitute sustainable groundwater management for the Subbasin. The sustainable management criteria include the processes by which undesirable results are characterized, and by which minimum thresholds and measurable objectives are established for each applicable sustainability indicator.

5.1.1 Sustainability Indicators

A sustainability indicator is defined in SGMA as one of six effects caused by groundwater conditions that, when significant and unreasonable, cause undesirable results. The six sustainability indicators are described by the DWR in the document *Sustainable Management Criteria, Best Management Practices for the Sustainable Management of Groundwater* (DWR, 2017) as follows:

Indicator Symbol	Explanation
	Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.
	Significant and unreasonable reduction of groundwater storage.
	Significant and unreasonable seawater intrusion.
	Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies.
	Significant and unreasonable land subsidence that substantially interferes with land uses.
	Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water.

SGMA allows several pathways to meet the distinct local needs of each subbasin, including:

- Development of sustainable management criteria for each sustainability indicator.
- Use of groundwater elevation as a proxy metric for other sustainability indicators
- Exclusion of specific indicators that are not applicable to the subbasin

Five sustainability indicators are applicable to the Subbasin:


- Chronic lowering of groundwater levels


- Reduction of groundwater storage


- Degraded water quality


- Inelastic land subsidence


- Depletions of interconnected surface water

Sustainable management criteria have been established herein for the chronic lowering of groundwater levels, degraded water quality, and inelastic land subsidence. For sustainability indicators that have a significant, demonstrated correlation to groundwater levels, the sustainable management criteria for groundwater levels may be used as a proxy metric. Both depletions of interconnected surface water and reduction of groundwater storage are significantly correlated to groundwater levels (as described below), and thus utilize groundwater levels as a proxy. Seawater intrusion is not applicable to the Subbasin due to the distances between the Subbasin and the Pacific Ocean, bays, deltas, or inlets ranging from about 30 to

60 miles. Because seawater intrusion is neither occurring nor anticipated to occur in the subbasin over the planning horizon, only the five applicable sustainability indicators are addressed hereinafter.

Continued data collection and an improved understanding of Subbasin conditions in the future may lead to changes in the sustainable management criteria discussed herein. Section 7.8 describes the 5-year GSP update process. Including an evaluation of the progress towards meeting interim goals and a reassessment of sustainable management criteria in light of new data.

5.2 SUSTAINABILITY GOAL

23 CCR §354.24 requires establishment of a sustainability goal for the subbasin that culminates in the absence of undesirable results by 2042. The sustainability goal provides a qualitative description of the Subbasin's objectives relative to sustainable management and desired groundwater conditions in the Subbasin. Information from Chapter 3, Basin Setting, including information on historical, current, and future water budgets, have informed understanding of the status of the Subbasin and, subsequently, development of the sustainability goal for the Subbasin. The sustainability goal is consistent with avoidance of locally-defined undesirable results and is supported by the quantitative minimum thresholds, measurable objectives, and interim milestones identified in this chapter. Demonstration of the absence of undesirable results supports a determination that a Subbasin is operating sustainably and thus the sustainability goal has been achieved.

The sustainability goal for the Subbasin is:

> *… to maintain, through a cooperative and partnered approach, locally managed sustainable groundwater resources to preserve and enhance the economic viability, social well-being and culture of all Beneficial Uses and Users, without experiencing undesirable results.*

5.2.1 Sustainable Operation of the Subbasin

Projects and management actions that the GSAs and other partners could implement to ensure that the Subbasin is operated sustainably (i.e., to avoid undesirable results) are described in Chapter 6. The Introduction to Chapter 6 describes an adaptive management approach for implementing projects and management actions that will be informed by monitoring of groundwater conditions and will lead to implementation of additional projects if Measurable Objectives (MOs) are not being maintained and Minimum Thresholds (MTs) are being approached.

An adaptive management approach recognizes that undesirable results do not currently exist in the Subbasin, and it is uncertain that undesirable results will develop in the future. The uncertainty is primarily related to the relatively small groundwater storage imbalances estimated to occur under future conditions (see Chapter 3, Section 3.3, Water Budget Information), the uncertainty associated with those estimates, and uncertainty associated with when and how potential future climate change actually affects the Subbasin. Monitoring of actual groundwater conditions over time will determine whether, when, and where implementation of projects and management actions may be needed to avoid undesirable results.

Despite the long-term adaptive implementation approach described above, certain Subbasin projects are currently moving toward implementation to address localized declining groundwater levels that are

believed to be primarily drought-induced[2]. These planned projects are described in Chapter 6 and are regarded as projects that will contribute to long-term sustainable groundwater management in addition to alleviating temporary drought-induced effects in the near term.

5.2.2 Achieving Sustainability within 20 Years

As discussed above, the Subbasin does not currently have undesirable results, which shows that the Subbasin is being managed sustainably. Additionally, it is uncertain that undesirable results will occur in the future. If monitoring detects that Measurable Objectives are not being maintained and Minimum Thresholds are being approached, the GSAs and other project proponents are committed to implementing projects and management actions to avoid undesirable results, as described in Chapters 6 and 7.

5.3 UNDESIRABLE RESULTS

As described in 23 CCR §354.26, undesirable results occur when one or more significant and unreasonable effects are caused by groundwater conditions occuring throughout the Subbasin, as assessed using the five applicable sustainability indicators described earlier: chronic lowering of groundwater levels, reduction of groundwater storage, degraded water quality, inelastic land subsidence, and/or depletions of interconnected surface water. The DWR's *Sustainable Management Criteria Best Management Practices* was developed to help GSAs establish their sustainability criteria by first identifying the significant and unreasonable effects caused by groundwater conditions in the Subbasin that constitute undesirable results, and then identifying quantitative criteria to define when and where the effects of groundwater conditions cause undesirable results for each applicable sustainability indicator. These quantitative criteria define the number and location of monitoring points that may be below a specific minimum threshold prior to a GSA identifying conditions as an undesirable result. The *Sustainable Management Criteria* Best Management Practice (BMP) states that "undesirable results will be defined by minimum threshold exceedances" (DWR, 2017).

This section presents the undesirable results statements for the Subbasin, which were developed through a process that characterizes specific groundwater conditions that lead to undesirable results in the Subbasin and identifies minimum thresholds that, when exceeded, may indicate that undesirable results could occur. Input from Subbasin stakeholders, the public, and GSA members was used in conjunction with data collected and evaluated for preparation of the Plan Area and Groundwater Conditions chapters of this GSP (Chapter 2 and Chapter 3, respectively) to guide development of the undesirable results statements. These statements utilize quantitative thresholds (as described later in this section) to indicate where and when undesirable results might occur in the representative monitoring network, and therefore the Subbasin. Appendix 5A documents the decision-making process and adoption of the Subbasin sustainable management criteria by the CGA and GGA. The sustainable management criteria decision records identify these quantitative thresholds selected by the GSAs, and the process and considerations leading to these decisions.

Chapter 4 describes the Subbasin's monitoring networks and representative monitoring networks for each applicable sustainability indicator.

[2] A series of mostly dry years beginning in about 2007 has resulted in increased irrigation demands within the Subbasin and curtailments of Central Valley Project surface water supplies, and consequently increase in groundwater pumping. In some locations these effects of drought are compounded by expansion of irrigation lands served solely by groundwater.

The five applicable sustainability indicators are addressed to determine whether and when significant and unreasonable impacts are occurring on beneficial uses and/or users in the Subbasin. For each indicator, the potential for undesirable results is described. Causes of groundwater conditions leading to significant and unreasonable effects are identified, and undesirable results defined based on current Subbasin conditions, the California Water Code, SGMA regulations, BMPs, and stakeholder input. For each sustainability indicator, the following have been developed:

- Description of undesirable results – describes groundwater conditions causing the specific significant and unreasonable effects that constitute undesirable results.
- Identification of undesirable results – describes the criteria used to define when and where groundwater conditions cause undesirable results, defined and detected by minimum threshold exceedances.
- Potential causes of undesirable results – describes groundwater conditions that could lead to undesirable results.
- Potential effects of undesirable results – describes what could happen to beneficial uses and users of groundwater if undesirable results were to occur.
- Evaluation of the presence of undesirable results – describes whether undesirable conditions are present in the Subbasin and/or are detected through monitoring.

As previously noted, undesirable results related to seawater intrusion are neither occurring nor anticipated to occur in the subbasin over the planning horizon. Thus, criteria for undesirable results related to this sustainability indicator are not applicable to this GSP.

5.3.1 Chronic Lowering of Groundwater Levels



5.3.1.1 Description of Undesirable Results for Chronic Lowering of Groundwater Levels

The undesirable result for the chronic lowering of groundwater levels is a result that would cause significant and unreasonable reduction in the long-term viability of beneficial uses and users over the planning and implementation horizon of this GSP.

An undesirable result for chronic lowering of groundwater levels in the Subbasin is experienced if sustained groundwater levels are too low to reasonably satisfy beneficial uses and users within the Subbasin over the planning and implementation horizon of this GSP. Undesirable results for the chronic lowering of groundwater levels have not occurred historically and are not currently occurring. Per the projected water budget (Chapter 3), these effects are not likely to occur in the projected water budget analysis period (2016-2065).

Potential impacts of chronic lowering of groundwater levels and the extent to which they are considered significant and unreasonable were determined by the GSA members with input from local stakeholders and members of the public, as described in Chapter 2. During development of the GSP, potential undesirable results identified by stakeholders included:

- A significant and unreasonable number of wells going dry
- A significant and unreasonable reduction in the pumping capacity of existing wells
- A significant and unreasonable increase in the need for deeper wells or lower pump settings
- Adverse impacts to environmental uses and users, including reductions in the flows of interconnected surface waters and reductions in groundwater available to the root zones of groundwater-dependent ecosystems (GDEs)

As described in Chapter 2, most of the Subbasin is classified as an Economically Disadvantaged Area and has a high proportion of Disadvantaged Communities (DACs) and Severely Disadvantaged Communities (SDACs). These beneficial users, along with members of California Native American Tribes (Tribes), including the federally recognized Cachil Dehe Band of Wintun Indians and the Cortina Indian Rancheria of Wintun Indians of California, typically rely on groundwater to meet their drinking water needs. As expressed in California Water Code Section 106.3, "every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes." The human right to water extends to all Californians, including disadvantaged individuals and groups and communities in rural and urban areas (SWRCB, 2021). Undesirable results caused by chronic lowering of groundwater levels could affect the Human Right to Water by limiting the ability of drinking water beneficial users, including DACs, SDACs and Tribes, to access safe, clean, and affordable water for human consumption, cooking, and sanitary purposes. These drinking water beneficial users could experience cumulative effects of undesirable results caused by chronic lowering of groundwater levels and degraded water quality.

5.3.1.2 Identification of Undesirable Results

An undesirable result is considered to occur for the chronic lowering of groundwater levels during GSP implementation when 25 percent or more of the representative monitoring wells (i.e., 12 of 48 wells) in the Subbasin fall below their minimum groundwater elevation threshold levels for 24 consecutive months. The 12 wells must be the same subset of wells, not any combination of 12 wells. The subset of wells is not predetermined; rather, it is delineated only as wells collectively fall below their minimum threshold levels. Minimum threshold levels for each well were determined using the best available data by the process described in Section 5.4. Additional justification and information supporting the process and criteria used to define when and where the effects of the groundwater conditions may cause undesirable results are provided in Appendices 5B and 5C.

These criteria were determined based on an evaluation of the best available data pertaining to the Subbasin's specific conditions and characteristics, as described in the Plan Area and Basin Setting sections of this GSP (Chapter 2 and Chapter 3, respectively), in conjunction with input and feedback from the public, stakeholders, and GSA members. The GSAs determined these criteria based on the justification that minimum threshold exceedances of 25 percent or more of representative monitoring wells represent a "significant" impact, and that exceedance of these levels for 24 consecutive months or longer (e.g., no recovery of groundwater levels through two consecutive seasonal high periods) constitutes a chronic impact that would potentially harm the "long-term viability" of affected beneficial uses and users in the Subbasin. The criterion of 25 percent or more of the representative monitoring wells dropping below their

minimum thresholds for 24 consecutive months was regarded as an indicator of a significant, widespread problem representing undesirable results.

5.3.1.3 Potential Causes of Undesirable Results

Potential causes of groundwater conditions that would lead to this undesirable result for the chronic lowering of groundwater levels are excessive groundwater pumping, reductions in recharge of precipitation and applied surface water, and other factors. Potential local impacts to groundwater levels could be caused by one or more of the following:

- Reduction in surface water supplies available to the Subbasin, particularly surface water diversions from the Sacramento River and Stony Creek
- Increases in groundwater pumping to meet increased crop consumptive use caused by climate change or shifts to higher water use crops

For example, if reductions in surface water supplies available under existing contracts are reduced due to changes in federal water allocation policy or other factors, such as State Board decisions or orders limiting diversions and transfers, then the Central Valley Project (CVP) Settlement Contractors and the contractors receiving water under Tehama Colusa Canal Authority contracts would have to increase groundwater pumping to meet any water supply shortages. If surface water supplies remained unchanged but crop consumptive use increased due to climate change, groundwater pumping would need to increase to meet higher irrigation requirements. Excessive groundwater pumping could cause lowering of groundwater levels leading to undesirable results.

5.3.1.4 Potential Effects of Undesirable Results

If groundwater levels were to reach levels indicating undesirable results have occurred, specific undesirable effects to beneficial uses and users of groundwater, land uses, property interests, and others could potentially include:

- De-watering of some existing groundwater production wells, starting with the shallowest wells (which are primarly domestic wells)
- Decreased access to safe, clean, and affordable drinking water
- Increased production well construction costs
- Increased groundwater pumping costs due to increased lifts
- Adverse effects on GDEs if the depth to groundwater falls below the root zones of GDEs
- Forced changes to lower water use, lower economic return crops, or to idling of agricultural lands
- Adverse effects on property values and the regional economy
- Permanent loss of crops due to lack of water
- Hauling of water to meet minimum household needs
- Stock water impacts (hauling water, selling livestock, etc.)

Implementation of the GSP is intended to avoid these effects by monitoring and implementing projects and management actions as needed to maintain groundwater levels above the minimum thresholds at representative monitoring network wells. An economic analysis of groundwater level minimum thresholds

is included in Appendix 5C. Chapter 6 describes projects and management actions. Chapter 7 describes GSP implementation efforts directed towards maintaining groundwater levels and mitigating drought impacts to drinking water beneficial users.

5.3.1.5 Evaluation of the Presence of Undesirable Results

Section 5.4 discusses how minimum thresholds were selected. More information on how the thresholds were established is also included in Appendix 5B, along with hydrographs of groundwater levels for each monitoring site through 2020 and the established depth of the minimum threshold. Of the 48 monitoring wells, none were below the minimum threshold in the latest measurement in 2020, indicating that the Subbasin does not currently exceed the requirements for an undesirable result for the chronic lowering of groundwater levels. The GSAs will continue to monitor groundwater levels to identify potential undesirable results as part of GSP annual reports and five-year updates, and adapt GSP implementation, as needed, to avoid undesirable results.

5.3.2 Reduction of Groundwater Storage



5.3.2.1 Description of Undesirable Results for the Reduction of Groundwater Storage

The undesirable result for the reduction of groundwater in storage is a result that would cause significant and unreasonable reduction in the long-term viability of beneficial uses and users over the planning and implementation horizon of this GSP.

An undesirable result for the reduction of groundwater storage is experienced if storage volumes are insufficient to reasonably satisfy beneficial uses and users within the Subbasin over the planning and implementation horizon of this GSP. Undesirable results related to groundwater storage have not occurred historically and are not currently occurring. Per the projected water budget (Chapter 3), these effects are not likely to occur in the projected water budget analysis period (2016-2065).

5.3.2.2 Justification of Groundwater Levels as a Proxy

This GSP uses groundwater level minimum thresholds as a proxy for the reduction of groundwater storage sustainability indicator. GSP regulations allow GSAs to use groundwater level minimum thresholds as a proxy metric for any sustainability indicator provided the GSP demonstrates that there is a significant correlation between groundwater levels and the other metrics. In order to rely on groundwater levels as a proxy, one approach suggested by DWR is to:

> *Demonstrate that the minimum thresholds and measurable objectives for chronic declines of groundwater levels are sufficiently protective to ensure significant and unreasonable occurrences of other sustainability indicators will be prevented. In other words, demonstrate that setting a groundwater level minimum threshold satisfies the minimum threshold requirements for not only chronic lowering of groundwater levels but other sustainability indicators at a given site (DWR, 2017).*

Minimum thresholds for groundwater levels will effectively avoid undesirable results for reduction of groundwater storage if it is demonstrated that adequate storage remains in the Subbasin even if chronic lowering of groundwater levels occurs. Based on the estimated range of current storage volume in the Subbasin (Chapter 3) and the small percentage changes in storage estimated to occur over groundwater

levels ranging from current levels to the groundwater levels minimum thresholds, it is anticipated that an undesirable result related to the chronic lowering of groundwater levels would occur before the Subbasin would experience significant and unreasonable effects related to reduction of groundwater storage. This is because the base of fresh groundwater is generally far below the groundwater level minimum thresholds that have been adopted, and large volumes of groundwater would remain in storage even if minimum thresholds were reached.

As discussed in Chapter 3, the current groundwater storage volume within the Subbasin, above the crystalline basement rocks and base of freshwater, is estimated to be between about 26 million acre-feet (maf) and 140 maf. The estimated reduction of groundwater storage over the Subbasin brought about by the average decline from the lowest historical groundwater levels measured at each of the 48 wells in the representative monitoring network prior to January 1, 2015 to the groundwater level minimum threshold for each of the 48 wells ranges from 1.4 to 7.7 maf, using the range of specific yield documented in Chapter 3. This represents a change of approximately five percent across the range of total estimated current groundwater storage volumes. This small percentage change is unlikely to trigger undesirable results based on storage impacts alone. Also, this range of estimated reduction in storage would not be likely to occur, because undesirable results would be triggered and addressed when groundwater levels in the first 12 of the 48 representative wells dropped to their minimum thresholds for 24 consecutive months.

Therefore, by setting minimum thresholds for groundwater levels as they have been, groundwater storage is effectively protected. The use of groundwater levels as a proxy metric for the groundwater storage sustainability indicator is effective and appropriate.

As discussed in Section 5.2.1, implementation of the GSP will be based on adaptive management, as required to adapt to changing climatic conditions. The SMCs for groundwater levels and storage will continue to be evaluated and updated as new information about groundwater conditions is acquired and data gaps are filled.

5.3.2.3 Identification of Undesirable Results

The undesirable result for the reduction of groundwater storage is monitored by proxy using groundwater levels and is considered to occur during GSP implementation when 25 percent or more of representative monitoring wells (i.e., 12 of 48 wells) fall below their minimum groundwater elevation thresholds for 24 consecutive months. The 12 wells must be the same subset of wells, not any combination of 12 wells. The subset of wells is not predetermined; rather, it is delineated only as wells collectively fall below their minimum threshold levels. Minimum threshold levels for each well were determined using best available data by the process described in Section 5.4. Additional justification and information supporting the criteria used to define when and where the effects of the groundwater conditions cause undesirable results is provided in Appendix 5B.

These criteria were determined based on the evaluation of best available data pertaining to the Subbasin's specific conditions and characteristics, as described in the Plan Area and Basin Setting sections of this GSP (Chapter 2 and Chapter 3, respectively), in conjunction with input and feedback from the public, local stakeholders, and GSA members. The GSAs selected these criteria based on the justification that minimum threshold exceedances of 25 percent or more of representative monitoring wells represent a "significant" impact, and that exceedance of these levels for 24 consecutive months or longer (indicating a significant lack of groundwater recharge through two consecutive periods of seasonal groundwater fluctuation) constitutes a chronic impact that would potentially harm the long-term viability of affected beneficial uses and users in the Subbasin. The criterion of 25 percent or more of the representative monitoring wells

dropping below their minimum thresholds for 24 consecutive months was regarded as an indicator of a significant, widespread problem representing undesirable results.

5.3.2.4 Potential Causes of Undesirable Results

Potential causes of undesirable results for the reduction of groundwater storage are excessive groundwater pumping and decreases in recharge due to reductions in the availability of surface water or reductions in precipitation. Increases in groundwater pumping could be caused by increases in consumptive use of water due to increased agricultural productivity, and changes in land and water use. Increases in overall demand, especially for groundwater, and decreases in recharge of surface water and precipitation may cause groundwater conditions that lead to undesirable results if the reduction in groundwater storage is excessive (water budgets area described in Chapter 3).

Based on the estimated range of current storage volume in the Subbasin and the small percentage changes in storage estimated to occur over groundwater levels ranging from historical lows to the groundwater levels minimum thresholds, undesirable results due to decreases in groundwater levels would occur before undesirable results due to a significant reduction of groundwater storage. As such, the use of groundwater levels as a proxy for the establishment of thresholds for reductions in groundwater storage is protective of groundwater storage.

5.3.2.5 Potential Effects of Undesirable Results

Undesirable results for reductions in groundwater storage could potentially cause significant and unreasonable effects on beneficial uses and users of groundwater. These effects could be:

- De-watering of some existing groundwater production wells, starting with the shallowest wells (which are primarly domestic wells)
- Increased production well construction costs
- Increased groundwater pumping costs due to inreased lifts
- Adverse effects on GDEs if the depth to groundwater falls below the root zones of GDEs
- Forced changes to lower water use, lower economic return crops, or idling of agricultural lands
- Adverse effects on property values and the regional economy
- Stock water impacts (hauling water, selling livestock, etc.)

Implementation of the GSP is intended to avoid these effects by monitoring and implementing projects and management actions as needed to maintain groundwater levels above the minimum thresholds at representative monitoring wells.

5.3.2.6 Evaluation of the Presence of Undesirable Results

Section 5.4 discusses how minimum thresholds were selected; more information on the process used to establish minimum thresholds for groundwater levels (as a proxy for groundwater storage) is also included in Appendix 5B. Current groundwater level data show that none of the 48 monitored wells were below the minimum threshold in the latest measurement in 2020, indicating that the Subbasin does not currently exceed the requirements for an undesirable result for the reduction of groundwater storage. The GSAs will continue to monitor groundwater storage through groundwater levels to identify potential undesirable results as part of GSP annual reports and five-year updates, and adapt GSP implementation, as needed, to avoid these effects.

5.3.3 Seawater Intrusion



Seawater intrusion is not an applicable sustainability indicator because seawater intrusion is not present and is not likely to occur in the Subbasin due to the distances between the Subbasin and the Pacific Ocean, bays, deltas, or inlets ranging from about 30 to 60 miles.

5.3.4 Degraded Water Quality



5.3.4.1 Description of Undesirable Results for Degraded Water Quality

The undesirable result for degraded water quality is a result that would cause a significant and unreasonable reduction in the long-term viability of beneficial uses and users, including domestic, agricultural, municipal, environmental, or other beneficial uses and users over the planning and implementation horizon of this is GSP. An undesirable result for degraded water quality in the Subbasin is experienced if, as the result of projects and management actions implemented under the GSP or other groundwater development (such as groundwater extraction or groundwater recharge), groundwater quality for regulated constituents is degraded to levels exceeding historical levels existing prior to January 1, 2015, or applicable water quality objectives, including drinking water standards, whichever are greater over the planning and implementation horizon of this GSP.

Existing regulatory programs address most water quality concerns, and the CGA and GGA will coordinate with these programs, the lead regulatory agencies, and the regulated community within the Subbasin during implementation of this GSP, including during development and implementation of projects and management actions.

The State Water Resources Control Board (SWRCB) and the Central Valley Regional Water Quality Control Board (CVRWQCB) regulate point and nonpoint source discharges to land that have potential to impact groundwater quality under a range of policy and regulatory programs, including the Basin Plan Amendment for the Salt and Nitrate Control Program, and the Irrigated Lands Regulatory Program. The California Department of Toxic Substance Control regulates releases of toxic substances, including those that impact groundwater quality.

The California Safe Drinking Water Act addresses the regulation and control of public water systems in the State of California, including enforcing provisions of the federal Safe Drinking Water Act. The federal government first granted primary enforcement responsibility to the State in 1978. The SWRCB Division of Drinking Water is the agency responsible for enforcement in Colusa and Glenn Counties, including the entire Subbasin.

The CGA and GGA will rely on existing monitoring and reporting carried out by the regulated community within the Subbasin when and where possible to address water quality concerns. The CGA and GGA will conduct supplemental water quality monitoring using existing wells or new monitoring wells constructed for that purpose when and where necessary to fill data gaps and to develop and implement projects and management actions.

Groundwater quality in the Subbasin is generally good, with local exceedances of water quality objectives for some constituents. The sole groundwater quality concern not addressed by the existing groundwater quality regulatory programs is mobilization of saline water from deeper parts of the aquifer along faults, other geologic structures, or other naturally-occurring zones with high salinity as a result of GSP projects and management actions and other groundwater development. Sustainable management criteria for salinity have been established to supplement existing regulatory programs.

Potential impacts of degraded water quality caused by GSP projects and management actions and the extent to which they are considered significant and unreasonable were determined by the GSA members with input from local stakeholders and members of the public. During development of the GSP, potential undesirable results identified by stakeholders included:

- A significant and unreasonable number of additional public supply wells requiring treatment, blending, control or replacement to remain in service
- A significant and unreasonable reduction in pumping capacity in existing public supply due to water quality degradation
- A significant and unreasonable reduction in pumping capacity in existing irrigation or stock water supply wells due to water quality degradation
- A significant and unreasonable increase in the number of domestic supply wells exceeding water quality objectives
- Adverse impacts to environmental uses and users, including significant and unreasonable impairment to water quality of interconnected surface waters and groundwater available to the root zones of GDEs

Undesirable results caused by degraded water quality could affect the Human Right to Water by limiting the ability of drinking water beneficial users, including DACs, SDACs and Tribes, to access safe, clean, and affordable water for human consumption, cooking, and sanitary purposes. These drinking water beneficial users could experience cumulative effects of undesirable results caused by chronic lowering of groundwater levels and degraded water quality.

5.3.4.2 Identification of Undesirable Results

The undesirable result for degraded water quality is considered to occur during GSP implementation when 25 percent of representative monitoring sites (i.e., 6 of 25 wells) exceed their minimum thresholds for two consecutive years. The six sites must be the same subset of sites, not any combination of six sites. The subset of sites is not predetermined; rather, it is delineated only as sites collectively exceed their minimum threshold values. Minimum thresholds were selected for each site by the process described in Section 5.4.

These criteria were determined based on the evaluation of best available data pertaining to the Subbasin's specific conditions and characteristics, as described in the Plan Area and Basin Setting sections of this GSP (Chapter 2 and Chapter 3, respectively), in conjunction with input and feedback from the public, local stakeholders, and GSA members. The GSAs selected these criteria based on the justification that minimum threshold exceedances at 25 percent or more of representative monitoring sites represent a "significant" impact, and that exceedance of these levels for two years or longer (indicating a significant and prolonged degradation of groundwater quality through two consecutive periods of seasonal groundwater fluctuation) constitutes an impact that would potentially harm the long-term viability of affected beneficial uses and users. Exceedance of minimum thresholds for two consecutive years at twenty-five

percent of the representative network wells was estimated to be an indicator of a significant, widespread problem indicating undesirable results.

5.3.4.3 Potential Causes of Undesirable Results

Potential causes of undesirable results for degraded water quality may be caused by:

- Mobilization of saline water from deeper parts of the aquifer along faults, other geologic structures, or other naturally-occurring zones with high salinity as a result of GSP projects and management actions and other groundwater development
- Mobilization of poor quality water, including contaminant plumes, monitored under existing regulatory programs as the result of GSP projects and management actions and other groundwater development
- Mobilization of naturally-occurring constituents in soils, the unsaturated zone, or the aquifer matrix as the results of projects involving direct groundwater recharge
- Direct groundwater recharge using water with constituent concentrations exceeding applicable water quality objectives or historical concentrations for the same constituents in groundwater

5.3.4.4 Potential Effects of Undesirable Results

If groundwater quality were degraded such that undesirable results occurred, the effects could potentially cause a shortage in supply to groundwater users without additional treatment, with domestic wells being most vulnerable as treatment costs or access to alternate supplies can be high for small users. This could limit access to safe, clean, and affordable drinking water for drinking water beneficial users, including DACs, SDACs and Tribes.

High salinity can impact both drinking water uses and agricultural uses, as there are maximum values associated with aesthetics (taste, color, and odor) for drinking water and crop health and yield for agriculture. Water quality degradation could potentially impact GDEs, surface water quality and the health of aquatic species, cause changes in crops grown and irrigation practices, and cause adverse effects to property values.

5.3.4.5 Evaluation of the Presence of Undesirable Results

Section 5.4 discusses how minimum thresholds were selected. Appendix 5D presents the historical salinity results expressed as electrical conductivity (EC) and the established minimum threshold for each representative monitoring site. Of the 25 monitoring sites, four wells exceeded their respective minimum thresholds in the most recent monitoring event after January 1, 2015. Although the Subbasin does not currently exceed the requirements for an undesirable result for degraded water quality, the CGA and GGA will coordinate with the entities responsible for monitoring, reporting, and compliance with applicable regulations to assess whether actions are required and being taken to achieve compliance for the wells.

The GSAs will continue to coordinate with the regulated community to identify potential undesirable results as part of GSP annual reports and five-year updates, and adapt GSP implementation, as needed, to avoid undesirable results. Chapter 7 describes GSP implementation efforts directed towards coordinating with drinking water providers and regulatory agencies to support drinking water beneficial uses and users.

5.3.5 Inelastic Land Subsidence



5.3.5.1 Description of Undesirable Results for Inelastic Land Subsidence

The undesirable result for inelastic land subsidence due to groundwater withdrawal is a result that would cause significant and unreasonable impacts to critical infrastructure over the planning and implementation horizon of this GSP.

An undesirable result is experienced if groundwater withdrawal causes inelastic land subsidence that substantially interferes with the condition or functionality of critical infrastructure within the Subbasin over the planning and implementation horizon of this GSP.

Potential impacts of inelastic land subsidence and the extent to which they are considered significant and unreasonable were determined by the GSA members with input from local stakeholders and members of the public. During development of the GSP, potential undesirable results identified by stakeholders included:

- Significant and unreasonable impacts to critical infrastructure in the Subbasin, including canals, pipelines, roadways, bridges, and groundwater wells.

5.3.5.2 Identification of Undesirable Results

Inelastic land subsidence within the Subbasin is monitored at 63 sites in DWR's Sacramento Valley Subsidence Monitoring Benchmark Network. An undesirable result is considered to occur during GSP implementation when 20 percent or more of representative monitoring locations (i.e., 13 of 63 locations) measure a subsidence rate greater than the specified minimum threshold of 0.5 feet per five years. The 13 locations must be the same subset of locations, not any combination of 13 locations. The subset of locations is not predetermined; rather, it is delineated only as sites collectively exceed their minimum threshold values. Minimum threshold levels were selected for each monitoring point by the process described in Section 5.4.

These criteria were determined based on the evaluation of best available data pertaining to the Subbasin's specific conditions and characteristics, as described in the Plan Area and Basin Setting sections of this GSP (Chapter 2 and Chapter 3, respectively), in conjunction with input and feedback from the public, local stakeholders, and GSA members. The GSAs selected these criteria based on the justification that minimum threshold exceedances at 20 percent or more of representative monitoring sites represent a significant impact, and that exceedance of these levels for 24 consecutive months or longer (indicating significant inelastic land subsidence through two consecutive periods of seasonal groundwater fluctuation) would substantially interfere with the condition or functionality of critical infrastructure within the Subbasin. Exceedance of the minimum thresholds for 24 consecutive months at 20 percent of monitoring sites was estimated to be an indicator of a significant, widespread problem indicating undesirable results.

5.3.5.3 Potential Causes of Undesirable Results

Inelastic land subsidence due to groundwater withdrawal is caused by a reduction in pore pressure brought about by pumping. The reduction in pore pressure increases the effective stress borne by the aquifer skeleton. The increase in the effective stress causes compaction of compressible clays.

The potential causes of undesirable results for inelastic land subsidence are:

- Increasing pumping or decreasing recharge in subsidence-prone areas
- Initiating pumping in areas or at depths with no or minimal historical groundwater pumping

5.3.5.4 Potential Effects of Undesirable Results

If inelastic land subsidence reaches levels indicating that undesirable results have occurred, the effects could potentially cause damage to local infrastructure such as canals, pipelines, roadways, bridges, and groundwater wells. Excessive subsidence may also lead to decreased groundwater storage and decreased hydraulic conductivity, with a resultant increase in well operations and maintenance costs.

5.3.5.5 Evaluation of the Presence of Undesirable Results

Section 5.4 discusses how the minimum thresholds were selected. Chapter 3 presents maps showing the extent and rate of historical subsidence. Of the 63 monitoring sites, none were below the minimum threshold in the latest measurement from 2017 indicating that the Subbasin does not currently exceed the requirements for an undesirable result for inelastic land subsidence. However, recognizing that there is uncertainty in Subbasin conditions and that data gaps exist, the GSAs will continue to monitor inelastic land subsidence to identify potential undesirable results as part of GSP annual reports and five-year updates, and adapt GSP implementation, as needed, to avoid undesirable results.

Ongoing monitoring of Subbasin conditions and data collection will inform potential updates to the SMC in the periodic updates. Chapter 7 documents plans to coordinate and fund additional surveys of the subsidence benchmarks.

5.3.6 Depletions of Interconnected Surface Water



5.3.6.1 Description of Undesirable Results for Depletions of Interconnected Surface Water

The undesirable result for depletions of interconnected surface water is a result that causes significant and unreasonable adverse effects on beneficial uses and users of interconnected surface waters within the Subbasin over the planning and implementation horizon of this GSP. During development of the GSP, potential undesirable results identified by stakeholders included:

- Significant and unreasonable impacts to stream flows
- Significant and unreasonable impact to riparian and riverine habitat
- Significant and unreasonable impacts to GDEs
- Significant and unreasonable impacts to springs

5.3.6.2 Justification of Groundwater Elevations as a Proxy

The use of groundwater elevation as a proxy metric for this sustainability indicator is necessary because the network of existing stream gages is not adequate to measure changes in stream accretions and depletions as related to the Subbasin. The network is inadequate because gages are not located such that changes in streamflow can be correlated directly and solely to Subbasin groundwater conditions. Additionally, it is unlikely that the relatively small, expected changes in streamflow associated with changes in groundwater

conditions can be accurately quantified given the measurement error associated with the gages. In contrast, changes in streamflow volume and rates can be estimated by modeling of groundwater levels and stream stages together with characterization of soil and aquifer properties. However, the levels of uncertainty in the available Subbasin groundwater model are currently too great to allow sufficiently reliable quantification of the rates and volume of stream depletions during GSP implementation.

Depletions of interconnected surface water are driven by the gradient between water surface elevation in the surface water body and groundwater elevations in the connected, shallow groundwater system. By setting minimum thresholds in representative monitoring wells near interconnected surface water, the GGA and CGA can monitor and manage this gradient, and in turn, manage potential changes in depletions of interconnected surface water. Monitoring for impacts to interconnected surface waters will occur utilizing a subset of wells in the Subbasin's groundwater elevation monitoring network selected for this purpose (see Chapter 4).

5.3.6.3 Identification of Undesirable Results

The undesirable result for depletions of interconnected surface water is considered to occur during GSP implementation when 25 percent of representative monitoring wells (i.e., 3 of 12 wells) fall below their minimum groundwater elevation thresholds for 24 consecutive months. The three wells must be the same subset of wells, not any combination of three wells. The subset of wells is not predetermined; rather, it is delineated only as wells collectively fall below their minimum threshold levels. Minimum thresholds were selected for each site by the process described in Section 5.4. Additional justification and information supporting the criteria used to define when and where the effects of the groundwater conditions cause undesirable results is provided in Appendix 5B.

These criteria were determined based on the evaluation of best available data pertaining to the Subbasin's specific conditions and characteristics, as described in the Plan Area and Groundwater Conditions sections of this GSP (Chapter 2 and Chapter 3, respectively), in conjunction with input and feedback from the public, local stakeholders and GSA members. The representative monitoring network was selected based on identification of existing monitoring wells with locations and depths considered appropriate for monitoring groundwater with potential to influence interconnected streams in the Subbasin. These interconnected streams are the Sacramento River, the Colusa Drain and portions of Stony Creek below Black Butte Dam. Monitoring wells with screened intervals less than 200 feet deep located within 2,000 feet to five miles of the interconnected streams were selected.[4] These wells are expected to provide the best available monitoring of groundwater levels that have an influence on the volume and rates of stream depletion. Wells closer than 2,000 feet were excluded based on the assumption that wells in too close a proximity to an interconnected stream may be directly influenced by stream stage. Wells deeper than 200 feet and farther than five miles from interconnected streams were excluded because pumping at greater depths or distances was assumed to cause capture from multiple sources (e.g., recharge zones, springs, ponded water, and other wells), which cannot be resolved with existing data and models. The GSAs selected these criteria based on the justification that minimum threshold exceedances at 25 percent or more of representative monitoring sites represent a significant impact, and that exceedance of these levels for 24 consecutive months or longer (indicating significant depletions of interconnected surface water through two consecutive periods of seasonal groundwater fluctuation) constitutes an impact that would potentially harm the long-term viability of affected beneficial uses and users. The criterion of 25

[4] For wells within a few thousand feet of a waterway, groundwater levels are expected to be controlled by the elevation of the connected surface water. For wells in intermediate locations between waterways and groundwater pumping centers, declines in water levels could also indicate current and future streamflow depletion (EDF, 2018).

percent or more of the representative monitoring wells dropping below their minimum thresholds for 24 consecutive months was regarded as an indicator of a significant, widespread problem representing undesirable results.

5.3.6.4 Potential Causes of Undesirable Results

Potential causes of undesirable results for depletions of interconnected surface water are likely tied to groundwater production, which could result in lowering of groundwater elevations in shallow aquifers near the connected streams. Increased groundwater production near interconnected streams may cause groundwater conditions that lead to undesirable results if this production changes the hydraulic gradient between the stream stage and the groundwater level. For the connected streams, an increase in the hydraulic gradient between the shallow groundwater and the stream bed may result in increases in the rate and volume of stream depletions.

5.3.6.5 Potential Effects of Undesirable Results

If depletions of interconnected surface waters reach levels indicating that undesirable results have occurred, the effects could potentially reduce the availability or change the timing of streamflow available for beneficial uses and users of surface water. Additionally, reduced streamflow could potentially reduce the availability of water to GDEs and riparian habitats. In addition, reduced stream flows can lead to increased water temperatures which can also potentially negatively impact certain species.

5.3.6.6 Evaluation of the Presence of Undesirable Results

Section 5.4 discusses how minimum thresholds were selected; more information on how the thresholds were established is also included in Appendix 5B, along with hydrographs of groundwater levels through 2020 for the depletions of interconnected surface waters monitoring points and the established depth of the minimum threshold for each monitoring site. Of the 12 monitoring sites, none were below the minimum threshold in the latest measurement in 2020, indicating that the Subbasin does not currently exceed the requirements for an undesirable result for depletions of interconnected surface water.

5.4 SUSTAINABILITY THRESHOLDS

Sustainability thresholds include minimum thresholds, measurable objectives, and interim milestones. Sustainability thresholds are described below by sustainability indicator. No management areas are identified for the Subbasin (see Chapter 3), and the same methodology for establishing sustainability thresholds was applied subbasin-wide for each applicable sustainability indicator. Potential effects of the selected sustainability thresholds on other neighboring subbasins are summarized at the end of this section.

Table 5-1 summarizes the sustainability thresholds for all applicable sustainability indicators in the Subbasin. Additional information and considerations are provided in the sections that follow.

Table 5-1. Summary of Sustainability Thresholds for All Sustainability Indicators Applicable to the Subbasin

Sustainability Indicator	Monitoring Network	Undesirable Result	Minimum Threshold (MT)	Measurable Objective (MO)
Chronic Lowering of Groundwater Levels	48 Representative Monitoring Network (RMN) wells monitored at least 2 to 3 times annually by DWR	25% (12 of 48) RMN wells fall continuously below their MT for 24 consecutive months	The lower of 50% of measured historical groundwater elevation range below the historical measured low elevation and the elevation corresponding to the 20th percentile of domestic well depths in the RMN well's Thiessen polygon, subject to interbasin coordination and consistency to ensure operational compatibility	Mean of the most recent 5 years of available groundwater elevation measurements up to 2020 subject to interbasin coordination and consistency to ensure operational compatibility; A fixed value, not a rolling average
Reduction in Groundwater Storage	48 RMN wells monitored at least 2 to 3 times annually by DWR (same as Groundwater Level monitoring network)	Use groundwater levels as proxy	Use groundwater levels as proxy	Use groundwater levels as proxy
Seawater Intrusion	Not applicable	Not applicable	Not applicable	Not applicable
Degraded Groundwater Quality	25 RMN wells monitored by others at variable intervals under existing State of California regulatory programs	Electrical conductivity (EC) in 25% (6 of 23) of the RMN wells exceeds the MT for two (2) consecutive years	The higher of EC of 900 microSiemens per centimeter (µS/cm) (the recommended California Secondary Maximum Contaminant Level) OR the pre-2015 historical maximum measured EC	EC of 700 µS/cm (corresponding to an agricultural water quality objective providing for no yield reduction for crops commonly grown in the Subbasin)
Land Subsidence	Existing Sacramento Valley Height Modernization Project (SVHMP) benchmarks (63 sites)	20% or more (13 of 63) monitoring sites (benchmarks) experience subsidence rates above the MT	0.5 feet per five years	0.25 feet per five years
Depletions of Interconnected Surface Waters	12 RMN wells less than 200 feet deep and between 2,000 feet and five miles of interconnected stream (Sacramento River, Colusa Drain, Stony Creek)	25% (3 of 12) RMN wells fall below their MT for 24 consecutive months	Ten (10) feet below the observed fall 2015 groundwater level (Fall 2015 level is the measured elevation recorded on the date closest to Oct 15)	Mean of last 5 years available groundwater elevation measurements subject to interbasin coordination and consistency to ensure operational compatibility; A fixed value, not a rolling average

5.4.1 Chronic Lowering of Groundwater Levels

As described in Section 5.3.1, chronic lowering of groundwater levels is considered to be significant and unreasonable when:

> *… it causes a significant and unreasonable reduction in the long-term viability of beneficial uses and users over the planning and implementation horizon of this GSP.*

Chronic lowering of groundwater levels may cause undesirable results when 25 percent of monitoring wells fall below the minimum threshold for 24 consecutive months. The following subsections describe the sustainability thresholds used to monitor and track the chronic lowering of groundwater levels. Appendix 5B provides additional information describing how the minimum thresholds and measurable objectives were established. Appendix 5C documents an economic analysis of the groundwater level minimum thresholds. That analysis generally supports setting minimum thresholds at the specified levels.

As described in Chapter 3, Basin Setting, the Subbasin has one principal aquifer, and therefore one groundwater level monitoring network. Thresholds have been established for all 48 groundwater level representative monitoring wells, as presented in Chapter 4, Monitoring Networks.

5.4.1.1 Minimum Thresholds

Minimum thresholds for the chronic lowering of groundwater levels were developed primarily by considering historical and current groundwater conditions, with lesser emphasis on projected future groundwater conditions. In general, groundwater levels during the 26-year historical period from 1990 through 2015 were used as the primary reference. This period includes relatively wet and dry periods including the back-to-back critically dry years of 2014 and 2015. Evaluation of historical and projected groundwater use in the Subbasin is further discussed in the Plan Area and Basin Setting chapters of this GSP (Chapter 2 and Chapter 3, respectively). Minimum threshold values were defined for individual representative monitoring wells as the groundwater level below which conditions may lead to undesirable results for beneficial uses and users in the vicinity of each well. The minimum threshold for each groundwater level representative monitoring well was calculated by utilizing a simple stepwise function. The minimum threshold is calculated by finding the deeper value of:

1. **20th percentile of shallowest domestic well depths in the monitoring well's Thiessen polygon**: Based on stakeholder input, it was determined that dewatering of domestic wells may be a potential undesirable result that could potentially be used to confirm the adequacy of the minimum threshold methodology. Domestic wells are generally shallower than agricultural and municipal wells and thus more sensitive to undesirable effects from decreases in groundwater elevations, such as well stranding. Additionally, the loss of a domestic well usually results in a loss of water for consumption, cooking, and sanitation purposes, which can often have substantial impacts on the users of the water and can be financially difficult for the well owner to mitigate. These potential adverse effects are addressed in the State's commitment to the Human Right to Water as codified in California Water Code Section 106.3. To protect the beneficial uses and users of groundwater from domestic wells, including supporting the Human Right to Water, groundwater levels need to remain higher than the bottom depth of domestic wells. Analysis of the DWR Well Completion Report (WCR) Database by the GSAs suggests that not all wells provided in the database are still active. Some of the wells included in the database are old enough that the usable lifespan of the well has been exceeded, some wells may not be constructed to meet current health standards (e.g., sanitary seals or other aspects of the well construction or

condition may be deficient), and some well depths and screen intervals would suggest that some wells have been dewatered prior to the implementation of SGMA (i.e., prior to January 1, 2015). The GSAs therefore determined, based on the analysis and feedback from the public and stakeholders, that protection of 100 percent of domestic wells in the WCR database was not reasonable or warranted, and that protection of 80 percent of wells in the WCR database was reasonable and acceptable. Consequently, it was determined that minimum threshold exceedances at more than 20 percent of domestic wells in the current version of the WCR database may constitute an undesirable result. This results in a minimum threshold that would protect 80 percent of domestic wells contained in the current version of the WCR database.

2. **50 percent of range below the historical low groundwater elevation**: To protect the conjunctive use of groundwater for agricultural production, groundwater levels must be able to fluctuate, lowering during droughts when groundwater pumping increases to augment reduced surface water availability, and increasing during years when surface water is available for recharge. For agricultural conjunctive use, the effects of declining groundwater levels are expected to be significant and unreasonable when groundwater levels drop below the lowest historical groundwater elevation by more than 50 percent of the historical range. After an analysis of available historical data, and with considerations of groundwater conditions, the GSAs determined that 50 percent of the historical range below the historical low groundwater level provided adequate operational flexibility at each representative monitoring well site. Consequently, minimum threshold exceedances of this level may constitute an undesirable result.

Appendices 5B and 5C provide additional information on the setting and evaluation of the minimum thresholds. As documented in Appendices 5B and 5C, for the Subbasin as a whole, approximately 46 percent of the domestic wells in the WCR database are shallower than the pre-2015 historical groundwater levels as defined by the groundwater level representative monitoring network. Many of these shallow wells may no longer be used, or they may have been deepened because they would have otherwise been dry at times prior to 2015. Nevertheless, all wells in the WCR database were considered in the calculation of the groundwater level minimum thresholds. Including these shallow, potentially unused or deepened wells in the analysis of well completions depths resulted in groundwater level minimum thresholds that are shallower than they would have been if the wells had been excluded.

Setting minimum thresholds using this methodology is protective of beneficial users and uses of groundwater, including agricultural, municipal, environmental and domestic uses in the Subbasin. The minimum thresholds align with the State's Human Right to Water policy by supporting the ability of drinking water beneficial users, including DACs, SDACs and Tribes, to access safe, clean, and affordable water for human consumption, cooking, and sanitary purposes. The GSAs chose this methodology for calculating the minimum threshold to balance the needs of multiple beneficial uses and users of the groundwater by allowing for adequate flexibility to compensate for drought periods while potentially protecting approximately 80 percent of nearby domestic wells, therefore avoiding undesirable results. Additionally, anecdotal evidence provided by the GSA member stakeholders suggests that groundwater levels seen in recent drought periods did not result in significant and unreasonable Subbasin-wide impacts to beneficial uses and users. The GSAs therefore consider the 2015 historical low groundwater elevation to be protective of current and future beneficial uses and users. In addition, this methodology includes consideration of the spatial location of each monitoring site and variable conditions (such as hydrogeological conditions or nearby infrastructure) across the Subbasin.

Figure 5-1 is a sample hydrograph with the calculated thresholds plotted, including the minimum threshold, in relation to historical groundwater levels. Similar hydrographs for all wells in the representative monitoring networks are included in Appendix 5B.

Table 5-2 presents the minimum thresholds for representative monitoring wells in the chronic lowering of groundwater levels monitoring network in the Subbasin. Additional information on the calculation of minimum thresholds is provided in Appendix 5B.

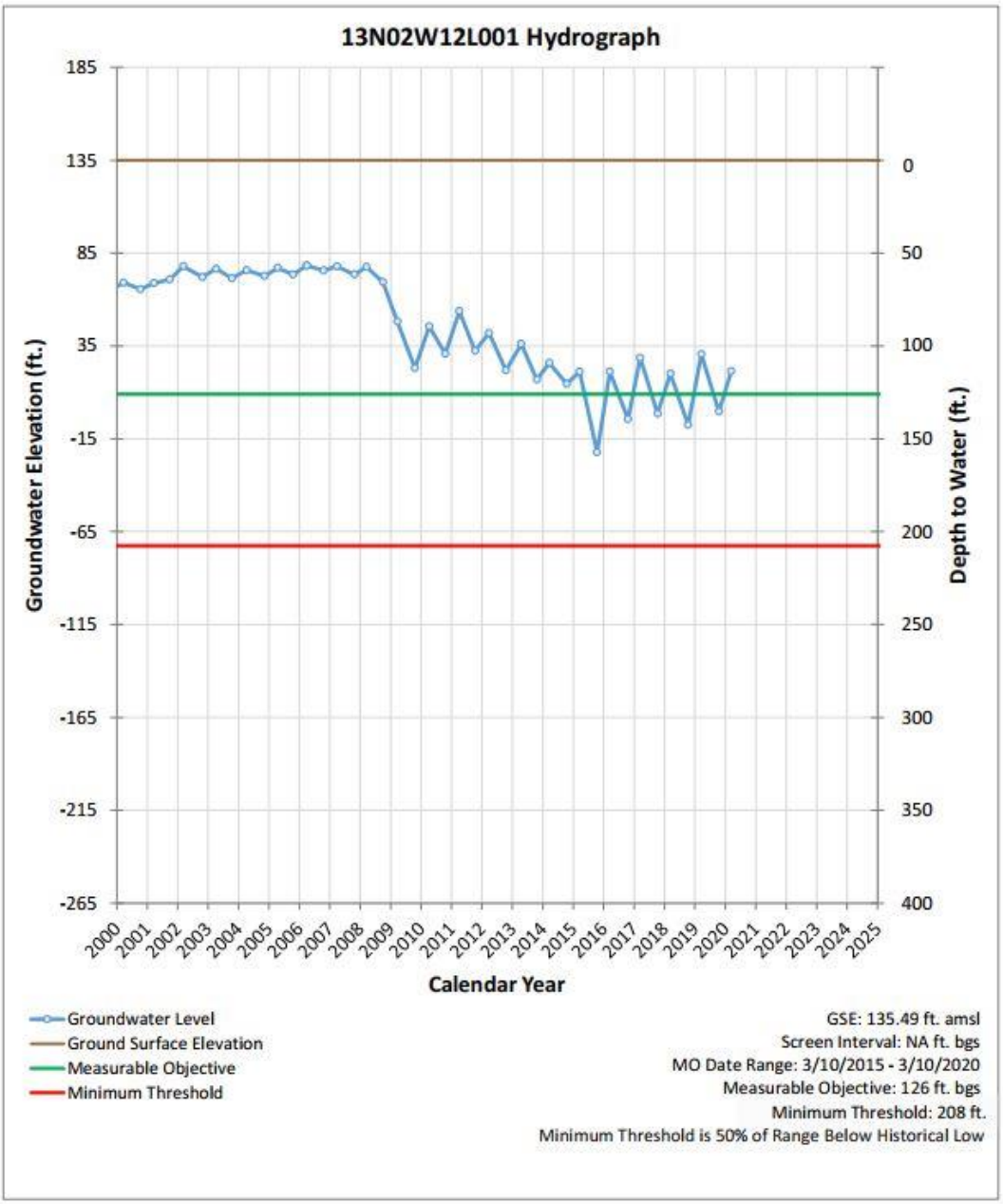


Figure 5-1. Hydrograph, Measurable Objective and Minimum Threshold for Groundwater Monitoring Well 13N02W12L001

5.4.1.1.1 Potential Effects on Other Sustainability Indicators

Groundwater levels have the potential to impact all other sustainability indicators applicable to the Subbasin. These potential effects are described below by sustainability indicator.

- **Reduction of Groundwater Storage:** Chronic lowering of groundwater levels is directly related to reduction of groundwater storage, as changes in groundwater levels are indicative of changes in groundwater storage in the Subbasin. As described in Section 5.4.2.1, the minimum thresholds for groundwater levels will effectively avoid undesirable results for reduction of groundwater storage since undesirable results related to chronic lowering of groundwater levels are expected to occur before the Subbasin would experience significant and unreasonable impacts related to groundwater storage, predominantly as a result of the large volume of groundwater in storage in the Subbasin.
- **Degraded Water Quality:** Chronic lowering of groundwater levels can impact groundwater quality by affecting the direction and rate of groundwater flows, potentially mobilizing saline water, and by affecting the location and characteristics of groundwater recharge or discharge, impacting the concentration of water quality parameters. The minimum thresholds determined for groundwater levels are not expected to contribute to undesirable results for degraded water quality, as they are protective of existing domestic well depths and historical groundwater elevations. Evaluation of 25 groundwater quality representative monitoring sites indicates that the Subbasins does not currently have undesirable results for degraded water quality. Implementation of the GSP is expected to maintain groundwater levels at the average of the last five years of measured groundwater level data (see Section 5.4.1.2). Given the similar trends in historical, current, and projected future groundwater levels, groundwater level sustainable management criteria are expected to support the maintenance of the generally good groundwater quality of the Subbasin.
- **Inelastic Land Subsidence:** Chronic lowering of groundwater levels can potentially cause inelastic land subsidence if it results in compaction of compressible clays in the subsurface. The minimum thresholds for groundwater levels are not expected to contribute to undesirable results for inelastic land subsidence, as they are protective of a range around historical groundwater elevations. Minimum thresholds for land subsidence have also been determined based on consideration of historical subsidence data between 2006-2017, providing flexibility around that range. Evaluation of 63 subsidence monitoring sites indicate that none were below the minimum threshold in the latest measurement from 2017, indicating that historical groundwater levels have not contributed to undesirable results for inelastic land subsidence.
- **Depletions of Interconnected Surface Water:** Reductions in groundwater levels can impact the rate and volume of stream depletions in interconnected streams and reduce the amount of groundwater available for GDEs. The representative groundwater level monitoring network used for monitoring the potential for depletions in interconnected streams is comprised of a selected, collocated subset of the representative monitoring network used for monitoring reductions in groundwater levels. For these selected wells, the interconnected stream depletions sustainable management criteria are more restrictive than the groundwater levels sustainable management criteria and take precedence over them. Therefore, coordinated implementation of the groundwater levels and the depletions of interconnected surface water sustainable management criteria are expected to be protective of interconnected surface waters and GDEs.

5.4.1.2 Measurable Objectives

Measurable objectives are quantitative goals that reflect desired Subbasin conditions and allow the Subbasin to achieve and maintain its sustainability goal. The measurable objectives for chronic lowering of groundwater levels in the Subbasin are shown in Table 5-2. The methodology for establishing these measurable objectives was determined by the Subbasin GSAs, including their respective Technical Advisory Committees, and bases the measurable objectives on the average of the last five years of measured groundwater level data. This method is generally representative of drought and recovery conditions within the Subbasin, as most wells utilize data collected between 2015 and 2020. These measurable objectives are expected to support achievement of the GSP sustainability goal and maintenance of groundwater sustainability over the planning and implementation horizon.

5.4.1.3 Margin of Operational Flexibility

The margin of operational flexibility is the difference between the measurable objective and the minimum threshold for each well. The margin of operational flexibility is intended to provide adequate flexibility to allow for increased groundwater production during drought years with recovery during normal or wet years, accounting for uncertainty in each. This ensures undesirable results are not triggered due to drought conditions that the GSAs cannot control, while allowing for adequate local recovery of groundwater levels after those drought periods, therefore maintaining sustainability in the long term. Because the measurable objective and minimum threshold at each well take into consideration the historical water budgets, seasonal and long-term trends, and periods of drought, the margin of operational flexibility also accounts for these factors.

The margins of operational flexibility for chronic lowering of groundwater levels are shown in Table 5-2.

5.4.1.4 Interim Milestones

Interim milestones are intended to provide a glidepath towards sustainability over the implementation horizon by providing progressive targets for groundwater levels every five years after GSP submittal. After sustainability is reached, interim milestones are not required and subbasins are managed according to the measurable objective (defined in the GSP Emergency Regulations as "…specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions…to achieve the sustainability goal for the basin"). For subbasins that are already sustainable (such as the Subbasin), interim milestones are intended to provide numerical metrics for GSAs to track progress toward meeting the subbasin's sustainability goal and ensuring that the subbasin remains sustainable. Because the minimum thresholds and measurable objectives for chronic lowering of groundwater levels were established to support Subbasin sustainability, the interim milestones were established to maintain water levels in the Subbasin's margin of operational flexibility as established by the minimum thresholds and measurable objectives. The interim milestones for chronic lowering of groundwater levels are consistent with the measurable objectives, as shown in Table 5-2.

Table 5-2. Groundwater Level Representative Monitoring Network and Sustainability Criteria

SWN	CASGEM ID	Ground Surface Elevation, ft	Minimum Threshold GWE, ft amsl	Minimum Threshold DTW, ft bgs	Minimum Threshold Method	Measurable Objective GWE, ft amsl	Measurable Objective DTW, ft bgs	Interim Milestone GWE, ft amsl	Interim Milestone DTW, ft bgs	Margin of Operational Flexibility, ft	20th Percentile Domestic Wells, ft bgs	50% of Range Below Historical Low, ft bgs
12N01E06D004	16331	28	-108	136	(a)	-1	29	-1	29	107	136	94
13N01E11A001	18534	32	-75	106	(a)	22	10	22	10	96	106	28
13N01W07G001	36246	90	-106	196	(b)	-9	99	-9	99	97	153	196
13N01W13P003	18549	32	-88	120	(a)	8	24	8	24	96	120	67
13N01W22P002	16357	60	-124	184	(a)	26	34	26	34	150	184	116
13N02W12L001	31899	135	-72	208	(b)	9	126	9	126	82	200	208
13N02W15J001	39884	213	-62	274	(b)	61	152	61	152	122	215	274
13N02W20H002	25005	343	95	248	(a)	174	169	174	169	79	248	201
14N01E35P003	38718	47	-118	165	(a)	28	19	28	19	146	165	32
14N01W04K003	18554	37	-86	124	(a)	12	25	12	25	99	124	44
14N02W13N001	18563	62	-80	142	(a)	24	38	24	38	104	142	78
14N02W22A002	54756	84	-126	210	(a)	84	0	84	0	210	210	0
14N02W29J001	18566	163	-86	248	(b)	22	141	22	141	107	216	248
14N03W14Q003	32324	173	-89	261	(b)	-13	186	-13	186	75	115	261
14N03W24C001	16691	173	-5	178	(b)	38	135	38	135	43	138	178
15N01W05G001	14309	47	-54	101	(a)	28	19	28	19	82	101	51
15N02W19E001	14319	87	-13	100	(a)	73	14	73	14	86	100	50
15N03W08Q001	N/A	113	43	70	(a)	107	6	107	6	64	70	10
15N03W20Q002	38293	129	60	69	(a)	113	16	113	16	53	69	28
16N02W05B003	25511	65	-71	136	(a)	47	18	47	18	118	136	48
16N02W25B002	33868	55	-25	80	(a)	30	25	30	25	55	80	54
16N03W14H006	24683	66	-94	160	(a)	51	15	51	15	145	160	40
16N04W02P001	16308	163	63	100	(a)	139	24	139	24	76	100	42
17N02W09H004	25514	67	-52	119	(a)	56	11	56	11	108	119	32
17N02W30J002	16960	63	-119	182	(a)	44	19	44	19	163	182	51
17N03W08R001	39127	107	-13	120	(a)	88	19	88	19	101	120	28
17N03W32H001	35475	100	-38	138	(a)	92	8	92	8	130	138	35
18N02W18D004	24953	85	-80	165	(a)	62	23	62	23	142	165	62

Table 5-2. Groundwater Level Representative Monitoring Network and Sustainability Criteria

SWN	CASGEM ID	Ground Surface Elevation, ft	Minimum Threshold GWE, ft amsl	Minimum Threshold DTW, ft bgs	Minimum Threshold Method	Measurable Objective GWE, ft amsl	Measurable Objective DTW, ft bgs	Interim Milestone GWE, ft amsl	Interim Milestone DTW, ft bgs	Margin of Operational Flexibility, ft	20th Percentile Domestic Wells, ft bgs	50% of Range Below Historical Low, ft bgs
18N02W36B001	16914	75	-3	78	(a)	53	22	53	22	56	78	59
19N02W08Q002	25762	108	12	96	(a)	98	10	98	10	86	96	40
19N02W33K001	19793	87	21	66	(a)	71	16	71	16	50	66	53
19N04W14M002	25787	186	46	140	(a)	151	35	151	35	105	140	50
20N02W11A001	17170	125	49	76	(a)	119	6	119	6	70	76	22
20N02W18R008	23986	131	47	84	(a)	120	11	120	11	73	84	18
20N02W25F004	23989	102	37	65	(a)	97	5	97	5	60	65	12
20N02W33B001	17174	105	31	74	(a)	100	5	100	5	69	74	17
20N03W07E004	37860	179	31	148	(a)	100	79	100	79	69	148	124
21N02W01F003	38535	161	71	90	(a)	124	37	124	37	53	90	67
21N02W04G004	24993	178	51	127	(b)	121	57	121	57	70	92	127
21N02W05M002	39676	189	55	134	(a)	140	49	140	49	85	134	112
21N02W33M003	38536	149	67	82	(a)	119	30	119	30	52	82	52
21N02W36A002	21239	135	24	112	(b)	91	44	91	44	68	81	112
21N03W01R002	25232	203	48	155	(b)	151	52	151	52	103	108	155
21N03W23D002	23992	205	84	121	(b)	140	65	140	65	56	89	121
21N03W34Q004	25789	167	42	125	(a)	112	55	112	55	70	125	89
21N04W12A002	24650	248	18	230	(b)	73	175	73	175	55	98	230
22N02W30H003	25726	204	82	122	(b)	150	54	150	54	68	76	122
22N03W24E002	25236	231	122	109	(b)	176	55	176	55	54	90	109

SWN = State Well Number
CASGEM ID = California Statewide Groundwater Elevation Monitoring Identification Code
GWE = groundwater elevation
DTW = depth to water
ft = feet
amsl = above mean sea level
bgs = below ground surface
Minimum Thresholds were calculated as either (a) the 20th percentile of domestic well depth near the monitoring well, or (b) 50 percent of the measured water level range below the historical low within the monitoring well.

5.4.2 Reduction of Groundwater Storage

The undesirable result for the reduction of groundwater storage is:

> *…a result that would cause significant and unreasonable reduction in the long-term viability of beneficial uses and users over the planning and implementation horizon of this GSP.*

The undesirable result for the reduction of groundwater storage is monitored by proxy using groundwater levels. The thresholds set for the reduction of groundwater storage have been established so that when 25 percent of monitoring wells fall below the minimum threshold for 24 consecutive months, an undesirable result is detected. The following subsections describe the sustainability thresholds used for the reduction of groundwater storage.

5.4.2.1 Proxy Monitoring

Monitoring for a reduction of groundwater storage in the Subbasin uses groundwater levels as a proxy for determining sustainability, as permitted by 23 CCR §354.28(d). As described above, any benefits to groundwater storage are expected to coincide with groundwater level management.

The limiting factor to storage use is existing well infrastructure (depth of wells) and near surface conditions, not the volume of groundwater in storage (see Section 5.3.2.2). Therefore, the established groundwater levels minimum thresholds are protective against significant and unreasonable changes in groundwater storage. Minimum thresholds for groundwater levels will effectively avoid undesirable results for reduction of groundwater storage since undesirable results related to chronic lowering of groundwater levels would occur before the Subbasin would experience significant and unreasonable impacts related to groundwater storage, predominantly as a result of the large volume of groundwater in storage in the Subbasin (see Section 5.3.2.2). Therefore, by setting minimum thresholds for groundwater levels, storage is also effectively managed and the use of groundwater levels as a proxy metric for the groundwater storage sustainability indicator is appropriate. Minimum thresholds for groundwater levels, and thus for groundwater storage, are calculated with consideration of historical trends, water year type, and historical and projected groundwater use within the Subbasin, and support sustainable operation, as described in Section 5.2.

5.4.3 Seawater Intrusion

Seawater intrusion is not an applicable sustainability indicator because seawater intrusion is not present and is not likely to occur in the Subbasin due to the distance between the Subbasin and the Pacific Ocean, bays, deltas, or inlets.

5.4.4 Degraded Water Quality

The undesirable result for degraded water quality is described as:

> *Significant and unreasonable degradation of water quality that occurs when GSP projects or management actions cause an increase in the concentration of applicable constituents of concern in groundwater supply wells that lead to adverse impacts on beneficial uses or users of groundwater.*

The thresholds set for degraded water quality have been established so that when 25 percent of representative monitoring sites exceed the minimum threshold for two consecutive years, an undesirable result is detected. The following subsections describe the sustainability thresholds used for degraded water quality. The foregoing sustainability thresholds were established with the GSAs' understanding that additional new or existing wells will need to be added to the monitoring network over time. Additionally, the GSAs acknowledge that the sustainability thresholds will need to be reviewed and evaluated, and potentially refined, as additional wells are added, and additional data is collected and analyzed.

Thresholds have been established for all 25 groundwater quality representative wells, as presented in Appendix 5D. Management areas were not used in the calculations of any thresholds.

5.4.4.1 Minimum Thresholds

The minimum threshold for degraded water quality has been established as the higher of either 900 microSiemens per centimeter (μS/cm) EC, which is consistent with the recommended California Secondary Maximum Contaminant Level (SMCL), or the pre-2015 historical maximum recorded EC value.[5] In developing the minimum thresholds for groundwater quality, beneficial uses of groundwater as a drinking water supply and as an agricultural supply were considered. The potential adverse effects to drinking water addressed in the State's commitment to Human Right to Water as codified in California Water Code Section 106.3 were considered. Setting minimum thresholds using this methodology is protective of beneficial uses and users of groundwater, including agricultural, municipal, and domestic uses in the Subbasin.

The minimum threshold for degraded water quality is calculated to be at an EC level that allows for adequate flexibility within the pre-2015 historical maximum EC level, to compensate for changing groundwater conditions during drought periods, while protecting SMCLs established for aesthetic reasons, such as taste, odor, and color. It is important to note that SMCLs are not based on public health concerns and established to address other non-health related concerns. Exceedance of these minimum threshold values may therefore cause undesirable results for domestic well users related to non-health related concerns at wells where the pre-2015 historical maximum EC level did not exceed the SMCL. At wells where the pre-2015 historical maximum EC level exceeded the recommended California SMCL, groundwater management through coordination with existing regulatory and monitoring programs with respect to this minimum threshold will ensure that degradation of groundwater quality does not exceed historical levels as a result of Subbasin groundwater management activities pursuant to the GSP.

5.4.4.2 Measurable Objectives

The measurable objective for degraded water quality is 700 μS/cm EC, which is consistent with the agricultural water quality objective providing for no yield reduction for crops commonly grown in the Subbasin. The measurable objective for degraded water quality therefore supports ongoing sustainability by protecting water quality within levels that are suitable for drinking water use and agricultural water use, among other beneficial uses. Measurable objectives have not been determined for other water quality constituents.

[5] Consistent with SGMA, the GSP "is not required to address undesirable results that occurred before, and have not been corrected by, January 1, 2015" (Water Code Section 10727.2 (b) (4)).

5.4.4.3 Margin of Operational Flexibility

The margin of operational flexibility for degraded water quality is 200 μS/cm EC (the difference between the measurable objective and minimum threshold). The margin of operational flexibility is intended to provide adequate flexibility to allow for changes in groundwater quality constituent concentrations during various subbasin conditions, such as drought years. This ensures undesirable results are not triggered due to temporary fluctuations in conditions that are anticipated to occur during the implementation horizon, accounting for uncertainty in future conditions. Because the measurable objective and minimum threshold at each site take into consideration historical water quality characteristics, the margin of operational flexibility also accounts for these factors.

5.4.4.4 Interim Milestones

Interim milestones are intended to provide a glidepath towards sustainability over the implementation horizon by providing progressive targets for groundwater quality every five years after GSP submittal. After sustainability is reached, interim milestones are not required and basins are managed according to the measurable objectives (defined in the GSP Emergency Regulations as "…specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions…to achieve the sustainability goal for the basin"). For basins that are already sustainable (such as the Subbasin), interim milestones are intended to provide numerical metrics for GSAs to track progress toward meeting the Subbasin's sustainability goal and ensuring that the Subbasin remains sustainable. Because the minimum thresholds and measurable objectives for degraded water quality were established to support Subbasin sustainability, the interim milestones were established to maintain water quality constituent levels in the Subbasin's margin of operational flexibility as established by the minimum thresholds and measurable objectives. The interim milestone for degraded water quality is consistent with the measurable objective, and is set at 700 μS/cm. This interim milestone is also consistent with the GSAs' role in working with the State of California to guarantee the Human Right to Water to the residents of the Subbasin. Additional discussion of the Human Right to Water and its relationship to the GSAs and the GSP is provided in Chapter 2.

5.4.5 Inelastic Land Subsidence

The undesirable result for inelastic land subsidence is:

> *…a result due to groundwater extraction that would cause significant and unreasonable impacts to critical infrastructure over the planning and implementation horizon of this GSP.*

The undesirable result for inelastic land subsidence is monitored by DWR extensometers, continuously operating global positioning system (CGPS) benchmarks, and traditional benchmarks. The thresholds set for inelastic land subsidence have been established so that when 20 percent of representative monitoring locations (i.e., 13 of 63 locations) exceed their minimum thresholds, an undesirable result is detected. The 13 locations must be the same subset of locations, not any combination of 13 locations. Management areas were not used in establishing or calculating thresholds.

5.4.5.1 Minimum Thresholds

Minimum thresholds for inelastic land subsidence were determined based on consideration of historical subsidence using data available from the Sacramento Valley Height Modernization Project. Minimum thresholds were calculated as the maximum rate of subsidence, described below, above which conditions could collectively generate undesirable results in the Subbasin. While the sensitivity of local infrastructure to land subsidence is not well understood at this time, the Subbasin has extensive networks of pipelines and

open canals and drains owned by various surface water suppliers that are used to convey irrigation and drain water. These networks are likely the existing infrastructure most sensitive to land subsidence. A study is proposed in Chapter 7 that would evaluate the sensitivity of local infrastructure to potential subsidence in the Subbasin. Should additional information be developed on the vulnerability of this infrastructure to subsidence, these minimum thresholds may be refined. The GSAs will continue monitoring to continue to improve subbasin understanding during GSP implementation. Refinement of minimum thresholds and any improved understanding of subsidence in the subbasin will be reported in annual reports.

The minimum threshold for this sustainability indicator has been set at 0.5 feet per five years (6 inches).

The sustainable management criteria will be reviewed and adjusted to account for potential changes in subsidence rates brought about by implementation of projects and management actions and future groundwater resource development. The extent of subsidence-prone areas, which may be underlain by sediments that have greater susceptibility to subsidence due to groundwater withdrawal, will continue to be delineated as data gaps are filled through the ongoing subsidence monitoring programs (using data from benchmarks, extensometers and InSAR surveys) and subsidence-prone sediments are characterized during drilling for well construction, extensometer installation or other subsurface investigations needed for the development of specific projects and management actions.

Managing groundwater conditions in the Subbasin to avoid exceedance of the rate of inelastic subsidence established by the minimum threshold is considered unlikely to cause a significant and unreasonable reduction in the viability of the use of critical infrastructure over the planning and implementation horizon of this GSP.

5.4.5.2 Measurable Objectives

The measurable objective for inelastic land subsidence is set at 0.25 feet (3 inches) of subsidence per five years at each site. This rate, in conjunction with sustainable extractions of groundwater over the implementation horizon, is believed to provide enough operational flexibility during drought periods while protecting infrastructure and beneficial users and uses in the Subbasin.

The selected minimum threshold rate of 0.5 feet per five years allows for possible future acceleration of land subsidence. However, because the measurable objective is set at 0.25 feet per five years, projects and management actions will be implemented before the minimum threshold rates are reached.

DWR reports that the probable error in the subsidence values reported for the monitoring benchmarks is ±0.17 feet, meaning that for any reported value, the actual subsidence value is likely to fall in a range between plus or minus 0.17 feet of the reported value. The selected measurable objective subsidence rate of 0.25 feet per five years is deliberately greater than the reported probable error of ±0.17 feet as a means of avoiding false exceedance of the measurable objective.

5.4.5.3 Margin of Operational Flexibility

The land subsidence margin of operational flexibility is 0.25 feet per five years. This value is more than the potential error (±0.17 feet) in the benchmark measurements, allowing for a range of allowable subsidence between the minimum thresholds and a measurable objective that is set within the measurable range (outside the typical range of measurement error and uncertainty) to allow for management if the measurable objective were to be exceeded. Because the measurable objective and minimum threshold at each site take into consideration historical data from the Sacramento Valley Height Modernization Project, the margin of operational flexibility also accounts for these data.

5.4.5.4 Interim Milestones

Interim milestones are intended to provide a glidepath towards sustainability over the implementation horizon by providing progressive targets for subsidence rates every five years after GSP submittal. After sustainability is reached, interim milestones are not required and basins are managed according to the measurable objectives (defined in the GSP Emergency Regulations as "…specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions…to achieve the sustainability goal for the basin"). For subbasins that are already sustainable (such as the Subbasin), interim milestones are intended to provide numerical metrics for GSAs to track progress toward meeting the subbasin's sustainability goal and ensuring that the subbasin remains sustainable. Because the minimum thresholds and measurable objectives for inelastic land subsidence were established to support Subbasin sustainability, the interim milestones are to ensure subsidence rates remain in the Subbasin's margin of operational flexibility as established by the minimum thresholds and measurable objectives. The interim milestones for land subsidence are consistent with the measurable objectives and are set at 0.25 feet (3 inches) of subsidence per five years at each site.

5.4.6 Depletions of Interconnected Surface Water

The undesirable result for depletions of interconnected surface water is:

> *…a result that causes significant and unreasonable adverse effects on beneficial uses and users of interconnected surface water within the Subbasin over the planning and implementation horizon of this GSP.*

The undesirable result for depletions of interconnected surface water is monitored by proxy using groundwater levels. The thresholds set for depletions of interconnected surface water have been established so that when 25 percent of monitoring wells (i.e., 3 of 12 wells) fall below the minimum threshold for 24 consecutive months, an undesirable result is detected. The following subsections describe the sustainability thresholds used for depletions of interconnected surface water. Additional information describing how the minimum thresholds and measurable objectives were established is also included in Appendix 5B.

The foregoing sustainable management criteria were established with the GSAs' understanding that additional new or existing wells will need to be added to the monitoring network over time. Additionally, the GSAs acknowledge that the sustainability thresholds will need to be reviewed and evaluated, and potentially refined, as additional wells are added, and additional data is collected and analyzed.

5.4.6.1 Minimum Thresholds

Minimum thresholds for depletions of interconnected surface waters were determined based on evaluation of historical data from the monitoring network for interconnected surface water, which is composed of 12 shallow groundwater wells located proximate to interconnected streams in the Subbasin. The minimum thresholds set at these sites for assessing impacts to interconnected surface waters were calculated by finding the groundwater elevations in Fall of 2015 and adding 10 feet to that depth. Measurements selected for Fall 2015 were found by selecting measurements closest to October 15, 2015, considered to the be period of lowest groundwater elevations during the last drought based on review of historical groundwater levels and hydrologic data. All wells recorded measurements within three days of this date, providing a relative "snapshot" of groundwater conditions during this time. Management areas were not used in calculating the minimum threshold, or any other threshold for depletions of interconnected surface waters. Figure 5-2 provides an example hydrograph with all depletions of interconnected surface water thresholds plotted. Minimum thresholds for interconnected surface water are provided in Table 5-3. Additional

information on the calculation of minimum thresholds is provided in Appendix 5B along with hydrographs for all representative monitoring wells in the interconnected surface water monitoring network showing the site-specific minimum thresholds. The minimum threshold was selected such that groundwater levels near interconnected surface water courses would be protective of the beneficial use and users of shallower groundwater near streams and rivers, including those of shallower domestic users and potential groundwater dependent ecosystems. Levels from Fall 2015 represent conditions during a drought period but are generally believed to have still protected beneficial users at that time and therefore avoid undesirable results. The addition of 10 feet to the Fall 2015 groundwater depth to water is intended to provide an appropriate margin of operational flexibility in the future during GSP implementation based on recommendations made through discussion with the GSAs and stakeholders.

Consideration for the location, quantity, and timing of depletions of interconnected surface water along the primary waterways in the Subbasin is described in Chapter 3 and Appendix 3D. Volumes of projected (future) streamflow depletion during the GSP implementation period and sustainability monitoring horizon were assessed using the C2VSimFG-Colusa model, the best available information to support quantification of streamflow depletion. Documentation of this model is provided in Appendix 3D. Results of these analyses indicate that streamflow gain and loss do not appear to be strongly affected by increases in groundwater pumping needed to satisfy increased irrigation requirements resulting from potential future climate change, or by recharge projects than could be implemented in the Subbasin. Therefore, it is concluded, on a provisional basis, that the effects of groundwater management in the Subbasin will not have significant and unreasonable effects on beneficial uses and users of surface water.

While information and understanding of interconnected surface waters is limited, groundwater levels that exceed the minimum threshold in the future for an extended period of time could impact the beneficial uses and users of shallow groundwater by dewatering domestic wells and limiting resources for groundwater dependent ecosystems. However, as additional data are collected during GSP implementation, the understanding of interconnected surface waters may change and the threshold calculations revised to reflect a better understanding of this complex interaction and the Subbasin's unique conditions.

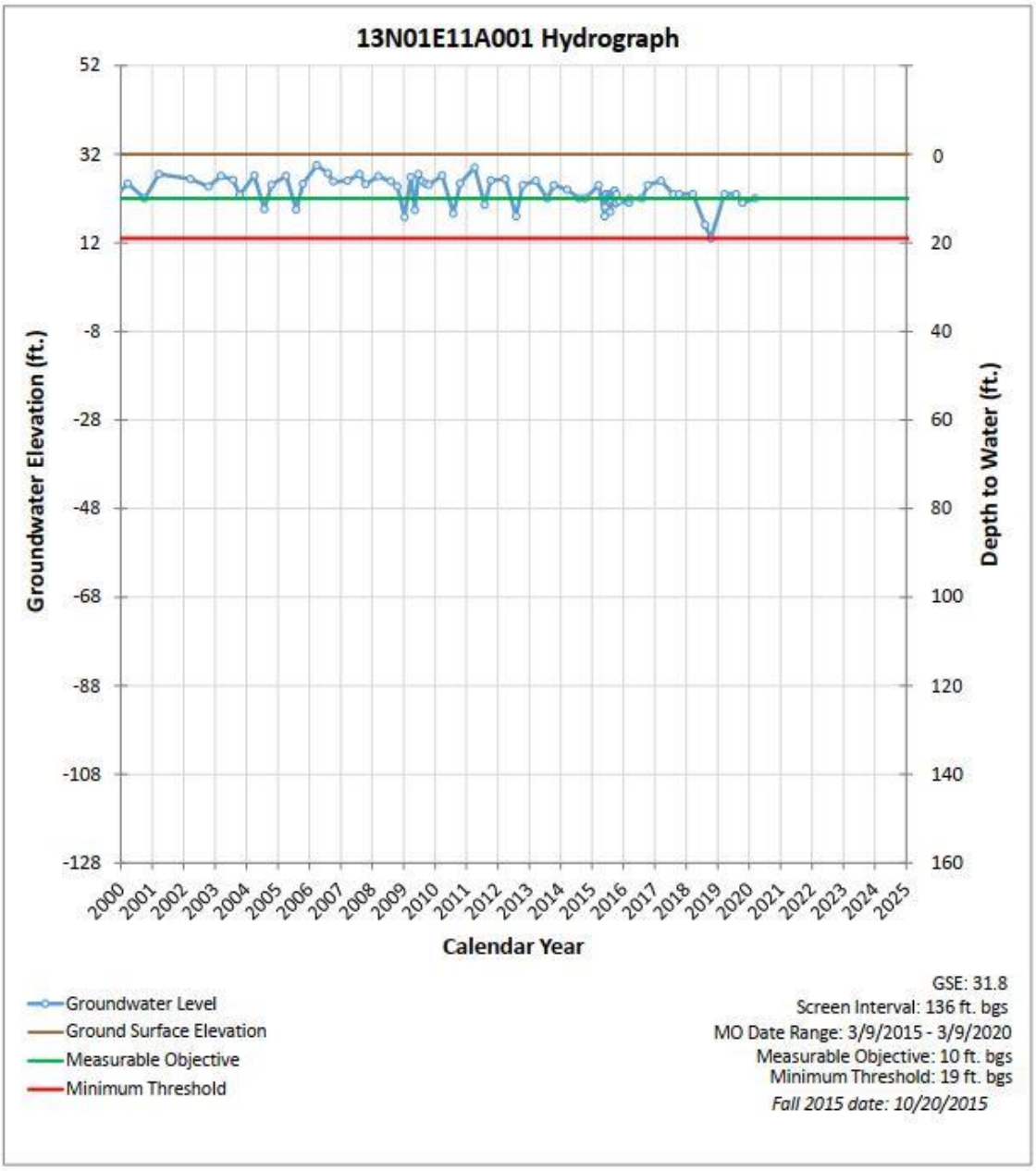


Figure 5-2. Hydrograph, Measurable Objective and Minimum Threshold for Interconnected Surface Water Monitoring Well 13N01E11A001

Table 5-3. Depletions of Interconnected Surface Water Representative Monitoring Network and Sustainability Criteria

SWN	CASGEM ID	Ground Surface Elevation, ft	Minimum Threshold GWE, ft amsl	Minimum Threshold DTW, ft bgs	Measurable Objective GWE, ft amsl	Measurable Objective DTW, ft bgs	Interim Milestone GWE, ft amsl	Interim Milestone DTW, ft bgs	Margin of Operational Flexibility, ft	Fall 2015 DTW, ft bgs
13N01E11A001	18534	32	13	19	22	10	22	10	9	9
13N01W07G001	36246	90	-19	110	-10	100	-10	100	10	100
14N01W04K003	18554	37	3	34	12	25	12	25	9	24
15N01W05G001	14309	47	19	29	27	20	27	20	9	19
17N02W30J002	16960	63	26	37	44	19	44	19	18	27
20N02W11A001	17170	125	106	20	119	6	119	6	14	10
20N02W25F004	23991	102	87	15	97	5	97	5	10	5
21N02W01F004	40029	162	105	57	126	36	126	36	21	47
21N02W05M003	23996	189	125	64	148	41	148	41	23	54
21N02W36A002	21239	135	59	76	91	44	91	44	32	76
22N02W30H004	38609	204	161	43	179	25	179	25	18	33
22N03W24E003	25758	231	194	36	208	23	208	23	13	26

CASGEM ID = California Statewide Groundwater Elevation Monitoring Identification Code
GWE = groundwater elevation
DTW = depth to water
ft = feet
amsl = above mean sea level
bgs = below ground surface

Special considerations were made in establishing the minimum threshold for monitoring well 21N02W36A002, which experienced drawdowns over an approximately eight-month period in 2015 and 2016. A deeper measurement recorded on October 20, 2015 was selected for the minimum threshold calculation for this well to better represent local conditions at that time, rather than adding an additional 10 feet (in order to be more protective). Figure 5-3 provides the depletions of interconnected surface water hydrograph with applicable thresholds plotted for well 21N02W36A002.

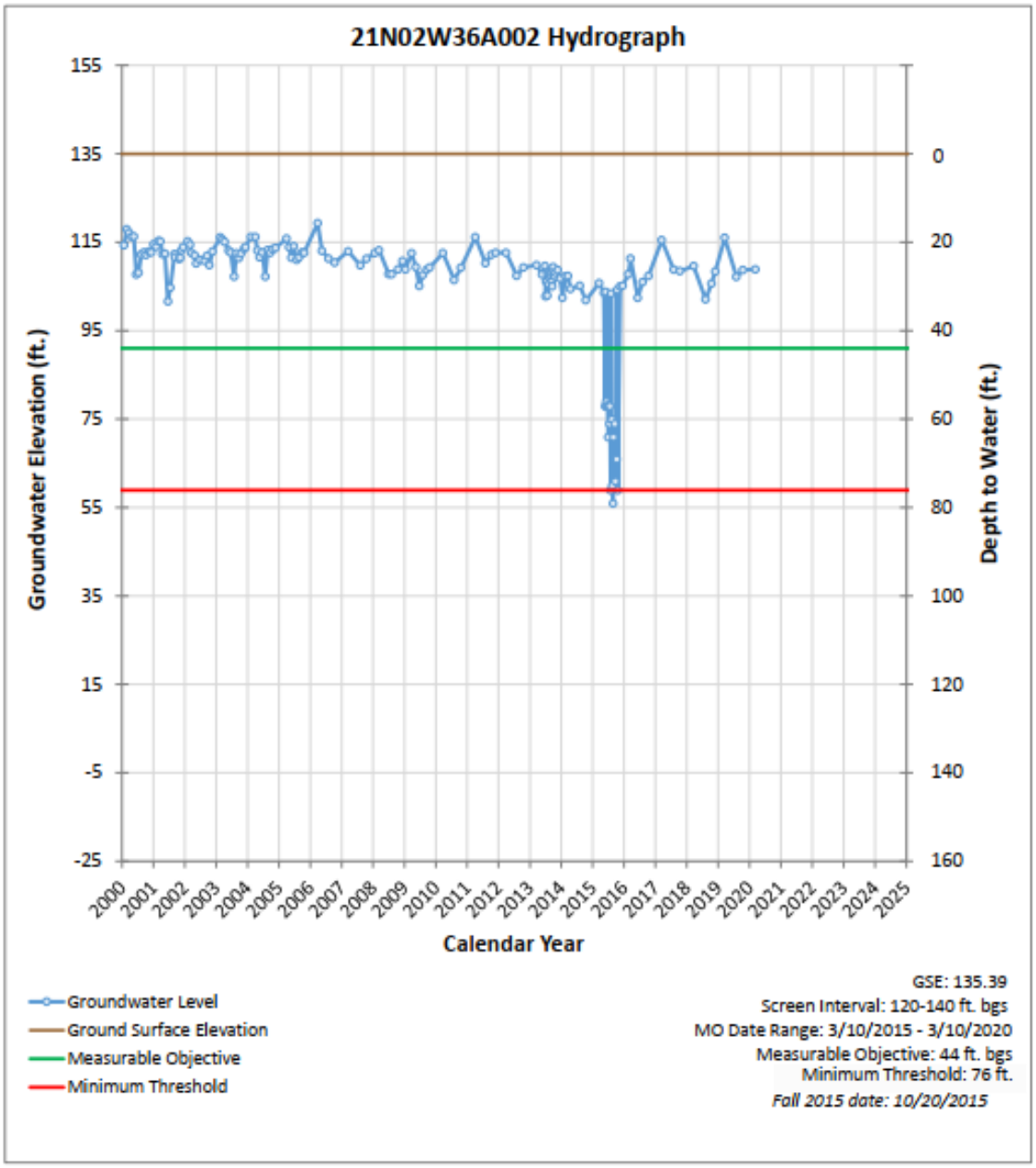


Figure 5-3. Hydrograph, Measurable Objective and Minimum Threshold for Interconnected Surface Water Monitoring Well 21N02W36A002

5.4.6.2 Measurable Objectives

Measurable objectives for depletions of interconnected surface water at representative monitoring locations are shown in Table 5-3. The measurable objective was calculated for each well using the average of the most recent five years of available groundwater level measurements. This methodology is consistent with that used in setting the measurable objectives for the chronic lowering of groundwater levels measurable objectives. This method is generally representative of drought and recovery conditions within the Subbasin as most wells utilize data recorded between 2015 and 2020. It is also consistent with the measurable objective calculation method for groundwater levels sustainability indicator.

5.4.6.3 Margin of Operational Flexibility

The margin of operational flexibility is the difference between the measurable objective and the minimum threshold for each well. The margin of operational flexibility is intended to provide adequate flexibility to allow for increased groundwater production during drought years with recovery during normal or wet years, accounting for uncertainty in each. This ensures undesirable results are not triggered due to drought conditions that the GSAs cannot control while allowing for adequate local recovery of groundwater levels after those drought periods, thereby maintaining sustainability in the long term. The margins of operational flexibility for depletions of interconnected surface water are shown in Table 5-3. The methodology used to set these margins of operational flexibility is consistent with that used for setting the margins of operational flexibility for the chronic lowering of groundwater levels. Because the measurable objective and minimum threshold at each well take into consideration the historical water budgets, seasonal and long-term trends, and periods of drought, the margin of operational flexibility also accounts for these factors.

5.4.6.4 Interim Milestones

Interim milestones are intended to provide a glidepath towards sustainability over the implementation horizon by providing progressive targets for groundwater levels every five years after GSP submittal. After sustainability is reached, interim milestones are not required and subbasins are managed according to the measurable objectives (defined in the GSP Emergency Regulations as "…specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions…to achieve the sustainability goal for the basin"). For subbasins that are already sustainable (such as the Subbasin), interim milestones are intended to provide numerical metrics for GSAs to track progress toward meeting the subbasin's sustainability goal and ensuring that the subbasin remains sustainable. Because the minimum thresholds and measurable objectives for the depletions of interconnected surface waters were developed to support Subbasin sustainability, the interim milestones were established to maintain water levels within the Subbasin's margin of operational flexibility as set by the minimum thresholds and measurable objectives. The interim milestones for depletions of interconnected surface water are shown in Table 5-3. The methodology used to set these interim milestones is consistent with that used for setting the interim milestones for the chronic lowering of groundwater levels.

5.4.7 Effects of Minimum Thresholds on Adjacent Subbasins

The minimum thresholds described in the preceding sections have been selected and evaluated to ascertain that they do not cause undesirable results in adjacent subbasins, and that they do not affect the ability of adjacent subbasins to achieve their groundwater sustainability goals.

Based on groundwater model results, sustainable management of the Subbasin under SGMA is not expected to significantly affect the net groundwater exchange with surrounding subbasins. Table 3-9 in Chapter 3, *Basin Setting*, summarizes the average annual groundwater system inflows and outflows over the historical, current, and projected (future) water budget periods. Over all scenarios, subsurface inflows and subsurface outflows to and from the Subbasin generally remain unchanged. Total subsurface inflows are approximately 200 to 209 thousand acre-feet per year (taf/yr), on average, while total subsurface outflows are approximately 146 to 149 taf/yr, on average. The variations between scenarios are considered to be within the uncertainty of the model, indicating no significant change in the net groundwater exchange with surrounding subbasins.

Likewise, groundwater model results do not suggest that sustainable management of the Subbasin will significantly affect the net depletions of interconnected surface water along waterways that flow through the Subbasin. As summarized in Appendix 3D, streamflow gain and loss along the Sacramento River, Stony Creek, and the Colusa Drain do not appear to be strongly affected by increases in groundwater pumping needed to satisfy increased irrigation requirements resulting from potential future climate change, or by recharge projects than could be implemented in the Subbasin. Therefore, it is concluded, on a provisional basis, that the effects of groundwater management in the Subbasin will not have significant and unreasonable effects on beneficial uses and users of interconnected surface water.

The Subbasin GSAs and the GSAs in the adjacent subbasins coordinated their approach to developing sustainable management criteria during development of their respective GSPs and will continue to coordinate their efforts during plan implementation. The Subbasin GSAs and the GSAs in the adjacent subbasins developed similar sustainable management criteria for degraded water quality and inelastic land subsidence. Because of the similarity in these sustainable management criteria across the subbasins, and the ongoing interbasin coordination efforts, it is anticipated that the minimum thresholds established in the Subbasin for degraded water quality and inelastic land subsidence will help avoid undesirable results for the Subbasin and the adjacent subbasins. Section 7.1.2 describes implementation activities focused on interbasin coordination for the degraded water quality, inelastic land subsidence, and other sustainability indicators.

The GSAs will continue to monitor the effects of groundwater management according to the sustainability thresholds described in this chapter throughout GSP implementation, including those effects on adjacent Subbasins. The CGA, GGA, and neighboring GSAs have coordinated throughout GSP development and will continue to coordinate and share technical data during GSP implementation. Ongoing and planned coordination activities are described further in Chapter 7 of the GSP.

CHAPTER 6
Projects and Management Actions

This chapter describes the projects and management actions (PMAs) that are ongoing or planned for implementation by agencies in the Subbasin, and potential PMAs in various stages of development. In accordance with 23 CCR §354.44, PMAs were developed to achieve the Subbasin sustainability goal by 2042 and avoid undesirable results over the GSP planning and implementation horizon. Projects generally refer to structural features whereas management actions are typically non-structural programs or policies designed to support sustainable groundwater management.

6.1 PROJECTS AND MANAGEMENT ACTIONS DEVELOPMENT APPROACH

6.1.1 Overview

PMAs developed for the Subbasin are described in this chapter in accordance with 23 CCR §354.44. PMAs were formulated primarily to address possible future changes in Subbasin conditions that could cause undesirable results over the long term, and in the near term, to address effects of recent historical (2014-2015) and current (2020-2021) drought conditions that pose challenges to groundwater management in the northwest and southwest portions of the Subbasin respectively.

PMA development and implementation in the Subbasin applies an adaptive management approach informed by continued monitoring of groundwater conditions using the monitoring network and methods described in Chapter 4. The adaptive management approach is consistent with SGMA (CWC §10728.2, §10733.8) and with DWR recommendations.

Recognizing the GSP data gaps and uncertainties in the basin setting (per 23 CCR §354.44(d)), and recognizing known areas with declining groundwater levels, the adaptive management approach in the Subbasin includes:

- Planned PMAs that are expected to be implemented primarily to address current, localized declining groundwater levels in the Orland and Arbuckle areas. This includes five groundwater recharge projects that are currently moving toward implementation, including three substantial in-lieu recharge projects, one multi-benefit managed aquifer recharge project, and another direct recharge pilot project. At full implementation, planned PMAs are expected to provide more than 80 thousand acre-feet per year (taf/yr) in combined gross average annual benefits that will offset groundwater pumping and support groundwater sustainability in the Subbasin.
- A portfolio of other ongoing and potential PMAs to achieve and maintain long-term sustainable groundwater management across the Subbasin. Potential PMAs will be further evaluated and implemented if established measurable objectives (MOs) cannot be maintained and minimum thresholds (MTs) are being approached.

In the adaptive management approach, GSAs will continue monitoring sustainability indicators throughout the GSP planning and implementation horizon and will address any challenges related to maintaining groundwater sustainability by scaling and implementing PMAs in a targeted and proportional manner in accordance with the needs of the Subbasin. Ongoing management of the Subbasin under this GSP is planned to achieve and maintain sustainability and respond to unforeseen future conditions that may impact sustainable operation of the Subbasin. If the planned and ongoing PMAs are insufficient to

achieve and maintain sustainable groundwater conditions, additional PMAs will be considered and implemented. Any changes to the PMAs will be described in GSP annual reports and periodic evaluations.

Per 23 CCR § 354.44(b)(9), PMAs described in this GSP are expected to manage the balance of groundwater extractions and recharge to ensure that lowering of groundwater levels or depletion of supply during periods of drought is offset by increases in groundwater levels or storage in other years. In particular, PMAs that provide in-lieu and direct recharge benefits in the Arbuckle areas are planned to increase the use and recharge of available surface water supplies during wetter years, offsetting any potential increases in groundwater pumping during drought when curtailments of surface water supplies may occur. The expected recharge benefits of these PMAs are described in Section 6.3. The GSAs' extensive portfolio of additional PMAs will be informed by continued monitoring of groundwater conditions and implemented, as needed, to achieve and maintain long-term sustainable groundwater management.

6.1.2 Evaluation of Projected Future Conditions to Develop Projects and Management Actions

The possible future changes in Subbasin conditions without PMAs were assessed through comparison of the projected future water budget conditions without climate change and projected future water budget conditions adjusted by 2070 central tendency (CT) climate change factors (see Chapter 3 for additional water budget information).

Table 6-1 provides a comparison of key water budget parameters considered in formulation of PMAs. All water budget quantities are expressed in average annual volumes of taf/yr over the 50-year model simulation periods. An effect of climate change on Subbasin hydrology is a nearly 7 percent increase in agricultural evapotranspiration (ET), from 1,494 taf/yr to 1,596 taf/yr. A portion of this increased agricultural ET will be met by an approximate 6 percent increase in precipitation expected to result from 2070 CT climate change. The remaining increase in agricultural ET is expected to be met by increased groundwater pumping since projected future surface water diversions into the Subbasin from the Sacramento River and Stony Creek are not expected to be affected by climate change[1]. Pumping is projected to increase by 58 taf/yr, a nearly 13 percent increase from the projected future conditions without climate change.

Under projected future conditions without climate change, groundwater storage is forecast to increase modestly, at an average rate of 0.6 taf/yr. With 2070 CT climate change and the associated increase in groundwater pumping to meet increased irrigation demands, groundwater storage is projected to decrease at a rate of 7.3 taf/yr. This net change of -7.9 taf/yr is 0.8 percent of the approximately one million acre-feet (maf) that flow into and out of the Subbasin groundwater system annually.

[1] Average streamflow volumes in the Sacramento River and its tributaries are generally expected to increase slightly under 2070 Central Tendency climate change due to slightly increased precipitation. However, because Sacramento River and Stony Creek diversions are generally regulated in storage reservoirs, and because Central Valley Project water supplies from the Sacramento River are limited by contracts, it was assumed that future surface water supplies would be the same with and without climate change.

Table 6-1. Summary of Key Subbasin Water Budget Parameters Influencing Formulation of Projects and Management Actions (average annual volumes, taf/yr)

Water Budget Parameter[a]	Projected Future Conditions without Climate Change	Projected Future Conditions with 2070 Central Tendency Climate Change	Difference (Projected future with 2070 Central Tendency climate change minus without climate change)	Percent Difference[b]
Avg. Agricultural Evapotranspiration	1,494	1,596	102.0	6.8%
Precipitation	1,183	1,258	75.0	6.3%
Agricultural Pumping	458	516	58.0	12.7%
Avg. Rate of Change in Groundwater Storage, af/yr	0.6	-7.3	-7.9	-0.8%
Sacramento River and Stony Creek Diversions to Subbasin	1,287.0	1,287.0	0.0	0.0%
Net Steam Accretion	125	77	-48.0	-38.3%

(a) Water budget parameter values may differ from other summary tables due to rounding or slight changes in how parameters are aggregated from the C2VSimFG-Colusa model results.

(b) Calculated as the difference in the fourth column divided by the Projected Future Condition without Climate Change quantity in the second column, except for Avg. Rate of Change in Groundwater Storage, for which the percent difference is based on the approximately 1 million acre-feet that flow into and out of the Subbasin on an average annual basis. Water budget uncertainty is discussed in Chapter 3, Basin Setting, and model uncertainty is discussed in Appendix 3D. The average change in groundwater storage is considered to be within standard modeling error for this type of groundwater model analysis.

Under projected future conditions without climate change, net stream accretion (stream accretion minus stream depletion) is projected to be 125 taf/yr on average. This aggregate net stream accretion is for the Sacramento River, Stony Creek, and the Colusa Drain combined[2]. With 2070 CT climate change, net stream accretion is projected to remain positive but to decrease by about 48 taf/yr, or by 38 percent, with respect to the without climate change condition. Viewed in relation to the average Sacramento River flow above the Feather River confluence of approximately 11.7 million acre-feet per year (maf/yr) the projected change is roughly one half of one percent. The aggregate changes in groundwater storage, 0.8 percent, and net stream accretion, 0.5 percent of the average Sacramento River Flow, are considered to be within standard modeling error for this type of analysis.

Nevertheless, the GSAs have identified several planned PMAs (Section 6.3) that are expected to provide more than 80 taf/yr in combined gross average annual benefits that will offset groundwater pumping and support groundwater sustainability in the Subbasin. The GSAs will also continue to evaluate and review all Subbasin water budget parameters, including net stream accretion, as part of continued work to address data gaps and as part of ongoing monitoring to be reported in GSP annual reports. Chapter 4, Monitoring

[2] A more detailed assessment of projected streamflow accretion-depletion is presented in Appendix 3G. The analysis considers the Sacramento River, Stony Creek, and the Colusa Drain individually and collectively, and evaluates temporal accretion-depletion patterns over the 50-year simulation period.

Networks, and Chapter 3, Basin Setting, identify data gaps that will be addressed as part of GSP implementation (Chapter 7), which will improve the modeled outputs, water budget parameters, and understanding of the Subbasin groundwater conditions.

Despite these findings in the Subbasin boundary water budget, there are localized declining groundwater levels that have occurred over the past 15 to 20 years in the northwest and southwest portions of the Subbasin near the cities of Orland and Arbuckle, respectively (Figure 6-1). Water budget analyses suggest that groundwater level decline in these areas is due primarily to drought. A series of mostly dry years beginning in about 2007 has resulted in increased irrigation demands, curtailments of Central Valley Project surface water supplies, and consequent increases in groundwater pumping in these areas. Similar dynamics exist in the Orland area, compounded by recent expansion of irrigated agriculture into previously undeveloped lands that rely on groundwater supplies only. Localized declines in groundwater levels have also coincided with shifts in irrigation practices away from flood irrigation, which supplies substantial groundwater recharge, and toward pressurized drip and microirrigation methods. Localized effects of declining groundwater levels include stranding of shallow domestic and irrigation wells and increased rates of land subsidence, raising concerns both locally and more broadly within the Subbasin that mitigation actions should be taken as soon as possible. The planned PMAs are expected to address these localized declining groundwater levels in the Orland and Arbuckle areas by providing direct groundwater recharge or in lieu groundwater recharge in those areas of the Subbasin.

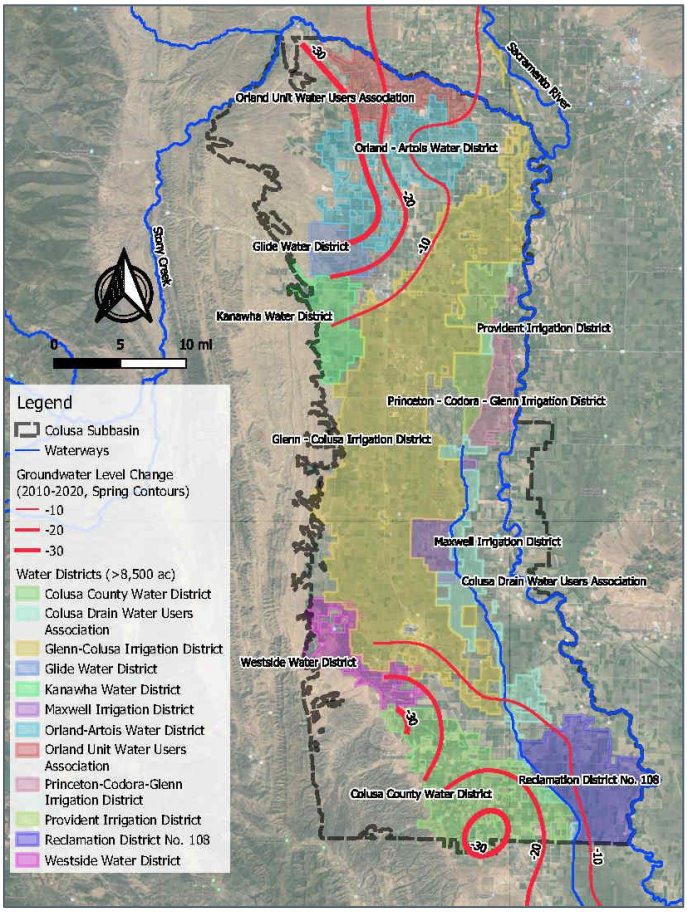


Figure 6-1. Localized Groundwater Level Declines in the Subbasin near Orland (Northwest) and near Williams and Arbuckle (Southwest)

6.1.3 Identification and Categorization of Projects and Management Actions

The PMAs included in this chapter have been planned or proposed by stakeholders, agencies, and interested parties in the Subbasin. During GSP development, the GSAs publicly requested that stakeholders and interested parties in the Subbasin submit plans and ideas for PMAs. The GSAs created a form to collect standard information about PMAs and hosted a webpage where PMA plans and ideas could be submitted by stakeholders and interested parties.[3] The GSAs and technical consultants reviewed the PMA plans and ideas, contacted project sponsors for clarifications and to gather additional PMA details, as needed, and proceeded through a screening process to categorize PMAs as "planned", "ongoing", or "potential." During GSP implementation, the GSAs plan to continue receiving PMA plans and ideas through this process, reviewing PMA submittals periodically and adding to the list of GSP PMAs if deemed appropriate.

PMAs are categorized and presented in this chapter according to the current status of implementation and development, as identified through the GSAs' screening process. However, the PMAs are not ranked. This categorization approach is consistent with the adaptive approach to PMA implementation and with development of PMAs based on the best available data and science (per 23 CCR §354.44(c)). This chapter also acknowledges ongoing investments made by agencies in the Subbasin (including prior to the passage of SGMA), such as projects that were identified and moved forward under regional water management planning efforts, including the Glenn and Colusa County Groundwater Management Plans and the Westside and Northern Sacramento Valley Integrated Regional Water Management Plans.

The PMA categories described in this chapter include:

- ***Planned*** **Projects and Management Actions** are PMAs that the GSA or other project proponents are working to implement that will support sustainable groundwater management in the Subbasin and mitigate historical and current drought effects. Detailed descriptions of these PMAs are presented in the GSP, reflecting available information including preliminary design and associated cost estimates. In accordance with 23 CCR §354.44(a) these are PMAs that would allow GSAs to achieve the sustainability goal for the Subbasin and avoid reaching the minimum thresholds defined in this GSP under future, changing conditions.
- ***Ongoing*** **Projects and Management Actions** are PMAs that are ongoing and will support sustainable groundwater management in the Subbasin. In accordance with 23 CCR §354.44(a) these are PMAs that would allow GSAs to achieve the sustainability goal for the Subbasin and avoid reaching the minimum thresholds defined in this GSP under future, changing conditions.
- ***Potential*** **Projects and Management Actions** are PMAs that may be implemented if necessitated by groundwater conditions in the Subbasin. These may have been studied by the project proponent, or in earlier regional water planning documents, but most project design, costs, and planning work has yet to be completed, and would only be initiated if the project is eventually triggered for implementation as a result of continued monitoring of groundwater conditions.

[3] https://colusagroundwater.org/projects-and-management-actions-submittals/

The rest of this chapter is structured as follows. Section 6.2 provides a summary of all (ongoing, planned, and potential) PMAs. The three subsequent sections – Sections 6.3 through 6.5 – describe the PMAs in each of the three categories. Within each category, PMAs are further classified by type (project or management action), which are described in corresponding subsections. Appendix 6A provides additional analysis of water available for recharge and other projects, as well as an assessment of incentives to encourage utilization of surface water supplies. Appendix 6B describes potential demand management action costs and Subbasin agricultural economic conditions. Appendix 6C provides a matrix summary of all planned, ongoing, and potential PMAs. Lastly, Appendix 6D describes modeling of selected PMAs to estimate the effects of those PMAs on groundwater conditions in the Subbasin.

6.2 PROJECT AND MANAGEMENT ACTIONS SUMMARY

6.2.1 Overview of All Proposed Projects and Management Actions

Table 6-2 summarizes all PMAs identified in the Subbasin. Summary information includes the PMA name, type, proponent, and a brief description. PMA types include:

- **Direct groundwater recharge:** PMAs that recharge groundwater using available surface water, flood water, stormflows, or other surface water supplies.
- **In-lieu groundwater recharge:** PMAs that offset groundwater pumping by supplying or otherwise incentivizing use of surface water or other surface water supplies "in lieu" of groundwater.
- **Management action:** Non-structural programs or policies designed to support sustainable groundwater management.
- **Reduce groundwater demand:** PMAs that reduce or remove sources of groundwater demand and extraction, such as invasive and non-native plant species along riparian corridors.

PMAs are grouped into subsections in the table according to their status (planned, ongoing, or potential). As described under Section 6.1 above, ongoing projects are currently being implemented in the Subbasin. Planned PMAs are currently being developed to achieve sustainable management conditions in the Subbasin. Potential PMAs will be implemented in the future, if or as required by changing conditions in the Subbasin.

All PMAs are described according to the requirements of 23 CCR §354.44(b). Planned projects are described in detail. Ongoing and potential PMAs are described concisely, reflecting the current operational status and "as-needed" basis of these projects. It is anticipated that additional information will be prepared in annual reports and five-year GSP updates, as needed.

Not all PMAs are the responsibility of the GSAs: some PMAs will be completed through a partnership with other agencies and proponents, while other PMAs will be completed by the agency or other proponents with support from the GSAs. The GSAs and/or other project proponents will notify the public and other agencies of the planned or ongoing implementation of PMAs through the communication channels identified in Sections 6.3 through 6.5 (23 CCR §354.44(b)(1)(B)). Noticing will occur as potential projects are being considered for implementation, and as ongoing and planned projects are implemented. Noticing will inform the public and other agencies that the GSA and/or other project proponents are considering or will be implementing the PMA, and will provide a description of the actions that will be taken.

The following subsections describe the planned, ongoing, and potential PMAs in accordance with the requirements of 23 CCR §354.44(b). The information presented in this chapter is based on the best available data and science. The estimated groundwater recharge benefit and capital, operating, and maintenance costs of developing and operating each project are shown. To the extent possible, project costs are adjusted and reported on a consistent basis. All costs are indexed using an appropriate index[4] and reported in current (2021) dollars. GSAs, districts, and other partners in the Subbasin will further develop projects during the GSP implementation period and refine estimated costs in GSP annual reports and five-year updates. Additional information about all PMAs is provided in a matrix format in Appendix 6C.

Table 6-2. Summary of All Projects and Management Actions

Project/ Management Action Name	Project/ Management Action Type	Proponent	Brief Description
Planned			
Projects			
Colusa County Water District (CCWD) In-Lieu Groundwater Recharge	In-lieu Groundwater Recharge	CCWD	CCWD will utilize 30 taf of additional surface water for irrigation in all years but Shasta Critical years for in-lieu recharge. The additional surface water will be made available through full use of the district's existing Central Valley Project (CVP) contract and annual and multi-year water purchase and transfer agreements. Additional surface water deliveries are estimated to be 27 taf/yr, enabling reduction of groundwater pumping by a like amount.
Colusa Drain MWC (CDMWC) In-Lieu Groundwater Recharge	In-lieu Groundwater Recharge	CDMWC	CDMWC diverters use both ground and surface water because Colusa Drain supplies are insufficient to satisfy all irrigation requirements. This project would provide additional surface supplies averaging approximately 28 taf/yr in the Drain allowing CDMWC diverters to increase their diversions of surface water to provide in-lieu groundwater recharge of a like amount.
Subbasin Multi-Benefit Groundwater Recharge	Direct Groundwater Recharge	CGA, GGA and TNC	The Nature Conservancy (TNC) is partnering with entities for an on-farm, multi-benefit groundwater recharge incentive program. The pilot program was initiated in Colusa County in 2018 and concluded in the spring of 2021, with plans to expand and continue into the future. DWR is a partner in the Subbasin Multi-Benefit Groundwater Recharge project as it moves into the expanded program.

[4] Either the Implicit Price Deflator or the Engineering News Report Construction Cost Index.

Table 6-2. Summary of All Projects and Management Actions

Project/ Management Action Name	Project/ Management Action Type	Proponent	Brief Description
Orland-Artois Water District (OAWD) Land Annexation and Groundwater Recharge	Direct and In-lieu Groundwater Recharge	OAWD	OAWD is planning to annex approximately 12,000 acres of groundwater-dependent agricultural lands. Additional direct recharge may be considered on suitable annexed lands. The project is an area where groundwater levels have been in decline in recent years. It is estimated that a long-term average of approximately 23 taf/yr of surface water would be available, reducing groundwater pumping by approximately 23 taf/yr.
Sycamore Slough Groundwater Recharge Pilot Project	Direct Groundwater Recharge	Landowner	Proctor and Gamble (P&G) and Davis Ranches have entered into an agreement to implement a 10-year groundwater recharge pilot project. A 66-acre field on Davis Ranches will receive surface water for groundwater recharge and provide habitat for migrating shorebirds. Water would be diverted from the Sacramento River during fall/winter months using existing riparian rights or would be available from settlement contract supplies (should the project begin before November 1). An expansion of the project is planned for recharge and revegetation in the neighboring Sycamore and Dry Sloughs.
Ongoing			
Projects			
Reclamation District 108 (RD108) and Colusa County Water District (CCWD) Agreement for Five-Year In-Lieu Groundwater Recharge Project	In-lieu Groundwater Recharge	RD108 and CCWD	CCWD (and Dunnigan Water District [DWD]) purchases surface water from RD108 for distribution within its service area. The agreement expires in 2022. This project supplies additional surface water to CCWD (and DWD) that provides in-lieu recharge.
Glenn-Colusa Irrigation District (GCID) Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits	Direct and In-lieu Groundwater Recharge	GCID	GCID holds a water right for winter water. This project will increase the groundwater recharge and habitat enhancement benefits of winter water use by increasing use for rice straw decomposition, irrigation, and frost control provided that certain constraints can be alleviated.
Sycamore Marsh Farm Direct Recharge Project	Direct Groundwater Recharge	Landowner	Sycamore Marsh Farm is developing a groundwater recharge plan to store groundwater. The plan provides for 205 acres of year-round recharge basins and 163 additional acres of winter recharge areas.

Table 6-2. Summary of All Projects and Management Actions

Project/ Management Action Name	Project/ Management Action Type	Proponent	Brief Description
Glenn-Colusa Irrigation District Expansion of In-Basin Program for In-lieu Groundwater Recharge	In-lieu Groundwater Recharge	GCID	GCID has developed arrangements to supply district surface water to neighboring non-district agricultural lands that primarily use groundwater. These temporary arrangements expired in 2020. There is interest in continuing and expanding this in-basin surface water use for in-lieu groundwater recharge. Supplies would potentially be available only in Shasta Non-Critical years.
Orland Unit Water Users Association (OUWUA) Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping	In-lieu Groundwater Recharge	OUWUA	Modernization of OUWUA southside system for more reliable and flexible farm deliveries that will provide incentive for growers to use more surface water and less groundwater.
Management Actions			
Urban Water Conservation in Willows	Management Action	California Water Service – Willows District	This project includes urban water conservation measures through water waste prevention ordinances, metering, conservation pricing, public education, and outreach programs to assess and manage distribution system real loss, water conservation program coordination and staffing support, and other demand management measures.
Potential			
Projects			
Glenn-Colusa Irrigation District In-lieu Groundwater Recharge	In-lieu Groundwater Recharge	GCID	GCID will investigate, develop, and implement measures to incentivize additional use of surface water supplied by GCID, which will provide in-lieu recharge through reduced groundwater pumping.
Westside Streams Diversion for Direct or In-lieu Groundwater Recharge	Direct and In-lieu Groundwater Recharge	CGA and GGA	A portion of western ephemeral stream flows could be diverted for in-lieu or direct groundwater recharge.
Sites Reservoir	Direct and In-lieu Groundwater Recharge	Sites Project Authority	The Sites Project is a new off-stream storage facility that is currently in development. Depending on project operation and yield, there is potential for groundwater benefits to accrue to the Subbasin from Sites Reservoir.

Table 6-2. Summary of All Projects and Management Actions

Project/ Management Action Name	Project/ Management Action Type	Proponent	Brief Description
Delevan Pipeline Colusa Basin Drainage Canal System (Colusa Drain) Intertie	Direct and In-lieu Groundwater Recharge	Interested Stakeholder	Intertie between proposed Delevan Pipeline component of the Sites Reservoir Project and the Colusa Drain, providing a connection to downstream water users, and providing protection for the ecosystems, and earthquake resilience.
Orland Unit Water Users Association (OUWUA) Flood Water Conveyance	Direct Groundwater Recharge	OUWUA	Divert Stony Creek water at OUWUA's south diversion and convey it to various locations for direct recharge within the OUWUA service area.
Orland-Artois Water District (OAWD) Direct Groundwater Recharge	Direct Groundwater Recharge	OAWD	OAWD would directly recharge groundwater. A pilot project was conducted in 2017.
Sycamore Slough Colusa Drain Multi-Benefit Recharge Project	Direct Groundwater Recharge	Landowner	Restoration of portions of Sycamore Slough would support diversion of winter flows from the Colusa Drain for recharge and restoration.
Tehama-Colusa Canal Trickle Flow to Ephemeral Streams	Direct Groundwater Recharge	RD108	Operate Tehama-Colusa Canal (TCC) existing gates for discharge into ephemeral streams at a rate where they do not flow out of the Subbasin but recharge the groundwater system.
Enhanced Infiltration of Precipitation on Agricultural Lands	Direct Groundwater Recharge	CGA and GGA	Develop and adoption of on-farm cultural practices to reduce precipitation runoff and increase infiltration, which would result in increased storage of precipitation in the crop root zone, thereby reducing irrigation water requirements and achieving some direct groundwater recharge.
Subbasin Flood-MAR	Direct Groundwater Recharge	CGA and GGA	The CGA and GGA would investigate, develop, and implement a program to divert flood waters within the Subbasin, when available, for spreading across agricultural lands for direct groundwater recharge.
Reclamation District 108 “Boards In” Program	Direct Groundwater Recharge	RD108	RD108 would institute a voluntary or financially incentivized program in which landowners leave spill boards in place during the winter to capture rainfall and hold it on the fields for recharge.
Colusa County Public Water System Water Treatment Plant	In-lieu Groundwater Recharge	Interested Stakeholder	Construct a water treatment plant on the Sacramento River between Colusa and Grimes to provide treated surface water to public water supply systems in Colusa and possibly Sutter and Yolo Counties.

Table 6-2. Summary of All Projects and Management Actions

Project/ Management Action Name	Project/ Management Action Type	Proponent	Brief Description
Glenn-Colusa Irrigation District Water Transfers to Tehama-Colusa Canal Authority (TCCA) CVP Contractors	In-lieu Groundwater Recharge	GCID	Evaluate potential for transferring water to CVP contractors served by the TCC for in-lieu groundwater recharge.
Subbasin In-lieu Recharge & Banking Program	In-lieu Groundwater Recharge	South Valley Water Resources Authority	Incentivize taking available contract surface water in-lieu of pumping groundwater, providing dedicated contribution to local groundwater sustainability, with a portion available to San Joaquin Valley partners.
Sycamore Marsh Farm In-lieu Recharge Project	In-lieu Groundwater Recharge	Landowner	Sycamore Marsh Farm is developing an in-lieu groundwater recharge plan, and could partner with additional lands in the CDMWC, allowing for diversion of surface water from CDMWC.
Westside Off-stream Reservoir and In-Lieu Groundwater Recharge	In-lieu Groundwater Recharge	TCCA Contractors	Construct off-stream surface reservoirs along the western edge of the Subbasin and up-slope from the TCC to divert surplus Sacramento River flows (e.g., Section 215 water) into these storage reservoirs. Release stored water on demand to serve lands otherwise served by groundwater.
Management Actions			
Domestic Well Mitigation Program	Management Action	CGA and GGA	To mitigate the effects of domestic well stranding due to groundwater level decline, the CGA and GGA will investigate implementing domestic well mitigation programs in their respective portions of the Subbasin.
Drought Contingency Planning for Urban Areas	Management Action	CGA, GGA, and cities (GSA member agencies)	The CGA and GGA will coordinate with M&I water suppliers dependent on groundwater to encourage drought planning consistent with the GSP.
Long-Term Demand Management Action	Management Action	CGA and GGA	Demand management broadly refers to any water management activity that reduces the consumptive use of irrigation water. A demand management action is one that incentivizes, enables, or possibly requires water users to reduce their consumptive use.
Strategic Short-Term Demand Management	Management Action	CGA and GGA	Develop a voluntary, flexible, short-run financial incentive program to alleviate impacts of drought in target areas through idling lands in drought-affected areas or in participating surface water-using portions of the Subbasin and conveying the saved surface water to the drought-affected areas.

Table 6-2. Summary of All Projects and Management Actions

Project/ Management Action Name	Project/ Management Action Type	Proponent	Brief Description
Well Abandonment Outreach and Funding Program	Management Action	CGA and GGA	Create a program providing outreach and education to landowners regarding the proper procedures for well decommissioning and abandonment, as well as funding sources. This effort would be accomplished by working with well permitting agencies.
Preservation of Lands Favorable for Recharge	Management Action	CGA and GGA	Working cooperatively with the counties, investigate, design, and implement a program providing incentives to landowners with lands favorable to groundwater recharge to preserve them as agricultural or undeveloped lands on which groundwater recharge.
Review of County Well Permitting Ordinances	Management Action	CGA and GGA	Review and revise the county well permitting processes in the Subbasin to ensure that future well permitting aligns with the Subbasin sustainability goal and that future changes to well permitting are reviewed by the GSAs. The GSAs would work with the counties to review and suggest revisions to ordinances (these are outside of the jurisdiction of the GSAs).
Reduce Non-beneficial Evapotranspiration/ Invasive Species Eradication	Reduce Groundwater Demand	CGA and GGA	Removal of invasive, non-native plant species from riparian corridors and other areas to reduce evapotranspiration from shallow groundwater and support native ecosystem restoration.
Development of a Dedicated Network of Shallow Monitoring Wells for GDE Monitoring	Management Action, Closing Data Gaps	CGA and GGA	Evaluate and develop a dedicated network of shallow monitoring wells specifically planned and sited for monitoring conditions in areas of the Subbasin where GDEs are most likely to be found. This action is also expected to incorporate biological monitoring to inform the location of new shallow monitoring wells and monitor whether GDEs are being impacted by changing groundwater conditions.

6.2.2 Benefits of Projects and Management Actions to Sustainability Indicators and Communities in the Subbasin

Volumetric benefits of all planned PMAs are identified in Table 6-2 and in Section 6.3. In total, the planned PMAs are expected to provide more than 80 taf/yr in gross average annual benefits at full implementation by offsetting groundwater pumping, providing direct recharge, and otherwise supporting groundwater sustainability. These benefits are expected to address potential sustainability concerns in the projected future conditions water budgets, even under the effects of 2070 CT climate change (Table 6-1). Planned PMAs are expected to help the GSAs achieve the sustainability goal for the Subbasin and avoid reaching the minimum thresholds defined in this GSP under future, changing conditions.

Table 6-3 summarizes how each type of PMA would benefit sustainability indicators in the Subbasin. All proposed PMAs are expected to benefit groundwater levels and groundwater storage, whether through direct or in-lieu groundwater recharge, management of water supplies, or demand reduction. Projects that incentivize additional use of available surface water in lieu of groundwater are also expected to reduce depletions of interconnected surface water. Planned PMAs will provide direct and in-lieu groundwater recharge benefits to the Subbasin, which the GSAs do not expect will significantly affect water quality conditions, including those experienced by domestic well users and DACs. However, the GSAs are planning to monitor groundwater quality during GSP implementation (Section 4.2.2), and will investigate additional PMAs and studies to improve water quality if they find that groundwater quality conditions are approaching MTs.

Many of the communities within the Subbasin are considered either a Disadvantaged Community (DAC) or a Severely Disadvantaged Community (SDAC)[5]. Additionally, nearly all of the Subbasin is considered an Economically Distressed Area (EDA).[6] The only area within the Subbasin that is not considered an EDA is the small portion of the Subbasin that exists within Yolo County (approximately 2.4 square miles, or 1,500 acres). Additional information about DACs, SDACs, and EDAs in the Subbasin is provided in Chapter 2, Plan Area. To the extent that PMAs are implemented directly in areas where these communities reside – the majority of areas across the Subbasin – and to the extent that PMAs benefit groundwater conditions throughout the Subbasin, PMAs are expected to benefit DACs, SDACs, and EDAs and prevent undesirable results for these communities. Ongoing outreach and implementation of the GSP and PMAs will directly benefit these communities and ensure that their concerns and feedback continue to be incorporated into PMA development and implementation.

Table 6-3. Sustainability Indicators Expected to Benefit from Projects and Management Action Types Proposed in the Subbasin

Project/ Management Action Type	Project/Management Action Names	Sustainability Indicators Expected to Directly Benefit				
		GW Levels	GW Storage	SW Depletion	Land Subsidence	Water Quality
Planned						
Direct Groundwater Recharge	Colusa Subbasin Multi-Benefit Groundwater Recharge; Sycamore Slough Groundwater Recharge Pilot Project	X	X	X	X	
In-lieu Groundwater Recharge	CCWD In-Lieu Groundwater Recharge; Colusa Drain MWC In-Lieu Groundwater Recharge	X	X	X	X	
Direct and In-lieu Groundwater Recharge	OAWD Land Annexation and Groundwater Recharge	X	X	X	X	
Ongoing						

[5] A DAC is identified as a community whose median household income is less than 80 percent of the statewide median household income (MHI), and an SDAC is identified as a community whose median household income (MHI) is less than 60 percent of the statewide MHI.

[6] Portions of the Subbasin that are identified as EDAs are areas of rural counties with a low population density and a median household income of less than 85 percent of the statewide MHI.

Table 6-3. Sustainability Indicators Expected to Benefit from Projects and Management Action Types Proposed in the Subbasin

Project/ Management Action Type	Project/Management Action Names	Sustainability Indicators Expected to Directly Benefit				
		GW Levels	GW Storage	SW Depletion	Land Subsidence	Water Quality
Direct Groundwater Recharge	Sycamore Marsh Farm Direct Recharge Project	X	X	X	X	X
In-lieu Groundwater Recharge	RD 108 and CCWD Agreement for Five-Year In-Lieu Groundwater Recharge Project; GCID Expansion of In-Basin Program for In-lieu Groundwater Recharge; OUWUA Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping	X	X	X	X	
Direct and In-lieu Groundwater Recharge	GCID Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits	X	X	X		
Management Action	Urban Water Conservation in Willows	X	X	X		
Potential						
Direct Groundwater Recharge	OUWUA Flood Water Conveyance; OAWD Direct Groundwater Recharge; Sycamore Slough Colusa Basin Drain Multi-Benefit Recharge Project; TCC Trickle Flow to Ephemeral Streams; Enhanced Infiltration of Precipitation on Agricultural Lands; Colusa Subbasin Flood-MAR; Reclamation District 108 "Boards In" Program	X	X	X		
In-lieu Groundwater Recharge	Colusa Subbasin In-lieu Recharge & Banking Program; Sycamore Marsh Farm In-lieu Recharge Project; GCID In-lieu Groundwater Recharge	X	X	X	X	X
In-lieu Groundwater Recharge	Colusa County Public Water System Water Treatment Plant; Colusa Drain MWC In-Lieu Groundwater Recharge; GCID Water Transfers to TCCA CVP Contractors; Westside Off-stream Reservoir and In-Lieu Groundwater Recharge	X	X	X		
Direct and In-lieu Groundwater Recharge	Westside Streams Diversion for Direct or In-lieu Groundwater Recharge; Sites Reservoir; Delevan Pipeline Colusa Drain Intertie	X	X	X	X	
Management Action	Domestic Well Mitigation Program	X				

Table 6-3. Sustainability Indicators Expected to Benefit from Projects and Management Action Types Proposed in the Subbasin

Project/ Management Action Type	Project/Management Action Names	Sustainability Indicators Expected to Directly Benefit				
		GW Levels	GW Storage	SW Depletion	Land Subsidence	Water Quality
Management Action	Drought Contingency Planning for Urban Areas; Strategic Short-Term Demand Management; Preservation of Lands Favorable for Recharge; Development of a Dedicated Network of Shallow Monitoring Wells for GDE Monitoring	X	X	X		
Management Action	Review of County Well Permitting Ordinances	X	X	X	X	X
Reduce Groundwater Demand	Reduce Non-beneficial Evapotranspiration/Invasive Species Eradication (Arundo, Eucalyptus, Tamarisk, etc.)	X	X	X		

6.3 PLANNED PROJECTS AND MANAGEMENT ACTIONS

The GGA and CGA have included five groundwater recharge projects that are planned for implementation. All five projects involve the use of surface water for direct or in-lieu recharge. Three of the five projects are substantial in-lieu recharge projects, meaning that they will require regulated surface water sources available on an irrigation demand schedule. These three projects are planning to acquire all or most of the required surface water through transfers of CVP water supplies that are available from other CVP water supply or Settlement Contractors.

Figure 6-2 illustrates the location and name of the five planned PMAs in the Subbasin. Planned projects are targeted to areas where groundwater levels have been declining in the Subbasin due primarily to historical and current drought conditions. In addition, recharge opportunities are targeted near the Sacramento River to provide multiple benefits including potential habitat and streamflow benefits.

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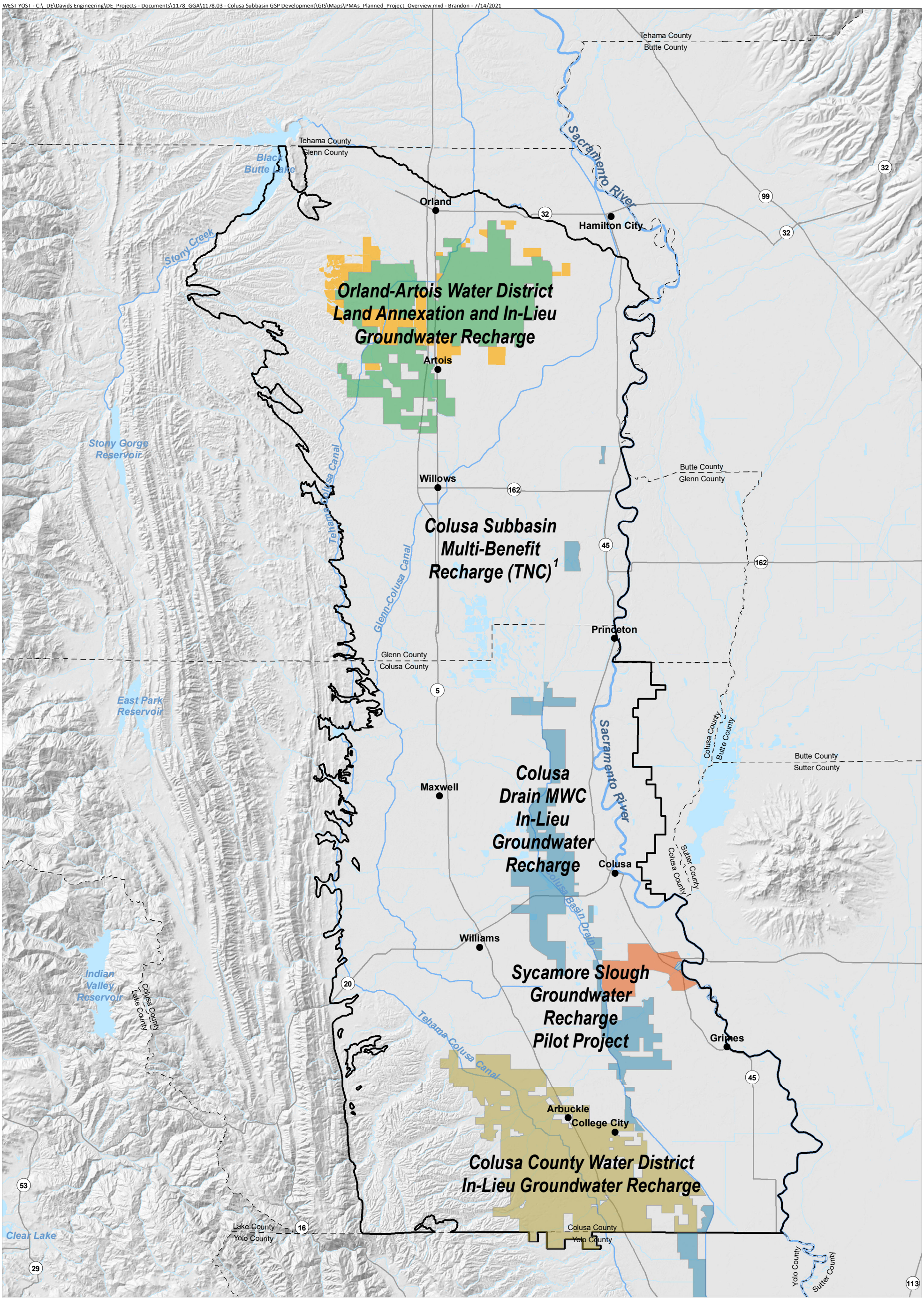


- Sycamore Slough Pilot Project Recharge Area
- Davis Ranches Boundary
- Colusa County WD Boundary
- Colusa Drain MWC Boundary
- Orland-Artois WD Boundary
- Orland-Artois WD Planned Annexations
- Colusa Subbasin Boundary

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Note:
1. Multi-benefit recharge locations will depend on grower enrollment and could be anywhere within the Colusa Subbasin where surface water supplies are available and recharge conditions are favorable.

N

0 2.5 5

Scale in Miles

Figure 6-2

Planned Projects Overview

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

Table 6-4 lists the planned PMAs, project type, proponent, expected first year of implementation, estimated capital cost, and estimated gross annual benefit (taf/yr).

Table 6-4. Summary of Planned Projects

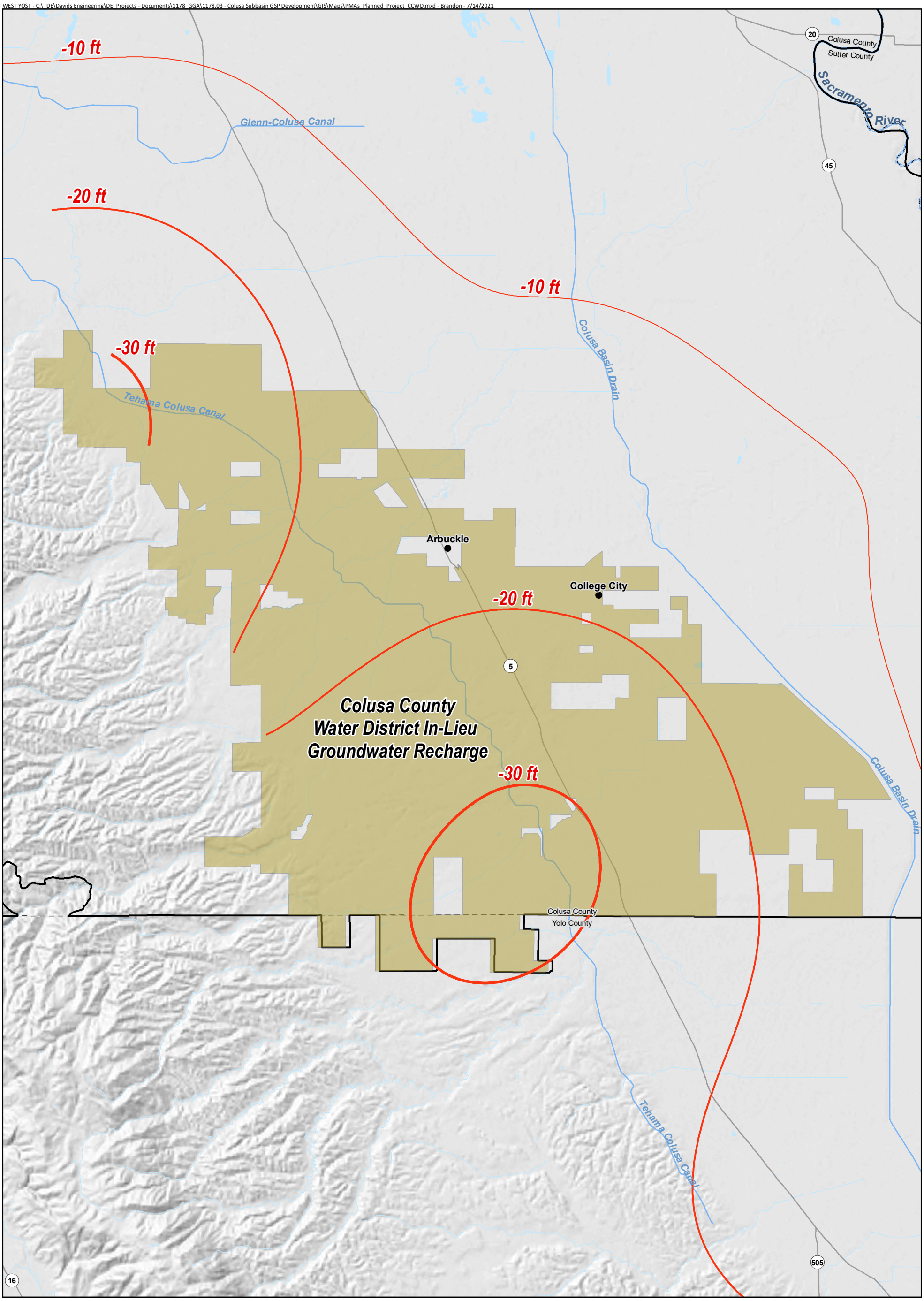
Project	Project Type	Proponent	Year Implemented	Estimated Capital / Establishment Cost, $ (thousands)[a]	Gross Average Annual Benefit, taf/yr
Colusa County Water District In-Lieu Groundwater Recharge	In-Lieu GW[b] Recharge	CCWD	2021	$100	27
Colusa Drain MWC In-Lieu Groundwater Recharge	In-Lieu GW Recharge	CDMWC	2021	$100	28
Colusa Subbasin Multi-Benefit Recharge	Direct GW Recharge	CGA, GGA, and TNC[c]	2021	$4 per site	5.2
Orland-Artois Water District Land Annexation and In-Lieu Groundwater Recharge	Direct and In-Lieu GW Recharge	OAWD	2020	$20,000	23
Sycamore Slough Groundwater Recharge Pilot Project	Direct GW Recharge	Landowner	2021	$28	0.5[d]

(a) Annual costs are summarized in the "Project Costs" sections of the project descriptions, below.
(b) GW = Groundwater
(c) TNC = The Nature Conservancy
(d) Project goal is to recharge 5 taf over 10 years.

6.3.1 Colusa County Water District In-Lieu Groundwater Recharge

6.3.1.1 Project Overview

Colusa County Water District (CCWD) includes over 45,000 acres within its service area, of which roughly 35,000 acres are irrigated. In this project, CCWD will utilize up to an additional 30 taf of surface water for irrigation in all years but Shasta Critical years, resulting in a long-term average annual additional surface water supply of 27 taf/yr. Shasta Critical conditions are declared when the forecast inflow to Lake Shasta for a particular water year is equal to or less than 3.2 maf. The additional surface water will be made available through full use of the district's existing CVP contract and annual and multi-year water purchase and transfer agreements. The additional water will be conveyed through the existing Tehama-Colusa Canal (TCC) and CCWD facilities and will be used primarily on existing district lands, resulting in in-lieu groundwater recharge through reduction of groundwater pumping. As an optional component of this project, CCWD is considering relatively small annexations of lands adjoining the district and supplying surface water to these lands in-lieu of groundwater pumping. If these annexations proceed, the additional water may also be used on the newly annexed lands that are currently dependent on groundwater and require construction of additional infrastructure for surface water delivery. Figure 6-3 illustrates the general location in CCWD where in-lieu recharge could occur, along with the groundwater elevation change between spring 2010 and spring 2020.



Spring 2010 to Spring 2020 Groundwater Elevation Change

-30 ft -20 ft -10 ft

Colusa County WD Boundary

Colusa Subbasin Boundary

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Notes:
1. Planning for this project is currently ongoing and map depictions are subject to change.
2. In-lieu recharge will occur within the Colusa County WD boundary.

N

0 1 2

Scale in Miles

Figure 6-3

Colusa County Water District In-Lieu Groundwater Recharge Overview

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

Use of additional surface water within CCWD will require a combination of incentivizing additional use of CCWD existing CVP supplies and transfer arrangements with other districts. Transfers already occur in many years and would continue to be negotiated between parties as part of GSP implementation. Incentivizing use of existing CVP supplies would require making the cost comparable to the cost of pumping groundwater. Historically, according to federal law under the CVP improvement Act of 1992, CVP irrigation water supply contracts required payments of tiered water rates for contractual water entitlements. The lowest, Tier 1, rate applied to 80 percent of the contractual water entitlement. The highest, Tier 3, rate reflected the full cost rate and applied to the last 10 percent of the contractual water entitlement. The Tier 2 rate, applied to the middle 10 percent, is an average of the Tier 1 and 3 rates.

Even when blended with Tier 1 water, using Tier 2 and Tier 3 water resulted in excessive water cost, and so some or all of the Tier 2 and Tier 3 water went unused. CCWD, along with other CVP contractors in the Subbasin, has recently converted its water service contract to a repayment contract, thus paying off and removing the capital component from CVP rates. However, repayment of CVP capital required borrowing money that the district will pay off over the next 15 years or more, which is reflected in water rates to growers.

Depending on the relative costs of district supply versus groundwater, under the repayment contracts, CCWD rates may be low enough already to encourage full use of CVP supply. However, if groundwater pumping remains a lower cost alternative to CVP water for some growers, incentivizing their use of CVP water in lieu of pumping would require an incentive that is at least equal to the difference between district surface supply and the variable cost of pumping groundwater.

Appendix 6A provides a summary of CVP rates, repayment contracts, and incentives to encourage additional use of district surface water supplies.

6.3.1.2 Implementation

Planning is currently underway for utilization of this additional surface water through CCWD's existing CVP contract and annual and multi-year water purchase and transfer agreements, as shown in Table 6-5 below. Utilization of additional surface water is anticipated to begin in 2022 (subject to the availability of water).

Table 6-5. CCWD In-Lieu Groundwater Recharge Implementation Timeline

Phase	Description	Start	End
Program Structure and Planning	Specify program goals, structure, and targets for implementation	2020	2022
Evaluate Incentives, Partners, and Develop Strategy	Evaluate grower incentives and on-farm costs for surface and groundwater irrigation, quantify willingness to pay for each system, and define program incentives. Work with partner districts to identify transfers	2020	2022
Initial/Pilot Program Implementation	Develop and implement a pilot program to evaluate participation, incentives, and assess landowner feedback	2022	2023

Table 6-5. CCWD In-Lieu Groundwater Recharge Implementation Timeline			
Phase	Description	Start	End
Program Implementation	Implement full program and scale up over time to achieve specified program goals for in-lieu recharge	2023	Ongoing
Monitoring	Monitor and report on the status of program development for GSP implementation (annual reports and five-year updates)	2021	Ongoing

6.3.1.3 Notice to Public and Other Agencies

Public noticing for this project will be done in accordance with noticing requirements in National Environmental Policy Act (NEPA) and CEQA (as needed), as well as noticing for public meetings held by the CGA, GGA, CCWD, Tehama-Colusa Canal Authority (TCCA), and Colusa Local Agency Formation Commission (LAFCO).

6.3.1.4 Construction Activities and Requirements

The project plans to utilize existing water conveyance facilities, including the TCC and the CCWD's piped distribution system. Under this project configuration, no additional construction activities would be required.

As an optional component of this project, CCWD is considering relatively small annexations of lands adjoining the district and supplying surface water to these lands in-lieu of groundwater pumping. However, the operation, benefits, and expected costs of the project does not depend on these annexations. Annexing lands would require construction of new water conveyance facilities for delivery and measurement of surface water to these newly annexed lands. These costs would be assessed as part of program development, if CCWD decides to annex lands.

6.3.1.5 Water Source

The surface water source for the project will come from CCWD's existing CVP contract and from multiple Sacramento Valley entities with existing surface water entitlements that are regularly available in below-normal to wet year types. These entities include CVP water supply and Settlement Contractors and, potentially, Sacramento River water rights holders.

The intent is to first utilize existing CCWD CVP supplies by making the cost of that supply comparable, or less, than the cost to pump groundwater. Additional water supply would be acquired through annual and multi-year, renewable water purchase or transfer agreements, building on similar existing agreements that CCWD has with certain Sacramento Valley entities. New surface supplies would be diverted from the Sacramento River at the Red Bluff Pumping Plant and Fish Screen facility and conveyed through the Tehama-Colusa Canal, which is operated and maintained by the Tehama-Colusa Canal Authority.

Appendix 6A summarizes an assessment of the volumes of water potentially available for in-lieu recharge. The CCWD project would acquire surface water primarily via water transfers from other entities with available CVP contract supplies and CVP Settlement Contract project water under the provisions of Central Valley Project Improvement Act (CVPIA) Section 3405(a). Transfer of project supplies under Settlement

Contracts alone would meet most of the needs of in-lieu recharge, with full use of existing contract supplies in CCWD and potential transfers of additional available CVP contract supplies adding to that amount.

6.3.1.6 Circumstances and Criteria for Implementation

This project is planned for immediate implementation. As described above, CCWD has already converted its water service contract to a repayment contract and is evaluating potential transfer opportunities with partner districts in the region. This process in 2021 was hampered by historically dry conditions across the state and the resulting lack of surface water. Beginning later in 2021, and into 2022 as water conditions hopefully improve, CCWD will begin evaluating incentives to encourage additional use of CVP supplies. It is anticipated that the utilization of additional surface water will begin in 2022.

Implementation of the in-lieu recharge program in CCWD does not depend on the implementation or performance of other PMAs or district activities. While operation of this project is not expected to terminate, any future changes will be made to align with CCWD goals and the overall Subbasin sustainability goal.

6.3.1.7 Legal Authority, Permitting Processes, and Regulatory Control

CCWD has the legal authority as a water district to provide for the acquisition and conveyance of supplemental surface water to its lands and pursue expansion of its service area. The planning and implementation of this project will be done in accordance with the required permitting processes and regulatory control. Required permitting and regulatory review is being initiated through consultation with applicable governing agencies.

Because the additional surface water supplies will be conveyed through the existing TCC and CCWD facilities and used primarily on existing district lands, there are no anticipated permitting requirements for this project. However, if additional land is annexed and new facilities are required to serve those lands, then permits will be required. In that case, governing agencies with which consultation may need to be initiated include, but are not limited to: DWR, the California State Water Resources Control Board (SWRCB), the California Department of Fish and Wildlife (CDFW), the Central Valley Flood Protection Board (Flood Board), Regional Water Boards, the United States Bureau of Reclamation (Reclamation or USBR), the United States Army Corps of Engineers (USACE), the United States Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), LAFCOs, the Counties of Colusa and/or Glenn, and the California Air Resources Board (CARB). Specific permitting and regulatory processes that may affect the construction of additional infrastructure include, but are not limited to:

- USACE Section 404 Permits (potential exemption under Section 404(f)(1)(C) of Clean Water Act)
- Regional Water Quality Control Board Section 401 Water Quality Certification (not required if exempt from USACE Section 404)
- SWRCB Construction General Permit and Storm Water Pollution Prevention Plan (SWPPP)
- State Historic Preservation Office (SHPO) and National Historic Preservation Act (NHPA) Section 106 Coordination
- California Endangered Species Act (CESA) Consultation
- Endangered Species Act (ESA) Compliance
- National Environmental Policy Act (NEPA) Compliance
- California Environmental Quality Act (CEQA) Compliance

6.3.1.8 Project Operations and Monitoring

CCWD will operate and maintain its existing district facilities and conduct project monitoring. If CCWD annexes additional lands into the district, the district would operate and maintain facilities developed for these lands, and conduct project monitoring.

Project monitoring will include a range of activities to evaluate the benefits described in the next section. This will include local monitoring to track the additional volumes of water made available through transfers and estimates of the reduction in pumping relative to pre-project baselines. Additionally, the district may monitor grower adoption through delivery records and periodic grower surveys during project design and implementation. Information gathered from these surveys would be used to refine the initial program design and encourage additional adoption.

The benefit of in-lieu recharge on sustainability indicators in the Subbasin (groundwater levels and groundwater storage) will be monitored using the monitoring network sites and monitoring practices described in the GSP (Chapter 4).

6.3.1.9 Project Benefits

The primary benefit of the project is reduction of groundwater pumping resulting from in-lieu groundwater recharge with benefits to the sustainability indicators previously shown in Table 6-3. It is estimated that approximately 30 taf of surface water would be delivered to annexed lands in all years but Shasta Critical years, resulting in an average annual reduction of groundwater pumping of approximately 27 taf/yr over the long term. Transfer volumes would vary in Shasta Non-Critical years based on the terms of the transfer agreements, and broader water market conditions, but the average annual quantity in all Shasta Non-Critical years is estimated to be 27 taf/yr. These benefits are expected to begin to be realized in 2022. Table 6-6 summarizes the expected annual volume. These project benefits have been assessed, and may continue to be assessed, using the C2VSimFG-Colusa model developed for GSP development by simulating groundwater conditions with and without the project. Additional information on the project modeling is described in Appendix 6D.

Table 6-6. CCWD In-Lieu Groundwater Recharge Estimated Average Recharge Volume by Year Type, in af/yr (2016-2065)

Year Type	Total Annual Volume	% of Years	Weighted Avg.
Shasta Non-Critical	Up to 30,000	90%	27,000
Shasta Critical	0	10%	0
Average Annual			**27,000**

6.3.1.10 Project Costs

Project costs include the cost of purchased water, applicable CVP costs associated with the use of the TCC, and CCWD operation and maintenance costs. If some additional lands are annexed into the district, costs will also include capital costs associated with construction of new facilities, but none are included in preliminary planning costs. Other fixed costs include $100,000 for CCWD effort to develop a preliminary project plan, and establish potential incentives based on an assessment of grower willingness to pay.

An initial estimate of $75 per af corresponding to estimated CCWD fully-loaded water rates (see Appendix 6A) is applied for the initial planning-level annual operating cost assessment. As described in Appendix 6A, this is CCWD staff's rough estimate of CCWD's 2021 water rate if it had received full CVP supply. It includes its repayment rate for CVP water, other CVP charges, Tehama-Colusa Canal Authority charges, and District charges. Using this rate, the total water supply cost would be approximately $2.0 million per year. Efforts are currently underway by CCWD to estimate and refine these project costs, and to identify funding sources and establish repayment terms. Table 6-7 summarizes project costs.

Table 6-7. CCWD In-Lieu Groundwater Recharge Estimated Project Costs

Item	Total Cost	Year Incurred	Notes
Capital Costs			
Project planning and development	$100,000	2021-2022	Project studies and planning; does not include any capital costs
O&M Costs			
Fully-loaded water supply cost	$2.0 million	All	Assumed water supply cost equal to CCWD fully-loaded rate in full water supply years

23 CCR §354.44(b)(8) requires a summary of how the district plans to pay these costs. It is anticipated that the cost of incentivizing additional use of CVP supplies, and transfer purchases would primarily be recovered through district assessments. This may include more land-based assessments to reduce the variable cost of water rates, thereby making district water comparatively less expensive than groundwater. Other potential funding sources include grants, loans, and bonds for capital financing, if new facilities are needed to serve any annexed lands. Debt service and operations would be funded through assessments and charges. Potentially, a type of cost-share program could be developed where other groundwater-dependent water users in the Subbasin share a portion of the costs since they will also realize regional benefits through this in-lieu recharge project. Appendix 7A in Chapter 7 describes different funding mechanisms, and the conceptual approach for allocating project costs across multiple potential project beneficiaries.

6.3.2 Colusa Drain Mutual Water Company (CDMWC) In-Lieu Groundwater Recharge

6.3.2.1 Project Overview

The CDMWC encompasses approximately 46,000 acres of agricultural land and environmental habitat adjacent to the Colusa Drain. Shareholders in CDMWC divert water for summer irrigation from the drain under a combination of appropriative water rights held individually by the shareholders, a long-term service supply agreement with the United States Bureau of Reclamation (Reclamation or USBR), and annual and multi-year transfer agreements with neighboring Settlement Contractors. Figure 6-4 illustrates the general locations of CDMWC, neighboring Settlement Contractors, and other entities in the surrounding area. Historically, many CDMWC diverters use both groundwater and surface water for summer irrigation because physical supplies of surface water in the Colusa Drain are often unreliable and insufficient to satisfy all irrigation requirements.

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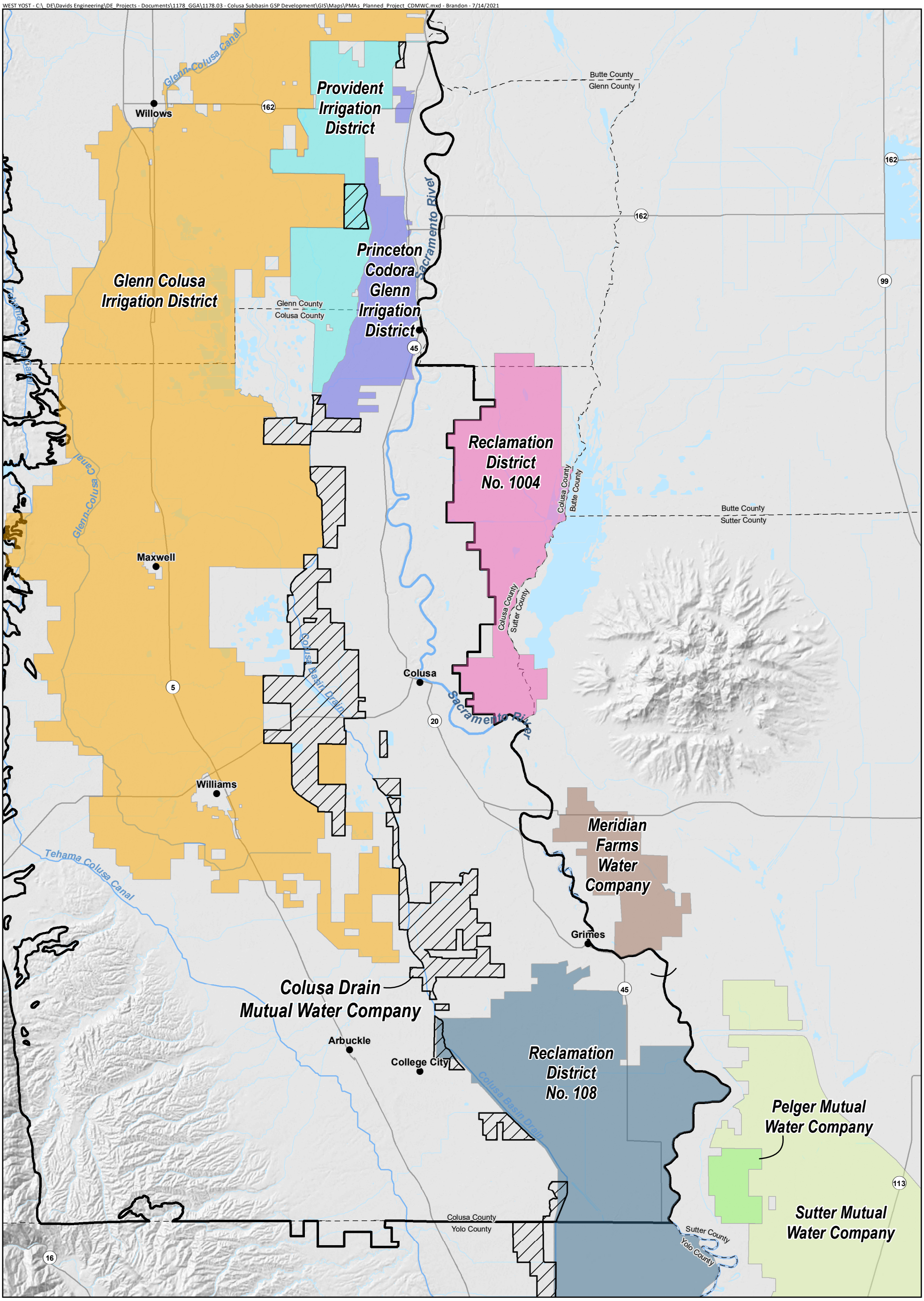

- Meridian Farms Water Company
- Pelger Mutual Water Company
- Princeton-Codora-Glenn Irrigation District
- Provident Irrigation District
- Reclamation District No 1004
- Reclamation District No. 108
- Sutter Mutual Water Company
- Glenn Colusa Irrigation District
- Colusa Drain MWC Boundary
- Colusa Subbasin Boundary

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Note:
1. Sacramento River Settlement Contractors (SRSC) in the vicinity of the Colusa Drain MWC within the Colusa Subbasin are included in this map, although there are other SRSCs that exist and could potentially provide a water source for this project.

N

0 2.5 5

Scale in Miles

Figure 6-4

Colusa Drain MWC In-Lieu Groundwater Recharge

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

The purpose of this project is to provide a reliable and sufficient supply of surface water in the Drain allowing CDMWC diverters to increase their diversions of surface water and decrease groundwater pumping by an equal amount. It is estimated that an average annual yield of up to 28 taf of in-lieu groundwater recharge could be realized through this project.

6.3.2.2 Implementation

The project is currently being planned for implementation. The planned implementation timeline is shown in Table 6-8. CDMWC has existing transfer agreements with Settlement Contractors upon which the transfer terms under this project would be based. In addition, CDMWC has existing water rights, permitting, and infrastructure in place to operate the program. Initial program implementation will require a planning study of water transfer, prices, full-cost of transferred water delivered to CDMWC diverters, and a comparison to the cost to continue utilizing groundwater. This would establish program feasibility and potential program scale. Preliminary program design is already under way and will continue through 2022.

Benefits could begin to accrue as early as during the 2022 irrigation season, depending on availability of surface water via transfers. 2021 is a Shasta Critical year, with dry conditions across the state. Several criteria necessary for implementation are already in place:

- Most CDMWC shareholders have necessary infrastructure required to divert water from the drain and deliver it to their agricultural lands, and several Settlement Contractors have the infrastructure in place to introduce surface water supplies into the Colusa Drain for CDMWC diversion and use (pursuant to transfer agreements).
- CDMWC shareholders have the necessary licenses and permits in place with DWR and SWRCB to allow diversions from the drain.
- CDMWC has a long-term supply agreement with Reclamation to supply water into the Sacramento River to offset shareholders diversions from the drain that would otherwise infringe the rights of senior water right holders in the Sacramento River.
- CDMWC and Glenn-Colusa Irrigation District (GCID, a Settlement Contractor) currently have a transfer agreement in place that includes the necessary environmental permitting with Reclamation and DWR.

Following the model of the transfer agreement with GCID, CDMWC would establish transfer agreements with other Settlement Contractors or other entities to provide surface water to the Colusa Drain for CDMWC diversion and use.

These transfer agreements would need to be designed to provide settlement contractors with sufficient economic incentive to deliver water to the Colusa Drain and, at the same time, provide CDMWC diverters with a sufficient incentive to access and utilize this surface water supply in-lieu of using groundwater. Coordination and planning for these transfer agreements is currently underway.

Table 6-8. CDMWC In-Lieu Groundwater Recharge Implementation Timeline			
Phase	Description	Start	End
Project Planning and Concept Development	Evaluate lands, existing infrastructure, permitting, and potential partners	2020	2021
Program Development and Incentives Analysis	Develop program costs and financial parameters; assess groundwater costs to CDMWC irrigators and willingness to accept payment for transfer from partners; establish program costs and structure	2021	2022
Transfer Agreements	Model and pursue transfer agreements based on the existing agreement with GCID	2019	Ongoing
Program Operation	Program implementation, monitoring, updates, and ongoing agreements	2022	Ongoing

6.3.2.3 Notice to Public and Other Agencies

Public noticing for this project will be done in accordance with noticing requirements and in public meetings held by CDMWC and others. This would include CGA public meetings.

6.3.2.4 Construction Activities and Requirements

There are no infrastructure construction activities and requirements, as the project will use existing infrastructure and facilities.

6.3.2.5 Water Source

The surface water source for the project will come from multiple Sacramento Valley entities with existing surface water entitlements that result in water available for transfer in some normal to wet year types. These entities include Settlement Contractors, Sacramento River water rights holders, and potentially others. The intent is to acquire the water through annual and multi-year, renewable water transfer agreements. A framework for this has already been established based on the existing agreement between CDMWC and GCID. New surface supplies would be provided to the Colusa Drain for diversion and use by CDMWC shareholders.

Appendix 6A summarizes an assessment of the volumes of water available for transfer in the Subbasin. The water availability assessment finds there is sufficient water available for transfer for the CDMWC project, in addition to the other four planned GSP recharge projects.

6.3.2.6 Circumstances and Criteria for Implementation

This project is planned for immediate implementation. Coordination and planning are currently underway, and depending on outcomes, implementation and project benefits could potentially begin in 2022.

Implementation of the CDMWC program does not depend on the implementation or performance of other PMAs or district activities. While operation of this project is not expected to terminate, any future changes will be made to align with CDMWC goals and the overall Subbasin sustainability goal.

6.3.2.7 Legal Authority, Permitting Processes, and Regulatory Control

As a mutual water company, CDMWC has the legal authority to plan for and pursue the acquisition and conveyance of supplemental surface water to its shareholders' lands. The planning and implementation of this project will be done in accordance with the required permitting processes and regulatory control. CDMWC already has water rights, permitting, and infrastructure in place to operate the program. CDMWC shareholders have the necessary licenses and permits in place with DWR and SWRCB to allow diversions from the drain, and CDMWC and GCID currently have a transfer agreement in place that includes the necessary environmental permitting with Reclamation and DWR. No additional permitting requirements are anticipated, though CDMWC will consult with governing agencies, as needed.

6.3.2.8 Project Operations and Monitoring

CDMWC will operate, maintain, and monitor its existing facilities that would be utilized for the project during implementation and operation. No new additional facilities are planned for development.

Ongoing project monitoring will include a range of activities to evaluate the benefits described in the next section. This will include local monitoring to track the use of additional volumes of surface water made available through the project and estimates of the reduction in groundwater use relative to pre-project baselines. Assessments of economic incentives will also be conducted to evaluate their utility in encouraging surface water usage. Monitoring may include additional outreach to shareholders, which would be used to refine the program design and encourage additional adoption. It is further anticipated that annual and multi-year transfer agreements would be continually reviewed, negotiated, and executed to ensure sufficient supplies to achieve the desired program scale.

The benefit of utilizing additional surface water for in-lieu recharge on sustainability indicators in the Subbasin (groundwater levels and groundwater storage) will be monitored using the monitoring network sites and monitoring practices described in the GSP (Chapter 4).

6.3.2.9 Project Benefits

CDMWC anticipates that the project would scale up over time, based on water transfer availability and the economics of utilizing those available supplies. A detailed assessment of project benefits will be completed during GSP implementation, as additional information is available from potential water transfer partners. A preliminary project benefits assessment was developed for the GSP.

The primary benefit of the project is reduction of groundwater pumping resulting from in-lieu groundwater recharge with benefits to the sustainability indicators previously shown in Table 6-3. A preliminary analysis estimates this project has the potential to provide 28 taf/yr of additional surface water for in-lieu recharge to CDMWC. The quantities transferred in each year would depend on water supply conditions in the Sacramento and San Joaquin Valleys. In Shasta Critical years, such as 2021, it is estimated that no water would be available for transfer for the project. Under recent historical conditions, this occurs approximately 1 in 10 years. In other, Shasta Non-Critical years it is estimated that an average of approximately 31 taf/yr would be transferred under agreements entered for this project.

Transfer volumes would vary in Shasta Non-Critical years based on the terms of the transfer agreements, and broader water market conditions. Prices for water transfers to the San Joaquin Valley have increased in recent years, affecting volumes available for transfer, particularly in drier years. Delta capacity constraints limit transfer potential south of the Delta in wet years. It is anticipated that CDMWC transfer volumes would vary with availability of CVP supplies in Shasta Non-Critical years. Table 6-9 summarizes

the historical CVP final allocation for North of Delta agricultural water service contracts. Average CVP contract deliveries were 75 percent between 1990 and 2021, over the more recent 15 years, average deliveries were 67 percent of contracts.

Table 6-9. North of Delta CVP Water Service Contract Allocations Summary

CVP Water Service Contract Allocation (%)	Historical Period	
	1990 - 2021	2007 - 2021
>90%	63%	53%
50%-90%	13%	13%
25% - 50%	16%	13%
<25%	9%	20%
Average	**75%**	**67%**

Table 6-10 summarizes estimated project benefits. Project benefits would also be assessed using the C2VSimFG-Colusa model developed for GSP development by simulating groundwater conditions with and without the project. Benefits assume 31 taf/yr of transfers in Shasta Non-Critical years. As described above, the specific volume in each year type would be specified in transfer agreements. It is estimated that groundwater pumping within the CDMWC area is approximately 40 taf/yr. This project has the potential to provide an average of 28 taf/yr of additional surface water for in-lieu recharge. Therefore, assuming there is no development of groundwater on previously unirrigated lands, the project potential benefit would be 28 taf of in-lieu recharge, reducing the 40 taf annual pumping in CDMWC by 70 percent.

Table 6-10. CDMWC In-Lieu Groundwater Recharge Estimated Average Recharge Volume by Year Type, in af/yr (2016-2065)

Year Type	Total Annual Volume	% of Years	Weighted Avg.
Shasta Non-Critical	Up to 31,000	90%	28,000
Shasta Critical	0	10%	0
Average Annual			**28,000**

6.3.2.10 Project Costs

The primary project cost is the cost of purchased and transferred water. Water transfer prices will be defined in the water transfer agreements. A detailed assessment of the water transfer market in the Subbasin and greater Sacramento Valley is beyond the scope of this initial project investigation for the GSP. Water transfer prices have increased substantially over the last decade. This is due to a combination of more limited supply due to drought, GSP implementation in the San Joaquin Valley, and the biological opinion regarding operation of the CVP system, as well as demand driven by plantings of permanent crops and strong nut prices. Historical (1993 – 2020) data for water transfers (price and volume) for agricultural water within the Sacramento Valley were reviewed.

Table 6-11 summarizes that average and range of within-Sacramento Valley transfer prices. The range highlights the variability in observed prices. Water conditions are classified according to the Sacramento River Index (Sacramento 40-30-30 index), which is formally defined in the State Water Board's Decision 1641. Year types are classified as follows: Wet (Wet), Average (Above Normal, Below Normal, Dry), and Dry (Critical). Prices are typically lower in longer-term agreements, which would be included under this project. As such, the lower end of the range is applied for planning cost estimates in this GSP.

Table 6-11. North of Delta Water Transfer Price Summary

Sacramento Valley WY Index	Average, $/af	Range, $/af	
		Low	High
Wet	$140	$50	$225
Average	$210	$75	$415
Dry	$265	$95	$430
Weighted-Average	$192	$83	$347

Table 6-12 summarizes the estimated project costs. An initial estimate of the anticipated cost of the project is approximately $1.7 million per year. This assumes a water transfer cost of $62 per af for an average annual transfer volume of 28,000 af. This is within the range of prices observed in wetter conditions. It is anticipated that water transfer prices will depend on the length of the transfer, terms, and hydrologic conditions. The price of $62 per af is used for initial planning purposes and does not include any additional conveyance or delivery costs.

Table 6-12. CDMWC In-Lieu Groundwater Recharge Estimated Project Costs

Item	Total Cost	Year Incurred	Notes
Capital Costs			
Project planning and development	$100,000	Start of project	Initial project design, planning, and implementation
O&M Costs			
Water supply cost	$1.7 million	Annual average	Average annual water purchase cost that does not include any additional O&M or overhead costs.

23 CCR §354.44(b)(8) requires a summary of how CDMWC plans to pay the costs of the project. It is anticipated that the cost of transfer purchases would primarily be recovered through CDMWC assessments. Other potential funding sources include grants, loans, and potentially, a type of cost-share program where other groundwater-dependent water users in the Subbasin share a portion of the costs since they will also realize regional benefits through this project. Appendix 7A describes different funding mechanisms, and the conceptual approach for allocating project costs across multiple potential project beneficiaries.

6.3.3 Colusa Subbasin Multi-Benefit Groundwater Recharge

6.3.3.1 Project Overview

The Nature Conservancy (TNC) is partnering with private landowners and the Colusa and Glenn Groundwater Authorities for an on-farm, multi-benefit groundwater recharge incentive program. Program objectives are to benefit:

- Disadvantaged communities and other communities by replenishing critical domestic and agricultural water supplies,
- Private landowners economically through incentive payments,
- Migratory shorebirds through the creation of critical winter habitat on farms, and
- Groundwater conditions (via groundwater recharge).

Surface water from the Sacramento River, subject to availability, is conveyed and applied to participating fields using existing diversion, conveyance, and on-farm infrastructure, flooding and maintaining ponded conditions during the program's annual implementation period.

The pilot program was initiated on Davis Ranches in Colusa County and in other locations within the Subbasin in 2018 and concluded in the spring of 2021. The pilot program evaluated different durations and locations of flooding that would provide multiple benefits for migratory shorebird habitat and groundwater recharge. The habitat and recharge benefits are equal goals of the project.

The program is planned to expand into the future. DWR will be participating in the Multi-Benefit Groundwater Recharge Project as it is expanded into a larger program. Program expansion would include:

- Identifying willing landowner participants to participate in the program. Preliminary mapping based on migratory bird habitat and recharge suitability using the Soil Agricultural Groundwater Banking Index (SAGBI[7]) has been developed to identify potential areas of interest.
- Review and analyze pilot program data to quantify potential multi-benefits and evaluate economic incentives that would be required to support additional program enrollment.
- Evaluate options for funding sources to support program implementation. This may include State funding earmarked for the Department of Conversation to support multi-benefit agricultural land repurposing, or additional funding that may be allocated under potential bill AB-252 or similar initiatives.
- Develop program incentives and funding opportunities to encourage enrollment. Monitor and revise the program annually in response to landowner participant feedback and changing incentive conditions in the Subbasin (e.g., changes in the returns to farming that would affect willingness to accept payment to participate in the program). Continue to refine program to achieve desired multi-benefit outcomes.

[7] SAGBI is a suitability index indicating the potential for groundwater recharge on agricultural land, determined according to five main factors: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. SAGBI ratings for lands in California are developed by the California Soil Resource Lab at University of California, Davis and University of California Agriculture and Natural Resources (UC-ANR) and are available online at: https://casoilresource.lawr.ucdavis.edu/sagbi/ .

With an incentive structure developed, the project would provide financial compensation for recharging groundwater through normal farming operations while also providing critical wetland habitat for shorebirds migrating along the Pacific Flyway, and potential ancillary benefits for water levels near disadvantaged communities or other communities in the Subbasin, depending on where the multi-benefit recharge projects are implemented.

Figure 6-5 below illustrates the location of lands that are potentially suitable for participation in the program near the Sacramento River, identified according to elements in the C2VSimFG-Colusa model domain. The areas indicated in Figure 6-5 were selected for modeling the potential project effects near the Sacramento River[8], though in general fields can be selected throughout the Subbasin by evaluating the SAGBI index to identify areas suitable for recharge and by evaluating land characteristics that benefit migratory shorebird habitat. In practice, the location and scale of the project will depend on the effectiveness of incentives to attract willing landowners, which might or might not be located near the river. Locations will depend on grower enrollment and could be anywhere within the Subbasin where surface water supplies are available and recharge conditions are favorable. Landowner participation would be voluntary, and subject to incentives that would be developed as part of ongoing program implementation.

6.3.3.2 Implementation

Following successful completion of a pilot program from 2018 to 2021, continuation and expansion of the project is currently being planned within the Subbasin. DWR will be participating in the Multi-Benefit Groundwater Recharge project as it is expanded into a larger program. Table 6-13 summarizes the expected implementation timeline for the expanded program.

Table 6-13. Colusa Subbasin Multi-Benefit Groundwater Recharge Implementation Timeline

Phase	Description	Start	End
Pilot Program	Completion of a pilot project for multi-benefit recharge on Davis Ranches	2018	2021
Planning for Expansion of Multi-Benefit Groundwater Recharge	Planning and coordination for expansion and continuation of multi-benefit recharge projects within the Subbasin	2018	2022
Implementation of Multi-Benefit Recharge	Implementation of multi-benefit recharge projects within the Subbasin	2022/2023	Ongoing, if deemed appropriate

[8] Project modeling is described in Appendix 6D. For modeling, proximity of lands to the Sacramento River was considered when selecting potential recharge areas because these lands are expected to have the greatest positive impact on streamflows.

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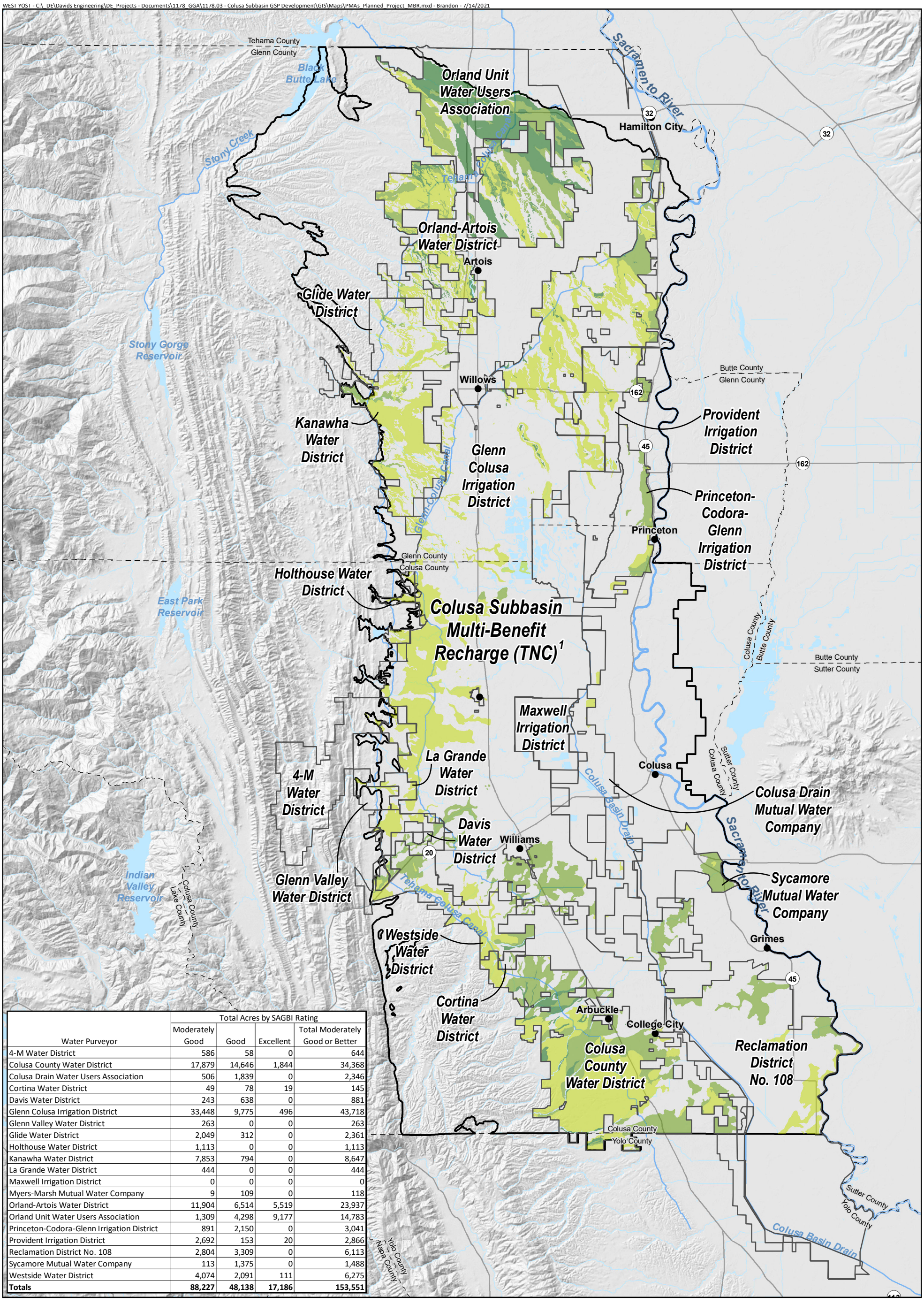

Water Purveyor	Total Acres by SAGBI Rating			
	Moderately Good	Good	Excellent	Total Moderately Good or Better
4-M Water District	586	58	0	644
Colusa County Water District	17,879	14,646	1,844	34,368
Colusa Drain Water Users Association	506	1,839	0	2,346
Cortina Water District	49	78	19	145
Davis Water District	243	638	0	881
Glenn Colusa Irrigation District	33,448	9,775	496	43,718
Glenn Valley Water District	263	0	0	263
Glide Water District	2,049	312	0	2,361
Holthouse Water District	1,113	0	0	1,113
Kanawha Water District	7,853	794	0	8,647
La Grande Water District	444	0	0	444
Maxwell Irrigation District	0	0	0	0
Myers-Marsh Mutual Water Company	9	109	0	118
Orland-Artois Water District	11,904	6,514	5,519	23,937
Orland Unit Water Users Association	1,309	4,298	9,177	14,783
Princeton-Codora-Glenn Irrigation District	891	2,150	0	3,041
Provident Irrigation District	2,692	153	20	2,866
Reclamation District No. 108	2,804	3,309	0	6,113
Sycamore Mutual Water Company	113	1,375	0	1,488
Westside Water District	4,074	2,091	111	6,275
Totals	**88,227**	**48,138**	**17,186**	**153,551**

SAGBI Rating Group

- Excellent
- Good
- Moderately Good

- Surface Water Purveyors
- Colusa Subbasin Boundary

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Notes:
1. SAGBI is an acronym for the Soil Agricultural Groundwater Banking Index, which is a standard suitability index for groundwater recharge on agricultural land.
2. SAGBI results are shown within the service area boundaries of surface water purveyors within the Colusa Subbasin; locations where water conveyance infrastructure already exists.
2. Multi-benefit recharge locations will depend on grower enrollment and could be anywhere within the Colusa Subbasin where surface water supplies are available and recharge conditions are favorable.

N

0 2.5 5

Scale in Miles

Figure 6-5

Multi-Benefit Recharge Project

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

6.3.3.3 Notice to Public and Other Agencies

Public noticing for this project will be done in accordance with noticing requirements in coordination with the CGA and GGA.

6.3.3.4 Construction Activities and Requirements

There are no infrastructure construction activities and requirements, as the project will use existing infrastructure and facilities.

This project may be configured and operated to utilize existing diversion and conveyance infrastructure and facilities. If existing infrastructure and facilities are available and used for this project, there would be no anticipated infrastructure construction activities and requirements upstream of participating fields.

The program would involve some on-farm activities for participating landowners to develop "pop up" recharge sites on existing fields. The program is designed to work within existing field infrastructure and irrigation systems. Any on-farm water management modifications are expected to be modest to increase standing water on fields in specific months to support both habitat and recharge.

Depending on the existing infrastructure available in participating fields, the project may also require some on-farm activities to support project monitoring. Required project monitoring equipment may include flow meters and groundwater level monitoring devices. Prior to field flooding, the project proponents could facilitate a survey of the fields and install pressure transducers and/or flow meters at inlets and outlets and in adjacent wells to facilitate measurement of applied water and changes in groundwater depth.

6.3.3.5 Water Source

The surface water source for the project will be Sacramento River water available under existing rights, subject to availability and agreements established between TNC, CGA, GGA, and private landowners that choose to participate in this voluntary program. The water supply would need to be available during prime flooding windows that support migratory bird habitat and recharge, which are generally in the late summer and early fall (July 15 through October 15) and/or spring (March 15 through April 15). It is anticipated that water will generally be available for this project in all years except Shasta Critical years.

6.3.3.6 Circumstances and Criteria for Implementation

This pilot program was completed in spring 2021. The expanded project is currently planned for implementation, and TNC is working with potential partners. However, due to dry conditions in 2021, the project implementation was delayed. Depending on the outcome of current implementation, and landowner interest, implementation and project benefits could potentially begin in 2022/2023.

Implementation will proceed in several phases. The first phase will be selection of sites suitable for multi-benefit recharge (see above). This would concurrently include initiation of any required environmental documentation. Site selection will be based on:

- Lands that would provide multiple benefits for bird habitat and local communities.
- Soil characteristics that are suitable for recharge, using the SAGBI index in addition to local data developed for the GSP or in coordination with landowner partners.

- Identification of crop types that are suitable for recharge and could accept flooding in late summer and early fall (July 15 through October 15) and/or spring (March 15 through April 15), with minimal impacts (costs) to crops and farming operations.
- Availability of surface water rights and infrastructure to support implementation of the program.
- Availability of existing measurement and monitoring infrastructure.

The second phase of implementation will include developing incentives to encourage landowner participation. This would concurrently include identification of potential funding sources to support the program. Incentives would consider:

- Landowner costs to participate in the program (e.g., on-farm costs, potential crop damage, other direct costs to implement recharge).
- Benefits that would accrue to the local region, the Subbasin, and general public from implementation of the program. These may include improved groundwater levels, other groundwater sustainability indicators, and regional benefits of improved habitat for migratory birds.
- Funding sources would be identified to develop financial incentives. In addition, some program costs could be covered with GGA and CGA participation, where costs would be allocated in proportion to benefits received.

The final phase of program implementation would include ongoing monitoring to measure groundwater (and habitat) benefits for the Subbasin. It is expected that this would result in adjustment to program parameters to support continued expansion and adoption of the program.

Implementation of the multi-benefit program does not depend on the implementation or performance of other PMAs or district activities. Operation of this pilot project could be continued if deemed appropriate. Any future changes will be made to align with landowner participant goals and the overall Subbasin sustainability goal.

6.3.3.7 Legal Authority, Permitting Processes, and Regulatory Control

The multi-benefit recharge project will be implemented as a collaborative effort between private landowners that have the legal authority to implement this project and facilitate multi-benefit recharge on their lands. Implementation will be done in accordance with the required permitting processes and regulatory control.

The following agencies have potential permitting roles for the multi-benefit groundwater recharge project: the Counties of Colusa and/or Glenn, the CGA and GGA, SWRCB, and Reclamation. The project may also require applications for permits required from the SWRCB for diversion of surface water to the extent that diversion is not already permitted under existing water rights and contracts. Recharge projects may also require an environmental 1199 process under CEQA. If required, this project would need either an Environmental Impact Report and Negative Declaration or Mitigated Negative Declaration.

6.3.3.8 Project Operations and Monitoring

Operations and monitoring will be completed by the various project proponents to evaluate the benefits described in the next section. It is anticipated that the total amount of surface water applied to the field will be measured, other flow paths will be measured or estimated, and the amount of recharge achieved will be determined using a mass balance approach. This is consistent with the approach used in the pilot program.

During the implementation period, participants will spread water on their fields and maintain a shallow depth (4 inches maximum) for four to six weeks. Landowner participants will record any changes in water flow in an irrigation log, or other field measurement as appropriate. TNC would coordinate monitoring of field depth, bird presence, water delivery, and changes in groundwater depth.

Project performance would be summarized as part of GSP annual reports and five-year updates.

6.3.3.9 Project Benefits

The primary benefits of the project are direct groundwater recharge and temporary habitat creation for migrating shorebirds, with benefits to the sustainability indicators previously shown in Table 6-3. The potential project groundwater recharge benefits were evaluated in the C2VSimFG-Colusa model, assuming that approximately 4,100 acres participate in the program each year that water is available (anticipated in all but Shasta Critical years). The model was used to simulate field flooding on participating land within the elements identified in Figure 6-5 during the annual project implementation period.[9] From this analysis, it is estimated that an average of 11.5 taf/yr of surface water could be delivered to those participating lands over all year types for multi-benefit recharge, or approximately 2.8 feet per acre of participating land. Over all years simulated, this results in an average annual net groundwater recharge benefit of approximately 5.2 taf/yr, or approximately 1.3 feet per acre of participating land. Additionally, environmental benefits will occur through habitat for migrating shorebirds. All benefits will ultimately depend on grower participation in the program, as it affects the scale of recharge areas and the location where recharge occurs.

During project implementation, actual benefits each year will be evaluated as described in Section 0. Potential project benefits have been assessed, and may continue to be assessed, using the C2VSimFG-Colusa model developed for GSP development by simulating groundwater conditions with and without the project. Additional information on the project modeling is described in Appendix 6D.

Program participation will vary from year to year, depending on landowner interest, financial incentives, water availability, changes in crop market conditions, and sustainability indicators. The program is anticipated to continue every year, providing both groundwater recharge and migratory bird habitat along the Pacific Flyway.

6.3.3.10 Project Costs

Project costs include costs of incentive payments to landowners, land preparation, water conveyance and application, and operations and monitoring.

[9] Multi-benefit recharge was modeled by applying water during a 30-day flooding window (September) to designated irrigated lands (approximately 4,100 acres total) within the selected model elements. Soil characteristics were set to simulate flooding by setting the target soil moisture equal the total porosity of the soil.

Table 6-14 summarizes typical program costs based on the results of the pilot project. Costs are greatest in the initial year of the program due to coordination and site preparation but would be expected to fall over time. Site-specific costs will vary based on field conditions and changes to the program over time. As such, the total costs of the program will vary over time, depending on the number of participating landowners.

Table 6-14. Colusa Subbasin Multi-Benefit Groundwater Recharge Estimated Project Costs

Item	Total Cost	Year Incurred	Notes
Capital Costs			
Site preparation	$4,000	First project year	Per site cost
O&M Costs			
Site management	$3,000	All years	Per site cost. Includes on-farm equipment, labor, and administration costs.
Other O&M cost	TBD	All years	Additional water costs, conveyance, and other site-specific costs would be assessed as part of entering into an agreement with willing landowners

23 CCR §354.44(b)(8) requires a summary of how the project proponent plans to pay these costs. It is anticipated that the cost of incentivizing multi-benefit on-farm recharge would primarily be recovered through funding sources including grants, loans, and potentially, a type of cost-share program where other groundwater-dependent water users in the Subbasin share a portion of the costs since they will also realize regional benefits through this multi-benefit recharge project. Appendix 7A describes different funding mechanisms, and the conceptual approach for allocating project costs across multiple potential project beneficiaries.

6.3.4 Orland-Artois Water District Land Annexation and In-Lieu Groundwater Recharge

6.3.4.1 Project Overview

Orland-Artois WD (OAWD), a Central Valley Project (CVP) water contractor, is working with a group of neighboring non-district landowners to annex approximately 12,000 acres into the district. Figure 6-6 illustrates the location of lands that would be annexed into the district. These lands are already developed agricultural lands that currently rely solely on groundwater for irrigation water supplies. Supplemental surface water for the annexed lands would be secured through annual and multi-year purchase or transfer agreements with willing sellers, conveyed through the existing TCC, and distributed to the annexed lands through new distribution facilities. New facilities include turnouts off the TCC, pipelines, pumping plants, and metered farm deliveries.

It is estimated that approximately 25 taf of surface water would be delivered to annexed lands in all years but Shasta Critical years, resulting in a reduction of groundwater pumping of 23 taf/yr on average across all years. Additionally, certain annexed lands with high infiltration characteristics would be configured for direct recharge by surface spreading. Direct recharge would be done primarily with Section 215 water. Preliminary project design shows seven proposed recharge areas totaling 371 acres in the project. OAWD is evaluating recharge potential and will refine these estimates.

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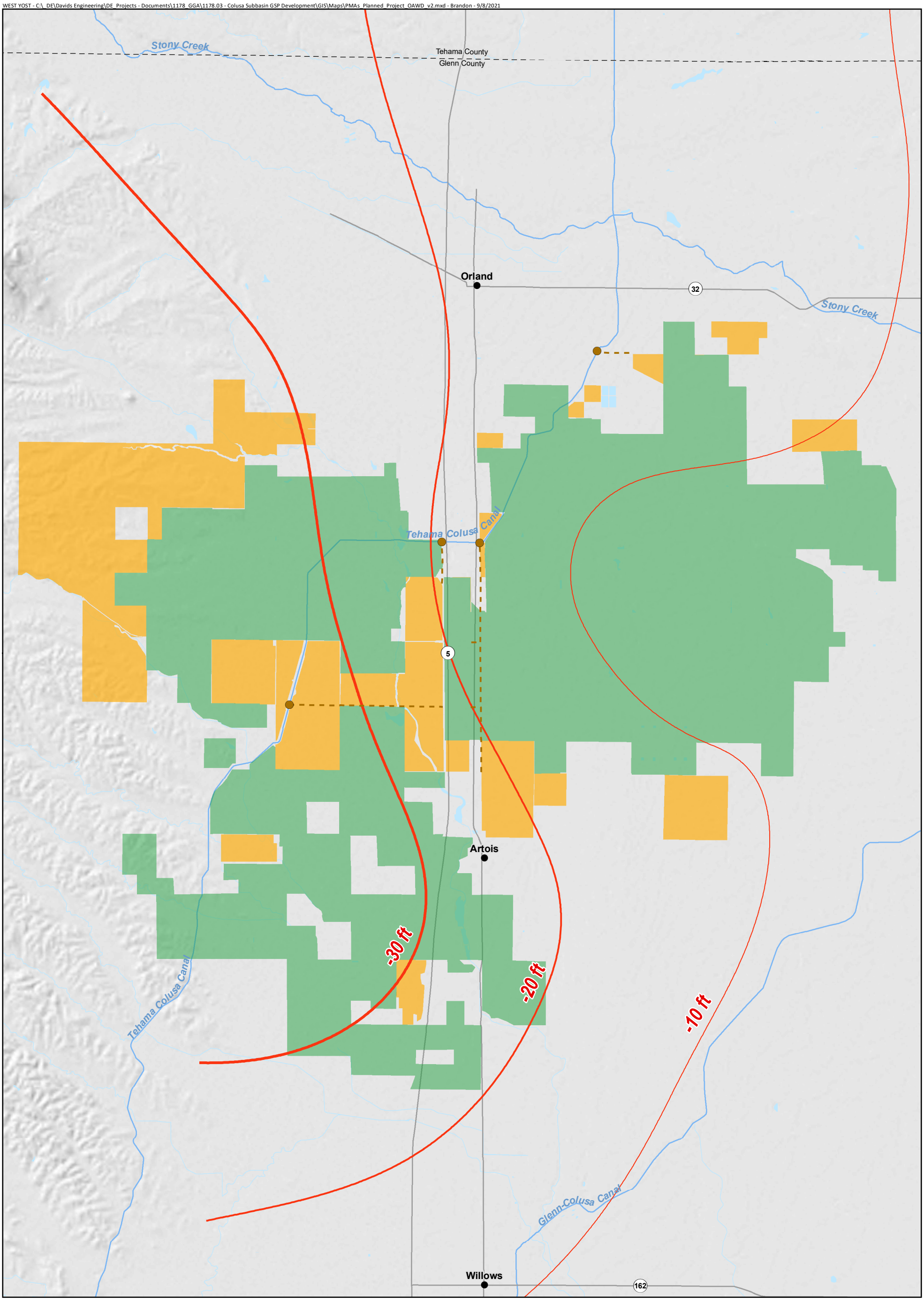

Spring 2010 to Spring 2020 Groundwater Elevation Change

-30 ft -20 ft -10 ft

Proposed New TCC Turnout
Proposed New Pipeline
Orland-Artois WD Boundary
Orland-Artois WD Planned Annexations

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Note:
1. Planning for this project is currently ongoing and map depictions are subject to change.

N

0 1 2
Scale in Miles

Figure 6-6

Orland-Artois WD Land Annexation and Groundwater Recharge Overview

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

This project would address an area within the Subbasin where groundwater levels have been in decline in recent years due to increasing irrigation demands being met through groundwater pumping, compounded in recent years by drought and related curtailments of surface water supplies to OAWD and other neighboring CVP contractors. The sustainability indicators expected to benefit from the project are groundwater levels, groundwater storage, and depletion of interconnected surface water.

6.3.4.2 Implementation

Planning is currently underway for annexation of these lands into OAWD and extension and expansion of the OAWD distribution system. Table 6-15 summarizes the current and planned implementation of the project. It is anticipated that annexed lands would receive surface water deliveries starting in 2025.

Table 6-15. OAWD Land Annexation and In-Lieu Groundwater Recharge Implementation Timeline

Phase	Description	Start	End
Annexation of Additional Lands	Determination of terms and conditions of annexation; development of agreements between OAWD and landowners; requires approval by OAWD, Reclamation, and Glenn LAFCO	2020	2022
Negotiation of Annual and Multi-year Water Purchase or Transfer Contracts	Including engineering and environmental review; requires approval by TCCA, Reclamation and OAWD	2021	2022
Design of New Facilities	Including engineering and environmental review; requires approval by TCCA, Reclamation, and OAWD	2021	2022
Construction of New Facilities	Construction of new turnouts off Tehama-Colusa Canal, pumping plants, pipelines, and metered farm deliveries	2023	2025
Delivery of Surface Water to Annexed Lands	Delivery of purchased or transferred surface water under multi-year agreements	2025	Annually, in perpetuity, except for Shasta-Critical years

6.3.4.3 Notice to Public and Other Agencies

Public noticing for this project will be done in accordance with noticing requirements in NEPA and CEQA, as well as noticing for public meetings held by OAWD, TCCA, and Glenn LAFCO.

6.3.4.4 Construction Activities and Requirements

Construction of new water conveyance facilities will be required for distribution of surface water from the existing TCC to the newly annexed lands. The new facilities include the following:

- Approximately four new turnouts on the TCC to regulate releases from the canal into newly constructed distribution facilities
- Pumping plants on the TCC to lift water to annexed lands that are up-gradient from the TCC

- Distribution pipelines ranging in size from approximately 12 to 36 inches in diameter
- Farm deliveries with instantaneous and totalizing flow measurement devices
- Recharge basins for surface spreading in certain locations with high infiltration rate (gravelly) soils

6.3.4.5 Water Source

The surface water source for the project will come from multiple Sacramento Valley entities with existing surface water entitlements that are willing to transfer water in normal to wet year types. These entities include CVP water supply and settlement contractors and, potentially, Sacramento River water rights holders. The intent is to acquire the water through annual and multi-year, renewable water purchase or transfer agreements, building on similar existing agreements that OAWD has with certain Sacramento Valley entities. Surface water supplies would be diverted from the Sacramento River at the Red Bluff Pumping Plant and Fish Screen facility and conveyed through the Tehama-Colusa Canal, which is operated and maintained by the Tehama-Colusa Canal Authority.

Appendix 6A summarizes an assessment of the volumes of water available for transfer in the Subbasin. The water availability assessment finds there is sufficient water available for transfer for the OAWD project, in addition to the other four planned GSP recharge projects.

6.3.4.6 Circumstances and Criteria for Implementation

This project is planned for implementation as soon as possible, with planning for annexation and new facilities design already underway. In the latter half of 2020 and in 2021, the planning effort has included multiple discussions with OAWD, TCCA and Glenn LAFCO. A formal letter has also been submitted by OAWD to the USBR notifying them of the proposed project. The initial feedback from all agencies has been positive to date.

6.3.4.7 Legal Authority, Permitting Processes, and Regulatory Control

As a Water District, OAWD has the legal authority to pursue expansion of their service area and provide for the acquisition and conveyance of supplemental surface water to these additional lands. The planning and implementation of this project will be done in accordance with the required permitting processes and regulatory control.

Governing agencies with which consultation may need to be initiated include, but are not limited to: DWR, SWRCB, CDFW, the Flood Board, Regional Water Boards, Reclamation, USACE, USFWS, NMFS, LAFCO, the County of Colusa and/or Glenn, and CARB.

Specific permitting and regulatory processes that may affect the construction of new infrastructure include, but are not limited to:

- USACE Section 404 Permits (potential exemption under Section 404(f)(1)(C) of Clean Water Act)
- Regional Water Quality Control Board Section 401 Water Quality Certification (not required if exempt from USACE Section 404)
- SWRCB Construction General Permit and SWPPP
- SHPO and NHPA Section 106 Coordination

- California Endangered Species Act (CESA) Consultation
- ESA Compliance
- NEPA Compliance
- CEQA Compliance

6.3.4.8 Project Operations and Monitoring

OAWD plans to operate and maintain its existing district facilities, new facilities for annexed lands, and conduct project monitoring.

Project monitoring will include a range of activities to evaluate the benefits described in the next section. This will include local monitoring to track the additional volumes of water made available through transfers and estimates of the reduction in pumping relative to pre-project baselines. The district plans to monitor deliveries of surface water to newly annexed lands in-lieu of groundwater pumping. The benefit of in-lieu recharge on sustainability indicators in the Subbasin (groundwater levels and groundwater storage) will be monitored using the monitoring network sites and monitoring practices described in the GSP (Chapter 4).

6.3.4.9 Project Benefits

The primary benefit of the project is reduction of groundwater pumping resulting from in-lieu groundwater recharge with benefits to the sustainability indicators previously shown in Table 6-3. It is estimated that approximately 25 taf of surface water would be delivered to annexed lands in all years but Shasta Critical years, resulting in an average reduction of groundwater pumping of 23 taf/yr across all years.

Certain annexed lands with high infiltration characteristics would be configured for direct recharge by surface spreading. Direct recharge would be done primarily with Section 215 water. The direct recharge capacity has not yet been estimated. These benefits would be realized after construction of the water delivery infrastructure is complete and delivery of surface water to these newly annexed lands begins.

Table 6-16 summarizes the expected annual volume of in-lieu recharge under the OAWD program. Project benefits have been assessed, and may continue to be assessed, using the C2VSimFG-Colusa model developed for GSP development by simulating groundwater conditions with and without the project. Additional information on the project modeling is described in Appendix 6D. Transfer volumes would vary in Shasta Non-Critical years based on the terms of the transfer agreements, and broader water market conditions. It is anticipated that OAWD transfer volumes would vary with availability of CVP supplies in Shasta Non-Critical years. Average CVP contract deliveries were 75 percent between 1990 and 2021, over the more recent 15 years, average deliveries were 67 percent of contracts. At full implementation (in 2025) the expected average annual volume equals 25 taf in Shasta Non-Critical years, with total average annual volume of 23 taf.

Table 6-16. OAWD Land Annexation and In-Lieu Groundwater Recharge Estimated Average Recharge Volume by Year Type, in af/yr (2016-2065)

Year Type	Total Annual Volume	% of Years	Weighted Avg.
Shasta Non-Critical	Up to 25,000	90%	22,500
Shasta Critical	0	10%	0
Average Annual	-	-	**22,500**

6.3.4.10 Project Costs

Project costs include the cost of purchased water, applicable costs associated with the use of the TCC, capital costs associated with construction of new facilities, and OAWD operation and maintenance costs for the facilities serving the annexed lands. Efforts are currently underway by OAWD and owners of proposed annexed lands to estimate these project costs, and to identify funding sources and establish repayment terms. Table 6-17 summarizes estimated project costs.

Table 6-17. OAWD Land Annexation and In-Lieu Groundwater Recharge Estimated Project Costs

Item	Total Cost	Year Incurred	Notes
Capital Costs			
Distribution system and LAFCO costs	$20 million	Start of project	Preliminary cost estimate; OAWD is currently refining the cost of expanding its distribution to serve the annexed lands. Annexed lands would be responsible for additional costs.
O&M Costs			
Water supply cost	$1.9 million	Annual average	Average annual water purchase cost to acquire water in W, AN, and BN years; costs are incurred in years when water is available.
Other O&M cost	$0.73 million	Annual average	Estimated O&M costs, not including volumetric charge.

The cost of purchased and transferred water will be defined in the water transfer agreements. A detailed assessment of the water transfer market in the Subbasin and greater Sacramento Valley is beyond the scope of this initial project investigation for the GSP. Water transfer prices have increased substantially over the last decade. This is due to a combination of more limited supply due to drought, GSP implementation in the San Joaquin Valley, and the biological opinion regarding operation of the CVP system, as well as demand driven by plantings of permanent crops and strong nut prices.

As shown in Table 6-11 in Section 6.3.2, the weighted-average cost for the lower range of within-Sacramento Valley transfer prices is $83 per af. With approximately 23 taf average annual supply, the expected annual water supply cost (excluding any additional O&M or overhead charges) is $1.9 million. Other operating and maintenance (O&M) costs for the annexed lands are estimated based on current OAWD charges, which include an operations charge of $38.11 per acre and CVP Construction charge of $23.00 per acre. This does not include any additional district O&M costs recovered through volumetric charges.

Potential funding sources include grants, loans, and potentially, a type of cost-share program where other groundwater-dependent water users in the Subbasin share a portion of the costs since they will also realize regional benefits through this in-lieu recharge project.

23 CCR §354.44(b)(8) requires a summary of how OAWD plans to cover the costs of the project. It is anticipated that the cost of transfer purchases would primarily be recovered through OAWD assessments. Landowners in annexed lands would pay for additional distribution system costs. Other potential funding sources include grants, loans, and potentially, a type of cost-share program where other groundwater-dependent water users in the Subbasin share a portion of the costs since they will

also realize regional benefits through this project. Appendix 7A describes different funding mechanisms, and the conceptual approach for allocating project costs across multiple potential project beneficiaries.

6.3.5 Sycamore Slough Groundwater Recharge Pilot Project

6.3.5.1 Project Overview

Proctor and Gamble (P&G) and Davis Ranches recently entered into a cooperative agreement to implement a 10-year groundwater recharge pilot project. The project will apply surface water diverted from the Sacramento River to a 66-acre field on Davis Ranches for groundwater recharge and to provide habitat for migrating waterfowl for 30 to 45 days during the fall or winter each year. The timing of the project may be targeted to provide fall and winter habitat for migratory shorebirds, in addition to groundwater recharge benefits. However, the precise timing of the project is flexible to accommodate changes in water availability and other factors between years.

Sacramento River water is available to Davis Ranches under riparian rights and a Sacramento River settlement contract with Reclamation. If the project starts before November 1, settlement contract water would be used. Otherwise, riparian water rights would be exercised for beneficial use (habitat). The objective is to recharge 5,000 acre-feet over the 10-year study period and to revegetate a portion of Sycamore Slough. Monitoring of groundwater conditions will be done in eight existing groundwater wells, including dedicated monitoring wells and agricultural production wells. If the project is successful and cost effective it could be continued in perpetuity to sustain long-term groundwater recharge and environmental benefits. Subject to acquisition of funding, an expansion of the project is planned for recharge and revegetation in the neighboring Sycamore and Dry Sloughs. The general project location is shown in Figure 6-7.

6.3.5.2 Implementation

The project implementation timeline is shown in Table 6-18. The pilot project is scheduled to begin in the early fall of 2021 and will proceed for ten consecutive years. Subject to acquisition of funding, an expansion of the project is planned for neighboring Sycamore and Dry Sloughs in future years.

Table 6-18. Sycamore Slough Groundwater Recharge Pilot Project Implementation Timeline

Phase	Description	Start	End
Pilot Project	Develop and implement pilot project program	2021	2030
Evaluation and Project Updates	Perform periodic project assessments and update project accordingly	2021	2030
Project Expansion	Evaluate opportunities to expand the project to additional lands in Dry and Sycamore Sloughs	2025	2030
Full Program Implementation	Adjust program based on pilot project performance, and scale program based on interest and funding availability; implement full program	2031	Annually, in perpetuity

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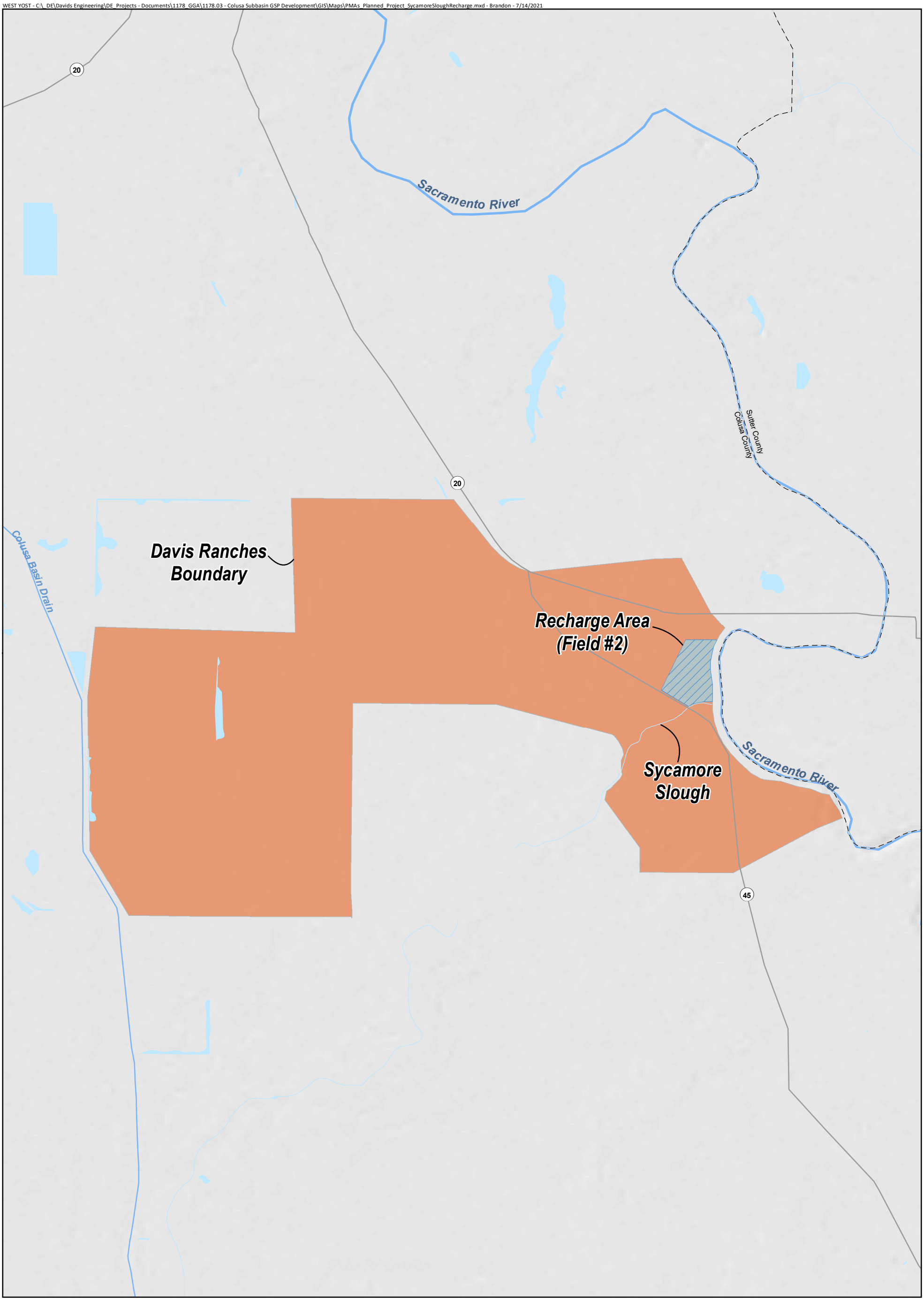

Figure 6-7

Sycamore Slough Groundwater Recharge Pilot Project Overview

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

Recharge Area (Field #2)
Davis Ranches Boundary

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Note:
1. Planning for this project is currently ongoing and map depictions are subject to change.

N

0 0.5 1
Scale in Miles

6.3.5.3 Notice to Public and other Agencies

Public noticing for this project will be done in accordance with all legal noticing requirements. The project is funded through a private grant, and there is no requirement for public notice at initiation. However, the project proponents plan to host public outreach events and field days to communicate and illustrate project goals, challenges, and successes.

6.3.5.4 Construction Activities and Requirements

There are no infrastructure construction activities and requirements, as the project will use existing infrastructure and facilities. Minor earthwork would be required on the pilot project field to support increased recharge and bird habitat.

Future expansion of the program to other participating lands may require a similar level of earthwork to increase recharge and habitat benefits. No major construction activities are anticipated at this time.

6.3.5.5 Water Source

The surface water source for the project will be Sacramento River water available to Davis Ranches under existing riparian rights and an existing Sacramento River settlement contract with Reclamation (before November 1). The water would be diverted and conveyed through existing facilities.

6.3.5.6 Circumstances and Criteria For Implementation

The pilot project is scheduled to begin in the early fall of 2021 and will proceed for ten consecutive years through 2030.

Subject to acquisition of funding, an expansion of the project is planned for neighboring Sycamore and Dry Sloughs in future years. If the project is successful and cost effective it could be continued in perpetuity to sustain long-term groundwater recharge and environmental benefits.

6.3.5.7 Legal Authority, Permitting Processes, and Regulatory Control

As a private landowner, Davis Ranches has the legal authority to implement this project. Implementation will be done in accordance with the required permitting processes and regulatory control.

The following agencies have potential permitting roles for the Sycamore Slough groundwater recharge pilot project: the County of Colusa, SWRCB, and Bureau of Reclamation. Davis Ranches has access to water through existing riparian rights and a Sacramento River settlement contract with Reclamation.

Recharge projects may also require an environmental 1199 process under CEQA. If required, this project would need either an Environmental Impact Report and Negative Declaration or Mitigated Negative Declaration.

6.3.5.8 Project Operations and Monitoring

Davis Ranches will operate and maintain project facilities and monitoring equipment. Monitoring will be completed to evaluate the benefits described in the next section. The total amount of surface water applied to the field will be measured, other flow paths will be measured or estimated, and the amount of recharge achieved will be determined using a mass balance approach. Groundwater levels in eight groundwater wells in the project vicinity will be monitored and analyzed to determine the extent and magnitude of benefits to groundwater conditions.

6.3.5.9 Project Benefits

The primary benefits of the project are direct groundwater recharge and temporary bird habitat formation, with benefits to the sustainability indicators previously shown in Table 6-3. The objective of the pilot project is to recharge 5,000 acre-feet of water over ten years, with the potential to increase this volume if the project is expanded for neighboring Sycamore and Dry Sloughs in future years. Groundwater recharge benefits could also be assessed using the C2VSimFG-Colusa model developed for GSP development by simulating groundwater conditions with and without the project. Additionally, environmental benefits will occur through habitat for migrating waterfowl and revegetation of a portion of Sycamore Slough.

6.3.5.10 Project Costs

Project costs include costs of land preparation, water application, operations and monitoring, and revegetation costs. The estimated capital cost for monitoring equipment is approximately $28,000, and the estimated annual costs for project implementation total approximately $26,000 per year. The pilot project has secured funding through P&G for ten years, and Davis Ranches is currently working with the Freshwater Trust to identify other potential funders for expansion of the recharge program or longer-term funding beyond the 10-year pilot project.

23 CCR §354.44(b)(8) requires a summary of how P&G and Davis Ranches would cover the costs of the project. Initial program costs are covered under a grant. Potential future funding sources include grants, loans, and potentially, a type of cost-share program where other groundwater-dependent water users in the Subbasin share a portion of the costs since they will also realize regional benefits through this project. Appendix 7A describes different funding mechanisms, and the conceptual approach for allocating project costs across multiple potential project beneficiaries.

6.4 ONGOING PROJECTS AND MANAGEMENT ACTIONS

Several agencies and other proponents have ongoing projects and actions which could provide benefits with respect to one or more of the sustainability indicators. In accordance with 23 CCR §354.44(a) these are PMAs that would allow GSAs to achieve the sustainability goal for the Subbasin and avoid minimum thresholds defined in this GSP under future, changing conditions.

Data for these PMAs will be developed under future monitoring, and as the GSAs continue to identify and fill data gaps and reported in annual reports. Ongoing PMAs are classified by projects and management actions, which are described in the following subsections. Projects are generally structural activities that include direct recharge and in-lieu recharge. Management actions are activities to improve water management or reduce groundwater pumping. There is one ongoing management action, which is an urban water conservation project in the Willows area. Figure 6-8 illustrates the location of ongoing PMAs in the Subbasin.

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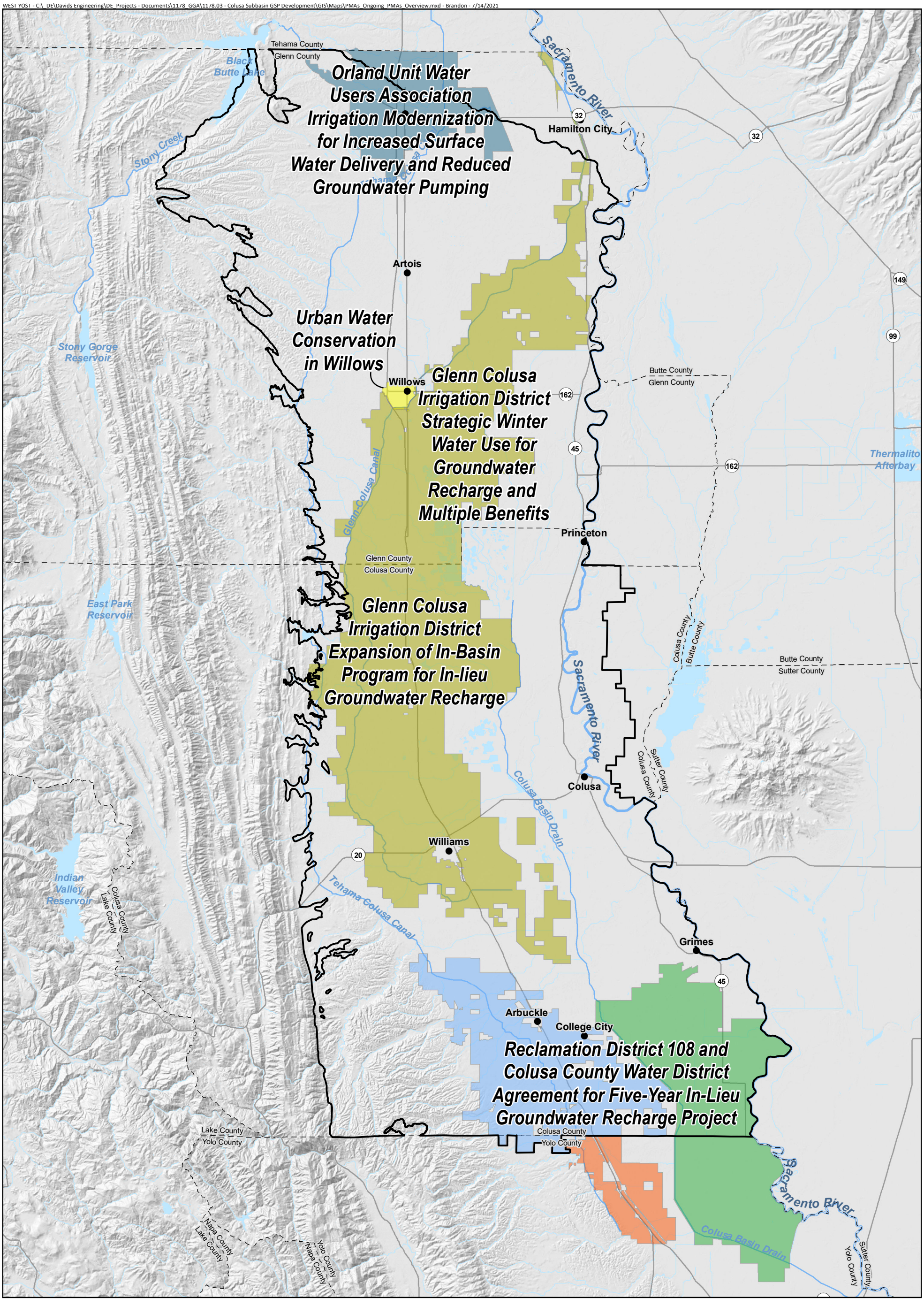

Colusa Subbasin Boundary
Colusa County WD Boundary
Dunnigan WD Boundary
Orland Unit WUA Boundary
Reclamation District No. 108 Boundary
Glenn Colusa ID Boundary
City of Willows

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Notes:
1. Ongoing projects will take place within the service area boundaries of the project proponents.
2. The Sycamore Marsh Farm Direct Recharge Program is not depicted on the map.

N

0 2.5 5

Scale in Miles

Figure 6-8

Ongoing Projects and Management Actions Overview

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

Ongoing PMAs are described at a reconnaissance-level of detail relative to the planned projects described under Section 6.3, above. However, project information is still reported in accordance with 23 CCR §354.44(b). The required information is summarized in a table following the general description for each ongoing PMA. The information provided with each ongoing project table maps to the GSP regulation requirements as follows:

- Implementation (§354.44(b)(1)(A))
- Timeline (§354.44(b)(4))
- Notice to public and other agencies (§354.44(b)(1)(B))
- Water source and reliability (§354.44(b)(6))
- Legal authority, permitting processes, and regulatory control (§354.44(b)(3), (§354.44(b)(7))
- Benefits and benefit evaluation methodology (§354.44(b)(5), (§354.44(b)(9))
- Costs (§354.44(b)(8))

6.4.1 Ongoing Projects

This section describes ongoing projects. Ongoing projects include direct and in-lieu recharge opportunities being implemented across the Subbasin. Table 6-19 summarizes the ongoing projects included in the GSP. The following subsections provide project descriptions for each project.

Table 6-19. Summary of Ongoing Projects

Project	Project Type	Proponent	Year Implemented	Estimated Capital / Establishment Cost, $M	Gross Average Annual Benefit, af/yr
Reclamation District 108 and Colusa County Water District Agreement for Five Year In-Lieu Groundwater Recharge Project	In-lieu Groundwater Recharge	RD108 and CCWD	Pending Extension	Under Development	8,000
Glenn-Colusa Irrigation District Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits	Direct and In-lieu Groundwater Recharge	GCID	2021	Under Development	TBD
Sycamore Marsh Farm Direct Recharge Project[(a)]	Direct Groundwater Recharge	Landowner	2020	Under Development	TBD
Glenn-Colusa Irrigation District Expansion of In-Basin Program for In-lieu Groundwater Recharge	In-lieu Groundwater Recharge	GCID	2021	Under Development	TBD
Orland Unit Water Users Association Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping	In-lieu Groundwater Recharge	OUWUA	2021	Under Development	TBD

(a) Project is not depicted on the map in Figure 6-8.

6.4.1.1 Reclamation District 108 and Colusa County Water District Agreement for Five-Year In-Lieu Groundwater Recharge Project

RD108 and CCWD (and Dunnigan Water District [DWD] located in the neighboring Yolo Groundwater Subbasin) are entering the final year (2022) of a five-year agreement that provides for the purchase of water by CCWD (and DWD) from RD108. The purchased water is available to RD108 through contractual rights under Sacramento River Settlement Contract 14-06-200-876A between RD108 and the Bureau of Reclamation. Under the five-year agreement, 10,000 acre-feet is purchased by and transferred to CCWD and DWD, with 80 percent of the 10,000 acre-feet going to CCWD and 20 percent to DWD. Water purchased under the agreement is diverted at the Red Bluff Pumping Plant and Fish Screen facility and conveyed via the Tehama-Colusa Canal for distribution within CCWD and DWD. The price schedule for the water is tied to Reclamation's annual water rates with an additional charge per acre-foot that depends on CCWD's annual allocation under its CVP contract. The additional charge varies from $0 per acre-foot to $50 per acre-foot. However, in years when RD108's water supply under its settlement contract is cut by 75 percent, the price schedule does not govern and instead the price is $275 per acre-foot. It is expected that the five-year agreement will be extended with the price schedule potentially renegotiated.

This project supplies additional surface water to CCWD (and DWD) that provides in-lieu recharge to meet water demands that otherwise would be met through groundwater pumping.

A summary of the project is provided in Table 6-20.

Table 6-20. Reclamation District 108 and Colusa County Water District Agreement for Five-Year In-Lieu Groundwater Recharge Project Summary

Item	Description
Implementation	RD108 and CCWD proposed this project, if extended, for GSP implementation in the CCWD service area. The project provides in-lieu groundwater recharge through utilization of surface water supplies available to RD108. This is an ongoing project, which will be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	The current project is ending, and extension is still pending. Thus, the start and completion dates for this project have yet to be determined and will be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing is being facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source is Sacramento River water available to RD108 through contractual rights under existing Sacramento River Settlement Contract 14-06-200-876A between RD108 and the Bureau of Reclamation.

Table 6-20. Reclamation District 108 and Colusa County Water District Agreement for Five-Year In-Lieu Groundwater Recharge Project Summary

Item	Description
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review is project specific and being initiated through consultation with applicable governing agencies. Governing agencies for which consultation is being initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, land subsidence, and depletion of interconnected surface water. The expected yield of the project is 8,000 af/yr in Shasta Non-Critical years, and about 7,000 af/yr on average across all years. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and land subsidence. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	The current project is ending, and extension is still pending. Thus, the anticipated costs of this project have yet to be determined and will be reported in GSP annual reports and five-year updates when known. The project proponent is identifying funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.4.1.2 Glenn-Colusa Irrigation District Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits

In addition to the water supply available to Glenn-Colusa Irrigation District under its settlement contract with the Bureau of Reclamation, GCID holds a 1999 water right permit[10] to divert Sacramento River water for irrigation and rice straw decomposition annually between November 1 and March 31. Water used under the permit is referred to as "winter water." Use under the permit began in 2000 and on average between 2000 and 2019, about 43 percent of the district land planted to rice each year has used winter water. Additionally, use for winter irrigation of a variety of permanent and annual crops has gradually expanded, particularly to meet late fall irrigation demands of almonds. Finally, winter water is occasionally used for frost control purposes, particularly on almonds. Water applied for rice straw decomposition creates multiple benefits, including habitat enhancement for Pacific Flyway migrating waterfowl and groundwater recharge in the Subbasin. Water used for winter irrigation and frost control of non-rice crops contributes to in-lieu recharge to the extent that groundwater would have been used absent the availability of winter water.

The potential exists to increase the groundwater recharge and habitat enhancement benefits of winter water use by increasing winter use for rice straw decomposition, winter irrigation, and frost control provided that certain constraints can be alleviated. The main constraints include: the current cost of winter water; the labor cost and management effort involved with applying winter water; GCID's inability to provide of winter water during its annual system construction and maintenance period traditionally

[10] GCID is currently preparing to petition the State Water Resources Control Board (SWRCB) to convert its winter water permit to a water right license.

from early January through late February each winter; and, water supply constraints posed by water right Term 91, which limits Sacramento River diversions during dry periods.

Under this project, working in collaboration with partners within the Subbasin and with environmental advocacy groups, GCID will investigate opportunities to increase winter water use by alleviating the constraints mentioned above. The objectives will be to incentivize growers to: 1) maximize winter water use on rice land including targeting rice lands with highest recharge potential, 2) expand use of winter water for irrigation and frost control where groundwater would otherwise be used, and 3) encourage temporary flooding of permanent and annual crop lands including targeting lands with the highest recharge potential. Critical elements of this investigation include demonstration on-farm economic and agronomic feasibility.

A summary of the project is provided in Table 6-21.

Table 6-21. Glenn-Colusa Irrigation District Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits Summary

Item	Description
Implementation	GCID proposed this ongoing project for GSP implementation in the GCID service area. The project would provide direct and in-lieu groundwater recharge through increased winter water utilization. This is an ongoing project, which will be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is beginning in 2021 and will be ongoing.
Notice to public and other agencies	Public and/or Inter-Agency Noticing is being facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source is an existing appropriative water right for diversion and use of "winter water" from November 1 through March 31 each year. Appropriative winter water supplies are subject to availability and curtailments according to water right Term 91.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review is being initiated through consultation with applicable governing agencies. Governing agencies for which consultation is being initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.

Table 6-21. Glenn-Colusa Irrigation District Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits Summary

Item	Description
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. Potential expansion of this project to increase recharge is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and will be reported in GSP annual reports and five-year updates when known. Other benefits are increased ponded habitat for migrating waterfowl and improved air quality through reduced rice straw burning. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	Project costs are primarily related to the cost of diverting and distributing winter water through the GCID canal network, with costs paid by participating growers. Current rates for winter water service vary between approximately $9 and $27 per acre depending on the level of service (duration of flooding), on top of a fixed assessment of about $42 per acre.

This project will be implemented by GCID working together with project collaborators by continuing use of winter water and investigating alternatives for alleviating constraints and developing incentives for expanding use of winter water. This will include the following actions, among others:

- Petitioning the SWRCB to license GCID's current water right permit, including investigation of provisions for relieving water supply limitations posed by Term 91.
- Characterizing baseline winter water use to better understand the destination of winter water to consumptive use, deep percolation (groundwater recharge), and surface return flows.
- Quantifying the groundwater recharge and habitat enhancement benefits derived from winter water use under baseline and potential future conditions with increased winter water use.
- Identifying beneficiaries of baseline and increased winter water use.
- Identifying and addressing data gaps associated characterizing winter water use and identifying beneficiaries.
- Exploring potential financial, operational, and other types of partnerships with beneficiaries and collaborators.
- Conducting temporary pilot programs to test operational and financial collaborations, potentially leading to implementation of permanent or long-term arrangements.
- Assessing environmental impacts and preparing environmental documents, as necessary.

Winter water would be diverted from the Sacramento River and delivered using GCID's existing distribution system, so no additional conveyance infrastructure is expected to be required. Minor facilities to connect the GCID system to lands currently served by groundwater only might be required.

6.4.1.3 Sycamore Marsh Farm Direct Recharge Project

Sycamore Marsh Farm has been in process of developing a groundwater recharge plan to store water in the aquifer by several different methods. The plan provides for 205 acres of year-round recharge basins and 163 additional acres of winter recharge areas. A summary of the project is provided in Table 6-22.

Table 6-22. Sycamore Marsh Farm Direct Recharge Project Summary

Item	Description
Implementation	The landowner proposed this ongoing project for GSP implementation which would be located on their property. The project provides direct groundwater recharge through several methods. This is an ongoing project, which will be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	The project began in 2020 and will be ongoing.
Notice to public and other agencies	Public and/or Inter-Agency Noticing is being facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source for this project is the Colusa Drain. The reliability is to be determined. However, no new water rights are expected to be necessary.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review is being initiated through consultation with applicable governing agencies. Governing agencies for which consultation is being initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, depletion of interconnected surface water, land subsidence, and potentially groundwater quality. This project is still developing. Thus, the expected yield of this project has yet to be determined and will be reported in GSP annual reports and five-year updates when known. Other benefits include ponded habitat for migratory waterfowl. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is still developing. Thus, the anticipated costs of this project have yet to be determined and will be reported in GSP annual reports and five-year updates when known. The project proponent is identifying funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.4.1.4 Glenn-Colusa Irrigation District Expansion of In-Basin Program for In-lieu Groundwater Recharge

In cooperation with the Bureau of Reclamation (Reclamation), GCID has developed temporary arrangements to supply district surface water to neighboring non-district agricultural lands that primarily use groundwater. These temporary arrangements were implemented under agreements that recently expired in 2020. There is continued interest from participating landowners, and interest from landowners in additional closely neighboring areas, in continuing and expanding this in-basin surface water use. GCID is currently working in cooperation with Reclamation to renew these agreements and expand this program for the purpose of reducing groundwater pumping and increasing in-lieu groundwater recharge. Construction of new water delivery infrastructure may be required to deliver surface water to some neighboring lands. GCID is also evaluating the possibility of annexing some or all of these lands into its service area. Supplies would potentially be available for this project only in Shasta Non-Critical years. A summary of the project is provided in Table 6-23.

Table 6-23. Glenn-Colusa Irrigation District Expansion of In-Basin Program for In-lieu Groundwater Recharge Summary

Item	Description
Implementation	GCID proposed this recently expired project to become an ongoing project for GSP implementation in GCID and neighboring areas. The project would provide in-lieu groundwater recharge through increased surface water utilization. This is an ongoing project, which will be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project would resume in 2021 and be ongoing.
Notice to public and other agencies	Public and/or Inter-Agency Noticing is being facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source is the Sacramento River under GCID's existing contractual and appropriative rights. Supplies would potentially be available in Shasta Non-Critical years. This is expected to be a reliable source during those years.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review is being initiated through consultation with applicable governing agencies. Governing agencies for which consultation is being initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.

Table 6-23. Glenn-Colusa Irrigation District Expansion of In-Basin Program for In-lieu Groundwater Recharge Summary	
Item	Description
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. Potential expansion of this project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and will be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	Potential expansion of this project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and will be reported in GSP annual reports and five-year updates when known. The project proponent is identifying funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.4.1.5 Orland Unit Water Users Association Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping

This project continues the modernization of the OUWUA's southside irrigation conveyance and distribution system involving the following features: regulating reservoirs, expanded and improved flow measurement and water level control, system interties, and expansion and upgrading of the existing supervisory control and data acquisition (SCADA) system. These improvements are expected to result in more reliable and flexible farm deliveries that will provide incentives for growers to use more surface water and pump less groundwater. In-lieu recharge is expected to increase groundwater levels within and neighboring the OUWUA service area. A summary of the project is provided in Table 6-24.

Table 6-24. Orland Unit Water Users Association Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping Summary	
Item	Description
Implementation	OUWUA proposed this ongoing project for GSP implementation in the OUWUA service area and neighboring areas. The project provides in-lieu groundwater recharge through more efficient utilization of existing surface water. This is an ongoing project, which will be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is still developing. Thus, the start and completion dates for this project have yet to be determined and will be provided in GSP annual reports and five-year updates when known.

Table 6-24. Orland Unit Water Users Association Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping Summary	
Item	Description
Notice to public and other agencies	Public and/or Inter-Agency Noticing is being facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source is Stony Creek water available to the OUWUA under the Angle Decree. This is highly reliable with significant shortages historically occurring once every 10 to 20 years on average.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review is project specific and being initiated through consultation with applicable governing agencies. Governing agencies for which consultation is being initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is still developing. Thus, the expected yield of this project has yet to be determined and will be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is still developing. Thus, the anticipated costs of this project have yet to be determined and will be reported in GSP annual reports and 5-year updates when known. The project proponent is identifying funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.4.2 Ongoing Management Actions

This section described ongoing management actions. There is one ongoing management action, summarized in Table 6-25. It incentivizes urban water conservation in the Willows area, providing an important benefit in reducing groundwater pumping in the area.

Table 6-25. Summary of Ongoing Management Actions					
Management Action	Management Action Type	Proponent	Year Implemented	Estimated Capital Cost	Gross Average Annual Benefit, af/yr
Urban Water Conservation in Willows	Management Action	RD108 and CCWD	2016	TBD	2

6.4.2.1 Urban Water Conservation in Willows

The California Water Service - Willows District is implementing urban water conservation measures through water waste prevention ordinances, metering, conservation pricing, public education and outreach, programs to assess and manage distribution system real loss, water conservation program coordination and staffing support, and other demand management measures. These are described in greater detail in Chapter 9 of the 2020 Urban Water Management Plant (UWMP) for the California Water Service - Willows District. A summary of the management action is provided in Table 6-26.

Table 6-26. Urban Water Conservation in Willows Summary

Item	Description
Implementation	California Water Service - Willows District proposed this ongoing management action for GSP implementation which would occur in the City of Willows. The action would reduce demand for groundwater. This is an ongoing management action, which will be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This management action began in 2016 and is ongoing.
Notice to public and other agencies	Public and/or Inter-Agency Noticing is being facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	Not applicable for this demand management action.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual proponents have the authority to plan and implement management actions. Required permitting and regulatory review is being initiated through consultation with applicable governing agencies. Governing agencies for which consultation is being initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. The expected yield of this management action is 2 af/yr. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	The cost is being covered by rate structure of Cal Water - Willows Division.

6.5 POTENTIAL PROJECTS AND MANAGEMENT ACTIONS

In addition to the planned and ongoing projects and management actions identified above, the GSAs and other project proponents are considering a number of other potential PMAs that could provide benefits with respect to one or more of the sustainability indicators. These PMAs are still under development and require additional information that would be developed under future monitoring, and as the GSAs continue to identify and fill data gaps and reported in annual reports. This section provides descriptions for these identified potential PMAs.

Figure 6-9 illustrates the location of potential PMAs in the Subbasin.

Potential PMAs are classified by projects and management actions, which are described in the following subsections. Projects are generally structural activities that include direct recharge, in-lieu recharge, and utilization of additional surface water supplies. Management actions are activities to improve water management or reduce groundwater pumping. Potential management actions include two demand management programs, which per 23 CCR §354.44(b)(2), could be rapidly implemented if the Subbasin is approaching minimum thresholds specified in the GSP.

Potential PMAs are described at a reconnaissance-level of detail relative to the planned projects described under Section 6.3, above. However, PMA information is still reported in accordance with 23 CCR §354.44(b). The required information is summarized in a table following the general description for each potential PMA. The information provided with each potential project table maps to the GSP regulation requirements as follows:

- Implementation (§354.44(b)(1)(A))
- Timeline (§354.44(b)(4))
- Notice to public and other agencies (§354.44(b)(1)(B))
- Water source and reliability (§354.44(b)(6))
- Legal authority, permitting processes, and regulatory control (§354.44(b)(3), (§354.44(b)(7))
- Benefits and benefit evaluation methodology (§354.44(b)(5), (§354.44(b)(9))
- Costs (§354.44(b)(8))

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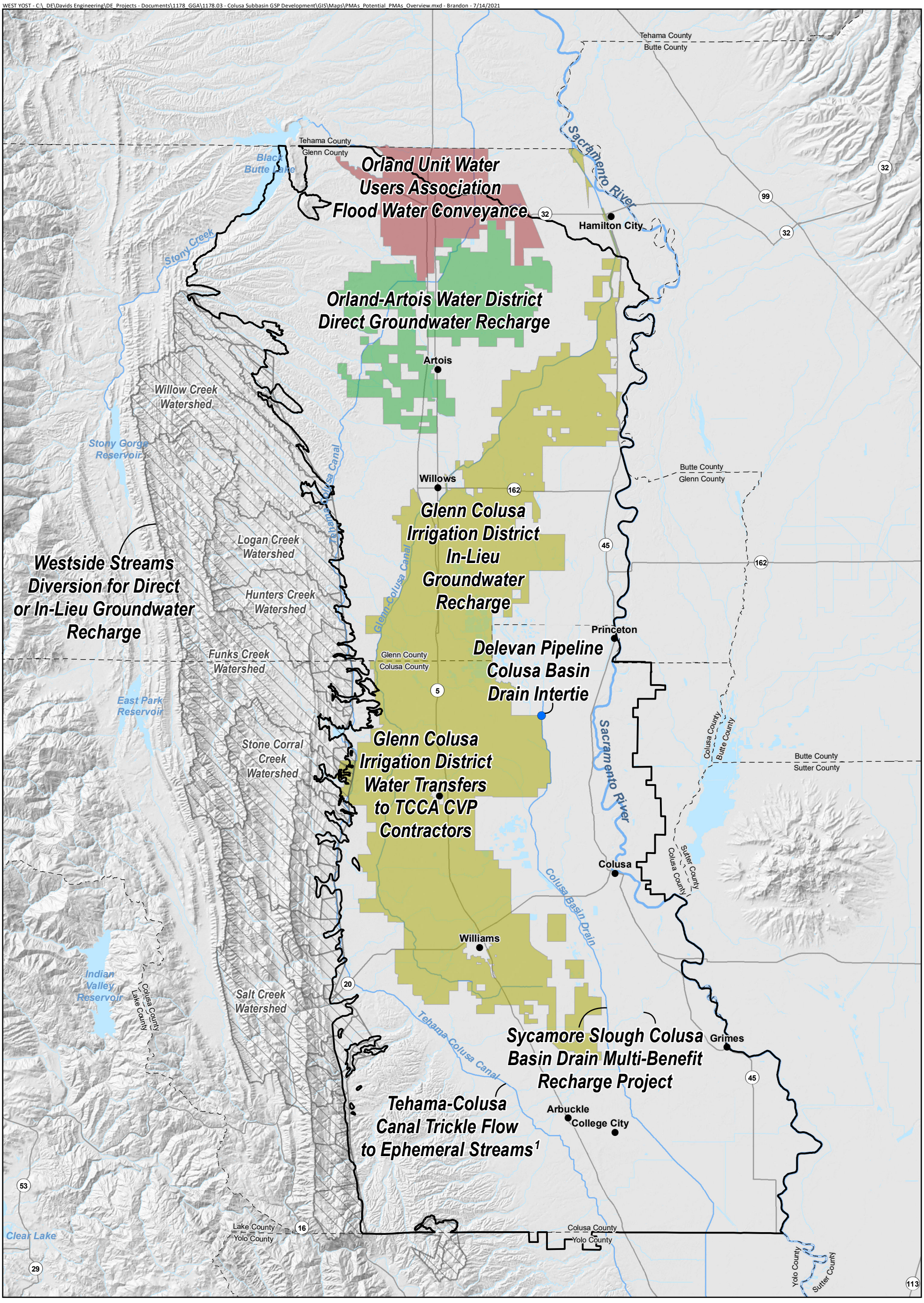

Potential Project Location
Orland-Artois WD Boundary
Orland Unit WUA Boundary
Glenn Colusa ID Boundary
Westside Stream Watersheds
Colusa Subbasin Boundary

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Note:
1. The Tehama-Colusa Canal (TCC) Trickle Flow to Ephemeral Streams project will occur at various points along the TCC where it intersects ephemeral streams, not in the location called out on the map.
2. There are an additional 14 potential projects and management actions that are not depicted on the map. This is due to either subbasin-wide implementation or the planning process not being far enough along to locate these projects at this time.

N

0 2.5 5

Scale in Miles

Figure 6-9

Selected Potential Projects and Management Actions Overview

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

6.5.1 Potential Projects

This section describes potential projects that would be implemented if determined to be necessary or desirable under future monitoring of the Subbasin. Potential projects include direct and in-lieu recharge opportunities that could be implemented across the Subbasin, as well as local and regional (e.g., Sites) storage projects. Table 6-27 summarizes the potential projects included in the GSP. The following subsections provide project descriptions for each project.

Table 6-27. Summary of Potential Projects

Project[(a)]	Project Type	Proponent
Glenn-Colusa Irrigation District In-lieu Groundwater Recharge	In-lieu Groundwater Recharge	GCID
Westside Streams Diversion for Direct or In-lieu Groundwater Recharge	Direct and In-lieu Groundwater Recharge	CGA and GGA
Sites Reservoir	Direct and In-lieu Groundwater Recharge	Sites Project Authority
Delevan Pipeline Colusa Drain Intertie	Direct and In-lieu Groundwater Recharge	Landowner
Orland Unit Water Users Association Flood Water Conveyance	Direct Groundwater Recharge	OUWUA
Orland-Artois Water District Direct Groundwater Recharge	Direct Groundwater Recharge	OAWD
Sycamore Slough Colusa Basin Drain Multi-Benefit Recharge Project	Direct Groundwater Recharge	Landowner
Tehama-Colusa Canal Trickle Flow to Ephemeral Streams	Direct Groundwater Recharge	RD108
Enhanced Infiltration of Precipitation on Agricultural Lands	Direct Groundwater Recharge	CGA and GGA
Colusa Subbasin Flood-MAR	Direct Groundwater Recharge	CGA and GGA
Reclamation District 108 “Boards In” Program	Direct Groundwater Recharge	RD108
Colusa County Public Water System Water Treatment Plant	In-lieu Groundwater Recharge	Landowner
Glenn-Colusa Irrigation District Water Transfers to TCCA CVP Contractors	In-lieu Groundwater Recharge	GCID
Colusa Subbasin In-lieu Recharge & Banking Program	In-lieu Groundwater Recharge	South Valley Water Resources Authority
Sycamore Marsh Farm In-lieu Recharge Project	In-lieu Groundwater Recharge	Landowner
Westside Off-stream Reservoir and In-Lieu Groundwater Recharge	In-lieu Groundwater Recharge	TCCA Contractors

(a) Fourteen projects and management actions are not depicted on the map in Figure 6-9. These projects and management actions are excluded either because they will be implemented subbasin-wide or because the planning process is not far enough along to locate these projects at this time.

6.5.1.1 Glenn-Colusa Irrigation District In-lieu Groundwater Recharge

Despite GCID having highly reliable surface water supplies, a small percentage of district lands rely primarily on groundwater for irrigation supply. GCID will investigate, develop, and implement measures to incentivize associated growers to utilize surface water supplied by GCID, which will provide in-lieu recharge through reduced groundwater pumping. A summary of the project is provided in Table 6-28.

Table 6-28. Glenn-Colusa Irrigation District In-lieu Groundwater Recharge Summary

Item	Description
Implementation	GCID proposed this planned project for GSP implementation in the GCID service area. The project will provide in-lieu groundwater recharge through increased surface water utilization. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early planning stage. Thus, the start and completion dates for this project have yet to be determined and will be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing will be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source is the Sacramento River under GCID's contractual rights according to its Sacramento River Water Right Settlement contract and under an appropriative water right for diversion and use of "winter water" from November 1 through March 31 each year. Settlement contract water supplies are subject to 25% reductions in Shasta Critical years; appropriative winter water subject to availability and curtailments according to water right Term 91.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review will be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation will be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the early planning stage. Thus, the expected yield of this project has yet to be determined and will be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.

Table 6-28. Glenn-Colusa Irrigation District In-lieu Groundwater Recharge Summary	
Item	Description
Costs	This project is currently in the early planning stage. Thus, the anticipated costs of this project have yet to be determined and will be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.5.1.2 Westside Streams Diversion for Direct or In-lieu Groundwater Recharge

There are numerous ephemeral streams that originate in the Coastal Range to the west of the Subbasin and flow eastward into the Subbasin. A portion of the winter and spring flows along these many streams could be diverted for a variety of in-lieu and direct groundwater recharge efforts in the Subbasin.

An analysis was completed to evaluate the potential recharge of diversions from the six largest streams along the western side of the Subbasin: Willow Creek, Logan Creek, Hunters Creek, Funks Creek, Stone Corral Creek, and Salt Creek[11]. A map of these watersheds and streams is shown on Figure 6-10. It is noted that other streams and creeks, such as Walker Creek and Hambright Creek, also provide significant recharge benefits and offer potential recharge opportunities. However, for the purposes of this preliminary analysis, only the six streams listed above were considered based on their size and available monthly flow estimates.

All of the westside streams considered in this preliminary analysis are tributary to the Colusa Drain, which flows southward out of the Subbasin at the Colusa-Yolo County boundary. The Colusa Drain is tributary to the Sacramento River near Knights Landing in Yolo County and has an average annual discharge of 358,000 acre-feet[12], including irrigation return flows as well as westside natural streamflow.

During periods of flow in the winter and spring, some portion of these flows could be diverted for either 1) off-stream storage and subsequent use for irrigation, or 2) direct groundwater recharge through Flood-MAR[13], dedicated recharge basins, or modified stream beds. A summary of the project is provided in Table 6-29.

[11] The location for Sites Reservoir is within the Funks and Stone Corral Creek watersheds. After construction of Sites Reservoir, flow through these creeks would primarily be inflow to Sites Reservoir and would no longer be available for downstream diversion and use within the Subbasin unless water were released into these creeks from Sites Reservoir in a pattern that matched historical flows.

[12] Average annual discharge of Colusa Drain at Knights Landing, 1986 through 2011.

[13] Flood-MAR stands for Flood-Managed Aquifer Recharge. It is a groundwater recharge strategy that takes advantage of periods of high flow to divert flood waters for aquifer recharge on agricultural lands or other working landscapes (i.e., wildlife refuges or flood bypasses).

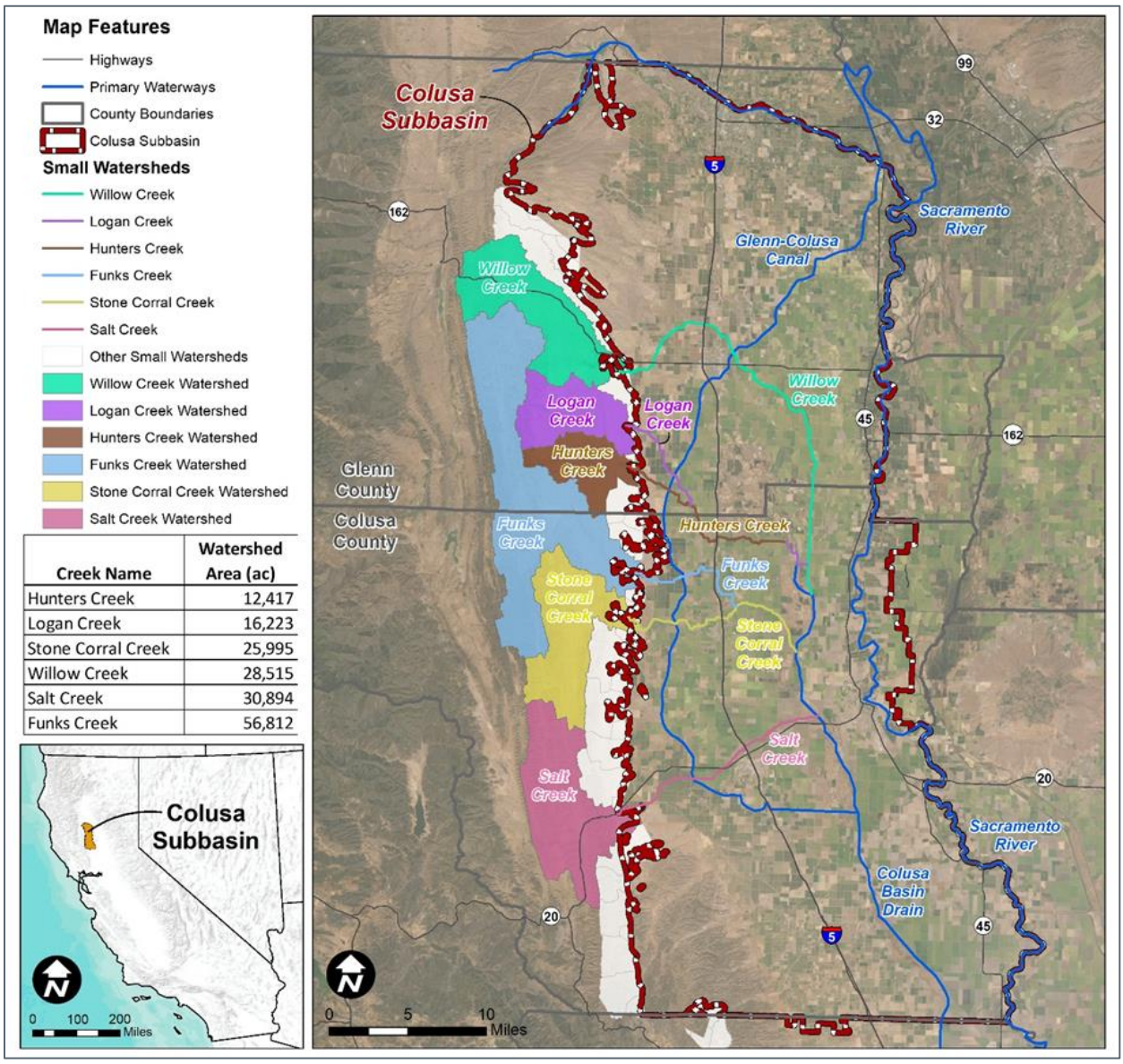

Figure 6-10. Watershed Area and Stream Path through Colusa Subbasin for the Six Largest Westside Streams

Table 6-29. Westside Streams Diversion for Direct or In-lieu Groundwater Recharge Summary

Item	Description
Implementation	This potential project is proposed by CGA and GGA and would be implemented in Colusa and Glenn Counties. The additional water diverted could be used as supplemental irrigation water to provide in-lieu recharge or be diverted to provide direct recharge through Flood-MAR, dedicated recharge basins, or modified stream beds. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and will be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The water source would be the Westside Streams, which includes Willow Creek, Logan Creek, Hunters Creek, Funks Creek, Stone Corral Creek, Salt Creek, and potentially smaller streams. Water will only be available during periods of runoff occurring during heavy precipitation events or wet years.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and will be reported in GSP annual reports and five-year updates when known. Multi-benefits would include reduced flood impacts to the extent that diversions reduce the severity of downstream flooding. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

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A new water right (or rights) through the State Water Resources Control Board (SWRCB) would have to be obtained for this water use. While it is recognized that water rights permitting can take significant time to complete, this potential project is not intended to be implemented quickly. Thus, there is considered to be sufficient time to complete water rights permitting for this project.

New diversion, conveyance, and recharge infrastructure would also have to be constructed. This infrastructure would likely be located on private property through collaborative arrangements with landowners. Depending on the scale of implementation, this project would be expected to result in an average annual benefit ranging from roughly 1,000 af to 16,000 af for the Subbasin. The estimated costs of the project will vary depending on the scale of implementation.

This project concept has already been explored by two private landowners in the Subbasin and implemented on a small scale. One project captures storm water runoff on private lands for groundwater recharge through an underground recharge structure designed to mimic a residential septic leach field, and the other considers diversion of flood flows off of Sand Creek into an existing gravel pit (former excavation site) adjacent to the creek to facilitate direct groundwater recharge.

As described below, evaluation of this project by the CGA and/or the GGA and interested parties within the Subbasin will be done in conjunction with evaluation of the full suite of potential PMAs under consideration by the GSAs. A series of increasingly detailed studies, culminating in a feasibility study, would be required to evaluate project costs and benefits to determine whether or not to proceed with implementation. Because the outcomes of these studies are uncertain, the project implementation schedule cannot be determined at this time. Public noticing for this project as it progresses will be done in accordance with the general plan outlined in the Notice/Communication section of the GSP.

The water source would be natural flow from these six ephemeral streams (and potentially other, smaller westside streams) that flow into the Subbasin from the Coastal Range. To provide preliminary estimates, the timing and volume of these flows, expressed as an average monthly flow, were estimated using C2VSim model rainfall-runoff algorithms. The original C2VSim small watershed rootzone parameters were used in the analysis, and flows runoff from these small Coastal range watersheds into the Subbasin were extracted from the C2VSim small watershed output file. Substantial flow does not occur through these creeks in every year and depends on the seasonal timing and volume of precipitation. Based on simulated rainfall-runoff, this water source is highly variable from year to year, including years of essentially zero runoff, and from month to month within years. When flow does occur, it is typically between the months of December and June and largely occurs between January and April.

A pre-requisite for studying this project concept would be to install stream gages and conduct monitoring to gather multiple years of streamflow records, including stream discharge, water quality measurements, and sediment loads at different flows and for the rising and falling legs of runoff hydrographs. A design objective would be to divert low sediment load flows, probably on the falling leg of runoff events, to minimize the potential for clogging of recharge facilities. Water quality monitoring would also be required to evaluate flow through these streams and determine whether or not poor water quality exists and may impact beneficial uses provided through diversion for direct or in-lieu recharge.

This project would require the design and construction of new diversion and conveyance facilities, as well as either off-stream storage facilities or recharge facilities (i.e., spreading basins)[14]. Further study would

[14] In some cases, these facilities may already be in place and would only need to be repurposed to facilitate this new water use.

need to be conducted to identify estimated volumes of water available for diversion and suitable locations for diversion and recharge facilities; these analyses would result in more detailed information about size and capacity of required infrastructure improvements, construction requirements. and estimated costs.

Further investigation into this project will provide more detailed information of project costs and benefits, which, in comparison with the current and projected conditions of the Subbasin, will allow for determination of whether or not the project should be implemented, and at what scale, to contribute to sustainable operation of the Subbasin. The results of any further analysis will be reported in the annual reports. If implemented, monitoring and quantification of benefits would be accomplished by the GSAs in coordination with other stakeholders and partners.

The timing and volume of flows into the Subbasin through these six creeks have been modeled and evaluated to estimate preliminary potential project benefits. Assuming a range of maximum flow thresholds that can be diverted from each of the six streams when they are flowing, the volumes available for diversion can be calculated. These numbers are long-term annual averages; in some years, no water would be available, while in other years volumes greater than those seen in Table 6-30 would be available. These numbers only represent an initial estimate of potential project benefit volumes and require more in-depth evaluation to verify their accuracy. As shown, initial estimated volumes range from roughly 1,000 af to 16,000 af at different levels of implementation.

Table 6-30. Timing and Volume (af) of Flows into the Subbasin

Maximum Flow Threshold	Dec.	Jan.	Feb.	March	April	May	June	**Total**
Flow = 10 cfs	170	240	204	186	157	165	30	**1,153**
Flow = 20 cfs	286	589	386	523	459	324	68	**2,635**
Flow = 40 cfs	406	1,266	979	1,575	1,281	507	68	**6,082**
Flow = 60 cfs	406	1,817	1,590	2,770	1,854	628	181	**9,246**
Flow = 80 cfs	499	2,571	1,970	3,699	2,432	708	181	**12,061**
Flow = 100 cfs	615	3,462	2,467	5,252	2,961	927	181	**15,865**

Project costs will depend on the scale of implementation and other factors and will need to be estimated through further study, including an economic analysis and finance strategy designed to outline alternatives for meeting the costs for project implementation.

6.5.1.3 Sites Reservoir

The Sites Project would utilize existing infrastructure to divert unregulated and unappropriated flow from the Sacramento River at Red Bluff and Hamilton City and convey water to a new off stream reservoir west of the town of Maxwell. New and existing facilities would move water into and out of the reservoir, with ultimate release back to the Sacramento River system via existing canals and a new pipeline located near Dunnigan. The reservoir capacity would be between 1.3 maf and 1.5 maf depending on the project alternative selected. The reservoir would be operated in coordination with the State Water Project and Central Valley Project, yielding approximately 250,000 to 300,000 af in dry and critical years, and more in other year types. The managing agency is the Sites Project Authority. A summary of the project is provided in Table 6-31.

Table 6-31. Sites Reservoir Summary	
Item	Description
Implementation	The Sites Project Authority proposed this project concept which would be located in the Antelope Valley west of the Subbasin. The project may provide direct and in-lieu groundwater recharge through utilization of surface water from this project, as available. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing will be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source would be Sacramento River under new appropriative water rights. Settlement contract water supply is subject to 25% reductions in Shasta Critical years. New water rights would have junior priority and therefore would be subject to senior rights and water right Term 91
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review will be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation is being initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water (to the extent that project yield is dedicated to recharge projects). This project is currently in the early conceptual stage. Thus, the expected yield of this project for the Subbasin specifically has yet to be determined and will be reported in GSP annual reports and five-year updates when known. Evaluation of benefits is being quantified through post project monitoring. Additional benefits could include increased local, regional, and statewide water supply reliability, climate change resiliency, recreation, and increased cold water pool for endangered salmon. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	The full cost of the project is $5.2 billion. The portion of this which would be covered by Subbasin water users specifically is uncertain at this time.

6.5.1.4 Delevan Pipeline Colusa Drain Intertie

This project would construct an intertie between the proposed Delevan Pipeline component of the Sites Reservoir Project and the Colusa Drain. Currently, the only proposed intertie is the Dunnigan intertie. This intertie would provide a connection to downstream water users to utilize surface water storage from Sites

Reservoir, improve conjunctive use, and potentially decrease groundwater pumping. This intertie would also provide protection for the ecosystems upstream of the proposed Dunnigan intertie and redundancy in case the TCC becomes inoperable due to subsidence or earthquake damage. A summary of the project is provided in Table 6-32.

Table 6-32. Delevan Pipeline Colusa Drain Intertie Summary

Item	Description
Implementation	A landowner proposed this project concept, which would be located at the intersection of Colusa Drain and the proposed Delevan Pipeline. The project would provide direct and in-lieu groundwater recharge through utilization of surface water. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and will be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source would be Sacramento River under new appropriative water rights (conveyed to Sites Reservoir and through Delevan Pipeline). The reliability is uncertain at this time.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and will be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.5.1.5 Orland Unit Water Users Association Flood Water Conveyance

During periods of high flow and reservoir release on Stony Creek, water would be diverted at OUWUA's south diversion and conveyed to various locations for direct recharge within the OUWUA service area. Direct groundwater recharge could be conducted by OUWUA or by participating landowners and growers who have the ability to assist with groundwater recharge. Types of recharge facilities that may be used include creek beds, existing irrigation canals and laterals, agricultural fields, new, dedicated recharge basins, and, potentially, dry groundwater production wells. For example, flood water may be conveyed through existing facilities from the South Canal into the "Low Line Ditch" and Hambright Creek, or flood water may be strategically delivered to provide recharge in fields where groundwater levels have declined. Existing water rights may be used for this project, or a new water right (or rights) through the SWRCB may need to be obtained. While it is recognized that water rights permitting can take significant time to complete, this potential project is not intended to be implemented quickly. Thus, there is considered to be sufficient time to complete any necessary water rights permitting for this project. A summary of the project is provided in Table 6-33.

Table 6-33. Orland Unit Water Users Association Flood Water Conveyance Summary

Item	Description
Implementation	OUWUA proposed this potential project for GSP implementation in the OUWUA service area. The project would provide direct groundwater recharge through utilization of high flow and reservoir release on Stony Creek. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source would be Stony Creek flood releases that cannot be held in Stony Creek reservoirs. This would be highly variable year to year depending on hydrology.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.

Table 6-33. Orland Unit Water Users Association Flood Water Conveyance Summary	
Item	Description
Benefits and benefit evaluation methodology	OUWUA would be responsible for operating and monitoring the project. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.5.1.6 Orland-Artois Water District Direct Groundwater Recharge

OAWD is interested in recharging groundwater through Managed Aquifer Recharge (MAR) on agricultural land to improve aquifer conditions, especially in the groundwater cone of depression to the west of Artois. A pilot project for MAR was conducted in 2017 on the VanTol site using water from a Section 215 Temporary Water Contract from USBR. The 215 water is low-cost but is only available during high flow conditions in rivers and streams. A summary of the project is provided in Table 6-34.

Table 6-34. Orland-Artois Water District Direct Groundwater Recharge Summary	
Item	Description
Implementation	OAWD proposed this project concept for GSP implementation in the OAWD service area. The project would provide direct groundwater recharge through MAR. OAWD completed a pilot project for MAR in 2017. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source would be Sacramento River Section 215 water. This would be highly variable, and available only during periods of high flow in Sacramento River and tributaries.

Table 6-34. Orland-Artois Water District Direct Groundwater Recharge Summary	
Item	Description
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and would be reported in GSP annual reports and five-year updates when known. An additional benefit would be possible ponded habitat for migratory birds depending on timing of flooding. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.5.1.7 Sycamore Slough Colusa Basin Drain Multi-Benefit Recharge Project

This project would restore portions of the Sycamore Slough through voluntary landowner participation in a multi-benefit recharge project. The recharge site will be hosted by Davis Ranches, a participating landowner within the Sycamore Mutual Water Company service. Water would be sourced from the Sacramento River during high flows in the system. The Sycamore Mutual Water Company is a Sacramento River Settlement Contractor, and could use a portion of its existing settlement contract water supplies for recharge if the project is initiated prior to November 1. If the project is initiated after November 1, water could be accessed using existing riparian water rights exercised for beneficial use (habitat). Field flooding would provide recharge, restoration, and multi-benefits such as winter floodplain habitat for migrating shorebirds/waterfowl as the field is pulse flooded, or habitat for monarch butterflies and other pollinator species. A summary of the project is provided in Table 6-35.

Table 6-35. Sycamore Slough Colusa Basin Drain Multi-Benefit Recharge Project Summary	
Item	Description
Implementation	This project would conduct multi-benefit groundwater recharge on fields within the Sycamore Mutual Water Company service area, restoring portions of the Sycamore Slough. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and will be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source would be the Sacramento River. Water could be accessed through existing riparian water rights or from existing settlement contract supplies (if the project is initiated before November 1). This source is expected to be reliable, but the precise volume of available water is unknown at this time.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Multi-benefits include ponded habitat for migratory birds, along with other environmental benefits. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and will be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

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6.5.1.8 Tehama-Colusa Canal Trickle Flow to Ephemeral Streams

The TCC has existing gates that are used to dewater sections of the canal. The gates discharge into ephemeral streams that intersect the canal. Water could be discharged from the TCC into these streams at a rate where they do not flow out of the Subbasin but recharge the groundwater system. Flow measurement devices would need to be added to the gates. Surface water for recharge would be Sacramento River available water under existing Bureau of Reclamation water supply contracts held by Tehama-Colusa Canal contractors, existing water rights settlement contracts, and annual Section 215 contracts. A summary of the project is provided in Table 6-36.

Table 6-36. TCC Trickle Flow to Ephemeral Streams Summary

Implementation	RD108 proposed this project concept which would be located at TCC and ephemeral stream crossings. The project would provide direct groundwater recharge through utilization of surface water. While this project is proposed for areas along the TCC, this concept could be applied throughout the Subbasin. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source would be the Sacramento River (conveyed through TCC). Water could be supplied under existing Reclamation water supply contracts held by Tehama- Colusa Canal contractors, existing water rights settlement contracts, and annual Section 215 contracts. The reliability is uncertain at this time.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.

Table 6-36. TCC Trickle Flow to Ephemeral Streams Summary	
Item	Description
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.5.1.9 Enhanced Infiltration of Precipitation on Agricultural Lands

Current cultural practices, particularly in almond orchards, tend to reduce infiltration and increase runoff of precipitation. Development and adoption of on-farm cultural practices to reduce precipitation runoff and increase infiltration would result in increased storage of precipitation in the crop root zone, thereby reducing irrigation water requirements and groundwater pumping. Additionally, to the extent that infiltrated precipitation percolates through the root zone, this would result in increased direct groundwater recharge. The resulting in-lieu and direct recharge would benefit groundwater levels and reducing runoff could reduce soil erosion and provide water quality benefits. This project is proposed as a potential research management action; for example, a collaborative initiative between the GSAs and University of California Cooperative Extension, the Natural Resources Conservation Service, local resource conservation district, California State University Chico, or other interested organizations. A summary of the project is provided in Table 6-37.

Table 6-37. Enhanced Infiltration of Precipitation on Agricultural Lands Summary	
Item	Description
Implementation	This potential project is proposed by CGA and GGA and would be implemented across the Subbasin through cooperating growers. The project would provide in-lieu groundwater recharge through storage of precipitation in the root zone, and direct groundwater recharge through increased percolation of precipitation. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The main source of water providing additional recharge is precipitation. The reliability would be variable.

Table 6-37. Enhanced Infiltration of Precipitation on Agricultural Lands Summary	
Item	Description
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Other benefits would include reduction of soil erosion and water quality benefits.
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.5.1.10 Colusa Subbasin Flood-MAR

The CGA and GGA, in coordination with landowners and other agencies, would investigate, develop, and implement a program to divert flood waters within the Subbasin, when available, for spreading across agricultural lands or other working landscapes for direct groundwater recharge. A summary of the project is provided in Table 6-38.

Table 6-38. Colusa Subbasin Flood-MAR Summary	
Item	Description
Implementation	CGA and GGA proposed this project concept which would be implemented across the Subbasin with cooperating growers. The project would provide direct groundwater recharge through cooperating grower properties using flood waters when available. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source and reliability of flood water for recharge are to be determined.

Table 6-38. Colusa Subbasin Flood-MAR Summary	
Item	Description
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.5.1.11 Reclamation District 108 "Boards In" Program

RD108, in coordination with landowners, would institute a voluntary or financially incentivized program in which landowners leave their spill boards in place during the winter months to capture rainfall and hold it on their fields for recharge. The project would occur in any fields with spill boards throughout RD108, though the program concept could be expanded across the Subbasin. A summary of the project is provided in Table 6-39.

Table 6-39. Reclamation District 108 "Boards In" Program Summary	
Item	Description
Implementation	RD108 proposed this project, which would be implemented in coordination with landowners in fields with spill boards throughout RD108. The program concept could also be expanded Subbasin-wide. The project would institute a voluntary or financially incentivized program in which landowners leave their spill boards in place during the winter months to capture rainfall and hold it on their fields for recharge. This project is ready for implementation now, but may also be initiated, monitored, and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the conceptual stage, but could be implemented immediately. However, the precise start and completion dates for this project have yet to be determined and would be provided in GSP annual reports and five-year updates when known.

Table 6-39. Reclamation District 108 "Boards In" Program Summary	
Item	Description
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings, and environmental/regulatory permitting notification.
Water source & reliability	This project relies on precipitation, not on water sources outside the Subbasin.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the conceptual stage. Assuming that approximately 20% of rice fields in RD108 participate each year, the estimated average annual recharge benefit of the project over the 2022 to 2065 period is approximately 1.8 taf/yr. The actual yield of this project would be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is currently in the conceptual stage. Thus, the anticipated costs of this project, if any, have yet to be determined and would be reported in GSP annual reports and five-year updates when known. It is anticipated that the project will have no costs if implemented as a voluntary program. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.5.1.12 Colusa County Public Water System Water Treatment Plant

This project would construct a water treatment plant on the Sacramento River between the Cities of Colusa and Grimes to provide treated surface water to public water supply systems in Colusa and possibly Sutter and Yolo Counties. A summary of the project is provided in Table 6-40.

Table 6-40. Colusa County Public Water System Water Treatment Plant Summary	
Item	Description
Implementation	A landowner proposed this potential project which would be implemented in Colusa County. By increasing the surface water available for drinking water supply this project would provide in-lieu groundwater recharge. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and will be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The water source would be the Sacramento River under new appropriative water rights. The reliability is uncertain at this time.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Other benefits would be improved drinking water quality, and less threat to 1) Arbuckle and Dunnigan facing loss of well supply, 2) Grimes and Princeton's drinking well arsenic contamination, and 3) Williams' elevated salinity (TDS) levels. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and will be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

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6.5.1.13 Glenn-Colusa Irrigation District Water Transfers to TCCA CVP Contractors

GCID is exploring the possibility of transferring surface water to Central Valley Project (CVP) contractors served by the TCC to provide in-lieu groundwater recharge and reduce groundwater pumping. The water to be transferred would be Sacramento River water available to GCID under its water rights settlement contract that is temporarily surplus to GCID's needs under certain conditions. Transferred water would be diverted into the Tehama-Colusa Canal at the Red Bluff Pumping Plant and Fish Screen facility rather than at the GCID pumping plant and fish screen facility north of Hamilton City. Priority would be placed on transfers to CVP contractors in areas where groundwater levels have been declining over the past approximately 20 years, particularly in the areas around the cities of Orland and Arbuckle. A summary of the project is provided in Table 6-41.

Table 6-41. Glenn-Colusa Irrigation District Water Transfers to TCCA CVP Contractors Summary

Item	Description
Implementation	GCID proposed this potential project for GSP implementation with participating TCCA CVP contractors. The project would provide in-lieu groundwater recharge through increased CVP water utilization. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source would be the Sacramento River under GCID's existing contractual rights according to its Sacramento River Water Right Settlement contract. Settlement contract water supplies are subject to 25 percent reductions in Shasta Critical years.
Legal authority, permitting processes, and regulatory control	GSAs, Districts and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. These analyses may include: flow measurement consistent with SBx7-7 (23 CCR §931-938), ET analysis, reductions in GW use, well monitoring, determination of infiltration rates, water balance analysis, as-built drawings and stream gaging. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.

Table 6-41. Glenn-Colusa Irrigation District Water Transfers to TCCA CVP Contractors Summary	
Item	Description
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.5.1.14 Colusa Subbasin In-Lieu Recharge & Banking Program

The project would incentivize landowners to take surplus contract surface water in-lieu of pumping groundwater by providing financial incentives (subsidizing surface water costs) to make surface water less expensive than groundwater. If needed, South Valley would subsidize the cost of new distribution systems to facilitate the delivery of additional surface water or provide funds to districts to implement other programs. The magnitude of such payments would depend on the size of the banking project but could exceed $100,000 per year per district. A predetermined portion of the additional water brought into the districts would be dedicated to contributing to local groundwater sustainability and some portion of the remaining quantities would be available for delivery, directly or by exchange, to South Valley members in the San Joaquin Valley. Additional groundwater production wells may need to be constructed to enable recovery of banked water. Such facilities would be paid for by South Valley but located and constructed in coordination with local districts. A summary of the project is provided in Table 6-42.

Table 6-42. Colusa Subbasin In-Lieu Recharge & Banking Program Summary	
Item	Description
Implementation	The South Valley Water Resources Authority proposed this project concept which would be located within the districts who participate. The project would provide direct and in-lieu groundwater recharge through utilization of surface water from this project, as available. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	To be determined.

Table 6-42. Colusa Subbasin In-Lieu Recharge & Banking Program Summary	
Item	Description
Legal authority, permitting processes, and regulatory control	GSAs, Districts and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, depletion of interconnected surface water, land subsidence, and potentially groundwater quality. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.5.1.15 Sycamore Marsh Farm In-Lieu Recharge Project

Sycamore Marsh Farm is in the process of developing an in-lieu groundwater recharge plan. Sycamore Marsh Farm encompasses approximately 420 acres in the Colusa Drain Mutual Water Company (CDMWC) and has an additional 449 acres that could potentially be annexed into the CDMWC, allowing for diversion of surface water from CDMWC. A summary of the project is provided in Table 6-43.

Table 6-43. Sycamore Marsh Farm In-Lieu Recharge Project Summary	
Item	Description
Implementation	The landowner proposed this project concept for GSP implementation which would be located on their property. The project would provide in-lieu groundwater recharge through annexation into CDMWC. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and would be provided in GSP annual reports and five-year updates when known.

Table 6-43. Sycamore Marsh Farm In-Lieu Recharge Project Summary	
Item	Description
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source for this project would be the Colusa Drain. The reliability is still to be determined.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, depletion of interconnected surface water, land subsidence, and potentially groundwater quality. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

6.5.1.16 Westside Off-stream Reservoir and In-Lieu Groundwater Recharge

TCCA Contractors would construct off-stream surface reservoirs along the western edge of the Subbasin and up-slope from the TCC. They would divert surplus Sacramento River flows (e.g., Section 215 water) at the Red Bluff Pumping Plant and Fish Screen, and convey water through the TCC and pump water up into storage reservoir(s). Stored water would be released into the TCC for irrigation supply to enable reduction of groundwater pumping (i.e., in-lieu groundwater recharge). New pumping plants on the TCC and new storage impoundments would need to be planned, designed, and constructed subject to a determination of economic and environmental feasibility. A summary of the project is provided in Table 6-44.

Table 6-44. Westside Off-stream Reservoir and In-Lieu Groundwater Recharge Summary	
Item	Description
Implementation	TCCA Contractors proposed this project concept for GSP implementation which would be located on the western edge of the Subbasin. The project would provide in-lieu groundwater recharge through increased storage of surface water. This project may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	The source for this project would be Sacramento River Section 215 water. The reliability is highly variable; available only during periods of high flow in the Sacramento River and tributaries.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The project proponent would identify funding sources to cover project costs as part of project development. These may include grants, fees, loans, and other assessments.

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6.5.2 Potential Management Actions

This section describes potential management actions that would be implemented if determined to be necessary under future monitoring of the Subbasin. Table 6-45 summarizes the potential management actions included in the GSP. The following subsections provide descriptions for each management action.

Table 6-45. Summary of Potential Management Actions

Management Action[(a)]	Management Action Type	Proponent
Domestic Well Mitigation Program	Management Action	CGA and GGA
Drought Contingency Planning for Urban Areas	Management Action	CGA, GGA, and cities (GSA member agencies)
Long-Term Demand Management Action	Management Action	CGA and GGA
Strategic Short-Term Demand Management	Management Action	CGA and GGA
Well Abandonment Outreach and Funding Program	Management Action	CGA and GGA
Preservation of Lands Favorable for Recharge	Management Action	CGA and GGA
Review of County Well Permitting Ordinances	Management Action	CGA and GGA
Reduce Non-beneficial Evapotranspiration/Invasive Species Eradication	Reduce Groundwater Demand	CGA and GGA
Development of a Dedicated Network of Shallow Monitoring Wells for GDE Monitoring	Management Action, Closing Data Gaps	CGA and GGA

(a) Fourteen projects and management actions are not depicted on the map in Figure 6-9. These projects and management actions are excluded either because they will be implemented subbasin-wide or because the planning process is not far enough along to locate these projects at this time.

6.5.2.1 Domestic Well Mitigation Program

Groundwater level measurable objectives (MOs) adopted for sustainable management of the Subbasin operation are based on the most recent five years of measured water levels in each representative monitoring well (generally 2015 through 2020 with some exceptions), and therefore should be highly protective of domestic water supply wells. However, it is possible that in certain portions of the Subbasin groundwater levels will fall below the adopted MOs and approach the adopted minimum thresholds (MTs) as projects and management actions are being implemented for recovery of groundwater levels. As a consequence, it is possible that that some domestic wells will go dry in the future.

To mitigate the effects of domestic well stranding due to groundwater level decline, the CGA and GGA will investigate implementing domestic well mitigation programs in their respective portions of the Subbasin. These programs may consider supporting consolidation of smaller public water systems and expansion of larger public water systems to cover domestic users that may see impacts to their existing wells. The exact details of the potential domestic well mitigation programs have yet to be determined, but will be reported in GSP annual reports and five-year updates when known. Outreach to domestic well users, including those in DACs, SDACs, and EDAs, will occur throughout program development and implementation using the communication pathways identified in Chapter 2 and in Table 6-46. Outreach will be conducted to ensure that the interests and feedback of domestic well users are known and considered throughout the development and implementation of these programs.

Program development would involve establishing a funding mechanism to accumulate mitigation funds, establishing a process and criteria for determining when dewatered wells are eligible for mitigation funding, and establishing criteria for scaling mitigation payments (for example, relatively new dewatered wells might qualify for more funding than old wells). Possible mechanisms that could be used to generate well mitigation funds include a groundwater extraction fee (which would require flow measurement at each well) and a per well assessment (which would not require measurement). A summary of the program is provided in Table 6-46.

Table 6-46. Domestic Well Mitigation Program Summary

Item	Description
Implementation	CGA and GGA proposed this potential management action for GSP implementation which would occur across the Subbasin. The action would respond to potentially changing conditions in the Subbasin and would be implemented as needed if groundwater levels fall. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This action is currently in the early conceptual stage. Thus, the start and completion dates have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	Not applicable for this demand management action.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual proponents have the authority to plan and implement management actions. Required permitting and regulatory review would be initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit is groundwater levels, as this management action would alleviate problems associated with potential changes in conditions. The expected yield of this management action is not quantified as it is proposed for responding to changing conditions. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This management action is currently in the early conceptual stage. Thus, the anticipated costs have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The proponent would identify funding sources to cover costs as part of development of this management action. These may include grants, fees, loans, and other assessments.

6.5.2.2 Drought Contingency Planning for Urban Areas

The CGA and GGA will coordinate with cities, towns, and other municipal and industrial water suppliers, which are all fully dependent on groundwater in the Subbasin, to encourage drought contingency planning and drought preparedness in a manner consistent with sustainable groundwater management according the GSP. A summary of the management action is provided in Table 6-47.

Table 6-47. Drought Contingency Planning for Urban Areas Summary

Item	Description
Implementation	CGA, GGA, and cities (GSA member agencies) proposed this potential management action for GSP implementation which would occur across the Subbasin. The action would reduce the demand for groundwater pumping. This action may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This action is currently in the early conceptual stage. Thus, the start and completion dates have yet to be determined and will be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	Not applicable for this management action.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement management actions. Required permitting and regulatory review would be initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The sustainability indicators expected to benefit are groundwater levels, groundwater storage, and depletions of interconnected surface water. This management action is currently in the early conceptual stage. Thus, the expected yield has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This management action is currently in the early conceptual stage. Thus, the anticipated costs have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The proponent would identify funding sources to cover costs as part of development of this management action. These may include grants, fees, loans, and other assessments.

6.5.2.3 Long-Term Demand Management Action

The planned PMAs described in this chapter will be pursued by the Colusa Subbasin GSAs to achieve and maintain sustainable groundwater conditions. The GSAs have also included a potential demand management program as a "backstop" to other PMAs. Events that may trigger this management action include, but are not limited to: severe, prolonged drought conditions result in groundwater levels approaching MT in specific parts of the Subbasin; other PMAs are not achieving the expected level of benefits; or new information about projected future conditions show that sustainability objectives will not be met. This section describes the demand management action.

Demand management broadly refers to any water management activity that reduces the consumptive use of irrigation water. To be effective for purposes of sustainable groundwater management, demand management must result in a reduction in net groundwater pumping (pumping net of recharge). That is, it must reduce consumptive use or irrecoverable losses into a saline water body. Activities that, for example, reduce canal seepage or reduce deep percolation from irrigation will not be effective. They may decrease quantity of water diverted or applied but they also reduce recharge to usable groundwater, so do not improve the net pumping from the aquifer.

For purposes here, a demand management action is one that incentivizes, enables, or requires water users to reduce their consumptive use, but does not dictate exactly how users have to do it. Users can respond to demand management by changing to lower water-using crops, water-stressing crops (providing less water than the crop would normally consume for full yield), reducing evaporation losses, and reducing irrigated acreage.

The following types of demand management activities are included under this management action:

- **Allocation**. Under an allocation, the different sources of groundwater are quantified and allocated to individual parcels, wells, or entities (such as, for example, farming operations). Sources of groundwater that can be included in the allocation can include the sustainable yield, natural recharge, imported water recharge, new developed recharge sources, and, for a limited period of time, overdraft (sometimes called "transitional water"). By defining the quantities of groundwater available to individuals this can incentivize reductions in use and development of new recharge opportunities. Allocation design may include specific considerations for managed wetlands and other habitat uses of water.

  Implementing an allocation does not necessarily result in reducing groundwater use. For example, if the allocation is greater than historical use this would not be a constraint for groundwater users and would not result in less consumptive groundwater use. In the context of GSP implementation, the allocation is typically tied to the sustainable yield of the Subbasin. When the sustainable yield (including yield of other PMAs like recharge projects) is less than current pumping, the effect of an allocation is an overall reduction in net groundwater use.

  An allocation is a rigid method for implementing demand management. It effectively limits water use on a well, parcel, or operation basis. This could require idling land or switching crop on lands that have insufficient allocation to meet crop demand, which imposes costs on water users (e.g., growers). There are ways to increase the flexibility of allocations to reduce the costs of demand management. For example, the allocation could be defined as an average over a period of time rather than a fixed amount every year, or users could be allowed to carry over unused allocation into the next year.

- **Allocation + Water Market**. An allocation that is less than historical water use can be coupled with a water market. A groundwater market is another way to increase the flexibility of an allocation to reduce costs of demand management. A market is an institution that allows willing buyers and sellers to exchange groundwater allocation ("credits"). The market allows groundwater users to shift allocation to higher-valued uses. Defining an allocation across an entire farming operation establishes a kind of market in which the owner or manager moves water to produce the highest return (e.g., remove an older block of an orchard and use the allocation to meet crop demand on a more productive block). More broadly, a market allows a means to exchange allocation with another groundwater user, whether for a single season or using a multi-year trade. Willing sellers trade a part of their allocation to willing buyers in exchange for a payment that the seller expects will exceed the return he/she would have earned from using the water for irrigation. This additional flexibility reduces the cost to the GSA's users of achieving demand reduction under an allocation.

  Development of a water market institution is a complex process that encompasses more than defining the groundwater allocation. The water market requires an administrator (e.g., the GSA or a third party) and methods for monitoring, enforcement, and accounting of groundwater use. It also requires development of market rules that determine what sources of the allocation are tradeable, under what conditions, and over what periods of time. For example, market rules would consider, and possibly limit, the potential impacts of local concentrations of groundwater pumping if trades occur within specific areas. Other market rules might consider habitat and ecosystem service benefits. Finally, the water market requires a marketplace for buyers and sellers to post bids, review prices, and execute deals. The GSAs would consider these factors in the future if a groundwater market is considered.

- **Land Repurposing**. Land repurposing programs are more targeted than an allocation or market program but maintain flexibility for participants by its voluntary nature. Such a program would provide a financial incentive to willing participants for their currently irrigated lands to be repurposed into other, non-irrigated uses. Programs can focus on short-term drought conditions, or they can provide multi-year reductions in demand if that is needed under some conditions. For longer-term programs, lands can be repurposed to achieve other multi-benefit objectives - for example, to create habitat corridors or to support local endangered species[15].

  Land repurposing programs typically include incentives to stop irrigating. These incentives need, at minimum, to exceed the return to farming on a parcel. An additional incentive may be provided to convert land into an alternative use. For example, the United States Department of Food and Agriculture (USDA) Conservation Reserve Enhancement Program (CREP[16]) will pay lands to forgo irrigation and offer an additional per acre payment to convert lands into different types of habitats. Other land repurposing program considerations might consider strategic location of repurposed lands considering proximity to protected areas (e.g., National Wildlife Refuges).

[15] See, for example: Environmental Defense Fund, Strategic Land Repurposing. The Nature Conservancy, Rewilding Agricultural Lands.

[16] Note that CREP is state-specific and is not currently being implemented in California.

- **Other financial incentives**. Demand management can also be achieved through a range of other financial incentives. This could include positive financial incentives to reduce consumptive groundwater use. It could also include groundwater extraction fees that disincentivize groundwater use. Financial incentives could consider public benefits (e.g., habitat) separately from private benefits (e.g., irrigation) of water use.

  As described above, the demand management action could be triggered if required under future monitoring by the GSAs. The following principles would guide development of the demand management program; these are in no order of preference and the GSAs recognize that tradeoffs exist among these principles:

  - Minimize the economic impacts of any demand management
  - Maintain established water rights
  - Incentivize investment in water supply infrastructure
  - Incentivize economically efficient water use
  - Complement other PMAs such as direct and in-lieu recharge projects in aggregate, and in specific regions
  - Allow sufficient program flexibility for groundwater pumpers to adjust over time
  - Ensure access for domestic water users (de minimis domestic use as defined by SGMA is less than 2 af annually per user for domestic purposes only)

This potential management action will be evaluated further in GSP annual reports and five-year updates, as required by conditions in the Subbasin. Appendix 6B summarizes the economic value of irrigated agriculture to the Subbasin and quantifies the direct economic costs of demand management. Table 6-48 summarizes GSP regulation requirements and describes how the management action meets those requirements.

Table 6-48. Long-Term Demand Management Action Summary

Item	Description
Implementation	CGA and GGA proposed this management action for GSP implementation, but it would only be implemented if groundwater conditions in the Subbasin, or specific areas of the Subbasin, require it. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This action is currently in the early conceptual stage. Thus, the start and completion dates have yet to be determined and would be provided in GSP annual reports and five-year updates when known, and only if the management action is triggered for implementation.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	Not applicable for this demand management action.

Table 6-48. Long-Term Demand Management Action Summary	
Item	Description
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement management actions. Required permitting and regulatory review would be initiated through consultation with applicable governing agencies. This would likely include local county agencies, as appropriate.
Benefits and benefit evaluation methodology	The measurable objective expected to benefit is groundwater levels, as this management action would reduce net pumping to achieve sustainability conditions in specific areas. The expected yield of this management action is not quantified because: 1) it will only be triggered if necessary, and 2) the scale of the demand management program is flexible. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This management action is currently in the early conceptual stage. Thus, the anticipated costs have yet to be determined and would be reported in GSP annual reports and five-year updates when known, and only if the management action is triggered for implementation. The proponent would identify funding sources to cover costs as part of development of this management action. These may include grants, fees, loans, and other assessments.

6.5.2.4 Strategic Temporary Land Idling for Drought and Localized Short-Term Groundwater Management

The Colusa Subbasin GSP identified potential areas of concern in the Subbasin where groundwater levels have declined significantly over recent years due to disproportionate reliance on groundwater to meet crop irrigation demands. Planning and constructing projects (e.g., conveyance or recharge) to offset short-run impacts of drought and local groundwater level impacts would take time and require substantial capital costs. This program is a potential management action that would provide the GSAs with a voluntary, flexible, short-run response to alleviate impacts in local areas of concern.

The program would be focused on specific drought-affected areas with sustainability challenges. It would be voluntary and provide financial incentives (payments) to encourage participation. Payment terms and other conditions would be specified as part of program design. Two potential structures for the program are: 1) participating groundwater-using lands in drought-affected areas in the Subbasin would be idled and the quantified groundwater saved would be left in the ground to alleviate sustainability challenges, or 2) participating surface water-using lands anywhere in the Subbasin would be idled, and the saved surface water would be conveyed to replace groundwater pumping in other areas of the Subbasin with groundwater sustainability challenges.

Appendix 6B summarizes the economic value of irrigated agriculture to the Subbasin and quantifies the direct economic costs of demand management in the potential areas of concern. A summary of the management action is provided in Table 6-49.

Table 6-49. Strategic Temporary Land Idling for Drought and Localized Short-Term Groundwater Management Summary

Item	Description
Implementation	CGA and GGA proposed this management action concept for GSP implementation which would occur across the Subbasin. The action would reduce the demand for groundwater pumping. This action may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This action is currently in the early conceptual stage. Thus, the start and completion dates have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	Not applicable for this demand management action.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual proponents have the authority to plan and implement management actions. Required permitting and regulatory review would be initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The measurable objectives expected to benefit are groundwater levels, groundwater storage, and depletions of interconnected surface water in areas with potential sustainability challenges. The expected yield of this management action will depend on the level of participation and water needs. There is also potential for multi-benefits on temporarily idled lands, depending on program design.
Costs	This management action is currently in the early conceptual stage. Thus, the anticipated costs have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The proponent would identify funding sources to cover costs as part of development of this management action. These may include grants, fees, loans, and other assessments.

6.5.2.5 Well Abandonment Outreach and Funding Program

The CGA and GGA will coordinate with Colusa and Glenn counties, respectively, to create a program providing outreach and education to landowners regarding the proper procedures for well decommissioning and abandonment, as well as a funding source to assist landowners with these procedures. This effort would be accomplished through coordination between the GSAs and well permitting agencies. This program is anticipated to improve the Subbasin well inventory and potentially have water quality benefits, as improperly abandoned wells are a potential point source for water quality contaminant transport from the ground surface to the underlying groundwater system. A summary of the management action is provided in Table 6-50.

Table 6-50. Well Abandonment Outreach and Funding Program Summary	
Item	Description
Implementation	CGA and GGA proposed this management action concept for GSP implementation which would occur across the Subbasin. The action would respond to potentially changing conditions in the Subbasin and would be implemented as needed based on the number of wells abandoned and water quality concerns. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This action is currently in the early conceptual stage. Thus, the start and completion dates have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	Not applicable for this management action.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement management actions. Required permitting and regulatory review would be initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The measurable objective expected to benefit is water quality. The expected yield of this management action is not quantified as it is proposed for responding to changing conditions. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This management action is currently in the early conceptual stage. Thus, the anticipated costs have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The proponent would identify funding sources to cover costs as part of development of this management action. These may include grants, fees, loans, and other assessments.

6.5.2.6 Preservation of Lands Favorable for Recharge

The CGA and GGA will coordinate with those agencies having authority over land use planning in Colusa and Glenn counties, respectively, to investigate, design, and implement a program providing incentives to landowners with lands favorable to groundwater recharge to preserve them as agricultural or undeveloped lands on which groundwater recharge will be possible in perpetuity. An update of ongoing coordination will appear in annual reports. A summary of the management action is provided in Table 6-51.

Table 6-51. Preservation of Lands Favorable for Recharge Summary	
Item	Description
Implementation	CGA and GGA proposed this management action concept for GSP implementation which would occur across the Subbasin. The action could help create additional direct groundwater recharge in the future. This action may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This action is currently in the early conceptual stage. Thus, the start and completion dates have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	Not applicable for this management action.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement management actions. Required permitting and regulatory review would be initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The measurable objectives expected to benefit are groundwater levels, groundwater storage, and depletions of interconnected surface water. This management action is currently in the early conceptual stage. Thus, the expected yield has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This management action is currently in the early conceptual stage. Thus, the anticipated costs have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The proponent would identify funding sources to cover costs as part of development of this management action. These may include grants, fees, loans, and other assessments.

6.5.2.7 Review of County Well Permitting Ordinances

Modification to well regulations is one potential mechanism to ensure that groundwater sustainability is achieved and maintained in the Subbasin. Well permitting regulations can help avoid adverse impacts on groundwater beneficial users by reducing the potential for mutual well interference or streamflow depletion through limitations on well screen depths, well spacing, and/or setbacks.

This management action would review and suggest potential revisions to the county well permitting processes in the Subbasin to ensure that:

- Future well permitting aligns with the subbasin sustainability goal
- Future changes to well permitting are reviewed by the GSAs

Through this management action, the Counties and GSAs would coordinate to establish processes whereby the GSAs would review and agree upon future changes to well permitting requirements. This coordination could occur through the potential framework for coordination between the Counties and GSAs that is described in Chapter 7, Plan Implementation. The Counties would also review existing well permitting processes and assess whether additional well permitting requirements are warranted to maintain sustainable groundwater conditions in the Subbasin. Existing well regulations may be modified to help protect water quality, allow for appropriate screening, require depths be deeper than MTs, and avoid interference or impacts of pumping on neighboring wells. Efforts may also be designed to be protective of domestic wells.

A summary of the management action is provided in Table 6-52.

Table 6-52. Review of County Well Permitting Ordinances Summary

Item	Description
Implementation	This management action would review and suggest potential revisions to the county well permitting processes in the Subbasin to ensure that future well permitting aligns with the Subbasin sustainability goal and that future changes to well permitting are reviewed by the GSAs. This action may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This action is currently in the early conceptual stage. Thus, the start and completion dates have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	Not applicable for this management action.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement management actions, and Counties have the authority to review and modify county well permitting ordinances. Required permitting and regulatory review would be initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.

Table 6-52. Review of County Well Permitting Ordinances Summary	
Item	Description
Benefits and benefit evaluation methodology	All sustainability indicators may benefit from changes in groundwater pumping that result from revisions to county well permitting ordinances. This management action is currently in the early conceptual stage. Thus, the expected yield has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. Measured parameters will include surface water deliveries, groundwater levels, and others to be determined. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
Costs	This management action is currently in the early conceptual stage. Thus, the anticipated costs have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The proponent would identify funding sources to cover costs as part of development of this management action. These may include grants, fees, loans, and other assessments.

6.5.2.8 Reduce Non-beneficial Evapotranspiration

This project would remove the invasive, non-native plant species (i.e., Arundo donax, eucalyptus, tamarisk, etc.) from riparian corridors and other areas they may be present. This would provide both a reduction in evapotranspiration from shallow groundwater and native ecosystem restoration. A summary of the management action is provided in Table 6-53.

Table 6-53. Reduce Non-beneficial Evapotranspiration Summary	
Item	Description
Implementation	This potential project is proposed by CGA and GGA and would be implemented across the Subbasin. This action could be done in coordination with neighboring GSAs, especially along Stony Creek. The project would reduce groundwater demand by reducing evapotranspiration. This action may be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, if sustainable levels are not reached following implementation of other projects and management actions. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	Not applicable.

Table 6-53. Reduce Non-beneficial Evapotranspiration Summary	
Item	Description
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The measurable objectives expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and would be reported in GSP annual reports and five-year updates when known. Other benefits would include decreased ET, increased native vegetation and habitat, and decreased sediment trapping.
Costs	This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The proponent would identify funding sources to cover costs as part of development of this management action. These may include grants, fees, loans, and other assessments.

6.5.2.9 Development of a Dedicated Network of Shallow Monitoring Wells for GDE Monitoring

This action would evaluate and develop a dedicated network of shallow monitoring wells specifically planned and sited for monitoring conditions in areas of the Subbasin where GDEs are most likely to be found. Although the GSAs used the best available scientific data and information to assess potential GDEs within the Subbasin during GSP development, significant data gaps exist in the understanding of GDEs and associated species in those GDEs. This action would be developed to close those data gaps, prioritizing installation of new monitoring sites in locations where the GSAs determine that GDEs are most likely to be found. It is expected that this action would also incorporate biological monitoring to collect biological data (e.g., biological surveys, remote sensing indexes, and/or assessment of vegetation rooting depth information). This data would be used to inform the location of new shallow monitoring wells and monitor whether GDEs are being impacted by changing groundwater conditions. A summary of the management action is provided in Table 6-54.

Table 6-54. Development of a Dedicated Network of Shallow Monitoring Wells for GDE Monitoring Summary

Item	Description
Implementation	This potential action is proposed by CGA and GGA and would be implemented across the Subbasin, focusing on areas determined during GSP development as most likely to be a GDE, and areas where GDE-related data gaps exist. This action could be done in coordination with neighboring GSAs and agencies, especially along Stony Creek and the Sacramento River. The action would evaluate and develop a dedicated network of shallow monitoring wells specifically planned and sited for monitoring conditions in areas of the Subbasin where GDEs are most likely to be found. This action is expected to be implemented and would be monitored and quantified with respect to groundwater conditions, as needed, during GSP implementation in order to close data gaps related to GDEs. This will be done in the context of Sustainable Management Criteria defined in Chapter 5 to ensure sustainable operation of the Subbasin.
Timeline	This action is currently in the early conceptual stage. Thus, the start and completion dates for this action have yet to be determined and would be provided in GSP annual reports and five-year updates when known.
Notice to public and other agencies	Public and/or Inter-Agency Noticing would be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
Water source & reliability	Not applicable.
Legal authority, permitting processes, and regulatory control	GSAs, Districts, and individual project proponents have the authority to plan and implement projects. Required permitting and regulatory review would be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation would be initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USFWS, NMFS, LAFCO, County of Colusa and/or Glenn and CARB.
Benefits and benefit evaluation methodology	The measurable objectives expected to benefit are groundwater levels, groundwater storage, and depletion of interconnected surface water. This action is currently in the early conceptual stage. Thus, the expected yield of this action has yet to be determined and would be reported in GSP annual reports and five-year updates when known.
Costs	This action is currently in the early conceptual stage. Thus, the anticipated costs of this action have yet to be determined and would be reported in GSP annual reports and five-year updates when known. The proponent would identify funding sources to cover costs as part of development of this action. These may include grants, fees, loans, and other assessments.

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CHAPTER 7
Plan Implementation

This chapter outlines the schedule and costs to implement the GSP over the first five years (through 2026) and describes implementation activities in accordance with §354.8(f)(3). Implementation of the GSP in the Subbasin will include GSA administrative requirements, periodic reporting required under 23 CCR §356.2 and §356.4, and studies to address data gaps and support implementation. In addition, to address possible future changes in the Subbasin conditions that could cause undesirable results over the long term, and in the near term, to address effects of recent historical (2014 to 2015) and current (2020 to 2021) drought conditions, a range of planned projects and management actions (planned PMAs) has been developed and will be implemented by the GSAs, as described in Chapter 6.

In accordance with 23 CCR §354.6(e), GSP implementation costs are estimated and described. Estimated costs are shown for the first five years of GSP implementation and any resulting changes from that set-forth herein will be reported in annual reports. Costs are split into the following two aggregate categories (which are further disaggregated in the subsequent subsections):

- **GSA Costs**. GSA costs are for activities related to GSP implementation that are (generally) not specific to a specific area or water district in the Subbasin. For example, this includes GSA administration costs for coordination, meetings, outreach, legal, and other general administrative requirements to support GSP implementation.
- **PMA Costs**. PMA costs are specific to PMAs that were described in Chapter 6 of this GSP. These costs may be covered by individual project proponents, the GSA more broadly, or be split between multiple entities. As such, they are reported separately from GSA costs.

The following GSP elements are described in this chapter:

- Costs for GSAs to administer GSP activities as required by 23 CCR §354.6(e)
- PMA-specific costs are summarized to illustrate the total cost of GSP implementation; however, PMAs are described in more detail (e.g., benefit, capital, and operating costs) in Chapter 6: Projects and Management Actions
- Financing approaches / funding mechanisms
- Timeline and roadmap for implementing all GSA projects and management actions between 2022 and 2042
- Implementation of additional actions to achieve Subbasin sustainability goals (Data Management System [DMS], monitoring wells, water model updates, etc.)
- Monitoring and reporting, including the contents of annual reports and five-year periodic evaluations that must be provided to the Department of Water Resources (DWR) (23 CCR §356.2 and §356.4)
- The Colusa Subbasin DMS

This chapter is structured as follows. The following section describes the different activities and costs that GSAs are estimated to incur for GSP implementation. This is followed by a summary of those costs and approximate breakdown by the two GSAs in the Subbasin. Section 7.3 summarizes costs for PMAs using the information presented in Chapter 6. Only planned PMAs are included in the GSP implementation cost estimates because these are the PMAs (in accordance with 23 CCR §354.44(a)) that would allow the GSAs to achieve the sustainability goal for the Subbasin and avoid reaching the minimum thresholds defined in this GSP under future, changing conditions. Section 7.4 summarizes all GSA and PMA costs, expressed on

an annual basis, which represents the estimated total cost of GSP implementation. Section 7.5 describes the implementation schedule for GSP activities. Section 6 provides a concise overview of financing and funding mechanisms that provides the basis for how the GSAs plan to cover GSP implementation costs and Sections 7.7, 7.8, and 7.9 describe the required elements for the GSP annual reporting, periodic (five-year) evaluations, and features of the DMS.

7.1 GSA COSTS FOR GSP IMPLEMENTATION

Total GSP implementation costs include both PMA-specific costs and costs for the CGA and GGA to administer and support all other aspects of the GSP. GSP implementation costs will include costs for managing the GSP, planning and studies, monitoring, and providing general administration.

Estimated GSA costs for GSP implementation are split into the following four categories:

- **GSA Administration**. General costs for GSA operations including meetings, coordination, outreach, legal, accounting, and other services that are required to support GSP implementation and updates.
- **GSP Studies**. Technical evaluations that are required for GSP implementation. These include addressing data gaps, updating groundwater information to satisfy GSP Regulations, and studies that are required to evaluate and manage the Subbasin to achieve the sustainability goal.
- **GSP Updates**. GSP updates includes annual reports and five-year periodic evaluations. These are required under the GSP Regulations, as described in detail under Section 7.6 and 7.7.
- **GSA Contingency**. An additional contingency is included to cover unanticipated legal costs and other unanticipated cost associated with GSP implementation.

The following subsections describe the general types of required activities and costs for each of the GSA cost categories.

7.1.1 GSA Administration

Administrative costs generally include meetings, reporting, record keeping, bookkeeping, legal, continued outreach to stakeholders, and government relations. GSAs will also need to continue to monitor projects and management actions to assess their benefit, feasibility, and coordinate with stakeholders and water managers if modification of projects and management actions is necessary to ensure the Subbasin meets the sustainability objectives.

GSAs will implement programs to monitor groundwater, measure elevations, and track total water use to satisfy reporting requirements in the GSP Regulations. Monitoring activities may include data management, installing monitoring wells, maintaining existing wells, and initiating studies to support GSP implementation. Other activities may include data collection for both groundwater and water quality monitoring networks.

GSAs will oversee the groundwater monitoring programs outlined in Chapter 4. This will include tracking Subbasin conditions and sustainability indicators. Data from the monitoring programs will be routinely evaluated to ensure progress is being made toward sustainability or to identify whether undesirable results are occurring.

GGA and CGA administrative costs are based on the existing rate studies[1] adopted by each GSA in 2018 and a review of audited financial statements for fiscal year 2020 (year ended June 30, 2020). Audited financial statements for fiscal year 2021 are not currently available as of the publication date of this GSP (December 2021). The rate studies covered the five-year period spanning fiscal years 2019/20 through 2023/24 and were prepared as property-related fees for water service under Proposition 218. The estimated annual operations (administration) expenses are approximately $465,000 for the CGA and up to $550,000 in the GGA.

7.1.2 GSP Studies

During the GSP development process, various data gaps were identified, in addition to areas where additional studies will be needed to support refinements to the GSP. This includes planning and technical studies that will be required to meet the annual and five-year reporting requirements under 23 CCR §356.2 and §356.4. It is anticipated that many of the studies to support GSP implementation—particularly those that affect sustainable management criteria in future revisions to the GSP—would be conducted in the same public and transparent process with which the GSP was prepared. These studies are described below.

Table 7-1 summarizes the technical studies to support GSP implementation. A total of15 studies have been identified. Many of the studies listed focus on filling data gaps associated with monitoring networks. This includes developing a well inventory and registration program. The studies and estimated costs are described in detail in the following subsections.

Table 7-1. Summary of GSP Implementation Studies

Study	Description
Expand Shallow Groundwater Level Monitoring Network	To expand the shallow groundwater monitoring network, additional monitoring wells must be evaluated. This includes existing monitoring wells and suitable locations for the construction of new monitoring wells.
Expand Water Quality Monitoring Network	This study will evaluate and expand additional groundwater quality monitoring wells.
Colusa Subbasin Western Boundary Investigation	This study will evaluate data to better understand the physical characteristics and groundwater conditions of the principal aquifer along the western margin of the Subbasin.
Westside Streams Monitoring Program	Streams originating from the Coastal Range west of the Subbasin will be evaluated for potential recharge volumes, water quality, and the interconnectedness of the streams and the groundwater system within the Subbasin.
Groundwater Well Monitoring Program	This pilot program will evaluate the costs and benefits of continuous groundwater monitoring data collection via six irrigation production wells. Program expansion throughout the Subbasin will be considered based on the data utility and costs of the pilot program.
Groundwater Financial Incentives Investigation	This analysis will quantify the total costs of groundwater use and switching to surface water. The analysis will also identify grower financial incentives for in-lieu recharge and options for structuring those incentives.

[1] Fee Study for the Glenn Groundwater Authority, May 2019 and Fee Study for the Colusa Groundwater Authority, May 2019.

Table 7-1. Summary of GSP Implementation Studies

Study	Description
CV2SimFG-Colusa Model Updates and Enhancement	This program will implement the periodic model data updates necessary to adequately represent near-term and future conditions within the Subbasin, and to support annual and five-year periodic GSP reporting to the DWR.
Well Inventory Program	This program will inventory the estimated 20% of groundwater wells unaccounted for within the Subbasin, and would seek to identify wells that are no longer active.
Well Registration Program	This study will evaluate the potential of a program for landowners to inventory their well data. This will complement the well inventory program.
Increasing GSA Involvement in County Well Permitting and Land Use Planning	CGA and GGA will explore options for allowing GSA input to the counties' well permitting processes and land use planning. The objective of GSA input would be to ensure that wells are permitted and land uses are planned in a manner consistent with sustainable groundwater management according to the GSP.
GSA Coordination with Water Quality Coalitions and Regulatory Agencies	GSAs will coordinate with the various water quality coalitions, water stakeholders, and regulatory agencies regarding GSP and other regulatory program implementation. This will include helping to identify and address water quality problems across the Subbasin, including those affecting disadvantaged communities (DACs) and severely disadvantaged communities (SDACs), and consideration of opportunities to expand public water systems and consolidate small public systems to improve drinking water quality delivered to DACs and SDACs.
Sutter Buttes Rampart Water Quality Interbasin Working Group	The CGA, GGA and the GSAs in the Butte, Sutter, Yolo, North Yuba and South Yuba Subbasins should participate in an interbasin working group focused on collaborative discussions, consensus-building and planning to address groundwater quality matters associated with the unique geology of the Sutter Buttes area.
Participation in Interagency Drought Task Forces	The CGA and GGA should coordinate their responses to droughts with their respective county and state agency partners through existing Interagency Drought Task Forces established in each county by the Colusa and Glenn County Boards of Supervisors.
Sacramento Valley Subsidence Interbasin Working Group	The CGA and GGA should consider participating in a Sacramento Valley Subsidence Interbasin Working Group with DWR, the other GSAs in the Sacramento Valley and federal partners. The working group would provide a forum for collaborative discussions, consensus-building, and planning to address inelastic land subsidence in the Sacramento Valley.
Evaluate Infrastructure Sensitivity to Subsidence	This study will evaluate the sensitivity of infrastructure in the Subbasin to potential subsidence rates.

7.1.2.1 Expand Shallow Groundwater Level Monitoring Network

The shallow groundwater monitoring network will be used to monitor groundwater levels and groundwater quality of the unconfined portion of the principal aquifer. Additionally, groundwater levels in shallow groundwater monitoring wells within five miles of major surface water features will be used to monitor stream-aquifer interactions and groundwater dependent ecosystems (GDEs). Understanding the flow relationships between the shallow groundwater aquifer and surface waters can assist in evaluating any possible occurrences of surface water depletions or riparian habitat. Monitoring wells with multiple completions (i.e., boreholes with more than one well casing installed, each casing screened at different depth intervals, and sealed between screens) can be used to characterize aquifer properties such as vertical hydraulic conductivity and transmissivity. Better understanding the flow mechanics of the

principal aquifer system improves the integrated hydrologic model, increases understanding of water flow relationships throughout the Subbasin, and can enable stakeholders to be more informed during their decision-making processes.

The current groundwater monitoring network contains 104 wells in 48 boreholes, of which 30 completions in 24 boreholes are screened at depths less than 200 feet and are considered to be in the shallow groundwater aquifer. The majority of these shallow wells are in the lowlands of the Subbasin. There are reports of domestic wells going dry in the western portion of the Subbasin, specifically near the uplands west of the City of Orland. Including additional shallow groundwater monitoring wells to the monitoring network in this area would be beneficial for monitoring and understanding the conditions of the shallow aquifer.

The representative surface water depletion monitoring network is comprised of a subset of the 30 shallow groundwater monitoring wells and includes 12 completions in 12 boreholes to monitor conditions within Stony Creek, the Sacramento River, and the Colusa Drain. Some of the wells are within range of more than one surface water feature, and will therefore be used to monitor conditions within multiple surface waters. Expanding the shallow groundwater monitoring network to include shallow wells closer to each specific surface water feature will provide better insight into how groundwater is influencing flows in their respective surface water feature.

This study proposes to evaluate additional existing wells to include in the shallow groundwater monitoring network and identify suitable locations for the construction of new monitoring wells. Evaluation of existing wells to add to the shallow groundwater monitoring network will cost approximately $50,000 and will include evaluation of existing wells and coordination. Newly constructed shallow wells will cost approximately $40,000 each and include planning through construction phases. It is anticipated that no more than ten new shallow wells will be considered.

7.1.2.2 Expand Water Quality Monitoring Network

The groundwater quality monitoring network is comprised of 25 wells, all of which are already being monitored for salinity under existing groundwater quality monitoring programs. Four wells are part of the Sacramento Valley Water Quality Coalition (SVWQC) monitoring network. Ten wells are part of the California Rice Commission (CRC) monitoring network. Eleven wells are municipal wells and are monitored under State Water Resources Control Board (SWRCB) Division of Drinking Water (DDW) regulations. The SVWQC and CRC wells are regulated by the Regional Water Quality Control Board.

Data gaps in this monitoring network are described in Chapter 4 and include lack of deep aquifer monitoring for upwelling of brackish connate waters and low spatial density of monitoring locations. The CRC wells are all shallow and may represent conditions of percolating water from rice ponds instead of groundwater conditions. Additionally, since these wells are included in existing monitoring programs managed by other agencies, the GSAs currently have no say on the frequency or continuation of monitoring beyond what the existing monitoring entities have already planned.

This study proposes to evaluate including additional wells as groundwater quality monitoring wells. Existing wells in appropriate locations with appropriate construction in existing monitoring programs will be prioritized over drilling new wells. Wells that are in close proximity and/or are most representative of groundwater quality conditions experienced by DACs, domestic wells, tribes, and GDEs will also be prioritized. Existing wells in appropriate locations with appropriate construction will be considered to either be requested additions to existing monitoring programs managed by other entities or included in a new monitoring program managed directly by the GSAs.

Establishing a new monitoring program managed by GSA staff, and potentially in coordination with DWR, will cost approximately $50,000 for implementation and coordination and an additional approximate $50,000 annual fee (assuming quarterly sampling from 30 well completions). Adding existing wells to existing programs will be approximately $5,000 per well, annually, and includes evaluation of wells and monitoring coordination with GSA staff, property owner, and the monitoring agency. Drilling new multiple-completion monitoring wells, including planning through construction phases, will be approximately $120,000 per well. Sites for new wells would need to be evaluated for property access, proximity to areas of concern, and suitability. It is anticipated that no more than ten existing or new wells will be considered.

7.1.2.3 Colusa Subbasin Western Boundary Investigation

Geologic and groundwater condition data is sparse throughout the western margin of the Subbasin. This includes the uplands west of the City of Orland in the north, southward along the Coast Ranges, and into the extension of the Dunnigan Hills west of the Arbuckle area in the south. There are few wells drilled in these areas that can provide information regarding the subsurface lithologic or groundwater conditions. The wells that do exist are shallow domestic wells with little, if any, historical record.

DWR is conducting an airborne electromagnetic survey (AEM) that will provide subsurface information regarding lithologic interfaces and potentially water level and saline water interface depth information. The survey for the Subbasin is not yet scheduled but is expected to occur before 2023. The GSAs intend to coordinate with DWR in determining the AEM flight paths to ensure coverage of the western margin of the Subbasin.

This study will be an evaluation of future existing data to better understand the physical characteristics and groundwater conditions of the principal aquifer along the western margin of the Subbasin. Lithologic interfaces will be updated using geophysical data from oil and gas wells, potentially new exploratory boreholes in key areas of interest, AEM survey data, and new well logs available from DWR. Future revisions of the Colusa Subbasin GSP will be updated to reflect the new information. This study is estimated to cost $100,000. New boreholes will be addressed during the study and are not reflected in the above estimate.

7.1.2.4 Westside Streams Monitoring Program

The CGA and GGA, in coordination with landowners and other agencies, would design and implement a monitoring program to collect data on the westside streams that originate in the Coastal Range to the west of the Subbasin and flow eastward into the Subbasin. The monitoring program would include monitoring flow, water quality parameters, and sediment loads. The objectives of the program would be to evaluate potential recharge volumes and water quality and to evaluate the interconnectedness of these streams and the groundwater system within the Subbasin.

The total cost estimate for planning, installation, and first year of monitoring is estimated at $225,000. Annual monitoring is $105,000.

7.1.2.5 Groundwater Well Monitoring Program

The CGA and GGA are currently implementing a pilot program to collect continuous groundwater monitoring data (e.g., water levels, pumping volumes) at six selected irrigation production wells spread across the Subbasin (three each in Colusa and Glenn counties). The objective of the pilot program is to test the utility of these data, and to evaluate installation and maintenance costs in order to estimate the costs and benefits of expansion of the program throughout the Subbasin. Estimated costs are presented for continued operation and maintenance of the pilot program, as well as for expansion of the program with an estimated per well cost. Measurement of groundwater pumping by some means will be needed to support implementation of a groundwater extraction fee, if the GSAs decide to do so.

The total cost estimate for planning, installation, and first year of monitoring is estimated at $265,000. Annual monitoring is estimated at $130,000.

7.1.2.6 Groundwater Financial Incentives Investigation

Sixteen (16) planned, ongoing, or potential PMAs included in the Colusa Subbasin GSP would provide in-lieu recharge benefits in targeted areas of the Subbasin (see Chapter 6). Water sources for in-lieu recharge are expected to include a mix of water transfers and utilization of existing district contract supplies. Successful in-lieu recharge projects will require growers being willing to pay for surface water and forgo groundwater pumping. Some of the perceived advantages of using groundwater over delivered surface water include the growers' convenience of having a clean, reliable, on-demand supply from their groundwater wells. Therefore, the effective cost of surface water must be less than that of groundwater. This study will include two phases to: (i) establish crop production costs under groundwater and surface water systems and (ii) and develop potential grower incentives structures for in-lieu recharge in selected areas of the Subbasin.

The initial phase of the study will quantify the total cost of groundwater use and the cost to switch to surface water. Total costs will include all direct costs (e.g., energy, equipment, and labor) in addition to indirect costs associated with each system (e.g., convenience, irrigation scheduling, frost protection, other perceived benefits). It is anticipated that this would include interviews with growers, agricultural engineering assessment of on-farm costs, and establishment of baseline crop budgets for groundwater and surface water irrigation for selected areas and crops. The initial phase of the study would provide a full cost comparison of groundwater and surface water.

Incentivizing the use of district surface water in-lieu of pumping would require paying at least the difference between district surface supply and the variable cost of pumping groundwater. The results of the baseline cost assessment will be used to establish potential incentives needed to encourage growers to switch from groundwater to surface water. This will include establishing the growers' willingness to pay for groundwater relative to surface water deliveries and establishing potential financial incentive structures. Incentive structures will also consider existing district rate structures. As of 2021, many Central Valley Project (CVP) contractors in the Subbasin have converted their contracts to repayment contracts, thus paying off and removing the capital component from their CVP water rates. The new repayment rates are allocated to land assessments and volumetric charges, which vary by district. The financial incentive analysis will consider the ability to shift district rates between fixed and variable costs to reduce the effective cost of surface water relative to pumping groundwater. The output of this second phase of the analysis will be a summary of grower financial incentives for in-lieu recharge and options for structuring those incentives for different in-lieu recharge areas.

The estimated cost of the study and cost assumptions are:

- The incentives investigation would consider up to two specific crops based on the crop mix in the in-lieu recharge areas; a preliminary assessment suggests walnuts or almonds would be the primary candidate crops.
- Interviews would be limited, coordinated by the GSA, and targeted to the key crops in the study.
- The focus areas would target Planned PMA in-lieu recharge projects but could be scaled up (or down) to consider incentives for additional (or fewer) areas.
- The estimated cost of the study is $165,000.

7.1.2.7 CV2SimFG-Colusa Model Updates and Enhancement

The C2VSimFG-Colusa model is an integrated hydrologic flow model (IHM) based on DWR's Central Valley Groundwater-Surface Water Simulation Model – Fine Grid Beta2 (C2VsimFG) released in May 2019 with updates, enhancements, and calibrations made to better represent local conditions in the Subbasin. The model is being used to support development and implementation of the Colusa Subbasin GSP, including characterization of historical, current, and projected water budgets, and evaluation of potential projects and management actions. The model is currently calibrated for the period 1990 through 2015 and needs to be updated periodically to adequately represent near-term and future conditions in the Subbasin. Calibration challenges were encountered during model development, leading to identification of several additional, potential model refinements including: adjustment of model layering in the northwest and southwest portions of the model domain to better represent local geology, adjustments to the vertical distribution of groundwater pumping, improved representation of westside tributary streams, and evaluation of inter-basin groundwater flows in coordination with neighboring GSAs.

These refinements may include:

- **Extension of time series data past Water Year 2015**. With the calibrated model, extending time series data (e.g., precipitation, land use, stream inflows, evapotranspiration, surface water diversions, urban demand, groundwater pumping) allows for use of more recent data and improved accuracy of the model for predicting near-term and future conditions in the Subbasin.
- **Model layering**. Model layer thicknesses may be adjusted locally, primarily in the southwest and northwest areas of the model, to better represent local geologic conditions and potential faults in these areas.
- **Distribution of groundwater pumping between layers**. Model layer thicknesses may be refined such that distribution of groundwater pumping between model layers better matches groundwater extraction from different depth and layers of the aquifer.
- **Small watersheds**. The water coming from the foothills is simulated using small watersheds representing small streams and groundwater flowing into the western side of the Subbasin. Theseephemeral streams may need explicit representation and simulation in the model to better control recharge and flows from the foothills as some observed groundwater levels near the foothills show signs of recharge from nearby small streams.
- **Interbasin flows**. C2VSimFG-Colusa model is well calibrated along the eastern boundary of the Subbasin and the five-mile zone on the eastern side of this boundary. Quantification of Sacramento River recharge along the eastern boundary of the Subbasin and subsurface groundwater underflow across this boundary into and out of Colusa, Butte and Vina

Subbasins will be useful in building consensus for management of groundwater by these neighboring subbasins.

- **Model Grid Resolution**. The observed groundwater level data show high spatial gradients in the northwestern and southwestern areas of the model. The model grid may be refined in these areas to better simulate these local high groundwater gradients.

The estimated cost for the model updates and enhancements is $225,000.

7.1.2.8 Well Inventory Program

Both Glenn and Colusa Counties have existing initial inventories and geographic information system mapping (GIS) of many of the water supply wells in each respective county. The mapping and associated databases were developed to gain a better understanding of well development over time in each county and to provide data for earlier water management efforts and initial SGMA planning efforts. Both well databases are based on information from public sources, including primarily well completion reports available from the DWR and in Glenn County, records from the County Environmental Health Department were also utilized.

While these initial efforts were extremely valuable, there remain many data gaps that will be necessary to fill. It is estimated that only about 80 percent of existing wells have well logs on file with DWR, so approximately 20 percent of the wells in the Subbasin remain to be identified and inventoried. It is also unknown how many of the inventoried wells are no longer in operation. Additionally, for SGMA purposes, the two County maps will need to be merged and refined to fit within the Subbasin boundaries.

The proposed well inventory program would complete further analysis of well logs and county well permits, ground truth actual well locations, and identify wells that are no longer active to ensure a complete and accurate well inventory exists. Additional data from well completion reports could also be entered into the well database to improve the understanding of the hydrogeology of the Subbasin. This will require a great deal of time and effort, especially given the size of the Subbasin. It will also be necessary to set up protocols for keeping the inventory updated as new wells are installed and as wells are decommissioned. These activities could be complemented by a well registration program where landowners submit information about their wells through an online portal, if this is determined by the GSAs to be an effective, acceptable means of well data acquisition.

This program would improve the accuracy and reliability of this dataset through additional data collection and outreach to improve both the quantity and quality of data in the well inventory.

A comprehensive, reliable well inventory is a pre-requisite for implementation of the following activities:

- Gaining a complete picture of groundwater development in the Subbasin
- Potentially initiating a per-well fee and/or extraction fee to fund SGMA implementation and PMAs
- Identifying potential new monitoring sites to help fill data gaps
- Improving the understanding of the hydrogeology of the Subbasin by conducting hydrogeologic investigations (AEM and similar)

The estimated cost of the program and cost assumptions are:

- Program conducted by GSA staff members with outside, on-call technical support
- Five-year period to develop the complete well data base at an estimated cost of $100,000 for the first year and $50,000 per year for years 2-5, totaling $300,000
- Annual updates to add new wells and delete old wells at an estimated cost of $20,000 per year

7.1.2.9 Well Registration Program

A well registration program could be developed for landowners to enter well information via an online portal to improve the accuracy of the current well inventory, including well location, well construction details (if known), and well type/use. The amount of information collected could be scaled up or down depending on the needs of the Subbasin. The registration program has the ability to provide the necessary information to improve the well inventory database, improve the understanding of the Subbasin hydrogeology, provide information to support potential future fee structures, and provide information to support specific future projects. The well registration program could be implemented on an annual timescale or some other timescale that is determined appropriate.

Other pertinent data potentially reportable through the well registration program could include information subject to change from year to year, such as the acreage (or number of people or livestock) served by a well, the crops irrigated and irrigation systems used (if the well is operated for agricultural use), and the volume of water pumped. This information could potentially feed into design and implementation of projects and management actions.

The estimated cost of the program and cost assumptions are:

- Program conducted by GSA staff members with outside, on-call technical support
- Two-year period to design and implement the on-line registration system and conduct public outreach at an estimated cost of $90,000 per year
- Three-year period to maintain outreach, compile data, and merge data into the well inventory database at an estimated cost of $40,000 per year
- Ongoing program implementation and maintenance cost of $15,000 per year

7.1.2.10 Increasing GSA Involvement in County Well Permitting and Land Use Planning

For this study, the CGA and GGA will explore options for allowing input to the counties' well permitting and land use planning processes by the GSAs. The objective of GSA input would be to ensure that wells are permitted and land uses are planned in a manner consistent with sustainable groundwater management according to the GSP. This could include consideration of:

- Well spacing, well construction, or other appropriate measures needed for well permitting
- Potential impacts to existing wells, springs, GDEs, water quality and recharge areas due to proposed development projects and changes in land use designation and zoning

Additionally, the GSA could provide information to the prospective well owners regarding the GSP and potential projects and/or management actions that may require the owner to report specific information or management actions that affect the ability of the well to be used (i.e., pumping restrictions).

The estimated cost of the program and cost assumptions are:

- Program conducted by GSA staff members with on-call technical support and legal counsel
- Two-year period to investigate, publicly vet, establish, and implement coordination protocols and procedures at an estimated cost of $75,000 per year
- Ongoing program implementation and maintenance cost of $15,000 per year

7.1.2.11 GSA Coordination with Water Quality Coalitions and Regulatory Agencies

GSAs intend to coordinate with the various water quality coalitions, beneficial users, water stakeholders, and regulatory agencies. These would include CRC and SVWQC, the municipal and small public water systems, and domestic well owners and users within the Subbasin. Coordination would ensure consistency regarding monitoring locations, monitored chemical constituents, monitoring procedures and frequencies, management plans and actions for out-of-compliance constituents, and responsible agencies for each management action. GSAs may need to get involved with management actions depending on any occurrence of undesirable results or input from the different regulatory boards.

The CGA and GGA recognize that disadvantaged communities and small water systems are disproportionately affected by degraded groundwater quality. As documented in Chapter 2, many of the communities within the Subbasin are considered Disadvantaged or a Severely Disadvantaged Communities (DACs and SDACs). Nearly all of the Subbasin is considered an Economically Distressed Area (EDA) because it is rural, has a low population density and has a low median household income. The CGA and GGA will coordinate with the regulating agencies, regulated entities, municipalities, small public water systems, and residential well owners and users to help identify and address potential water quality problems across the Subbasin, including those affecting DACs and SDACs. This will include consideration of opportunities to expand public water systems and consolidate small public systems to improve drinking water quality delivered to DACs and SDACs. This study will be an ongoing process. Costs for staff time are estimated at $20,000 per a year.

7.1.2.12 Sutter Buttes Rampart Water Quality Interbasin Working Group

The CGA, GGA, and the GSAs in the Butte, Sutter, Yolo, North Yuba, and South Yuba Subbasins intend to participate in an interbasin working group focused on collaborative discussions, consensus-building, and planning to address groundwater quality matters associated with the unique geology of the Sutter Buttes area. The goals of the working group should be to:

- Identify and prioritize groundwater quality conditions
- Coordinate with local, state and federal agencies
- Develop data and information needs
- Conduct high-level planning for groundwater studies and projects to protect or improve groundwater quality as needed
- Identify and pursue grant funding opportunities for groundwater studies and projects
- Provide a forum supporting cooperation, collaboration, and information sharing during implementation of studies and projects

It is expected that groundwater studies identified by the interbasin working group would be grant funded and implemented by research entities, such as U.S. Geological Survey (USGS) or DWR. If projects are identified to protect or improve groundwater quality, they would be led and implemented by local entities

such as the counties, agricultural water districts and agencies, municipalities, and other public water suppliers using a variety of funding sources, as described under Section 7.6.

Although the surface expression of the Sutter Buttes Rampart is limited to the Sutter Subbasin, the subsurface extent of volcanic deposits and associated geologic structures is greater and may influence groundwater quality in the adjacent Butte, Colusa, Yolo, North Yuba, and South Yuba Subbasins. Groundwater in the volcanic sediments of the Sutter Buttes Rampart has arsenic concentrations that frequently and significantly exceed the drinking water standard. The formation of the Sutter Buttes has resulted in the uplift of basement rocks, and corresponding reductions in the depth to the base of fresh groundwater. Faults may provide conduits or otherwise influence the movement of poor quality groundwater.

Objectives of the working group and the to-be-identified studies are to:

- Propose studies to:
  - Improve knowledge of the subsurface extent of the Sutter Buttes Rampart
  - Improve the understanding of local hydrogeology and faulting in the Sutter Buttes Rampart area
  - More fully characterize arsenic geochemistry within the subsurface extent of the Sutter Buttes Rampart
  - Improve knowledge of the depth to the base of freshwater and the structural features (folds and faults) that control the depth to the base of freshwater and groundwater movement in the area
  - Assess the risk of upwelling, or movement along faults, of saline or brackish connate groundwater
  - Assess the potential for mobilization of arsenic and/or connate waters beyond the subsurface extent of the Sutter Buttes Rampart
- Provide a forum for local entities to propose and develop projects to protect or improve groundwater quality

Participation in the working group will be an ongoing process. The estimated cost for GSA staff time is included in the GSAs' annual operating budget.

7.1.2.13 Participation in Interagency Drought Task Forces

The CGA and GGA intend to coordinate their responses to droughts with their respective county and state agency partners through existing Interagency Drought Task Forces established in each county by the Colusa and Glenn County Boards of Supervisors.

The Colusa County Interagency Drought Task Force consists of representation from the following entities:

- County Community Development Department
- County Water Resources Division
- County Office of Emergency Service (OES)/Sheriff's Office
- California OES
- DWR

- County Board of Supervisors
- County Administrative Officer
- Public Works Department
- Environmental Health Department
- City of Colusa
- City of Williams

The GGA participates in meetings of the Glenn County Drought Taskforce which are open to the public and consist of representation from a variety of entities, including:

- Planning and Community Development Services
- County OES/ Sheriff's Office
- California OES
- DWR
- County Board of Supervisors
- County Administrative Officer
- County Counsel
- Agricultural Commissioner
- Health and Human Services Agency
- UC Cooperative Extension
- Artois Community Services District
- City of Orland
- City of Willows
- California Water Service Company
- Water Agencies (Water Districts, Irrigation Districts, Reclamation Districts, Orland Unit Water Users Association, Stony Creek Water Master)
- Groundwater Sustainability Agency representatives
- California Legislator representatives
- Glenn County Farm Bureau
- Glenn County Resource Conservation District
- County Public works
- Fire Departments
- State Board Division of Drinking Water
- Members of the public

The drought task forces in both counties are ad hoc committees of the Board of Supervisors that meet in times of need such as the 2014 and 2021 drought emergencies. The primary purposes of the task forces are to:

- Coordinate the responses to drought at the local and state level
- Identify and track water supply instability, including dry wells and other drought-related issues
- Identify and make available resources that may be used to assist residents and businesses impacted by the drought
- Promote public awareness of the severity of the drought and the need for water conservation

The task forces implement the following coordinated functions at the county level:

- Education and outreach for drought preparedness
- Reporting and tracking of dry or impaired wells
- Identifying and applying for funding resources for programs to assist residents impacted by the drought
- Venue to share drought related experiences, challenges, and potential solutions

The task forces coordinate with the California Office of Emergency Services (OES), Department of Water Resources Northern Region Office, and the State Water Resources Control Board.

When households or small water systems in Colusa County experience a water shortage, they should fill out a "Well Outage Report" form and send that to the Colusa County Water Resources Division. The Water Resources Division verifies the information with the reporter and forwards the information to Colusa County OES.

When households or small water systems in Glenn County experience a water shortage, they should fill out a "Well Incident Report" form and send that to the Glenn County OES.

The respective County OES departments determines if assistance is available and coordinates with the California OES regional coordinators. The State (OES, DWR, SWRCB) provides funding for regional programs and short- and long-term solutions for water systems, and the drought task forces in each county work to procure funding for drought relief programs from these and other sources. Colusa and Glenn Counties are in Mutual Aid Region III of the Inland Administration Region of California OES.

Because the CGA and GGA will jointly implement the Colusa Subbasin GSP, their participation in the two drought task forces will help provide a coordinated response throughout the Subbasin and across the county line.

The CGA and GGA recognize that drought emergencies have a disproportionate effect on disadvantaged communities and small water systems. As documented in Chapter 2, many of the communities within the Subbasin are considered DACs or a SDACs. Nearly all of the Subbasin is considered an Economically Distressed Area because it is rural, has a low population density and has a low median household income. The CGA and GGA anticipate coordinating with the members of the Colusa and Glenn Interagency Drought Task Forces to address the effects of drought across the Subbasin and throughout these communities. The CGA and GGA also expect to coordinate with the members of the Colusa and Glenn Interagency Drought Task Forces to consider DWR's recommendations for drought and water shortage contingency planning

in Small Water Systems and Rural Communities Drought and Water Shortage Contingency Planning and Risk Assessment (DWR, 2021c).

Participation in the two drought task forces will be an ongoing process. The estimated cost for GSA staff time is included in the GSAs' annual operating budget.

7.1.2.14 Sacramento Valley Subsidence Interbasin Working Group

The CGA and GGA intend to participate in a Sacramento Valley Subsidence Interbasin Working Group with DWR, the other GSAs in the Sacramento Valley, and federal partners. The working group would provide a forum for collaborative discussions, consensus-building, planning and remedial actions where called for, to address inelastic land subsidence in the Sacramento Valley. The goals of the working group could include:

- Identify and prioritize areas of concern for inelastic land subsidence
- Identify and prioritize data collection efforts needed to fill data gaps
- Coordinate with local, state, and federal agencies
- Conduct high-level planning for data collection and implementation of projects to address or mitigate inelastic land subsidence
- Identify and pursue grant funding opportunities for data collection and project implementation
- Provide a forum supporting cooperation, collaboration, information sharing, and public outreach during implementation of data collection and projects

The Sacramento Valley Subsidence Network was last surveyed in 2017 and showed inelastic subsidence had occurred in the Sacramento Valley, including in the Subbasin, between 2008 and 2017. A key objective of the working group should be to confirm and reassess the locations and rates of historical subsidence identified based on the 2008 and 2017 surveys of the network. This new information about the locations and rates of inelastic subsidence would be used to reevaluate sustainable management criteria (SMCs) for inelastic land subsidence and help to guide the implementation of projects needed to address inelastic land subsidence.

It is expected that data collection needs identified by the interbasin working group would be grant-funded and implemented by state and federal agencies, such as DWR or USGS. If projects are identified to address or mitigate inelastic land subsidence, they would be led and implemented by local entities such as the counties, agricultural water districts and agencies, municipalities, and other public water suppliers using a variety of funding sources, as described under Section 7.6.

Participation in the working group will be an ongoing process. The estimated cost for GSA staff time is included in the GSAs' annual operating budgets and actions taken by the working group would be documented in subsequent annual reports.

7.1.2.15 Evaluate Infrastructure Sensitivity to Subsidence

The CGA and GGA have proposed a local assessment of infrastructure sensitivity to subsidence in the Subbasin. This study is proposed as one measure to close data gaps related to subsidence and its potential effects on beneficial uses and users in the Subbasin. The study would allow the GSAs to better characterize surface beneficial uses and users that may be susceptible to substantial interference as a result of

subsidence, and plan for actions to expand monitoring and mitigation of potential subsidence. The study would provide the GSAs better understanding of the infrastructure that is most at risk of interference from potential subsidence, and the possible impacts of interference on social, economic, transportation, and other activities in the Subbasin. The study should evaluate infrastructure Subbasin-wide to provide a comprehensive understanding of sensitivity to subsidence, though the study could be phased or structured to initially focus on areas of the Subbasin where the potential risk of subsidence and severity of impacts could be the greatest. Outcomes of the study could include:

- Identification of infrastructure (e.g., canals, pipelines, roads) most at risk of interference (e.g., damage, diminished capacity, loss of use) from subsidence, prioritized by severity of potential interference and severity of potential consequences of that interference on activities in the Subbasin.
- Identification of potential impacts that may result from infrastructure damage or loss of use, especially social, economic, transportation, and sustainability-related impacts.
- A plan for expanding subsidence monitoring to examine changing land subsidence conditions that may lead to potential adverse effects on infrastructure in the Subbasin.
- A plan for actions to respond to changing land subsidence conditions to resolve or mitigate potential adverse effects on infrastructure in the Subbasin.

The study would be a cooperative effort with infrastructure owners and other stakeholders in the Subbasin. The GSAs could, but do not necessarily need to, lead the assessment. It is expected that data collection and analysis in this study would be grant-funded, though local funding sources could also be used. This study would likely be interconnected with work completed through the Sacramento Valley Subsidence Interbasin Working Group (Section 7.1.2.14) and ongoing work to install additional subsidence benchmarks and expand subsidence monitoring in the Subbasin.

7.1.3 GSP Annual Reports and Periodic Evaluations

The GSAs will manage annual reports and periodic (five-year) GSP evaluations. It is anticipated that the cost for annual reporting will be substantially lower than the cost of the five-year evaluations. However, the GSAs will engage in required monitoring and technical studies that are required for the five-year evaluations. For example, it is anticipated that the necessary updates to the Subbasin groundwater model would commence prior to applying the model for the five-year periodic evaluation.

Annual Reports. 23 CCR §356.2 requires GSAs to prepare and submit annual reports to DWR. GSAs will prepare required technical analysis, data, summary material, and provide a report on sustainable management objectives. GSAs expect that annual reports will also require inter- and intra-GSA coordination as well as stakeholder outreach. See Section 7.6 for a description of annual report elements. The estimated cost for annual reports is between $40,000 and $60,000 based on the cost of similar services for Critically Overdrafted subbasins. A conservative cost estimate of $46,000 per year is applied and split equally between the GSAs.

Periodic Evaluations. 23 CCR §356.4 requires GSAs to prepare and submit five-year evaluation reports. In contrast to the annual report, this report requires additional evaluation of sustainability conditions, objectives, monitoring, and documentation of new information that is available since the last update to the GSP. See Section 7.7 for a description of five-year update elements. The estimated cost for periodic evaluations is substantially greater than the annual reports because of the additional analysis and full updates to the GSP. The estimated cost is between $200,000 and $250,000. A conservative cost estimate

of $226,000 per year is applied and split equally between the GSAs. This does not include the costs of GSP studies that are required for the five-year evaluations (e.g., updates/calibration to the groundwater model and groundwater monitoring). Those costs are reported separately (and described above) under GSP Studies.

7.1.4 Contingency

An additional contingency cost is included in estimated GSA budgets for planning purposes. Contingencies could include legal challenges or additional investigations required to support GSP implementation. A contingency cost of $50,000 per year for each GSA is added to the estimated costs.

7.2 GSA COSTS FOR GSP IMPLEMENTATION SUMMARY

The following subsections summarize estimated costs for each GSA to implement the GSP. Costs are presented for each of the four cost categories identified above. In practice, GSAs record expenses in different ways, and as such, may list different categories. Studies, annual reports, and five-year updates that apply to the entire Subbasin are split evenly between the CGA and GGA, though some details on the cost allocation between the GSAs remain to be finalized.

It is emphasized that costs are preliminary estimates based on the information available at the time of GSP development. As the GSP is implemented the GSAs will evaluate progress and adjust accordingly. It is anticipated that the GSP financing plan (see Section 7.4 for a summary of funding and financing approaches) would consider the cost-effectiveness of the GSP implementation plan, including planned PMAs and other GSA activities to support implementation. A cost-effective implementation plan would achieve GSP implementation benefits at the lowest feasible cost. Actual costs incurred will be made available in annual reports and yearly financial statements released by the GSAs.

7.2.1 Colusa Groundwater Authority GSA

Table 7-2 summarizes estimated CGA costs. The CGA estimated annual costs for GSP implementation averages approximately $780,000. This does not include PMA-specific costs (see Section 7.3). Several planned studies are assumed to begin in 2022. As such, estimated costs are greatest in 2023.

Table 7-2. Colusa Groundwater Authority GSA Estimated Implementation Costs

Cost Category	2022	2023	2024	2025	2026	2027+
GSA Administration	$322,000	$342,000	$322,000	$322,000	$322,000	$322,000
GSP Studies	$520,000	$560,000	$343,000	$230,000	$230,000	$315,000
GSP Updates	$23,000	$23,000	$23,000	$23,000	$23,000	$113,000
Contingency	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000
Total	**$915,000**	**$975,000**	**$738,000**	**$625,000**	**$625,000**	**$800,000**

7.2.2 Glenn Groundwater Authority GSA

Table 7-3 summarizes estimated GGA costs. The GGA estimated annual costs for GSP implementation averages approximately $945,000. GGA costs are slightly greater than CGA estimated costs based on the 2019 rate studies and actual expenditure summaries in the 2020 audited financial reports. This does not include PMA-specific costs (see Section 7.3). Several planned studies are assumed to begin in 2022. As such, estimated costs are greatest in 2023.

Table 7-3. Glenn Groundwater Authority GSA Estimated Implementation Costs

Cost Category	2022	2023	2024	2025	2026	2027+
GSA Administration	$445,000	$499,000	$499,000	$499,000	$499,000	$499,000
GSP Studies	$520,000	$560,000	$343,000	$230,000	$230,000	$315,000
GSP Updates	$23,000	$23,000	$23,000	$23,000	$23,000	$113,000
Contingency	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000
Total	**$1,038,000**	**$1,132,000**	**$915,000**	**$802,000**	**$802,000**	**$977,000**

7.3 PLANNED PMA IMPLEMENTATION COSTS

The costs for PMAs, described in Chapter 6, are reported separately from other GSP implementation costs. In addition, the costs of PMAs may be allocated to different entities or the Subbasin more broadly (see Section 7.5 and Appendix 7A).

There are currently five planned PMAs that the GSAs or other project proponents are working to implement (as described in GSP Section 6.3). Costs for ongoing and potential PMAs are not shown. This is because these projects are already underway (and therefore funded) or will not be implemented unless required by changing groundwater conditions in the Subbasin.

Table 7-4 summarizes planned PMA capital and initial study costs and ongoing operation and maintenance (O&M) costs. Capital and initial study costs are one-time expenses to build or design a project. For example, the Orland-Artois Water District (OAWD) land annexation project includes an initial capital cost for distribution system construction. OAWD is currently working to refine the estimated construction cost. Other PMAs include one-time expenses for studies to develop the project. O&M costs are annual costs after the project is implemented. The total estimated cost for capital and studies is approximately $20.6 million. Estimated annual O&M costs are approximately $6.7 million per year at full implementation of the planned PMAs.

Table 7-4. Planned Projects and Management Actions Estimated Implementation Cost Summary

Cost Category	2022	2023	2024	2025	2026	2027+
Colusa Subbasin Multi-Benefit Groundwater Recharge						
Capital/Studies	$328,000	-	-	-	-	-
O&M	-	$246,000	$246,000	$246,000	$246,000	$246,000
OAWD District Land Annexation and In-Lieu Groundwater Recharge						
Capital/Studies	-	$20,000,000	-	-	-	-
O&M	-	-	$2,642,000	$2,642,000	$2,642,000	$2,642,000
Sycamore Slough Groundwater Recharge Pilot Project						
Capital/Studies	$28,000	-	-	-	-	-
O&M	-	$26,000	$26,000	$26,000	$26,000	$26,000
Colusa County Water District (CCWD) In-Lieu Groundwater Recharge						
Capital/Studies	$100,000	-	-	-	-	-
O&M	-	$2,025,000	$2,025,000	$2,025,000	$2,025,000	$2,025,000
Colusa Drain Mutual Water Company (CDMWC) In-Lieu Groundwater Recharge						
Capital/Studies	$100,000	-	-	-	-	-
O&M	-	$1,736,000	$1,736,000	$1,736,000	$1,736,000	$1,736,000
Total (Planned PMAs)						
Capital/Studies	**$556,000**	**$20,000,000**	**-**	**-**	**-**	**-**
O&M	**-**	**$4,033,000**	**$6,675,000**	**$6,675,000**	**$6,675,000**	**$6,675,000**

7.3.1 Planned PMA Benefits

Figure 7-1 illustrates the expected gross average annual benefits of planned PMAs at full implementation. The gross average annual benefit to the Subbasin from planned PMAs is approximately 61,000 acre-feet in 2022 and will increase to 84,000 acre-feet by 2027 when planned PMAs are fully implemented.

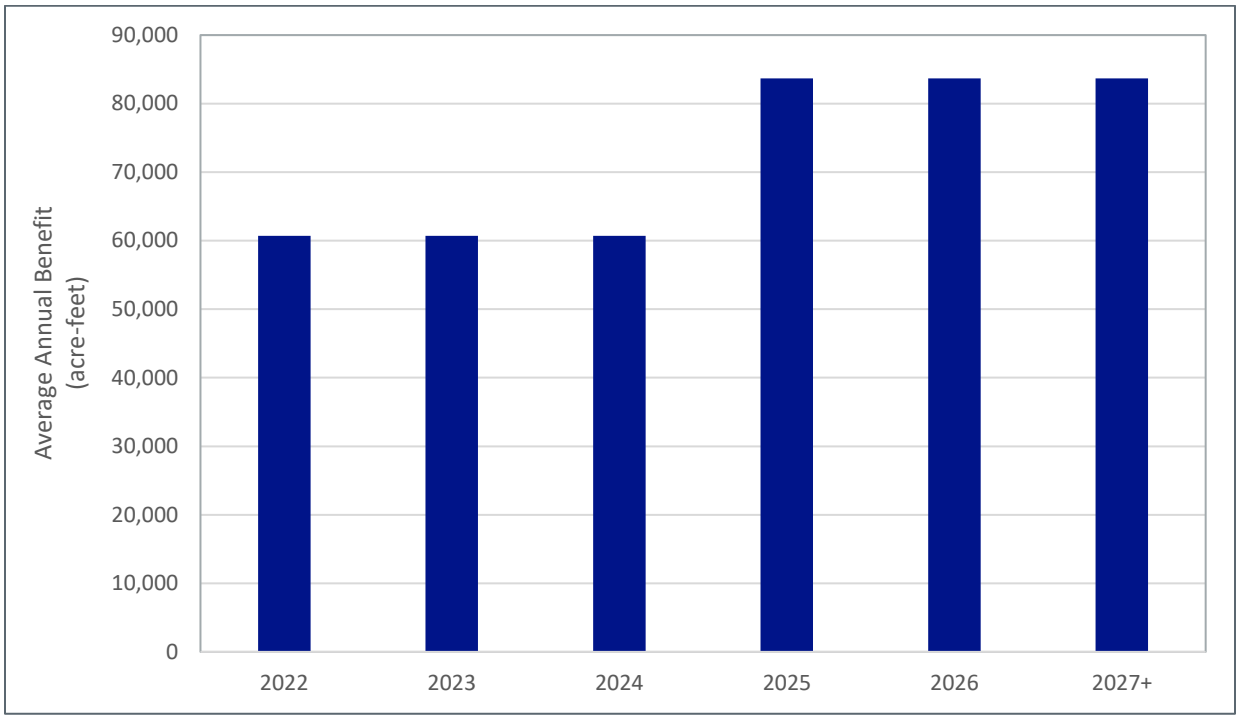

Figure 7-1. Colusa Subbasin Project Estimated Gross Benefit Timeline

7.4 GSP ANNUAL IMPLEMENTATION COST SUMMARY

The total GSP implementation costs include the sum of GSA costs (Section 7.2) and PMA costs (Section 7.3). These costs are expressed on an annual basis and summarized in Table 7-5. Estimated annual GSP implementation costs increase from approximately $1.5 million to around $9.5 million per year (including annualized capital costs). A substantial share of the total cost is attributable to surface water purchase costs for in-lieu recharge PMAs. Cost categories include:

- **Other Capital/Studies** includes one-time capital costs incurred from PMA implementation and GSP Study costs (See Section 7.1.2 and 7.3)
- **Debt-Financed PMA Capital Repayment** includes the estimated debt service for the OAWD District Land Annexation and In-Lieu Groundwater Recharge project capital costs (See Section 7.3). Capital costs for PMAs are annualized assuming repayment on a 30-year bond at 3 percent interest. All other costs are already annual expenses and reported as such
- **PMA O&M** costs are ongoing annual costs incurred after the first year of a PMA's implementation (See Section 7.3). These costs include annual surface water purchase costs. It is noted that this is the majority share of annual costs associated with each PMA
- **GSA Admin/Studies** costs are ongoing annual costs incurred by the GSAs that are not project specific (See Section 7.2)

Table 7-5. Total Estimated Cost Summary of GSP Implementation

Cost Category	2022	2023	2024	2025	2026	2027+
Other Capital/Studies	$556,000	$1,120,000	$685,000	$460,000	$460,000	$630,000
Debt-Financed PMA Capital Repayment	-	$1,020,000	$1,020,000	$1,020,000	$1,020,000	$1,020,000
PMA O&M	-	$4,033,000	$6,675,000	$6,675,000	$6,675,000	$6,675,000
GSA Admin/Studies	$914,700	$987,900	$968,200	$968,200	$968,200	$1,148,200
Total	**$1,470,700**	**$7,160,900**	**$9,348,200**	**$9,123,200**	**$9,123,200**	**$9,473,200**

7.5 IMPLEMENTATION SCHEDULE

Figure 7-2 illustrates the estimated implementation schedule for the GSP. The GSP implementation schedule allows time for GSAs to develop and implement projects and management actions to achieve the Subbasin sustainability goal. It is anticipated that Planned PMA implementation will commence in 2022, with initial project studies and project development. The GSP implementation schedule also shows mandatory reporting and updating for the GSP, including annual reports and five-year periodic evaluations prepared and submitted to DWR.

Task Name	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
Plan Implementation																					
GSP Submittal to DWR	X																				
Memorandum of Understanding	X																				
Annual Reports	X	X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X	
Five-Year Periodic Evaluation						X					X					X					X
Outreach and Communication																					
Monitoring and DMS																					
GSP Studies																					
Planned Projects and Management Actions																					
Colusa Subbasin Multi-Benefit Groundwater Recharge																					
OAWD District Land Annexation and In-Lieu Groundwater Recharge																					
Sycamore Slough Groundwater Recharge Pilot Project																					
CCWD In-Lieu Groundwater Recharge																					
Colusa Drain MWC In-Lieu Groundwater Recharge																					
Legend Submittal Planning and Development Implementation Ongoing Activity	X																				

Figure 7-2. Colusa Subbasin Implementation Schedule

7.6 GSP FINANCING AND FUNDING MECHANISMS

Administering the GSP and monitoring and reporting progress is projected to cost approximately $9.5 million per year once all planned PMAs are implemented. Costs are expected to be higher during years in which a five-year periodic evaluation and report is prepared, and slightly lower during other years when an annual report is prepared. These include all costs required for implementation, including for example, PMAs implemented by individual water agencies. To fund GSA operations and GSP implementation, GSAs are developing a financing plan that will include one or more of the following financing approaches:

- **Grants and low-interest loans**: GSAs will continue to pursue grants and low interest loans to help fund planning studies and other GSA activities. However, grants and low-interest loans are not expected to cover most GSA operating costs for GSP implementation.
- **Groundwater extraction charge**: A charge per acre-foot pumped could be used to fund GSP implementation activities.
- **Other Fees and charges**: Other fees may include permitting fees for new wells or development, transaction fees associated with contemplated groundwater markets, or commodity-based fees, all directed at aiding with sustainability objectives. Depending on the justification and basis for a fee, it may be considered a property-related fee subject to voting requirements of Article XIII D of the California Constitution (passed by voters in 1996 as Proposition 218) or a regulatory fee exempt from such requirements.
- **Assessments:** Special benefit assessments under Proposition 218 could include a per-acre (or per-parcel) charge to cover GSA costs, or other fees under Proposition 26.
- **Taxes:** This could include general property related taxes that are not directly related to the benefits or costs of a service (ad valorem and parcel taxes), or special taxes imposed for specific purposes related to GSA activities.

The GSAs are considering a combined approach, targeting available grants and low interest loans, and considering a combination of fees, assessments, and charges to cover operating and program-specific costs. Costs borne by individual water agencies will be allocated and recovered within that agency based on its policy decisions and customer preferences. As required by statute and the Constitution, GSAs and agencies would complete an engineer's report, rate study, and other analyses to document and justify any rate, fee, or assessment. For example, both the CGA and GGA have prepared rate studies to fund near-term (fiscal years 2019/20 through 2023/24) administrative costs as property-related service charges under Proposition 218. Appendix 7A provides a summary and additional discussion of the funding and financing options available to GSAs and other local entities in the Subbasin.

Some cost recovery approaches can affect the cost of water for specific uses in the Subbasin. Agencies supplying surface water recognize that recovering GSP related costs as part of their surface water charge can be counter-productive by disincentivizing surface water use. All agencies are concerned that any fees, charges, or assessments will affect business (farm) income and, if large, may affect cropping decisions and farming practices in the Subbasin. Based on groundwater monitoring, land use changes, and other future conditions, the GSAs will reconsider or adjust fees/assessments as needed to complete required PMAs and activities that are required to achieve sustainability.

An important consideration for GSA financing plans is the allocation of different types of costs to entities or areas. Cost allocation is a multi-step process that determines how costs of GSP implementation

components would be spread among and recovered from entities and areas covered by the GSP. For example, the implementation plan includes several categories of activities that must be paid for: administration, projects and management actions, monitoring, and studies. The categories may have their costs spread in different ways (among different entities and areas) depending on discussions and policy decisions. Considerations would include who is responsible for a cost, who benefits from an activity, what is fair, what is legally allowed or possible, what are the requirements for determining and justifying a cost allocation. Appendix 7A provides a summary overview of cost allocation concepts.

7.7 ANNUAL REPORTS

The GSP regulations require annual reports to be submitted to DWR by April 1 of each year following the adoption of the GSP (23 CCR §356.2). The GSAs will prepare and submit annual reports that comply with the requirements of §356.2. It is anticipated that the GSAs and their member agencies will need to develop independent analyses and data (e.g., quantifying surface water use within a particular GSA and/or member agency) as well as joint analyses (e.g., estimating the Subbasin-wide change in groundwater storage) in order to develop the required components of each annual report. The GSAs will work together to complete the annual reports.

Annual reports must provide general information about the Subbasin (23 CCR §356.2(a)) in addition to detailed, technical information that includes (23 CCR §356.2(b) and (c)):

- Groundwater elevation data from monitoring wells, analyzed and represented in:
  - Groundwater elevation contour maps
  - Groundwater elevation hydrographs
- Groundwater extractions in the preceding water year
- The surface water supply used or available for use in the preceding water year, including for groundwater recharge or other in-lieu uses
- Total water use in the preceding water year
- Change in groundwater storage, including maps and graphs
- A description of progress towards implementing the GSP, including achievement of interim milestones and implementation of PMAs

The following subsections provide a general outline of what information will be provided in each annual report. Each annual report submitted to DWR will fully comply with the requirements of §356.2.

7.7.1 General Information (§356.2(a))

General information provided in each annual report will include an executive summary that highlights the key content of the annual report. The executive summary will include:

- A description of the Subbasin sustainability goal
- A description of ongoing, newly implemented, and other planned GSP projects
- An updated implementation schedule
- A current map of the Subbasin

Any important changes or updates to the Subbasin, GSAs, or GSP implementation since the last annual report will be noted and described.

7.7.2 Subbasin Conditions (§356.2(b))

The Subbasin conditions section of each annual report will provide an update on groundwater conditions, surface water conditions, and water use in the Subbasin during the preceding water year.

Technical information will include a summary of current groundwater conditions in the Subbasin with respect to the Subbasin sustainability goal. The GSAs will summarize the groundwater monitoring network data and report the current groundwater elevation and change in groundwater elevation at monitoring sites. Data will be summarized in hydrographs and groundwater elevation contour maps for each aquifer in the Subbasin, tailored to specific hydrogeologic conditions across the region. This information will show seasonal high and low conditions within the current season and show historical data from at least January 1, 2015, to the current reporting year.

Groundwater extractions in the preceding water year will be summarized (in tabular and map form) by water use sector, and the method of measurement will be identified (e.g., metering, satellite analysis, crop-based evapotranspiration [ET] estimates, etc.). All data and methods used to characterize extractions and levels will follow best practices and be described in the annual report.

The surface water supply used or available for use in the Subbasin will be reported based on data that describes the total surface water diversions and total surface water inflows used or available for use in the Subbasin. The summaries will indicate whether the surface water supply was used or available for use for direct or in-lieu recharge, and will identify all data sources for each GSA.

Total water use from all sources will also be summarized by water use sector and water source type, with identification of the measurement method used to quantify all uses. Consumptive water use will also be summarized based on evapotranspiration of applied water (ET_{aw}) volumes, parsed into ET_{aw} of surface water and ET_{aw} of groundwater using the available information on applied surface water. All water use information will be collected using the best available measurement methods and data sources, which will be described in the annual report.

The Subbasin groundwater system water balance described in Chapter 3 will be used to estimate the change in groundwater storage each year. Change in storage will be summarized in tabular form and as a map for each principal aquifer in the Subbasin. A graph will show the water year type, groundwater use, annual change in storage, and cumulative change in storage for the Subbasin using historical data, including data from at least January 1, 2015, through the current reporting year.

7.7.3 Plan Implementation Progress (§356.2(c))

Each annual report will summarize the progress made over the past year in GSP implementation, including implementation of PMAs and other GSA-related activities. Each annual report will also describe progress toward established interim milestones and planned sustainability objectives. It will summarize sustainability conditions in the Subbasin.

7.8 PERIODIC EVALUATION (FIVE-YEAR UPDATES)

At least every five years, DWR will review the progress that GSAs have made toward meeting the GSP sustainability goals. Required components of the periodic evaluations are identified in 23 CCR §356.4. The GGA and CGA will prepare the periodic evaluation (or five-year update) at least every five years to summarize the status of GSP implementation, whether the GSP is meeting sustainability goals, and progress toward implementation of PMAs. An evaluation will also be made whenever the GSP is amended. Each periodic evaluation will fulfill all the requirements of 23 CCR §356.4. A summary of the general information that will be included in each periodic evaluation is provided in the following subsections.

7.8.1 Sustainability Evaluation (§356.4(a) - §356.4(d))

Each periodic evaluation will summarize current groundwater conditions for each applicable sustainability indicator and describe overall progress towards sustainability. Groundwater conditions will be evaluated and described in relation to interim milestones, measurable objectives, and minimum thresholds. If any minimum thresholds are found to be exceeded, the GSAs will investigate probable causes and implement actions to avoid undesirable results and correct groundwater conditions, as warranted.

Implementation of all PMAs will be documented and described in relation to the adaptive management strategy for the Subbasin. This description will include a summary of implementation timelines compared to the proposed timeline (Figure 7-1) and PMA implementation schedules described in Chapter 6. The description will also summarize the effect of the PMA on groundwater conditions in the Subbasin. If groundwater conditions are improving faster or slower than projected, the reason for the difference from the projection will be evaluated. If conditions are improving slower than projected because any PMAs are not being implemented according to the specified timeline, the deviation from the original plan will be documented and to the extent possible, corrective actions will be taken to speed implementation and/or implement other PMAs for adaptive management of the Subbasin.

The periodic evaluation will also analyze and describe the effects of PMAs on Subbasin sustainability indicators and compare those to the estimated gross benefits of the PMAs presented in Chapter 6. If differences are identified, those will be described in the periodic evaluation. If PMAs are not performing as expected, the periodic evaluation will describe steps the GSAs will take to implement additional PMAs or initiate demand management, if warranted. Those steps would include public outreach, notification, and other processes described in Chapter 6 for those PMAs. Any changes to the implementation schedule of PMAs will be described in the periodic evaluation.

As PMAs are implemented, monitoring data may indicate unanticipated effects. Also, land uses and economic conditions will change in ways that have not been anticipated or evaluated at this time. It may be necessary to revise the GSP to account for these changes. Elements of the GSP, including the basin setting, management areas, undesirable results, minimum thresholds, and measurable objectives will be reconsidered by the GSAs during the periodic evaluation. Any revisions will be proposed and documented in the evaluation.

7.8.2 Monitoring Network Description (§356.4(e))

Chapter 4 describes the planned monitoring network and protocols. The effectiveness of the monitoring network and overall GSP implementation depends on timely, accurate, and comprehensive data. The GSP includes Data Management System (DMS) protocols, as well as expanded monitoring wells and data collection. However, as described in Chapter 4, data gaps still exist in the Subbasin that will require expanding the monitoring network.

The periodic evaluation will include a description of the monitoring network within the Subbasin, will identify data gaps, and will identify any applicable areas within the Subbasin that are represented by data that does not satisfy the requirements established in the GSP regulations. A plan will be developed to improve the monitoring network, consistent with 23 CCR §354.38.

Additional data gaps may be identified in future GSP updates. The periodic evaluations of the GSP will assess changes to the monitoring program needed to acquire additional data sources, and how the new information will be used and incorporated into any future GSP updates. The installation of new data collection facilities and analysis of new data will be prioritized in the GSP.

7.8.3 New Information (§356.4(f))

The CGA and GGA will continue to monitor Subbasin conditions throughout GSP implementation. The DMS will allow GSAs to identify additional data gaps and implement procedures to secure additional data. Land use and economic incentives for farming and other water uses in the Subbasin will continue to change as the GSP is implemented. GSAs expect that new information about groundwater conditions, projects and management actions, and sustainability objectives will continue to be available. An adaptive management approach will be applied to identify, review, and incorporate all new information into the GSP.

Any significant new information available since GSP adoption, amendment, or the last periodic evaluation will be described. The evaluation will also clearly evaluate and indicate whether that new information warrants any changes to the GSP, including reassessment of the basin setting, measurable objectives, minimum thresholds, or the criteria that defines undesirable results.

7.8.4 GSA Actions ((§356.4(g) - §356.4(h))

The GGA and CCA will continue to monitor, manage, and collaborate to meet the sustainability goals specified in the GSP. Within their allowed authorities, if necessary, the GSAs will evaluate new regulations or ordinances that could be implemented to help achieve sustainability objectives. Any changes in regulations or ordinances will be summarized in the periodic evaluation.

The periodic evaluation will include a summary of state laws and regulations, or local ordinances related to the GSP that have been implemented since the previous periodic evaluation, and address how these may require updates to the GSP. Enforcement or legal actions taken by the GSAs in relation to the GSP will be summarized along with how such actions support sustainability in the Subbasin.

7.8.5 Plan Amendments, Coordination, and Other Information (§356.4(i) - §356.4(k))

Any proposed or completed amendments to the GSP will be described in the periodic evaluation. This will also include a summary of amendments that are being considered or developed at that time. Any changes to the basin setting, measurable objectives, minimum thresholds, or undesirable results will be described.

Any changes to applicable agreements will be documented and summarized in the periodic evaluation. GSAs will summarize any other information deemed appropriate to support the GSP and provide required information to DWR for review of an amended GSP.

7.9 DATA MANAGEMENT SYSTEM (§352.6)

The Subbasin DMS has been developed as an integrated network of digital file folders, databases and linked programs and tools. Each element is directly or indirectly linked the C2VSimFG-Colusa groundwater model and related water budget databases and tools that are used to calculate and summarize the Subbasin water budget (Figure 7-3). Inputs to the water budget are organized into inputs that are managed and implemented at the Subbasin-level and inputs that are managed at the GSA-level (or member agency-level). Subbasin-level inputs include:

- **Time series**: time series data managed in a database structure and used to quantify surface water inflows/outflows and groundwater levels
  - USGS station data
  - DWR-compiled data (Water Data Library [WDL] and California Data Exchange Center [CDEC])
- **Weather:** weather data managed in a database structure and used to quantify reference evapotranspiration and precipitation, and to support root zone water budget calculations (crop evapotranspiration, infiltration, runoff)
  - California Irrigation Management Information System (CIMIS) station data
  - National Oceanic and Atmospheric Administration's (NOAA's) National Centers for Environmental Information (NCEI) station data
  - PRISM Climate Group data
- **eWRIMS**: Electronic Water Rights Information Management System (eWRIMS) stores water rights diversion records managed publicly in a database structure and used to help quantify surface water supply utilized for irrigation
- **GIS:** spatially-defined geographic data managed in GIS and used to support land use analyses and spatial water use by sector
  - DWR spatial data (Subbasin boundaries, GSA boundaries, land use survey spatial coverages, Land IQ land cover classification and analysis)
  - DWR interpolation tool results (spatial and temporal interpolation of spatial coverages, using Ag Commission reports)
  - Local land use data comparison and validation

Inputs to the Subbasin water budget that are managed at the GSA or member-agency level include:

- **Time series:** time series data relating to GSA or member agency-specific inflows that are managed in a database structure and used to quantify surface water inflows/outflows
- **Local Data:** local data managed in spreadsheets and used to quantify GSA or member agency-specific inflows/outflows (diversions and deliveries not recorded in Subbasin-level data sources)
- **Deliveries**: Water district delivery data managed in a database structure and used to quantify surface water supply utilized for irrigation

The GSAs will manage data related to GSP project implementation within their boundaries. GSAs are continually working to refine data, identify data gaps, and incorporate additional information characterizing groundwater conditions in the Subbasin.

The GSAs are currently planning to review, update, and refine the current DMS to improve organization and more efficiently store, manage, and retrieve data. This will formalize the DMS, which will be developed to meet the requirements in the GSP Regulations, including 23 CCR §352.4, 23 CCR §352.6, and 23 CCR §354.4. The data will be managed so that appropriate tables, graphs, and maps supporting the GSP annual reports and periodic evaluations can be queried and provided to DWR.

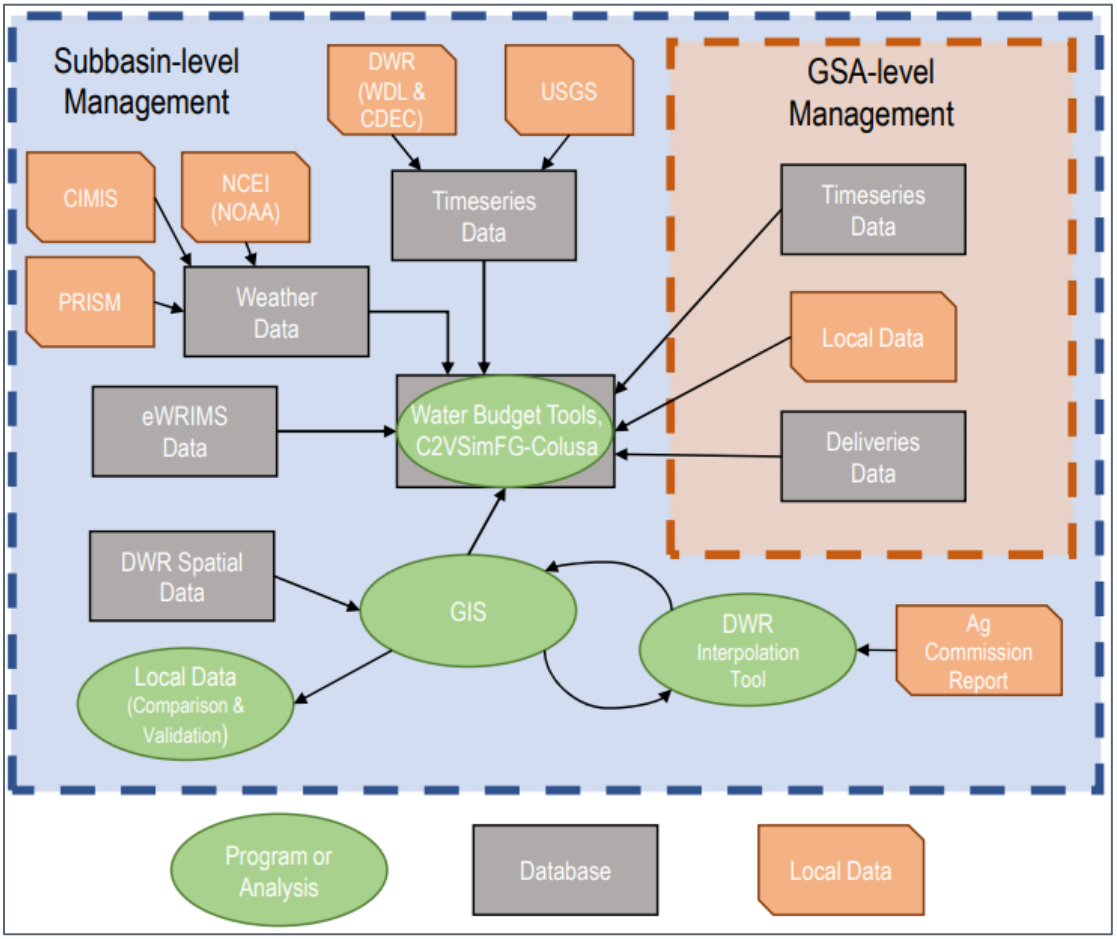

Figure 7-3. Data Management System Structure

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CHAPTER 8
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COLUSA SUBBASIN

Appendix 1A

Glossary of Terms

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GLOSSARY

This Glossary includes terms from a variety of legal and administrative sources relevant to SGMA and GSP development. These sources include:

- California Water Code Section 10721, Sustainable Groundwater Management Definitions (CWC Section 10721)
- California Code of Regulations Title 23 Section 341, Groundwater Basin Boundaries Definitions (23 CCR Section 341)
- California Code of Regulations Title 23 Section 351, Groundwater Sustainability Plan Definitions (23 CCR Section 351)
- DWR Bulletin 118 Definitions, updated 2003 (B118, 2003)
- Locally defined terms used in the GSP

The source of each term is provided in the citation following that term. Page numbers are included when a definition is not found in the referenced document's definitions or glossary. Additional information regarding each source are summarized at the end of this glossary.

Adjudication Action	The action filed in the superior or federal district court to determine the rights to extract groundwater from a basin or store water within a basin, including, but not limited to, actions to quiet title respecting rights to extract or store groundwater or an action brought to impose a physical solution on a basin. **(CWC Section 10721)**
Administrative Adjustment	The basin or subbasin boundary adjustment by the Department that either (1) amends existing basin or subbasin boundary data files to accurately reflect an unambiguous written basin or subbasin boundary description as defined in Bulletin 118 or amended pursuant to this Part, or (2) restates the description of a basin or subbasin boundary to more precisely reflect a mapped basin or subbasin boundary consistent with the original description. **(B118, 2003)**
Agency	The groundwater sustainability agency as defined in the Act. **(23 CCR Section 351)**
Agricultural Water Management Plan	The plan adopted pursuant to the Agricultural Water Management Planning Act as described in Part 2.8 of Division 6 of the Water Code, commencing with Section 10800 et seq. **(23 CCR Section 351)**
Alternative	The alternative to a Plan described in Water Code Section 10733.6. **(23 CCR Section 351)**
Annual Report	The report required by Water Code §10728. **(23 CCR Section 351)**
Aquifer	The three-dimensional body of porous and permeable sediment or sedimentary rock that contains sufficient saturated material to yield significant quantities of groundwater to wells and springs, as further defined or characterized in Bulletin 118. **(B118, 2003)**
Baseline or Baseline Conditions	The historical information used to project future conditions for hydrology, water demand, and availability of surface water and to evaluate potential sustainable management practices of a basin. **(23 CCR Section 351)**

Basin	Defined in the Sustainable Groundwater Management Act as a groundwater basin or subbasin identified and defined in Bulletin 118. Unless the context indicates otherwise, those terms are further defined as follows: (1) The term ***basin*** shall refer to an area specifically defined as a basin or ***groundwater basin*** in Bulletin 118, and shall refer generally to an aquifer or stacked series of aquifers with reasonably well-defined boundaries in a lateral direction, based on features that significantly impede groundwater flow, and a definable bottom, as further defined or characterized in Bulletin 118. (2) The term ***subbasin*** shall refer to an area specifically defined as a subbasin or ***groundwater subbasin*** in Bulletin 118 and shall refer generally to any subdivision of a basin based on geologic and hydrologic barriers or institutional boundaries, as further described or defined in Bulletin 118. **(B118, 2003)**
Basin Setting	The information about the physical setting, characteristics, and current conditions of the basin as described by the Agency in the hydrogeologic conceptual model, the groundwater conditions, and the water budget, pursuant to Sub article 2 of Article 5. **(23 CCR Section 351)**
Beneficial Use	Water in Bulletin 118 references 23 categories of water uses identified by the State Water Resource Control Board and are listed and briefly described in Appendix E. **(B118, 2003)**
Best Available Science	The use of sufficient and credible information and data, specific to the decision being made and the time frame available for making that decision, that is consistent with scientific and engineering professional standards of practice. **(23 CCR Section 351)**
Best Management Practice	The practice, or combination of practices, that are designed to achieve sustainable groundwater management and have been determined to be technologically and economically effective, practicable, and based on best available science. §351. **(23 CCR Section 351)**
Board	The State Water Resources Control Board. **(23 CCR Section 351)**
Bulletin 118	The department's report entitled "California's Groundwater: Bulletin 118" updated in 2003, as it may be subsequently updated or revised in accordance with § 12924. **(CWC Section 10721)**
CASGEM	The California Statewide Groundwater Elevation Monitoring Program developed by the Department pursuant to Water Code Section 10920 et seq., or as amended. **(23 CCR Section 351)**
Condition of Long-Term Overdraft	The condition of a groundwater basin where the average annual amount of water extracted for a long-term period, generally 10 years or more, exceeds the long-term average annual supply of water to the basin, plus any temporary surplus. Overdraft during a period of drought is not sufficient to establish a condition of long-term overdraft if extractions and recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods. **(CWC Section 10721)**
Coordination Agreement	The legal agreement adopted between two or more groundwater sustainability agencies that provides the basis for coordinating multiple agencies or groundwater sustainability plans within a basin pursuant to this part. **(CWC Section 10721)**
Data Gap	The lack of information that significantly affects the understanding of the basin setting or evaluation of the efficacy of Plan implementation and could limit the ability to assess whether a basin is being sustainably managed. **(23 CCR Section 351)**

Existing Stored Groundwater	Groundwater that is already underground from centuries of accumulated native groundwater. Historic pumping has been diminishing the existing stored groundwater at rates greater than the native groundwater can sustain, causing overdraft and unsustainable conditions. If more water is pumped from a basin than what is added from Native Groundwater and Introduced Groundwater, this water comes from the Existing Stored Groundwater. Continuing to use this previously stored groundwater will continue to exacerbate overdraft conditions. Temporarily using some of this water during the transition to sustainability will likely continue to cause lowering of groundwater levels.
Groundwater	Water beneath the surface of the earth within the zone below the water table in which the soil is completely saturated with water but does not include water that flows in known and definite channels. **(CWC Section 10721)**
Groundwater Basin	The groundwater basin or subbasin identified and defined in Bulletin 118 or as modified pursuant to Water Code 10722 et seq. **(23 CCR Section 351)**
Groundwater Dependent Ecosystem	The ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface. **(23 CCR Section 351)**
Groundwater Flow	The volume and direction of groundwater movement into, out of, or throughout a basin. **(23 CCR Section 351)**
Groundwater in Storage	The quantity of water in the zone of saturation. **(B118, 2003)**
Groundwater Overdraft	The condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average conditions. **(B118, 2003)**
Groundwater Recharge or Recharge	The augmentation of groundwater by natural or artificial means. **(CWC Section 10721)**
Groundwater Storage Capacity	The volume of void space that can be occupied by water in a given volume of a formation, aquifer, or groundwater basin. **(B118, 2003)**
Groundwater Sustainability Agency	One or more local agencies that implement the provisions of this part. For purposes of imposing fees pursuant to Chapter 8 (commencing with Section 10730) or taking action to enforce a groundwater sustainability plan, ***Groundwater Sustainability Agency*** also means each local agency comprising the groundwater sustainability agency if the plan authorizes separate agency action. **(CWC Section 10721)**
Hydrogeologic Conceptual Model	The description of the geologic and hydrologic framework governing the occurrence of groundwater and its flow through and across the boundaries of a basin and the general groundwater conditions in a basin or subbasin. **(23 CCR Section 341)**
Interconnected Surface Water	The surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted. **(23 CCR Section 351)**
Interested Parties	The persons and entities on the list of interested persons established by the Agency pursuant to Water Code Section 10723.4. **(23 CCR Section 351)**
Interim Milestone	The target value representing measurable groundwater conditions, in increments of five years, set by an Agency as part of a Plan. **(23 CCR Section 351)**
Introduced Groundwater	Water that is added to the sustainable yield of groundwater supply derived from percolation of imported surface water. This can be the directly through groundwater replenishment projects or groundwater banking or can be indirectly through percolation from irrigation and unlined canals.

Management Area	The area within a basin for which the Plan may identify different minimum thresholds, measurable objectives, monitoring, or projects and management actions based on differences in water use sector, water source type, geology, aquifer characteristics, or other factors. **(23 CCR Section 351)**
Measurable Objectives	The specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted Plan to achieve the sustainability goal for the basin. **(23 CCR Section 351)**
Minimum Threshold	The numeric value for each sustainability indicator used to define undesirable results. **(23 CCR Section 351)**
Monitoring Protocols	Designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin. The monitoring protocols shall be designed to generate information that promotes efficient and effective groundwater management. §10727.2. Required Plan Elements. **(CWC Section 10721)**
NAD83	The North American Datum of 1983 computed by the National Geodetic Survey, or as modified.
Native Groundwater	Water naturally infiltrating into the groundwater from precipitation and runoff. This is the average quantity of water annually added to the groundwater budget from rain, rivers, and streams, and reflects the portion of estimated sustainable yield of the groundwater supply that is not derived from imported surface water.
NAVD88	The North American Vertical Datum of 1988 computed by the National Geodetic Survey, or as modified. **(23 CCR Section 351)**
Plain Language	The language that the intended audience can readily understand and use because that language is concise, well-organized, uses simple vocabulary, avoids excessive acronyms and technical language, and follows other best practices of plain language writing. **(23 CCR Section 351)**
Plan	The groundwater sustainability plan as defined in the Act. **(23 CCR Section 351)**
Plan Implementation	The Agency's exercise of the powers and authorities described in the Act, which commences after an Agency adopts and submits a Plan or Alternative to the Department and begins exercising such powers and authorities. **(23 CCR Section 351)**
Plan Manager	An employee or authorized representative of an Agency, or Agencies, appointed through a coordination agreement or other agreement, who has been delegated management authority for submitting the Plan and serving as the point of contact between the Agency and the Department. **(23 CCR Section 351)**
Planning and Implementation Horizon	The 50-year time period over which a groundwater sustainability agency determines that plans and measures will be implemented in a basin to ensure that the basin is operated within its sustainable yield. **(CWC Section 10721)**
Principal Aquifers	The aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems. **(23 CCR Section 351)**
Qualified Map	The geologic map of a scale no smaller than 1:250,000 that is published by the U. S. Geological Survey or the California Geological Survey, or is a map published as part of a geologic investigation conducted by a state or federal agency, or is a geologic map prepared and signed by a Professional Geologist that is acceptable to the Department. **(23 CCR Section 341)**
Recharge Area	The area that supplies water to an aquifer in a groundwater basin. **(CWC Section 10721)**

Reference Point	The permanent, stationary and readily identifiable mark or point on a well, such as the top of casing, from which groundwater level measurements are taken, or other monitoring site. **(23 CCR Section 351)**
Representative Monitoring	The monitoring site within a broader network of sites that typifies one or more conditions within the basin or an area of the basin. **(23 CCR Section 351)**
Safe Yield	The maximum quantity of water that can be continuously withdrawn from a groundwater basin without adverse effect. **(B118, 2003)**
Saturated Zone	The zone in which all interconnected openings are filled with water, usually underlying the unsaturated zone. **(B118, 2003)**
Seasonal High	The highest annual static groundwater elevation that is typically measured in the Spring and associated with stable aquifer conditions following a period of lowest annual groundwater demand. **(23 CCR Section 351)**
Seasonal Low	The lowest annual static groundwater elevation that is typically measured in the Summer or Fall and associated with a period of stable aquifer conditions following a period of highest annual groundwater demand. **(23 CCR Section 351)**
Seawater Intrusion	The advancement of seawater into a groundwater supply that results in degradation of water quality in the basin and includes seawater from any source. **(23 CCR Section 351)**
Statutory Deadline	The date by which an Agency must be managing a basin pursuant to an adopted Plan, as described in Water Code Sections 10720.7 or 10722.4. **(23 CCR Section 351)**
Sustainability Goal	The existence and implementation of one or more groundwater sustainability plans that achieve sustainable groundwater management by identifying and causing the implementation of measures targeted to ensure that the applicable basin is operated within its sustainable yield. **(CWC Section 10721)**
Sustainability Indicator	The effects caused by groundwater conditions occurring throughout the basin that, when significant and unreasonable, cause undesirable results, as described in Water Code §10721(x). **(23 CCR Section 351)**
Sustainable Groundwater Management	The management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results. **(CWC Section 10721)**
Sustainable Yield	The maximum quantity of water calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result. **(CWC Section 10721)**
Technical Study	The geologic or hydrologic report prepared and published by a state or federal agency, or a study published in a peer-reviewed scientific journal, or a report prepared and signed by a Professional Geologist or by a Professional Engineer. **(23 CCR Section 341)**
Uncertainty	The lack of understanding of the basin setting that significantly affects an Agency's ability to develop sustainable management criteria and appropriate projects and management actions in a Plan, or to evaluate the efficacy of Plan implementation, and therefore may limit the ability to assess whether a basin is being sustainably managed. **(23 CCR Section 351)**

Undesirable Result	One or more of the following effects caused by groundwater conditions occurring throughout the basin: (1) Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply if continued over the planning and implementation horizon. Overdraft during a period of drought is not sufficient to establish a chronic lowering of groundwater levels if extractions and groundwater recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods. (2) Significant and unreasonable reduction of groundwater storage. (3) Significant and unreasonable seawater intrusion. (4) Significant and unreasonable degraded water quality, including the migration of contaminant plumes that impair water supplies. (5) Significant and unreasonable land subsidence that substantially interferes with surface land uses. (6) Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water. **(CWC Section 10721**
Urban Water Management Plan	The plan adopted pursuant to the Urban Water Management Planning Act as described in Part 2.6 of Division 6 of the Water Code, commencing with Section 10610 et seq. **(23 CCR Section 351)**
Water Budget	The accounting of the total groundwater and surface water entering and leaving a basin including the changes in the amount of water stored. **(CWC Section 10721)**
Water Source Type	The source from which water is derived to meet the applied beneficial uses, including groundwater, recycled water, reused water, and surface water sources identified as Central Valley Project, the State Water Project, the Colorado River Project, local supplies, and local imported supplies. **(23 CCR Section 351)**
Water Use Sector	The categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation. **(23 CCR Section 351)**
Water Year	The period from October 1 through the following September 30, inclusive. **(CWC Section 10721)** or the period from October 1 through the following September 30, inclusive, as defined in the Act. **(23 CCR Section 351)**
Water Year Type	The classification provided by the Department to assess the amount of annual precipitation in a basin. **(23 CCR Section 351)**
Wellhead Protection Area	The surface and subsurface area surrounding a water well or well field that supplies a public water system through which contaminants are reasonably likely to migrate toward the water well or well field. **(CWC Section 10721)**

REFERENCES

California Code of Regulations. Title 23, Section 341.

California Code of Regulations. Title 23, Section 351.

California Department of Water Resources (DWR). 2003. Bulletin 118: California's Groundwater.

California Water Code. Division 6. Part 2.74. Section 10721. Chapter 2. Definitions. (Amended by Stats. 2018, Ch. 255, Sec. 1. (AB 1944) Effective January 1, 2019.)

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Appendix 2A

Selected General Plan Goals and Policies

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Table 1. Selected Colusa County General Plan Goals and Policies

Goal or Objective	Policy or Action
Agriculture Element	
Goal AG-2: Maintain and enhance agriculture as the County's most critical land use, economic sector, and resource.	**Policy AG 2-1:** Agricultural-related industrial support operations shall be permitted on agricultural lands. Such uses may include, but are not limited to, processing, assembly, distribution and warehousing of agricultural materials and commodities and alternative energy systems that provide energy for on-site uses. These uses should be permitted on agricultural lands as principal permitted uses subject to the standards of the Zoning Ordinance provided the following findings are made: *d. The operational or physical characteristics of the use will not have a significant adverse impact on water resources or the use or management of surrounding agricultural properties within at least a one-quarter (1/4) mile radius.*
Objective AG 2-C: Preserve and Protect Water, Soil, and Natural Resources Necessary for Agricultural Operations	**Policy AG 2-8:** Support and promote water development projects which provide additional sources of water for agricultural uses. Policy AG 2-9: Support the procurement of expanded and additional water rights which provide for contractual supply reliability for agricultural use. **Policy AG 2-10:** Seek to increase the County's influence regarding water rights and distribution legislation at the state and federal level, to the greatest degree feasible for both surface water and ground water sources. This may occur through County support for local farm interest groups seeking to influence water-related legislation at the state and federal levels. **Policy AG 2-11:** Assist landowners in resolving water rights, water delivery, and water supply issues with other agencies such as the California Department of Fish and Game, the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, and the California Department of Water Resources. Policy AG 2-12: Within conservation easements and habitat conservation lands, preclude the practice of fallowing fields for the purpose of water export. **Policy AG 2-13:** Encourage the reuse of treated wastewater for agricultural purposes. **Policy AG 2-14:** Preserve water resources for agriculture, both in quantity and quality, from competition with development, non-agricultural uses, mitigation banks, and/or interests from outside of the County. **Policy AG 2-15:** Promote best management practices in agricultural operations (including animal operations) to reduce emissions, conserve energy and water, and utilize alternative energy sources. **Policy AG 2-16:** Promote wildlife-friendly farm practices, such as tailwater ponds, native species/grasslands restoration in field margins, hedgerows, ditch management for riparian habitat, and restoration of riparian areas in a manner consistent with ongoing agricultural activities, water delivery systems, reduction of pesticides, and other appropriate measures.
	Action AG 2-F: Coordinate with irrigation districts to identify cost-effective and feasible Best Management Practices for the application and use of water resources that address the range of agricultural activities in Colusa County. Work with entities such as the irrigation districts, Agricultural Commissioner, UC Extension Office, the Colusa County Resource Conservation District, and the Natural Resources Conservation Service to distribute Best Management Practices information to agricultural operations in the County. **Action AG 2-G**: Collaborate with water suppliers and wastewater treatment plant operators to increase the availability of treated or recycled water for agricultural purposes.
Community Character	
GOAL CC-2: Ensure that New Growth Addresses the Needs, Challenges and Opportunities Unique to Each Community	**Policy CC 2-6:** Require new residential development to connect to municipal water and sewer services. **Policy CC 2-19:** Prohibit lot splits or subdivision of land into new parcels smaller than two acres until centralized water and wastewater services are available. **Policy CC 2-24:** The use, expansion and development of private or mutually owned water and wastewater systems serving large-scale commercial and industrial land uses or multiple users shall be supported within the Sphere of Influence, provided that the systems meet the requirements outlined in Policy PSF 1-26 and all applicable State regulations. **Policy CC 2-25:** Encourage urban residential development within the City's Sphere of Influence to connect to municipal sewer and wastewater service and discourage the use, expansion and development of private or mutually owned water and wastewater systems serving residential uses within the Sphere of Influence. **Policy CC 2-42:** Require new urban development in Maxwell to connect to the municipal water and wastewater systems. **Policy CC 2-47:** Require new residential development in Princeton to connect to the municipal water and wastewater systems. **Policy CC 2-57:** Require applicants requesting land subdivisions or parcel splits in the Stonyford Lodge area to provide proof of adequate water supply for domestic use and fire protection. Additionally, sewage disposal meeting the County's standards and frontage for each parcel on a road built to County standards shall be ensured. **Policy CC 2-60:** Allow the subdivision of land designated Agriculture Transition (AT) and zoned Upland Conservation, 10 acre minimum (UC-10) into 10 acre parcels, provided that the project can demonstrate sufficient roadway access, water supply, septic capacity, no significant aesthetic impacts, and that no significant risk associated with wildland fires or slope stability would occur. **Policy CC 2-67:** Encourage urban residential development within the City's (Williams) Sphere of Influence to connect to municipal water and wastewater service. **Policy CC 2-69:** Discourage the use, expansion and development of private or mutually owned water and wastewater systems serving residential uses within the Sphere of Influence (Williams)

Table 1. Selected Colusa County General Plan Goals and Policies	
Goal or Objective	Policy or Action
Conservation Element	
Goal CON-1: Conserve and protect Colusa County's ecosystem.	**Policy CON 1-4:** Encourage conservation, rather than preservation, through the active management of natural resources, including wildlife, water, air, minerals, forests, and land. Conservation and management techniques include replacing trees, crops, and other renewable resources at a pace that ensures they are not consumed more quickly than they can be replaced; use of non-renewable resources in a manner that ensures the resources are not depleted but available to future generations for use; strategic forest thinning and fuels management to prevent wildfires; making resource areas accessible to the public while protecting resources from being diminished to non-recoverable levels; reducing incompatible wildlife/agricultural interface; and increasing public understanding and responsible use of resource conservation areas.
	Policy CON 1-7: Conserve and enhance those biological communities that contribute to the County's rich biodiversity including, but not limited to, blue oak woodlands, annual grasslands, mixed chaparral, pine woodlands, wetlands, riparian areas, aquatic habitat, and agricultural lands.
Objective CON-1B: Protect Endangered, Threatened and Special-Status Plant and Animal Species, their Habitats, and Other Sensitive Habitats	**Policy CON 1-13:** Sensitive habitats include oak woodlands, wetlands, vernal pools, riparian areas, wildlife and fish migration corridors, native plant nursery sites, waters of the U.S., and other habitats designated by state and federal agencies and laws. **Policy CON 1-14:** Require any proposed project that may affect special-status species, their habitat, or other sensitive habitat to submit a biological resources evaluation as part of the development review process. Evaluations shall be carried out under the direction of the Colusa County Department of Planning and Building and consistent with applicable state and federal guidelines. Additional focused surveys shall be conducted during the appropriate season (e.g., nesting season, flowering season, etc.), if necessary. **Policy CON 1-15:** Require that impacts to wetlands and riparian habitat protected by State or Federal regulations be avoided to the greatest extent feasible. If avoidance is not possible, fully mitigate impacts consistent with applicable local, State and Federal requirements. **Policy CON 1-16:** Require new development projects to incorporate measures that eliminate or avoid direct impacts to lakes, reservoirs, rivers, creeks, streams, wetlands, and other waterways to the greatest extent feasible. Measures may include, but are not limited to, appropriate setbacks or the implementation of best management practices approved by the Department of Planning and Building. **Policy CON 1-17:** All discretionary public and private projects that identify special-status species or sensitive habitats in a biological resources evaluation shall avoid impacts to special-status species and their habitat to the maximum extent feasible. Where impacts cannot be avoided, projects shall include the implementation of site-specific or project-specific effective mitigation strategies developed by a qualified professional in consultation with state or federal resource agencies with jurisdiction (if applicable) including, but not limited to, the following strategies: *a. Preservation of habitat and connectivity of adequate size, quality, and configuration to support the special-status species. Connectivity shall be determined based on the specifics of the species' needs.* *b. Project design measures, such as clustering of structures or locating project features to avoid known locations of special-status species and/or sensitive habitats.* *c. Provision of supplemental planting and maintenance of grasses, shrubs, and trees of similar quality and quantity to provide adequate vegetation cover to enhance water quality, minimize sedimentation and soil transport, and provide adequate shelter and food for wildlife.* *d. Protection for habitat and the known locations of special-status species through adequate buffering or other means.* *e. Provision of replacement habitat of like quantity and quality on- or off-site for special status species.* *f. Enhancement of existing special-status species habitat values through restoration and replanting of native plant species.* *g. Provision of temporary or permanent buffers of adequate size (based on the specifics of the special-status species) to avoid nest abandonment by nesting migratory birds and raptors associated with construction and site development activities.* *h. Incorporation of the provisions or demonstration of compliance with applicable recovery plans for federally listed species.* *i. Monitoring of construction activities by a qualified biologist to avoid impacts to on-site special status species.*
	Action CON 1-C: Review development project proposals, infrastructure projects, long range planning projects, and other projects that may potentially impact special-status species and sensitive resources to determine whether significant adverse impacts will occur. Where adverse impacts are identified, develop appropriate mitigation measures, in conformance with General Plan policies and relevant state and federal laws, to reduce or avoid impacts to the maximum extent feasible and practical. **Action CON 1-D**: Update the Zoning Ordinance to include standards to address significant impacts to special-status species and sensitive habitats consistent with Policies CON 1-13 through 1-18.
Objective CON-1C: Protect and Enhance Local Fisheries and Riparian and Aquatic Habitat	**Policy CON 1-21:** Protect riparian habitat along the Sacramento River in order to maintain suitable habitat for anadromous fish species, including salmon and steelhead trout, and for native sportfishing species
	Action CON 1-E: Coordinate with the California Department of Fish and Game to identify adversely impacted aquatic habitat within the County and to develop riparian management guidelines to be implemented by development, recreation, and other projects adjacent to rivers, lakes, reservoirs, and streams.

Table 1. Selected Colusa County General Plan Goals and Policies	
Goal or Objective	Policy or Action
Objective CON-1D: Protect Surface Water Quality in the County's Lakes, Streams, Creeks and Rivers	**Policy CON 1-22:** Maintain lakes, rivers, streams, creeks, and waterways in a natural state whenever possible. These water features may be actively managed and/or improved or modified in order to function as natural flood protection and storm water management features during storms and flooding events. **Policy CON 1-23:** Protect and enhance streams, channels, seasonal and permanent marshland, wetlands, sloughs, riparian habitat and vernal pools through sound land use planning, community design, and site planning. **Policy CON 1-24**: If a proposed project may result in impacts to wetlands or other Waters of the U.S., require the project proponent to consult with the appropriate regulatory agency and implement all applicable permit requirements as a condition of project approval. **Policy CON 1-25:** Balance the needs of aquatic and riparian ecosystem enhancement efforts with flood management objectives. Policy CON 1-26: Discourage development within 50 feet from the top of banks for all lakes, perennial ponds, rivers, creeks, sloughs, and perennial streams unless County-approved best management practices have been incorporated into the project's design in order to protect water quality and shoreline resources. Appropriate uses within the setback areas may include, but are not necessarily limited to: a. Fire and flood protection areas b. Maintenance of riparian habitat c. Recreational trails d. Vegetated landscaping e. Boat launch facilities Levees g. Docks h. Irrigation pumps **Policy CON 1-27:** Encourage agricultural land owners to improve on-site storm water retention features and implement feasible Best Management Practices (BMPs) to reduce site runoff and provide for natural removal of water pollutants. **Policy CON 1-28:** Support non-regulatory programs for protection of streams and riparian habitat, including education, technical assistance, tax incentives, and voluntary efforts to protect riparian resources. **Action CON 1-F:** Continue to require implementation of the County's Grading Ordinance. Review projects to ensure that BMPs are implemented during construction and site grading activities as well as in project design to reduce pollutant runoff into water bodies.
Objective CON-1E: Ensure a Sustainable and Long-Term Supply of Safe and Reliable Water to Support the Needs of County Residents, Businesses, and Agricultural Operations	**Policy CON 1-29:** Support water development, treatment, and storage projects that are needed to meet existing and future local and regional demand. **Policy CON 1-30:** Ensure that regional, state, and federal water projects, including proposed Sites Reservoir, protect local water rights and areas of origin. **Policy CON 1-31:** Encourage municipal water purveyors to install water meters and abandon flat-fee water use rate structures where feasible. **Policy CON 1-32:** Demonstrate leadership in water conservation by including water-efficient plumbing and landscaping at all new County facilities, and by reducing the County's own water use to the extent possible. **Policy CON 1-33:** Require new development and expansion of existing uses to incorporate best management practices for water use and include water conservation measures. **Policy CON 1-34:** Encourage the use of water conservation measures for agriculture and in existing residences and businesses. **Policy CON 1-35:** Encourage the use of water conservation measures, including low flow plumbing; reclaimed wastewater for non-potable uses; dual plumbing that allows grey water from showers, sinks, and washers to be reused for landscape irrigation in new developments; and native and drought-tolerant landscaping. **Action CON 1-G:** Adopt a Water Efficient Landscaping Ordinance for residential, park, recreational, and commercial uses, based on the state model ordinance as amended to address local concerns. The ordinance should address: 1. Water-efficient landscape designs using low water-use plants. 2. Efficient irrigation systems. 3. Minimized turf areas. 4. Soil improvements and mulch. 5. Regular maintenance and adjustment of irrigation systems. 6. Scheduling irrigation during early or late hours. 7. Water budgeting, when necessary. 8. Education of residents, customers and employees regarding the importance of efficient water use. **Action CON 1-H:** Continue to implement the policies, actions, and Basin Management Objectives (BMOs) contained in the Colusa County Groundwater Management Plan. Action CON 1-I: Continue to cooperate with Butte, Glenn, Tehama, Shasta and Sutter Counties through the Northern Sacramento Valley Integrated Regional Water Management Group, and continue to foster regional cooperation with other counties and water purveyors.

Table 1. Selected Colusa County General Plan Goals and Policies	
Goal or Objective	**Policy or Action**
Housing Element	
Goal HO-2: Provide Adequate Sites and Infrastructure to Accommodate the County's Housing Needs	**Policy HO-11:** Implement all policies and programs of the Housing Element with adequate consideration given to the protection of the County's agricultural and groundwater resources, and maintaining consistency with the County's Conservation Element of the General Plan.
	Program HO 2-5 Provision of Public Services The County will make every effort to ensure that infrastructure is available in a timely manner to accommodate development of its fair share of regional housing needs. Particular effort will be made to provide adequate infrastructure to accommodate the R-2, R-3, and R-4 sites in Arbuckle, Maxwell, Princeton, and the unincorporated area of Colusa. The County will coordinate with the local water and sewer agencies to assist in planning for adequate water and sewer service. The County will take the following actions, as needed, to provide service to developing areas: <u>All Service Providers</u> • Each water and sewer provider will be mailed a copy of the Housing Element, upon its adoption, along with a letter that includes: 1) the text of Government Code Section 65589.7 requiring water and sewer providers to grant priority for service allocations to proposed developments that include housing units affordable to lower (including very low and extremely low) income households; 2) a summary of the County's regional housing needs allocation; and 3) specific actions the provider should take to ensure adequate service (see below for actions specific to each district/area in the County). <u>Rural Areas</u> • Review potential treatment technologies that could be developed to provide water and sewer service for rural market-rate and affordable housing; develop performance standards for potential treatment technologies to assist public and/or private sewer and water providers in determining which will be most feasible in their locations within the County. • Allow a wide range of feasible alternative system sizes and treatment technologies to provide water and sewer service for rural market-rate and affordable housing. Program HO 2-6 Adequate Water and Wastewater Service for Subdivisions Revise the Zoning Ordinance to ensure parcel map or subdivision map approval is dependent on demonstrated ability to provide potable water and meet septic capacity requirements.
	Policy HO-18: Give priority for water service connections to extremely low, very low, and low income housing units in areas receiving water service from the County. Encourage local water and sewer providers to give priority to these lower income developments pursuant to Government Code Section 65589.7. Provide a copy of the Housing Element Update to local water and sewer providers upon its adoption.
Land Use Element	
Goal LU-1: Maintain the efficient and harmonious use of land in the county, promoting a well organized and orderly development pattern, avoiding random, haphazard growth, protecting public health and safety, and accommodating the orderly and sustainable growth of employment and population.	**Policy LU 1-4**: Locate lands designated for future development based on constraints associated with natural features, such as soil, slope, and drainage, preservation of the County's resources, including agriculture, open space, and scenic views, and by public service availability, such as sewer and water capability; policies and actions related to these requirements are set forth in more detail in the Safety, Conservation, and Public Facilities and Services Elements.
	Action LU 1-D: Review development projects, consistent with the requirements of the California Environmental Quality Act and other applicable laws, to identify potential impacts associated with aesthetics, agriculture, air quality, circulation, community character, natural and cultural resources, greenhouse gases, public health and safety, water quality and supply, public services and facilities, and utilities and to mitigate of adverse impacts to the maximum extent that is feasible and practical.
Objective LU-1C: Ensure a Streamlined and Equitable Process for Project Permitting and Outside Agency Coordination without Compromising the Enforcement of Local Land Use Regulations	**Policy LU 1-27:** Participate in countywide, regional and other multi-agency planning efforts related to agriculture, water supply, tourism, open space, air quality, housing, green infrastructure, recreation, habitat conservation, energy, emergency preparedness and flood protection to ensure that the needs of the County's residents and businesses are not overlooked.
Goal LU-3: Ensure that Future Development Achieves the County's Goals of Agricultural Conservation, Rural Character, Growth Focused Around Existing Communities and Uses Sustainable Practices through Application of Development Requirements	**Policy LU 3-1:** Require proposed urban and rural residential development to be consistent with the following: <u>Rural Residential</u> • The soil is determined to be suitable for septic tank use by the Environmental Health Department • Groundwater is determined to be sufficient to support a well by the Environmental Health Department • The parcel can be made accessible from a public street • It can be demonstrated that the development is compatible with surrounding uses and will not have a significant, adverse effect on adjoining properties. • The area is accessible for fire protection and can meet fire resistance guidelines if located in a high hazard area. • It can be demonstrated that potable water is available. <u>Urban Residential</u> • The community utility systems, including water, drainage, and sewer, if available, can accommodate the additional demand. • The area has access to a major transportation route. • The impact of the development on local streets can be mitigated to acceptable levels. • Adequate fire protection measures are provided. • The site adjoins existing urban (residential, commercial, public facility, etc.) development. • The project avoids the repetition of residential facades/designs within subdivisions. • The development is compact, is sensitive to natural resources, public safety, efficiently uses water and energy, maximizes bicycle and pedestrian opportunities, provides multimodal connections to nearby neighborhoods, bike/pedestrian routes and trails, and provides direct, safe routes to services, schools, and shopping.

Table 1. Selected Colusa County General Plan Goals and Policies	
Goal or Objective	Policy or Action
Objective LU-3B: Ensure that Reasonable Development Standards and the County's Rural Character and Quality of Life are Not Compromised in Efforts to Attract Commercial and Industrial Growth	**Policy LU 3-24:** Require proposed industrial development to be consistent with the following: • The area can be readily hooked up to public sewer and water facilities where these facilities are available, or to private sewer and water facilities where utilities do not yet exist. • If the industry uses community utilities, that community systems can accommodate the added demand without additional costs to the existing community. • If the project is to be served by groundwater wells, that reliable, scientific data be provided in the project development application that demonstrates that groundwater will be available under all conditions, including drought, that surrounding the wells will not have appreciable adverse effects on the quality and quantity of existing domestic and agricultural water supplies, and that private sewage disposal systems can comply with Environmental Health Department standards. • The project will not significantly contribute to air, water, light, and noise pollution.
Open Space Element	
Objective OSR 1-B: Balance Open Space Preservation with Economic Development Needs	**Policy OSR 1-9:** Maintain open space for future water and drainage projects.
Public Services and Facilities Element	
Objective PSF-1A: Provide Safe, Reliable, and Environmentally Sound Water Services to Existing County Land Uses and Areas of Planned Growth	**Policy PSF 1-3:** Coordinate with water providers throughout the County to manage water supplies in a way that ensures adequate supplies for existing residents, agricultural uses, and businesses, and for projected growth, and avoids groundwater overdraft, water quality degradation and other adverse environmental impacts. **Policy PSF 1-5:** Facilitate, and to the extent feasible, assist with the development of new and reliable sources of water, consistent with County land use plans and regional water needs. **Policy PSF 1-7:** Priority is given to serving existing water uses over new water uses. **Policy PSF 1-8:** Require proof of an adequate (as defined by the County Environmental Health Division) potable water supply to serve the entire project prior to approval of any division of land or use permit. **Policy PSF 1-11:** New residential development on parcels two acres in size or smaller shall be required to connect to a public water system, with the exception of existing Rural Residential and Rural Service Center parcels which may be allowed to have an on-site well if approved by the County Department of Environmental Health.
Safety Element	
Objective SA 1-D: Take Appropriate Steps to Reduce the Risks to Life, Property, and Public Services Associated with Flooding.	**Policy SA 1-27:** Maintain adequate lands that can be used for groundwater recharge and storm water management. These lands may include parcels designated Agriculture General (AG), Designated Floodway (DF), and Resource Conservation (RC). **Policy SA 1-35:** Encourage and accommodate multi-benefit flood control projects that incorporate recreation, resource conservation, preservation of natural riparian habitat, and scenic values of the County's streams, creeks and lakes. Where appropriate and feasible, the County shall also encourage the use of flood and/or stormwater retention facilities for use as groundwater recharge facilities.

Table 2. Selected Glenn County General Plan Goals and Policies	
Goal or Objective	**Policy or Action**
Natural Resources	
Agriculture/Soils	
NRG-1 Preservation of agricultural land	**NRP-3:** Recognize the value of ricelands for waterfowl habitat, watershed management, and for groundwater recharge in an effort to preserve such lands and to maintain necessary water supplies in Glenn County. **NRP-4:** Support efforts underway to explore the potential to utilize ricelands as temporary storage reservoirs in the winter months, thus increasing groundwater recharge and supplies of surface water for both agriculture and wildlife, and potentially providing an alternative to rice straw burning. **NRP-19:** Support the erosion control programs, resource management programs, and agricultural conservation efforts of the Glenn County Resource Conservation District that benefit the county as a whole. Implementation Strategies, Programs and Priorities **NRI-3:** Encourage rice growers as well as other agricultural crop growers and cooperative to emphasize the value of rice land for waterfowl habitat, air quality enhancement, and groundwater recharge through promotions and advertisement. **NRI-4:** Monitor and participate in efforts of State and federal agencies and private conservation groups to find alternatives to rice straw burning, including winter flooding of fields. **NRI-16:** Establish a County notification process for requests to convert land from agricultural and grazing use to wetlands.
Water Resources	
NRG-2 Protection and management of local water resources	**NRP-22:** Oppose the exportation of groundwater resources outside the county. **NRP-23:** Support legislation which will provide for a locally controlled Glenn County groundwater management district. **NRP-24:** Recognize the following local priorities when dealing with questions of ground and surface water use: • Highest: 1) Household/Domestic, 2) Agriculture, 3: Industrial/Commercial, 4) Wildlife/Conservation Lowest: 5) Exportation **NRP-25:** Protect groundwater recharge areas in the county from overcovering and contamination by carefully regulating the type of development which occurs within these areas. **NRP-26:** Discourage onsite sewage disposal systems in areas with high groundwater recharge potential and eliminate existing concentrations of septic tanks in such areas through construction of community sewage treatment and disposal systems. **NRP-27:** Prohibit uses with the potential to accidentally discharge harmful groundwater pollutants in areas of high groundwater recharge, unless appropriate mitigation measures have been incorporated into the operation of such uses. **NRP-28:** Identify and monitor potential sources of groundwater pollution, including harmful agricultural practices. **NRP-29:** Limit structural coverage and impervious surfaces within areas of high groundwater recharge through application of zoning that recognizes the importance of this feature. **NRP-30:** Protect important watershed areas from poor development practices and potential degradation. **NRP-31:** Monitor actions taken at the State and federal level which impact water resources in order to evaluate the effects of these actions on the county's resources. **NRP-33:** Carefully study the potential impact that any future reservoir construction may have on groundwater recharge areas in Glenn County. **NRP-34:** Recognize the value of irrigation system infrastructure by discouraging development within established irrigation district boundaries which would prematurely reduce the utility of such systems. **NRP-35:** Encourage the development of water conservation programs by water purveyors for both agricultural and urban uses. **NRP-36:** Encourage development of educational programs to increase public awareness of water conservation opportunities and the potential benefits of implementing conservation measures and programs. **NRP-37:** Recognize that efforts to reserve water in Glenn County for wildlife may also bring long-term benefits to the effort to retain water resources locally. **NRP-38:** Recognize the impacts of gravel extraction on groundwater quantity and quality and encourage extraction methods that preserve and enhance groundwater resources. Implementation Strategies, Programs and Priorities **NRI-18:** Establish a local groundwater management program including strategies for advancing State legislation supportive of a locally controlled groundwater management district. **NRI-19:** Apply the priorities for water consumption included in this General Plan when reviewing discretionary actions. **NRI-20:** Establish an overlay designation to provide appropriate protections for areas of the county where groundwater recharge occurs, such as limitations on overcovering of soils with impervious surfaces. To provide for appropriate groundwater protection, new zoning proposals that could result in residential lots less than one acre should not be approved until a sewer system is available. Consult with the State Department of Water Resources, the Glenn County Health Department and the Glenn County Planning Department, and incorporate protective measures into the *Glenn County Zoning Code.* **NRI-22:** Work with State and federal agencies to improve local groundwater pollution detection and monitoring. **NRI-23:** Amend County ordinances to include development standards, as contained in this *General Plan,* which protect watershed areas, and coordinate application of the standards with the U.S. Forest Service and other agencies. **NRI-24:** Monitor and participate in efforts of the Bureau of Reclamation and Army Corps of Engineers to study the impacts of additional reservoir construction and of reservoir siltation. **NRI-25:** Develop and actively seek funding to develop water conservation and educational programs.

Table 2. Selected Glenn County General Plan Goals and Policies

Goal or Objective	Policy or Action
Biological Resources	
NRG-3 Preservation and enhancement of the county's biological resources in a manner compatible with a sound local economy.	**NRP-39:** Approach the retention and enhancement of important habitat by preserving areas or systems which will benefit a variety of species or resources rather than focusing on individual species, resources or properties. **NRP-41:** Preserve natural riparian habitat, especially along Stony Creek and the Sacramento River and Butte Creek. **NRP-42:** Eliminate the E-M (Extractive Industrial) Zone from areas containing natural riparian vegetation/habitat and replace it with a category affording greater protection to stream courses and riparian habitats. **NRP-46:** Promote protection of native biological habitats of local importance such as riparian forests, foothill oak woodlands, Stony Gorge and Black Butte Reservoirs. **NRP-50:** Recognize the Sacramento River corridor, the Sacramento National Wildlife Refuge, migratory deer herd areas, naturally occurring wetlands, and stream courses such as Butte and Stony Creeks as areas of significant biological importance. **NRP-53:** Direct development away from naturally occurring wetlands to the extent such policy is consistent with the concept of compact and contiguous development. **NRP-61:** Support efforts to improve water availability and management when the potential exists to benefit fish and wildlife in cooperation with Glenn County agricultural water users. Implementation Strategies, Programs and Priorities **NRI-27:** Amend the *Glenn County Zoning Code* to include a Streamside Protection Zone and rezone those areas along stream courses currently zoned E-M (Extractive industrial Zone) in accordance with a locally prepared riparian zone management plan. **NRI-32:** Meet with the U.S. Fish and Wildlife Service to determine if there is interest in establishing buffer areas around the Sacramento National Wildlife Refuge and other areas of biological importance, and how the federal government would participate in their formation. **NRI-34:** Identify biologically important areas, such as the Sacramento River Corridor, Sacramento National Wildlife Refuge, deer herd ranges, naturally occurring wetlands, and stream courses such as Butte and Stony Creeks, and show them as constraints to development in this *General Plan* (Reference Biological Importance Overlay and Restorable Wetlands Overlay).
Public Safety	
Water Quality	
PSG-6 Protection and enhancement of water quality.	**PSP-43:** Support ongoing regulatory and compliance efforts at the federal and State level for the protection of water quality. **PSP-45:** Zone floodways and stream channels in a manner that promotes protection of water quality. **PSP-47:** Support the preparation of area groundwater studies to the protection of groundwater and to ensure that the holding capacity of the area is not exceeded. Implementation Strategies, Programs and Priorities **PSI-42:** Sponsor and assist with educational efforts which have as a goal greater public awareness and compliance with established water quality standards.
Community Development	
Land Use/Growth	
CDG-2 Avoidance of land use conflicts in agricultural areas.	**P-45:** Discourage urban growth in floodplains, aquifer recharge areas, scenic and historic sites, or other sensitive areas as specified in this General Plan. **CDP-17:** Encourage agricultural water suppliers to make changes in their service requirements to increase the minimum sized parcel to be served in agricultural areas to ten (10) acres, and recommend that new parcels created within water supply district boundaries which are less than ten (10) acres in size be detached from the district(s), except for the Orland Unit Water Users' Association, for which the minimum size shall be 5.01 acres. **CDP-18:** Within the Orland-Artois Water District, approve no zone changes allowing parcels smaller than twenty (20) acres in size, and approve no tentative maps for parcels less than twenty (20) acres in size. Implementation Strategies, Programs and Priorities **CDI-10:** Contact agricultural water suppliers and formally request establishment of a ten (10) acre minimum parcel size for agricultural water service. **CDI-11:** Apply zoning to properties located within the Orland-Artois Water District that reflects a minimum parcel size of twenty (20) acres or larger.
Public Services and Facilities	
CDG-17 Provision of adequate and cost-effective public services.	**CDP-129:** Maintain coordination and cooperation between the County and water purveyors, and encourage special districts to comply with State law by referring capital projects to the County for review and evaluation for consistency with the General Plan. Implementation Strategies, Programs and Priorities **CDI-83:** Convene a task force composed of representatives of Glenn County and the cities of Willows and Orland to formulate a memorandum of understanding which establishes uniform polities and standards for building construction, public utility connections, sewer and water service, and other matters related to cost-effective development of unincorporated areas within city urban limit lines. **CDI-88:** Request LAFCO to initiate and undertake studies of existing special districts and cities which include inventorying those agencies and determining their maximum service area and service capacities. **CDI-89:** Request LAFCO to adopt standards and procedures for the evaluation of service plans submitted by cities and special districts with annexation/reorganization applications. **CDI-94:** Request the Environmental Health Department to review minimum parcel size standards for areas without public or community water service for adequacy as new information becomes available e.g. soil surveys, new regulations.

Table 3. Selected City of Colusa General Plan Goals and Policies

Goal or Objective	Policy or Action
Land Use Elements	
Comprehensive Planning	
Goal LU-6: To provide a comprehensive, logical land use planning process rather than an incremental, piecemeal approach.	**Policy LU-6.3:** Growth shall be managed to ensure that adequate public facilities and services are planned for and provided in a manner that protects the public's health, safety, and welfare.
	Implementing Actions Implementing Action LU-6.3.e: Water Master Plan The City will adopt and implement a Water Master Plan. Development projects will be evaluated for consistency with this plan. The plan will provide a framework for timed capital improvements and facility expansion projects and will aid the City in identifying and establishing funding sources beyond monthly service charges to finance improvements related to water quality, supply, recycling, distribution, and water conservation. Municipal water is discussed is discussed in detail in the Municipal Facilities and Services Element. Implementing Action LU-6.3.f: Wastewater Master Plan The City will adopt and implement a Wastewater Master Plan. Development projects will be evaluated for consistency with this plan. The plan will provide the framework for timed capital improvements and facility expansion projects and will identify funding sources beyond monthly service charges to finance improvements related to expansion and upgrades to wastewater capacity, flow, treatment, and reclamation. The City will refer to this plan when constructing improvements and upgrades to the Wastewater Treatment Plant as needed to accommodate existing customers and any approved development. Wastewater is discussed in detail in the Municipal Facilities and Services Element. Implementing Action LU-6.3.g: Storm Drainage Master Plan The City will adopt and implement a Storm Drainage Master Plan. Development projects will be evaluated for consistency with this plan. The plan will identify drainage facilities that will be constructed to eliminate drainage problems in the City and will describe the means for financing the improvements. The Storm Drainage Master Plan will address Regional Water Quality Control Board water quality standards, including Best Management Practices for storm drainage management. Storm drainage is discussed in detail in the Municipal Facilities and Services Element.
Community Character and Design	
Environmental Sustainability	
Goal CCD-2: To ensure that new development respects the natural environment.	**Policy CCD-2.2:** New development shall respect the contours of drainage ways as important recognizable features of the City.
	Implementing Actions Implementing Action CCD-2.2.c: Improvement Standards The City will update and adopt improvement standards to be applied to improvements and private works to be dedicated to the public and accepted by the City for maintenance or operation, as well as improvements to be installed within existing rights of-way and easements. These standards shall serve to regulate and guide the design and preparation of plans for street construction, alleys, drainage, sewer, street lighting water supply facilities, and related public improvements.
	Policy CCD-2.5: The City shall ensure that infrastructure improvements demonstrate sensitivity to any natural systems affecting a project site.
	Policy CCD-2.5: The City shall ensure that infrastructure improvements demonstrate sensitivity to any natural systems affecting a project site.
	Implementation Actions Implementing Action CCD-2.5.b: Development Review Impacts of proposed new development will be evaluated with each proposal. Mitigation of significant impacts to the natural environment, including biological resources, water quality and air quality, will be required as part of the development review process. Mitigation measures to minimize impacts on these natural resources will be implemented as appropriate.
Safety Element	
Goal SAF-2: To minimize the potential for loss of life and damage to property due to flooding.	**Policy SAF-2.2:** The City shall minimize the potential for flood damage to buildings and other structures, particularly from storm water runoff.
	Implementing Actions Implementing Action SAF-2.2.a: Storm Drainage Master Plan The City will adopt a Storm Drainage Master Plan for Colusa. The Master Plan will identify drainage facilities that will be constructed to eliminate or mitigate drainage problems in the City, and describe the means for financing the proposed improvements. The Storm Drainage Master Plan will be consistent with any Capital Improvements Plan prepared by the City and will address Regional Water Quality Control Board water quality standards, including Best Management Practices for storm drainage. Implementing Action SAF-2.2.b: Development Review The City will require new development to ensure that the cumulative rate of peak runoff does not exceed pre-development levels. New development and redevelopment of existing sites will provide storm water detention or retention facilities (on- or offsite), if necessary, to prevent flooding due to runoff or where existing storm drainage facilities are unable to accommodate increased storm water drainage. Implementing Action SAF-2.2.c: Ordinance and Regulation Review and Update The City will review and revise its Subdivision Ordinance as needed to incorporate specific data and design requirements related to storm water drainage that are contained in this General Plan update.

Table 3. Selected City of Colusa General Plan Goals and Policies	
Goal or Objective	**Policy or Action**
Parks, Recreation and Resource Conservation	
Water Quality and Water Conservation	
Goal PRC- 9: To manage and protect the City's water resources.	**Policy PRC – 9.1:** The City shall require natural drainage flows be maintained in new development projects to the greatest extent feasible.
	Implementing Action Implementing Action PRC-9.1.a: Development Review As part of the development review process, the City will review individual projects to determine the setback requirements that will adequately buffer natural drainage corridors from development. The City will require that new development protect natural drainage corridors and other watercourses from the adverse effects of construction activities and urban runoff.
	Policy PRC- 9.2: The City shall periodically review the status of the City's groundwater resources.
	Implementing Action Implementing Action PRC-9.2.a: Water Resources Report The City will prepare a Water Resources bi-annual report to the City Council. This report, in part, will include an analysis of groundwater resources, including groundwater quality. The City will use this report to ensure groundwater resources are protected from contamination and overdraft. As part of the bi-annual Water Resources Report, the Public Works Department will analyze the quality of drinking water in the City. The City will encourage activities that maintain and improve drinking water quality.
	Policy PRC – 9.3: The City shall maintain its ability to meet its water supply requirements. Implementing Action PRC-9.3.a: Development Review As part of the development review process, the City will evaluate the incorporation of water conservation techniques in all new development.
	Implementing Action Implementing Action PRC-9.3.b: Development Impact Fees (see Implementing Action MFS-1.1.b).
	Policy PRC-9.4: The City shall encourage the use of treated wastewater and other non-potable water sources for irrigation and groundwater recharge.
	Implementing Actions Implementation Action PRC-9.4.a: Landscape Ordinance The City will adopt and implement a landscape ordinance, which will establish standards for water-conserving landscaping in order to reduce water use in developed areas. Requirements will specify the use of reclaimed water, trees, and other vegetation. This ordinance will be applied in the design and development of private and public development projects and will be consistent with the provisions of the General Plan. Implementation Action PRC-9.4.b: Interagency Coordination In cooperation with the Colusa County Water District, the City will identify and develop opportunities for reuse of non-potable water, including reclaimed water, for non-domestic uses.
Municipal Facilities	
Water System	
Goal MFS – 7: To maintain and enhance a water system that meets the needs of existing and future residents of Colusa.	**Policy MFS-7.1:** The City shall establish development standards and plans to ensure that the water treatment and delivery system is not unduly burdened by new development.
	Implementing Action Implementing Action MFS-7.1.c: Water Master Plan The City will prepare and implement a Water Master Plan to provide a framework for timed capital improvements and facility expansion projects. The plan will aid the City in identifying and establishing funding sources beyond monthly service charges to finance improvements related to water quality, supply, recycling, distribution, conservation, and other issue areas identified issue areas identified by the City and the plan. The plan will evaluate the depth, size, recharge rate, and capacity of the aquifer to accommodate the City's projected future growth. The plan will also make determinations regarding the need to develop additional water sources during the planning period of this General Plan.
	Policy MFS-7.2: To minimize the need for the development of new water sources and facilities and to minimize sewer treatment needs, the City shall promote water conservation in City operations and in private development. The City shall annually monitor water usage to assess the effectiveness of the water conservation program.
	Implementing Action MFS-7.2.a: Water Master Plan The City will implement a water conservation program, to be defined and incorporated in its Urban Water Management Plan, to be prepared with the Water System Master Plan. If groundwater levels decline and/or if the "moderate" program does not achieve its intended results, the City will implement the "aggressive" or "maximum" water conservation program as defined in the Water Management Plan.
	Policy MFS-7.3: The City shall, to the extent practical, require the use of drought-tolerant plant species and water efficient irrigation systems in the landscaping of new public and private open space areas, common areas, and parks.
	Implementing Action MFS-7.3.a: Development Review Through review of development projects, the City will condition development, where practical, on water conservation practices.
Stormwater Drainage System	
Goal MFS – 9: To provide adequate stormwater drainage for all existing and future development.	**Policy MFS-9.1:** The City shall ensure its stormwater drainage system is upgraded in phases to adequately accommodate drainage resulting from new development prior to project construction.
	Implementing Action Implementing Action MFS-9.1.a: Storm Drainage Master Plan The City will prepare and adopt a Storm Drainage Master Plan for Colusa. The Master Plan will identify drainage facilities that will be constructed to eliminate existing drainage problems and avoid future drainage problems in the City and describe the means for financing the improvements. The Storm Drainage Master Plan will be consistent with any Capital Improvement Program prepared by the City and address Regional Water Quality Control Board water quality standards, including Best Management Practices for storm drainage.

Table 4. Selected City of Williams General Plan Goals and Policies	
Goal or Objective	**Policy or Action**
Land Use and Character	
Achieving a Quality Community Character	
	Policy 3.27: The land use plan and zoning districts will address for the character of development, which accounts for the design/intensity of development, the arrangement of buildings and parking areas, and the preservation of open space. Actions **3.hh.** Establish minimum open space standards within each district, which may be used for storm water detention, resource protection (e.g. riparian buffers along streams), bufferyards, and/or parks, trails, and open space. The amount of private or common open space relates to the character of development. For instance, in the Agriculture and Estate Residential districts, there is a high proportion of private open space whereas the Suburban Residential and Urban Residential districts have increasing percentages of common (public or semipublic) open space. **3.jj**. Incorporate development options within each zoning district. Different lot sizes and percentages of open space maintain the district character while allowing market flexibility and adjustment to site conditions. In other words, a smaller lot may be used and clustered to set aside adequate open space to preserve agricultural resources, such as the orchards, or to fulfill the City's storm water management objectives. A comparable density and character is achieved.
Service Provision	
	Policy 3.41: The City's land use pattern shall focus new development and significant redevelopment where adequate public services and utility capacity are already in place or projected for improvement, including streets, water, wastewater, and drainage infrastructure.
Environmental Sensitivity, Resource Protection, and Flood Prevention	
	Policy 3.45: Sensitive resources, including floodplains, wetlands, riparian buffer areas along stream channels, and valued view sheds, will be protected and preserved. **Policy 3.50:.** The City will consider the location of natural resources to be used for groundwater recharge and stormwater management.
Public Safety	
Flood Protection	
	Policy 4.9: The design of drainage improvements will be sensitive to community aesthetics, aquatic habitat, recreation (trails, playing fields), wetlands, and water quality mitigation. **Policy 4.10:** The City will encourage design strategies to reduce the impact of impervious surfaces on storm water quality through the use of water gardens, rain barrels or cisterns, pervious pavement, vegetated swales, swale blocks, and green roofs, among others. Actions **4.d.** Maintain a Flood and Drainage Master Plan that addresses the following, at a minimum: • Storm water and drainage improvements for all sections of the City that are needed to accommodate planned growth; • Coordination with irrigation districts, the County and other affected flood control agencies to develop uniform standards for irrigation and storm water conveyance infrastructure; and • Standard measures used for new development to address localized flooding, such as measures to avoid off-site drainage impacts from adjacent agricultural operations. **4.e.** At the time the City reaches a size by which it is required to comply with Section 402(p) of the Federal Clean Water Act, prepare a Storm Water Management Plan (SWMP) to fulfill the requirements for improving the quality of storm water discharges from Small Municipal Separate Storm Sewer Systems (MS4) for Phase II municipalities. **4.f.** Begin identifying Best Management Practices (BMPs), particularly construction site storm water runoff control and post-construction storm water management, to reduce the discharge of pollutants to the storm water system. These should be integrated as standards into the City's subdivision regulations. **4.g.** Through improved land development practices and regulations, establish a hierarchy for managing storm water with the following priorities: minimize impervious surfaces, attenuate flows by use of open, vegetated swales and natural depressions and preserve existing natural stream channels, infiltrate runoff 3, provide storm water retention and then detention structures, provide velocity dissipation structures or channel design, and construct storm sewers. **4.m.** Investigate the feasibility of the alternatives outlined in the Preliminary Technical Memorandum for Flood Hazard Mitigation Study Project Alternatives. The structural alternatives include improving the conveyance capacity of Freshwater and Salt Creeks and the supporting network of drainage laterals, replacing bridge crossings to remove obstructions, constructing diversion dams to channel flows away from the City, constructing flood detention and multi-purpose flood retention reservoirs, constructing levees to the west and north of the City with removable floodwall sections, and elevating existing structures. The non-structural alternatives include land acquisition, cropland storage, channel restoration, upland re-vegetation, and improved maintenance of stream channels.

Table 4. Selected City of Williams General Plan Goals and Policies	
Goal or Objective	Policy or Action
Public Facilities	
Water, Wastewater, and Storm Drainage	
	Policy 5.1: The City of Williams will provide utilities concurrently with development. Actions **5.b.** Continue developing the City's Capital Improvement Program (CIP) to repair and replace aging and deteriorated sewer lines, which will improve the flow efficiency, reduce inflow and infiltration into the collection and treatment systems, and help to mitigate ground water impacts. **5.c.** Execute plans to install a new water well. **5.d.** Further develop plans for a second water storage tank. **5.e.** Amend the zoning ordinance to include ground water protection measures in site development standards. Include open space provisions in the density standards. **5.f.** Amend the subdivision ordinance to include ground water protection measures in future subdivisions. **5.g.** In accordance with AB 1881, the Water Conservation Landscape Act of 2006, develop water efficient landscaping standards for new development to include: • Requirements for specific species of plantings; • Prohibition of invasive species; • Submittal requirements for landscaping and irrigation plans (and requirement for both to be installed per approved plans); • Landscaping and hardscaping to be designed based on "hydrozone" specifications; • Provision for recirculating and recycling water systems; • Requirements for a soil report with recommendations regarding the most efficient types of planting and irrigation for the specific soil types existing on a site; • Specific "plant factors" in compliance with state standards for high, medium and low water using plantings; and • Irrigation to be designed according to hydrozone needs. **5.k.** Incorporate into City standards and specifications means for addressing storm water quality, including a first preference for nonstructure best management practices such as bioretention, vegetated swales and buffer strips, constructed wetlands, and other environmentally sensitive design and construction practices.
Open Space and Conservation	
Vegetation	
	Policy 7.24: Preference will be given to native and drought-tolerant plant species to reduce water consumption, minimize invasive species, and preserve the appearance of the natural landscape. Actions **7.zz** Consider provisions in the subdivision regulations may require riparian buffers around all naturally occurring water bodies and wetlands. The standards shall restrict septic systems within the buffer area and include requirements for planting indigenous plants and trees to enhance the buffer's absorption and filtering potential. 7.aaa Include the use of bio-swales and permanent water features for drainage management to reduce the volume and rate of stormwater runoff from new developments. 7.bbb Support green roofs on new developments as a method of stormwater mitigation, as well as reduction of the urban "heat island" effect. For new construction, the use of green roofs shall result in a reduction in the extent of stormwater facilities that need to be constructed to meet standards. 7.ccc The City will identify areas that may accommodate floodwater for the purposes of groundwater recharge and stormwater management.

Table 5. Selected City of Orland General Plan Goals and Policies	
Goal or Objective	**Policy or Action**
Safety Element	
Subsidence	
	Policy 4.6.C: Applications for projects that extract groundwater, oil, or gas shall include a report evaluating the potential for resulting subsidence. Reports shall discuss appropriate mitigation measures to reduce the potential for subsidence.
Open Space, Conservation, and Public Facilities Element	
Water Quality	
Goal 5.6: Conserve, enhance, and manage water resources, protect their quality, and ensure an adequate long-term supply of water for domestic, agricultural, industrial, and recreational use.	**Policy 5.6.A:** Ensure that new development complies with State and federal regulations and standards in order to maintain and improve water quality. Program 5.6.A.1: The City shall require applicants for new development projects to adhere to RWQCB discharge standards, including identifying specific measures for minimizing project related erosion and resulting siltation of surface water features. Programs Program 5.6.A.2: The City shall require that a grading and erosion control plan be submitted with each tentative parcel and tentative subdivision map prior to action by the City. Standard RWQCB best management practices (BMPs) shall be incorporated in these plans as a means to control runoff and minimize erosion impacts. Program 5.6.A.3: The City shall ensure that new development has a minimal impact on natural drainage channels and flow capacity. **Policy 5.6.B:** Reduce the potential for sediment and other pollutants to contaminate surface and ground water resources. Programs Program 5.6.B.1: Where feasible, the City shall maintain the natural condition of waterways and floodplains and protect watersheds to ensure adequate ground water recharge and water quality. Program 5.6.B.2: The City shall require that new development at a density greater than one unit per acre and commercial and industrial areas annexed to the City be connected to the City's wastewater collection system. Existing residential development and individual homes where septic systems have failed also may be connected to the system. Program 5.6.B.3: The City shall review City standards for drainage structures and, if determined appropriate, adopt requirements for grease and sediment traps for roads and parking lots to improve water quality of urban runoff. **Policy 5.6.C:** Explore the use of pervious concrete/pavement to allow the continued filtration of groundwater into the soil. **Policy 5.6.D:** Encourage the use of site design techniques for non-residential uses that provide for the discharge of on-site stormwater into landscaped basins or swales prior to discharge to the City's storm drainage system. **Policy 5.6.E:** Encourage water conservation as a means of conserving not only water but also minimizing energy consumption and costs associated with pumping and delivery systems.
Water Supply	
Goal 5.7: Protect the quantity and quality of community water supplies	**Policy 5.7.A:** Ensure that groundwater resources in the vicinity of Orland are protected from contamination. Programs Program 5.7.A.1: The City shall require wells located on land annexed to the City and served by City water service to be properly abandoned or all possibility of cross connection with the City water system eliminated in accordance with Glenn County Health Department guidelines. Program 5.7.A.2: The City shall ensure that all City wells are operated and maintained to meet California Department of Health Services standards for public drinking water supplies. **Policy 5.7.B:** Avoid the wasteful use of water within the planning area. Program 5.7.B.1: The City shall promote the use of water-conserving devices and practices in both new construction and major alterations and additions to existing buildings.
Stormwater Drainage System	
Goal 5.9: Provide for the collection, transport, and stormwater in a safe manner to protect people and property from damage arising from storm drainage.	**Policy 5.9.A:** Require new development to ensure that the cumulative rate of peak runoff does not exceed pre-development levels. Programs Program 5.9.A.1: New development and redevelopment of existing sites should provide storm water detention or retention facilities (on- or offsite), if necessary, to prevent flooding due to runoff or where existing storm drainage facilities are unable to accommodate increased storm water drainage. Program 5.9.A.2: The City shall review and revise its Zoning and Subdivision Ordinances, as needed, to incorporate specific data and design requirements related to stormwater drainage that are contained in this general plan. Program 5.9.A.3: The City shall complete its Storm Drainage Master Plan. **Policy 5.9.B:** Minimize the potential for flood damage to buildings and other structures, particularly from storm water runoff. Programs Program 5.9.B.1: The City shall explore the use of pervious concrete and pavement to assist in the return of water to the regional aquifer and to assist in the management of storm drainage. Program 5.9.B.2: The City shall encourage the use of landscaped bioswales to filter oil and other pollutants from stormwater drainage. Program 5.9.B.3: The City shall consider the use of filtered storm drainage inlets to screen pollutants from drainage waters.

Table 6. Selected City of Willows General Plan Goals and Policies	
Goal	**Objective, Policy or Implementation**
Land Use Element	
Development	
DPS-1 Goal: Accommodate and plan for new growth.	Objective: During the life of this plan, maintain flexibility and responsiveness to the changing conditions and opportunities for development. Policy: The City should only approve development proposals that are consistent with this plan.
Community Services, Facilities, and Infrastructure	
DPS-4 Goal: Adequate community services, facilities, and infrastructure.	Objective: Maintain existing services, facilities, and infrastructure, and provide for expansion, extension, or upgrades to meet the needs of new development without adversely impacting existing levels of service or the revenues required to provide them. Policy: Before approving a development proposal, the City should determine through the California Environmental Quality Act (CEQA) process that a proposed project will not adversely impact existing community services, facilities, and infrastructure The City Council should determine that revenues are, or will be, available to maintain and/or expand, extend, or upgrade services related to new development.
High Groundwater	
DPS-13 Goal: Protect water quality.	Objective: Prevent septic system failure and ground water contamination in high groundwater areas. Policy: The City Council should only approve projects in the high ground water areas that will be served by city sewers.

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Appendix 2B

Comment Tracking System and Comment Availability

2B-1: Comment Tracking System and Table

2B-2: Letters

2B-3: Emails

2B-4: Projects and Management Actions Submittal Forms

2B-5: GSP Chapter Input Submittal Forms

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2B-1. Comment Tracking System and Table

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Colusa Subbasin Groundwater Sustainability Plan
Development Outreach Comment Tracking Table - General Input
Last Revised: December 2, 2021

Comments with an * have been abridged. The entirety of this input including any reference documents provided may be found under the hyperlink.
Comment Categories: General Input, Comment, Question, Request, Suggestion, Clarification.

#	Date Submitted	Commenter Name (if available)	Commenter Organization (if applicable)	Venue Received	Subject	Comment	Link to Full Comment/ Reference Materials (if applicable)	Categorized Comment	Response Needed
1	7/6/2020	Ben King	Land Owner	Email	Connate Water	My concern is that the connate seawater under the Sutter Buttes is contaminating groundwater and drinking water quality….My suggestion would be to pick up where the SWRCB left off in 1952 and examine salt water and arsenic levels within a 15 mile circumference around the Buttes and set up a monitoring network to monitor changes in ground water quality going forward. This would not only focus on the southern part of the Buttes but within the whole circumference.*	https://app.box.com/s/auy1v5yuwgoesm5dttz489jg41r7zl5b	General Input	Response included in Administrative Record Files
2	8/9/2019	Brian Cahill	Land Owner		Projects	While there will be private landowner sites for groundwater recharge ponds, private sites would be most effective if they augment a public effort by Colusa county to revamp road crossing drainage culverts such that storm flows are re directed to intermittent streams like Salt creek via trenching the side road ditches. At present, the road culverts facilitate storm flows crossing the public road (necessary) but because there is no attempt to re-direct the storm flows the volumes accumulate such that the volumes arriving on private property are difficult to manage.		General Input	Comments will be logged for consideration when the PMAs portion of the GSP is being developed. Will need to coordinate also with land use entities.
3	10/20/2020	Ben King	Land Owner	Email	Water Quality	I want to highlight the C 14 dating results and trace metal contamination levels for IASC 21 generally. See the Tables for IASC 21 at the end of the Report. (Referencing USGS Middle Sacramento Valley 2006 Water Quality Report)...Perhaps we can work with the USGS to expand its network around the Sutter Buttes. Even if we get USGS testing every 10 years that may be enough to detect water quality trends. We just need a baseline because this may be 100 year issues. My concern is how the increased pumping to support permanent crops may effect the lateral and upward movement of natural contaminants. I think that recharge probably can mitigate this and may have contained the issue before the levees were built. With recharge we can tactically simulate some of the the natural benefits of the historical benefits of flooding in the Sacramento Valley while benefiting from the State's investment in flood control and reclamation.*	https://app.box.com/s/45i9kz30hb3ci2qxah7r66dgrvi8s0iy	General Input	Response included in Administrative Record Files

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Comment Categories: General Input, Comment, Question, Request, Suggestion, Clarification.

#	Date Submitted	Commenter Name (if available)	Commenter Organization (if applicable)	Venue Received	Subject	Comment	Link to Full Comment/ Reference Materials (if applicable)	Categorized Comment	Response Needed
4	11/18/2019	Ben King	Land Owner	Email	Water Quality	I am concerned about the potential for further later movement of the salt water northward towards the Butte Sink that may be cause by future groundwater substitution on east side of the Sacramento River near Colusa. As you know Colusa, Grimes, Sutter and Meridian use groundwater. The other issue that came to my mind was the potential for further deterioration due to future earthquake activity. Perhaps – this area might be a good candidate for an Aerial mapping if the mapping could detect higher chloride levels in the groundwater? References: SWRCB Bulletin #6 (1952), Hydrogeology of the Sutter Basin (George Curtin 1920), USGS Geochemistry of groundwater in the Sacramento Valley (1984), USGS Late Cenozoic Tectonism of the Sacramento Valley (1987) *	https://app.box.com/s/7l3fswdsa97yzxm84zjdnwylf18jze29	General Input	Response included in Administrative Record Files
5	12/9/2020	Ben King	Land Owner	Email	Water Quality	I want to make the point that the current law is that the SWRCB will curtail Sacramento River and Sacramento River tributary diversions during critically dry years. This is the legal status quo after the 2015 year drought and the curtailments should be included in the Water Budget. The reason I am making this point is the recent decision regarding diversions from Deer Creek during the 2014/15 drought.This litigation was appealed to the California Appellate court which confirms the current power to curtail water supplies for the Colusa Basin. The California Supreme Court declined to review the Appellate Courts decision on September 23, 2020. I have attached the Appellate Court decision confirming existing law and current limitations of surface water supplies for the Colusa Basin. Just to reiterate the current law gives the SWRCB to enforce the current instream minimums under the Bay Delta Plan. Any voluntary settlement that may be less restrictive is speculative and does not represent the in stream requirements currently enforced.		General Input	
6	12/9/2020	Member of the Public	N/A	Public Meeting	Aquifer Depths	Has the consultant team ground-truthed the freshwater aquifer depths across the basin? Due to the seawater aquifer under the subbasin's groundwater system, these depths are an important consideration. The interplay between the two has resulted in areas where there are no wells due to water quality being impacted by the saltwater.		Question	Answer provided in 12/09 public meeting. See meeting summary for full response.
7	12/9/2020	Ben King	Land Owner	Public Meeting	Water Quality	I am concerned about drinking water quality and availability in Colusa county including arsenic contamination.*	https://app.box.com/s/xf8ke3p5morjfcmy870xays1lignnzwp	General Input	
8	12/9/2020	Ben King	Land Owner	Email	Subsidence	I would suggest that our most critical infrastructure is the transportation infrastructure of I-5 and the residential infrastructure of Arbuckle including the Arbuckle cemetery. The cemetery is very close to the greatest level of subsidence and I -5 crosses adjacent to the area of greatest subsidence. I believe we have to look at the potential for multi-feet subsidence over decades and we need to look at the subsidence potential in the context of historical events. *	https://app.box.com/s/jgjdb714deysi7rn3ofevevelu7egu8v	General Input	

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Comment Categories: General Input, Comment, Question, Request, Suggestion, Clarification.

#	Date Submitted	Commenter Name (if available)	Commenter Organization (if applicable)	Venue Received	Subject	Comment	Link to Full Comment/ Reference Materials (if applicable)	Categorized Comment	Response Needed
9	12/9/2020	Member of the Public	N/A	Public Meeting	Funding	What type of studies might be done with Proposition 68 funds?		Question	Answer provided in 12/09 public meeting. See meeting summary for full response.
10	12/9/2020	Member of the Public	N/A	Public Meeting	Water Supply	Under the Bay-Delta Plan, aren't we going to have only 40-50% of the surface water we had in the past? Have you tracked how much water we lose from the basin through water transfers? How much do we pump for groundwater substitution? These do not appear to be included in the budget.		Question	Answer provided in 12/09 public meeting. See meeting summary for full response.
11	12/9/2020	Member of the Public	N/A	Public Meeting	Water Supply	Do models show any significant variation in storage in some parts of the subbasin compared to others, and if so, would some areas have more issues than others?		Question	Answer provided in 12/09 public meeting. See meeting summary for full response.
12	12/9/2020	Member of the Public	N/A	Public Meeting	Water Budgets	Have zone water budgets been created at this point for sub areas of the basin and if not, are they are planned?		Question	Answer provided in 12/09 public meeting. See meeting summary for full response.
13	12/9/2020	Leslie Nerli	GGA Board Member Alternate	Public Meeting	Thresholds	Since conditions vary between wet years and dry years, will you take into account dry years vs wet years when setting thresholds? Can you set multiple thresholds?		Question	Answer provided in 12/09 public meeting. See meeting summary for full response.
14	12/9/2020	Member of the Public	N/A	Public Meeting	Water Supply and Quality	The residents in Colusa County rely on groundwater for drinking water. The County faces issues around water availability, such as when domestic wells run dry in critically dry years as a result of competition with agricultural use. Domestic use should be the priority and that use should grow in a reasonable way. Colusa County also faces issues around maintaining groundwater quality in critically dry years. The U.S. Environmental Protection Agency standard for arsenic is ten parts per million, and there are areas that exceed that. This issue will continue due to the connate water coming out of Sutter Buttes and can't be mitigated. In the future, Colusa County may need water from the Sacramento River, which is very expensive, but may be a good investment.		General Input	

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15	12/9/2020	Member of the Public	N/A	Public Meeting	Sites Project	Regarding his concerns about the Sites Reservoir project and the proposed interconnect between the Tehama-Colusa Canal and Colusa Basin Drain, the speaker stated that this project should be in Colusa County, because Sites Reservoir is in Colusa, and it needs to promote safe drinking water supply in Williams and Arbuckle. It should be close to Williams and Arbuckle. The Tehama-Colusa Canal jags southeast of Arbuckle. One of the closest distances between the canal and drain is south of Arbuckle. The County needs to push for the interconnect to be in Colusa County.		General Input	
16	12/10/2020	Member of the Public	N/A	Public Meeting	Groundwater Dependent Ecosystems	The Nature Conservancy (TNC) cuts off groundwater dependent ecosystems at a depth of 30 feet. However, the U.S. Department of Agriculture notes that Valley Oak groves can tap into groundwater as deep as 80 feet and are groundwater dependent. Thus, the GSP should take into consideration that Valley Oak woodlands may be tapping deeper than the TNC guidelines suggest. This information has also been presented to the Butte County Department of Water and Resource Conservation and should be shared in the upcoming Interbasin Coordination Group meeting.		General Input	
17	12/10/2020	Member of the Public	N/A	Public Meeting	Interbasin Coordination	There have been discrepancies between basin setting and water budget reports during the initial stages of groundwater sustainability planning. The Interbasin Coordination Group stated in their December 1st meeting agenda that they would review compiled data, identify significant differences, and discuss potential ways to reconcile those differences. Has there been an update? For example, is there an update on reconciling the discrepancies from the various water models used, since consistency is critical to the foundation of groundwater planning.		Question	Answer provided in 12/10 public meeting. See meeting summary for full response.
18	12/10/2020	Member of the Public	N/A	Public Meeting	Groundwater Dependent Ecosystems	Was the map on groundwater ecosystem also based on soil mapping based on the lines along with west side of the basin?		Question	Answer provided in 12/10 public meeting. See meeting summary for full response.
19	12/10/2020	Member of the Public	N/A	Public Meeting	Subbasin Mapping	Are the 38 subareas tools for data collection for management of the whole basin or 38 separate Management Areas?		Question	Answer provided in 12/10 public meeting. See meeting summary for full response.
20	12/10/2020	Member of the Public	N/A	Public Meeting	SGMA	Are other regions in the state where the State of California has taken over the monitoring--the thing we are trying to avoid?		Question	Answer provided in 12/10 public meeting. See meeting summary for full response.

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21	12/10/2020	Mathew E. Jones	T&P Farms	Email	Subbasin Mapping	In regards to the 38 subbasins, how can we access the interactive mapping for these? How were they determined etc.*	https://app.box.com/s/c4xl3rj9tdsfpr4ailf91gnp5ta90tz8	Question	Byron Clark followed up directly with Mathew Jones
22	12/10/2020	Mathew E. Jones	T&P Farms	Email	Recharge	Recharge was touched upon in the public meeting. I did not see or hear discussion regarding banking of in-lieu or recharged water within the basin. I am sure it would be a minimal amount, but may think about using within the water budget. Is banking being addressed in the GSP? *	https://app.box.com/s/c4xl3rj9tdsfpr4ailf91gnp5ta90tz8	Question	Byron Clark followed up directly with Mathew Jones
23	12/10/2020	Antionette Marsh	N/A	Public Meeting	Groundwater Dependent Ecosystems	Was the map on groundwater exosystem also based on soil mapping? Based on the lines along the West side?		Question	Answer provided in 12/10 public meeting. See meeting summary for full response.
24	12/17/2020	Karen Biane	"Stakeholder" in the Glenn County subwatershed basin	Email	Outreach Approach	I have attached a memo outlining my commentary on specific areas about the presentations and plans. I am aware of the incredible complexity and challenges the planning and implementation of the program will involve. The ideas presented are designed to potentially improve the communications to, and understanding by, the water community. *	https://app.box.com/s/8gnkuuq4xnuznj5e13cjxv028xjlkdxa	General Input	
25	12/17/2020	Sharon Wiggin	N/A	Email	General Input	One of our concerns is on Sand Creek. 50 years ago, that Creek spread out very wide and we believe that gave us recharge for out underground runs very fast. We can't do anything about it because of the California Department of Fish and Wildlife. They will allow some low berms as long as one side has no berm. This isn't much help.		General Input	
26	1/12/2021	Mathew E. Jones	T&P Farms	Email	Management Areas	Wanted to follow up regarding "management areas". It is a tough discussion and should include laying out the facts regarding areas of concern. I vague statement regarding an area does not do anybody justice and leads to speculation and possibly inaccurate conclusions. The attached maps paint a clearer picture of "areas" of concern, but more importantly it emphasizes how our basin is interconnected and impacts of "areas" not within the "management areas"? I would also like to follow up regarding recharge and banking. I am trying to get an understanding of how it will play a roll in the GSP or if it will be addressed within the GSP.*	https://app.box.com/s/c4xl3rj9tdsfpr4ailf91gnp5ta90tz8	General Input	

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27	2/2/2021	Ben King	Land Owner	Email	Geographical Features	I believe that it is important to have the correct location of the Willows Fault regarding the proximity of the Fault to the City of Colusa. As you will see in the attached Figure 7 from the Sutter County GMP it looks like a wishbone like structure near the City with one fork trending south east away from the City on the east side of the Sacramento River and another fork on the west side of the River nearer to the City trending more in a north south direction... The reason I think it is important to get the best information on this fork in the Willows Fault is the potential for the movement of arsenic contamination along the Willows Fault from the desorption of arsenic from the metal and iron oxides in the volcanic rock of the Sutter Buttes. So far the public water supply for the City does not seem to be contaminated but the location of this fork may be problematic for the future risk profile. *	https://app.box.com/s/lan700issfbfqeis565rjz6caxrarzqj	General Input	
28	2/8/2021	Ben King	Land Owner	Email	Geographical Features	The location of the Willows Fault appears to have a fork north of the Colusa State Park and ironically appears to run under the Colusa County Courthouse. I have included three photos from the link. https://maps.conservation.ca.gov/cgs/fam/app/ I believe this is a different location than set out in the Geologic Figure in the HCM. It seems to be very close to the City of Princeton and the Colusa Rancheria. It actually runs through Colusa and towards Grimes and Meridian along Hwy 20. As I mentioned before I wanted to raise the issue of the Fault as the mechanism whereby the arsenic and seawater contamination from the Sutter Buttes may be translocating.*	https://app.box.com/s/k6l7gg1slg0qhv23gx343pafk3tx0o8j	General Input	
29	2/27/2021	Ben King	Land Owner	Email	Maps	I wanted to point out that there are two different versions of the Presentation for the 2/17/21 on the CGA Website*	https://app.box.com/s/s0wz3qrux0gvolnabxdkn97h9u4uloyd	Clarification	
30	2/28/2021	Ben King	Land Owner	Email	Water Quality	I was finally able to get access to Stephen Springhorn's paper on the Sutter Buttes Rampart.I want to make sure that Mr. Clark and Mr. Loy are aware of his recommendations and concerns as they draft the Basin Setting for the Colusa Basin especially in light of the work highlighted in a recent USGS Paper on arsenic contamination.*	https://app.box.com/s/fw2ie13mxvwqctb5zw9i0n29isg5wszx	General Input	

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31	4/8/2021	William Vanderwaal	RD 208	Email	Hydrographs	Jim Wallace, Derrick Strain, Lewis Bair, Hilary Reinhard and I looked through these last week and we had some questions. We really like and appreciate the Google Earth set up. There are two potential controlling factors that determine the MT. Please label which controlling feature it is that controls for each well. I see from a cursory look at the package for the upcoming meeting that you've included MO's but we noted on these there were not MO's. We would like to see the MT/MO compared with the historical well data. We requested and appreciate seeing these compared to the model runs but also want to see how they compare to actual historical. Some MT's seem extremely deep on the initial look. It would be helpful to also see the number of wells per polygon for each well. That would help us understand the magnitude of wells that could be impacted if the controlling feature is the 20% of domestic wells criteria. I've attached a screen shot of what Yolo has provided in the past that shows domestic well density as an example of what could be helpful. We have some questions about the water budgets (we were looking through those also). We noticed in CCWD, that the change in storage and the net recharge numbers don't seem to align with what we'd expect. For example, change in storage increases in 'Dry' years, but decreases in 'BN' and 'Critical' years. Also, net recharge is greater (or less extreme) in 'Dry' vs 'BN'. Is there any known explanation for that? Also, this doesn't just occur in CCWD, we're not picking on them, it's just where we noticed it first.*	https://app.box.com/s/jq7totuwt0sxxb9l1fu9ccinrlgbwnrj	Request	
32	3/20/2021	Ben King	Land Owner	Email	Subarea Water Budgets	Can I get a map of all the model subarea in the Colusa County portion of the Colusa Basin? Also – Does the example on Page 24 tie into real numbers? The numbers and graph on the left side of Page 24 seem different than the graphs on Page 20 for example? Could I get the data tables for Subareas CDMWC and COLGWE? Thanks for your assistance. *	https://app.box.com/s/phbj56zzpmzf0ife7zmnpdeb6arksi6d	Request	

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33	4/12/2021	Donald Bills	USGS	Email	Subsidence	A couple of points were made during the discussion on subsidence in the TAC meeting on Friday April 9th. I had comments to add to the discussion but was having difficulty with an unstable ZOOM connection and was unable to contribute. Please feel free to pass this on to however is most appropriate. The points I wanted to comment on are: 1.—Subsidence in the regional aquifer is mostly going to be due to dewatering of clays. Little subsidence occurs related to dewatering of sand and gravels. 2.—Subsidence is largely a surface problem. 3.—There is a significant lag time between groundwater withdrawals and subsidence. 4.—What is critical infrastructure? 5.—Surveyed subsidence monuments every 5 years is not enough. *	https://app.box.com/s/zmjnrgcy6lsfag9wrh7eoo7bc134swpw	General Input	
34	4/26/2021	Donald Bills	USGS	Email	Invasive Phreatophytes	As I was thinking about evasive phreatophytes that could result in a significant GW savings, eucalyptus occurred to me. They were imported to California from Australia as a source of wood for RR ties in the mid to late 1880's before anyone realized that the wood splits easily. Since then, they have become obliquitous in the state. The tree has an extensive root structure that is capable of reaching 50 ft or more to access groundwater. I was hesitant to suggest this during the meeting because I did not know if it had been addressed in the past, or who I should suggest it to for further consideration. As with my comments on land subsidence, if you could pass it on, or not, as appropriate.		General Input	
35	7/2/2021	Jim Wallace			Data	Not sure if your challenge getting transfer data from reclamation is intentional or not, but a clear and complete picture of the water dynamics affecting the basin is a fundamental requirement to successful management. We can't manage what we don't understand. So ultimately, the business of water transfers, both inside and outside the basin, has to be transparent and well understood by the CGA. Gathering that data directly from USBR(as opposed to trying to collect from 33 separate districts/agencies) seems the most efficient way to do this. Perhaps a conference call with USBR that includes some CGA staff or board member to inquire how the CGA might best organize a formal request to gather this this information would help your efforts. Ultimately, a FOIA request might be necessary, but hopefully, USBR staff will be responsive to a reasonable request for the information relevant to the CGA's responsibilities.		Suggestion	Responded to by email Wednesday, July 7, 2021 8:02 AM

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36	7/2/2021	Jim Wallace			Baseline	I am not sure what kinds of practices or processes you have considered for capturing data and quantifying a recharge project, but establishing a baseline seems like it will be an important part of the process. A typical CDMWC shareholder, for example, uses a mix of well water and surface water in any given year. Once implemented should a recharge project consider all of the surface water diverted to be in-lieu recharge or only that portion in excess of some historical baseline diversion?		Question	Responded to by email Wednesday, July 7, 2021 8:02 AM
37	7/2/2021	Jim Wallace			Legal	I have read and re-read a few times the December 18, 2020 memo directed to the Vina GSA from its Administrator, Paul Gosselin, and Legal Counsel, Valerie Kincaid that was circulated during a recent CGA TAC meeting. Admittedly, there is much in this memo that I do not yet fully understand. But what is clear, is that recharge projects will potentially have legal implications that affect stakeholders across the sub-basin and that we (CGA) should consider these implications as part of our project development. I attached this memo here in case you have not yet seen it. I would be interested in a meeting with CGA counsel to review this memo (or perhaps a white paper of our counsels own origination) to better understand these issues and then discuss potential policies and priorities that CGA should consider to address these issues.		Request	Responded to by email Wednesday, July 7, 2021 8:02 AM
38	7/29/2021	Ben King	Land Owner	Public Meeting	PMAs	Ben King asks for clarification on process of approving PMAs. He also wants to know what it means when an action was recommended by the board. Response: This will be addressed in the next section of the presentation.		Question	Answer provided at the 7/29/2021 meeting. See comment section.
39	7/29/2021	Ben King	Land Owner	Public Meeting	PMAs	Ben King's question on the status of public approval and if the SMCs/PMAs been vetted through the TAC or had an approval process. Response: Presentations on the PMAs were presented to the Joint TAC along the way, but the full list of 33 PMAs were not formally approved by the TAC		Question	Answer provided at the 7/29/2021 meeting. See comment section.
40	7/29/2021	Ben King	N/A	Public Meeting	PMAs	Ben King would like to know who ranked the PMAs. Response: Lisa Hunter commented that they aren't ranked, but the top five are included because they are in process and ready to go. The ones that are in planning stage are in the next tier. Mary Fahey added that the PMA submittal process was very open and transparent and that projects are accepted on an ongoing basis. Ben King wanted there to be a TAC discussion for ranking, and including more PMAs possibly, as well as a process in place for adding and ranking them.		Question	Answer provided at the 7/29/2021 meeting. See comment section.

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41	7/29/2021	Joe Carancho	N/A	Public Meeting	TAC	Joe Carancho wanted transparency in who is on the TAC committee and what decisions they are making. Response: Dave Ceppos responded that TAC members are listed on the websites. Thirteen TAC Meetings were held and publicly noticed, and the PMA list is available in the matrix within the PMA chapter.		General Input	Answer provided at the 7/29/2021 meeting. See comment section.
42	7/29/2021	Joe Carancho	N/A	Public Meeting	PMAs	Joe Carancho wanted more ideas for PMAs from local farmers and ranchers. Response: John Amaro let him know that people on the TAC and GSA Boards are local and any decisions the TAC makes have to be approved by the full board. This led to introductions of board and TAC members who were present to show they were local and involved in agriculture/local activities.		General Input	Answer provided at the 7/29/2021 meeting. See comment section.
43	7/29/2021	Darrin Williams	N/A	Public Meeting	MTs	Darrin Williams asks about the timing for MTs. Stating that there is a two-year period before we reach an UR. He asks when the two-year period starts – is it on January 31, 2022 or has it already started? Response: Grant Davids and Ken Loy clarified that the two-year period would only start when 25% of the wells get below the MT. Darrin Williams is concerned that some MTs for some of the wells may be something we will reach too quickly.		Question	Answer provided at the 7/29/2021 meeting. See comment section.
44	7/29/2021	Lester Messina	N/A	Public Meeting	Slide 16	Lester Messina asks a question about the hydrograph on Slide 16. Are there any wells in the monitoring network that stopped being monitored in the 2015 drought, and will they be monitored in 2022? Response: Ken Loy said there are one or two wells in the current monitoring network that have not had recent measurements and he is not sure why. They will be reviewed		Question	Answer provided at the 7/29/2021 meeting. See comment section.
45	7/29/2021	Sharon Ellis	Land Owner	Public Meeting	Well Monitoring Network	Sharon Ellis asks who is responsible for monitoring the 48 wells in the Monitoring network. Response: Ken Loy responded that the GSAs are making use of existing monitoring wells and DWR currently does the monitoring.		Question	Answer provided at the 7/29/2021 meeting. See comment section.
46	7/29/2021	Sharon Ellis	Land Owner	Public Meeting	Undesirable Results	**Sharon Ellis** asks who is in charge of alerting DWR if we are experiencing UR, is it the County? Response: Ken Loy responded that the Groundwater Authorities will take the monitoring data and prepare annual and 5-year reports to DWR.		Question	Answer provided at the 7/29/2021 meeting. See comment section.

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47	7/29/2021	Sharon Ellis	Land Owner	Public Meeting	Dry Wells	Sharon Ellis expresses concern over dry wells on her property and drying of Stony Creek. She asks who to notify or who will address these concerns. She and Emil Cavagnolo discuss why people chose to use groundwater instead of surface water in a dry year. There is then a discussion of GSAs and the fact that they are the regulatory agency that has authority to take action. Sharon is implying that locally we are already experiencing UR.		General Input	Answer provided at the 7/29/2021 meeting. See comment section.
48	7/29/2021	Joe Carancho	N/A	Public Meeting	General Input	Joe Carancho mentions that farmers shouldn't be told how to farm. John Amaro comments that we have a fine line to walk to work locally to keep the management local.		General Input	Answer provided at the 7/29/2021 meeting. See comment section.
49	7/29/2021	Member of the Public	N/A	Public Meeting	GSP	Unknown person asks if we have to wait for the GSP to pass before taking action and moving forward with actions. He also asks who will police actions that will be needed if we fall below MTs. Does GSA have authority to place usage restrictions, etc.? Response: Darrin Williams responded that there can be self-regulation through the GSA and there should be regulation before MTs are reached. The goal is to operate at the MO. "SGMA has very few 'shalls', and very many 'mays'".		Question	Answer provided at the 7/29/2021 meeting. See comment section.
50	7/29/2021	Ben King	Land Owner	Public Meeting	General Input	Ben King mentions that the PMA section needs to be scrutinized as the Demand Management PMA will affect income and jobs in Colusa and Glenn County. He mentions the tomato subsidy to manage land and therefore use less water. Response: Grant Davids responded that there are 2 demand management actions in the Plan, but they are not preferred. In the end, it is one of the tools in the tool box that the GSAs can pull from as situations warrant actions. Just because it is in the toolbox does not mean it will be used. Discussion followed that Demand Management isn't the first choice for our area.		General Input	Answer provided at the 7/29/2021 meeting. See comment section.
51	7/29/2021	Member of the Public	N/A	Public Meeting	Surface Water Use	**Unknown person** addressed Emil Cavagnolo and asks if the GSAs have the power to have people use surface water to the extent its available before pumping? And can the price of the water be subsidized? Response: **Emil Cavagnolo** mentions that his district already works to lower surface water costs and make it more enticing to use it first. Discussion follows that surface water absolutely has to be used first to allow for recharge along with additional recharge projects. It was answered that a GSA can build incentive programs into it to encourage surface water, and use all available surface water.		Question	Answer provided at the 7/29/2021 meeting. See comment section.

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52	7/29/2021	Member of the Public	N/A	Public Meeting	Surface Water Cost	Unknown person asked how to reduce surface water costs? And how to keep discrepancies between districts low? Emil Cavagnolo offers an explanation of where Orland-Artois Water District comes from and how expensive transferred water is, as well as how different districts have access to different water.		Question	Answer provided at the 7/29/2021 meeting. See comment section.
53	7/29/2021	Sharon Ellis	Land Owner	Public Meeting	Undesirable Results	Sharon Ellis asks to address her original question. If we get significant UR who is responsible? Response: Ken Loy described how a landowner would want to communicate with your GSA board member and they would make sure DWR has the most up to date data. Emil Cavagnolo pointed out that there is a monitoring well near Sharon's house and she can see that data.		Question	Answer provided at the 7/29/2021 meeting. See comment section.
54	7/29/2021	Ben King	Land Owner	Public Meeting	Recharge	**Ben King** asks if the board would consider giving incentives for people participating in recharge.		Question	N/A
55	7/29/2021	Darrin Williams	N/A	Public Meeting	General Input	Darrin Williams comments that he is happy to see new people at the meeting. We are really fortunate that we are in this subbasin and that we have had dry years since 2015 but aren't terribly bad off. He is positive about the projects on the horizon and the future. He states that using 100% of available surface water needs to be at the top of the list to protect groundwater.		Comment	Answer provided at the 7/28/2021 meeting. See comment section.
56	7/28/2021	Pete Carr		Virtual Public Meeting	Table 5.1	Pete Carr noted that Chapter five describes the methodology of how those minimum thresholds are established, but the practical result then as illustrated by the sample monitoring well hydro graph in figure five dash one shows that well levels can at least this well, I will could get all the way down to 208 feet before it exceeds the minimum threshold, so that would suggest unless i'm misunderstanding this that a domestic well or municipal well that's a 200 feet is still acceptable and not considered unreasonable, in other words, I mean 200 feet would run most domestic wells and half of our municipal wells dry and yet that's not exceeding the threshold I don't understand how that could be. Response: Ken Loy responded that the minimum thresholds are not like the example that we showed that's just for that specific well. Each one of the 48 representative monitoring network wells has its own on site specific minimum threshold and measurable objective.		Question	Answer provided at the 7/28/2021 meeting. See comment section.

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57	7/28/2021	Member of the Public		Virtual Public Meeting		In the PMA you have a couple of these that are predicated on having an available surface water, and it was even brought into the equation that you have it tough to have the economics for the surface water. is maybe, as are more affordable than the groundwater and so when you bring this into the equation, knowing that it's outside of the base and where those economics are established i'm just wondering how that works. Response: Grant Davids responded that there are some entities with surplus water at times. Under the settlement contracts and some surplus project water and philosophically they might be predisposed to keeping that water in the sub basin for for local benefit rather than letting it go out but. Others, maybe not so much. I can't tell you how it's going to play out, but I think it comes down to negotiation and it depends kind of on the philosophy of the folks with the available surface water. Jeff Sutton added that project water held by the settlement contractors is only available for sale pursuant to section 3405 within the area of origin, so that water is not available to be sold outside of basin.		Question	Answer provided at the 7/28/2021 meeting. See comment section.
58	7/28/2021	H Brich		Virtual Public Meeting		H. Birch asked in the chat: You mentioned groundwater's impact on ecosystems, but can we say more specifically that groundwater is impacting forests, and that (lack of) groundwater is a contributing cause to the increased numbers and intensity of fires in CA? Response: Ken Loy responded that forests are not in the bounds of the ground water basin and to the extent that there are plants that are groundwater dependent that is something that we do look at, and we look at the routing depth of those plants that are generally along the riparian corridors of the sacramento river and other streams in the groundwater basin not up in the foothills that are you know up in the in the Highlands that are part of the counties that's those areas are not part of of the groundwater basin as defined by the Sigma regulations.		Question	Answer provided at the 7/28/2021 meeting. See comment section.

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59	7/28/2021	Scott Bradford		Virtual Public Meeting		Scott asked in the chat: Please briefly discuss the water balance. What are the present values of groundwater outputs to inputs? How long will the proposed recharge projects take to bring groundwater into balance? Will recharge projects have adverse impacts on groundwater quality? Response: Grant Davids responded You know the the system is going to be fairly well unbalanced, meaning that there's no large negative or positive change in groundwater storage. 01:40:35So that's what we think about the future, you know, in the near term or in the present we've got and looking backward in time we've got. 01:40:43Obviously, declining groundwater levels in a couple of areas within the sub base and even more generally throughout the seven days in which we feel is primarily a consequence of drought. 01:40:54And then the extension of that would be that you know if drought debates and we get some good water years back on the books that the groundwater levels would recover.		Question	Answer provided at the 7/28/2021 meeting. See comment section.
60	7/28/2021	Arne Gustafson		Virtual Public Meeting		It sounds as if the management of issues that arise but don't yet meet the standards of Undesirable Results is critical to the success of SGMA. Can you speak a little more specifically to how those activities will be addressed? Response: Grant Davids responded that how you balance that and where you begin to take action, all depends on decision making and policies at the board level and let them know what you think.		Question	Answer provided at the 7/28/2021 meeting. See comment section.
61	7/28/2021	Pete Carr		Virtual Public Meeting		Pete asked in the chat: Plan is based on an assumption of 26-140 maf of underground aquifer volume, and that this has only been depleted 5% in recent years. How confident are we that at least 26 maf actually exists? How stable and reliable is this data? Response: Ken Loy responded the best place to go for the that water budget information is in chapter three of the groundwater sustainability, where the plan authors talk about the water budget which is really a flux, it changes its water moving through the system it's not a static number.		Question	Answer provided at the 7/28/2021 meeting. See comment section.
62	7/28/2021	Pete Carr		Virtual Public Meeting		Pete asked in the chat: 1/2 foot per year of subsidence may be acceptable out in the county, but even a couple of inches in a year could/would be devastating to municipal services like sewer, water and storm drainage underground infrastructure. How can subsidence of up to 1/2 foot / year be considered not significant or unreasonable enough to trigger action? Response: Ken Loy responded that in Chapter Chapter three you'll see that there is very little subsidence up in the Orland area, if that were to change, then that would be the whole adaptive management part of this, then the the GSA would be looking for the local feedback on on what's going on in that area and then what's the right thing to do to mitigate it.		Question	Answer provided at the 7/28/2021 meeting. See comment section.

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63	7/28/2021	H Brich		Virtual Public Meeting		H Brich asked in the chat: Re Slide 24: you said it was dependent upon how many farmers sign up for the (Sacramento River?) program. How do farmers find out about what programs are available to them to participate in? We have a farm manager and several owners. Response: Lisa Hunter responded that you should email either LHunter@countyofglenn.net or mfahey@countyofcolusa.com and sign up for the interested parties list.		Question	Answer provided at the 7/28/2021 meeting. See comment section.
64	7/28/2021	H Brich		Virtual Public Meeting		H Brich asked in the chat: Re: Slide 17, how does the groundwater become electrically conducting when it is "degraded"? Is it full of metal contaminants? Response: Ken Loy responded that the Groundwater does become more electrically conducted as the salinity goes up and we want to pay attention to that, but it doesn't mean that it's full of metal contaminants you could have high conductivity and and low metal contaminants or vice versa, you could have low electrical conductivity and high metal contaminants you can't correlate one with the other necessarily.		Question	Answer provided at the 7/28/2021 meeting. See comment section.
65	10/13/2021	Shelly Morris		Virtual Public Meeting		What does "state intervention" include if "undesirable results"? Response: Ken Loy responded the State Water Resources Control Board can take over management and levy fines and fees.		Question	Answer provided at the 10/13/2021 meeting. See comment section.
66	10/13/2021	Erik Kolderup		Virtual Public Meeting		Is there precedent for the DWR not accepting the minimum thresholds established by local authorities? Are they likely to accept this plan? Response: Grant Davids responded of the four plans submitted so far 2 were not accepted. Pat Vellines recommended checking DWR website as the next round of GSP approvals will be out soon. Mary Fahey added that		Question	Answer provided at the 10/13/2021 meeting. See comment section.
67	10/13/2021	John Monroe		Virtual Public Meeting		How is this Sites project, which is in this subbasin taken into account, is it considered to be a PMA? Response: Grant Davids responded I believe it is a potential source of water for in lieu recharge. In ieu recharge is when you have got groundwater pumping going on, and you can deliver surface water, instead of pumping the groundwater.		Question	Answer provided at the 10/13/2021 meeting. See comment section.
68	10/13/2021	Anonymous		Virtual Public Meeting		One of the PMAs was ground water extraction fees. How would those fees be set and how frequently could those fees be increased. Response: Grant Davids responded that will be decided by the GSA once the GSP is adopted.		Question	Answer provided at the 10/13/2021 meeting. See comment section.
69	10/15/2021	Del Raymond		In-Person Public Meeting		Would be better to work to keep surface water in the area. Surface water users should not pay as much as ground water pumpers. Response: Grant Davids responded that the GSA will decide fees that it outside the scope of this plan.		Comment	Answer provided at the 10/15/2021 meeting. See comment section.
70	10/15/2021	Reimers		In-Person Public Meeting		Plan is to technical for average person to understand. Written so only an expert can understand. Trees are dying for lack of water. Only allowed to irrigate every 21 days instead of 14 days.		Comment	
71	10/15/2021	Anonymous		In-Person Public Meeting		Willing to pay an assessment to keep the GSA running but not to pay for projects to solve problems that I did not cause.		Comment	
72	10/15/2021	Ben King		In-Person Public Meeting		SIGMA regulations are a trojan horse. This is a way to turn our subbasin into a Sacramento water market.		Comment	

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73	10/15/2021	Ben King		In-Person Public Meeting		Request that the bylaws from the GSA require proof of residency to be on the board.		Comment	
74	10/15/2021	Anonymous		In-Person Public Meeting		When will the PMAs be reviewed? Response: Lisa Hunter responded that they have been reviewed by the TAC.		Question	Answer provided at the 10/15/2021 meeting. See comment section.
75	11/1/2021	Mary Fahey	CGA	Email	PMAs	Regarding the South Valley Water Resources project, the comment is that this project should be removed because it includes sending water out of the basin to the San Joaquin Valley		Comment	
76	11/1/2021	Mary Fahey	CGA	Email	PMAs	Regarding the Glenn-Colusa Irrigation District (GCID) Water Transfers to TCCA CVP Contractors – The comment on this project proposal is to update it to include all Settlement Contractors since there are many that transfer to the TCCA.		Suggestion	
77	10/30/2021	Ben King		Email		As discussed over the last couple of days the GSP Maps and Budget Subareas need to be adjusted to include the correct boundary and surface water delivery area for the CDMWC. The CDMWC delivery area on the west side of the Colusa Basin Drain south of Hahn Road needs to be included in the CDMWC Budget Subarea in Figure 3-6. Likewise the boundary for the CDMWC has to be adjusted throughout the GSP Maps in Chapter 2 and elsewhere.		Suggestion	
78	10/25/21	Holly Dawley	GCID	Letter		We ask that as GSAs move from planning to implementation and continue to look for opportunities to leverage surface water over groundwater, you consider those members and partners with senior water rights and stable contracts that contribute to our shared aquifers and provide high quality environmental habitat. We look forward to better identifying and quantifying this benefit for the subbasins during implementation. Further, we ask that GSAs work with their County partners to consider land use planning and accountability.		Request	
79		Ashley Driver	Driver Performance Improvement	Email		Was follow-up information provided on how the groundwater pumping fees will be calculated? Response: Mary Fahey responded there have been no decisions regarding a pumping fee. Those discussions will start happening early next year. It is still to be determined how/if fees will be instated. Those discussions and decisions will happen at public GSA Board meetings. There may be other subcommittee meetings where recommendations for the Boards will be developed.		Question	Response included with comment.

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80	11/4/2021	Ashley Driver	Driver Performance Improvement	Email		Also, how easy is it to adjust our compliance markers (e.g. minimum thresholds)? Is there a formal process, is the public included, and does the state have to approve changes? Response: Mary Fahey responded The GSAs are required to report annually on their progress and to update the Plans every five years. They can adjust the Sustainable Management Criteria during these updates. Any adjustments will need to be justified to DWR with data and reasoning, and DWR will have to approve any changes. It will be a public process, likely similar to what has been done the last couple years with information coming to the Technical Advisory Committees at public meetings and then to the Boards at their public meetings for final decisions.		Question	Response included with comment.

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1	1/21/2021	Ben King	Land Owner	PMA Form	PMA	See PMA suggestion using link to right	https://app.box.com/s/lu6rphiyxs6bhqg7g7t6ljijcztnyhax	PMA Submission	
2	4/15/2021	Scott Hamilton	South Valley Water Resources Authority	PMA Form	PMA	See PMA suggestion using link to right	https://app.box.com/s/uwxdng5fz9tci2hs7titczm31vj4j9bt	PMA Submission	
3	5/11/2021	Halbert Charter	H&A Charter Farm	PMA Form	PMA	See PMA suggestion using link to right	https://app.box.com/s/xuv9na4x006uh89fu91jpdzxjxl41asn	PMA Submission	
4	5/13/2021	Michael Doherty	Chamisal Creek Ranch, LLC	PMA Form	PMA	See PMA suggestion using link to right	https://app.box.com/s/a725mc27se172b0yaz29t4mrrmg52vue	PMA Submission	
5	6/17/2021	David Kehn	Cal Water	PMA Form	PMA	See PMA suggestion using link to right	https://app.box.com/s/0jnshdii9yxikh68s5d6nugud8g07gie	PMA Submission	
6	6/18/2021	Lorraine Marsh	Sycamore Marsh Farm	PMA Form	PMA	See PMA suggestion using link to right	https://app.box.com/s/rbskos3erj5j6a3pd49onrsevrswm6i6	PMA Submission	
7	6/18/2021	Lorraine Marsh	Sycamore Marsh Farm	PMA Form	PMA	See PMA suggestion using link to right	https://app.box.com/s/7ydonx5rc8b2x0mixl5tytcy3q846xce	PMA Submission	
8	6/18/2021	Ben King	Land Owner	PMA Form	PMA	See PMA suggestion using link to right	https://app.box.com/s/awk617yabd9tdur5m20ach7lpmwlkg90	PMA Submission	
9	6/19/2021	Jim Wallace	Colusa Drain Mutual	PMA Form	PMA	See PMA suggestion using link to right	https://app.box.com/s/5a5wqzn0kk7d5zzhroku1xo4u4tk46f2	PMA Submission	
10	6/21/2021	Jenny Scheer	Water & Land Solutions	PMA Form	PMA	See PMA suggestion using link to right	https://app.box.com/s/60motdbxwt2kdonery60belfae8ro9vh	PMA Submission	
11	10/27/2021	Lewis Bair or Bill Vanderwaal	RD-108	PMA Form	PMA	See PMA suggestion using link to right	https://app.box.com/s/x8gjutvrr6rx0bxrnavksymc20grogy3	PMA Submission	

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1	Emil Cavagnolo	GGA/OAWD	2	2.1.2	2-4			Monroeville is a Groundwater District	Comment acknowledged. Monroeville is a water district formed to give its landowners (groundwater pumpers) a voice during the SGMA process. Table 2-2 contains municipal public potable water suppliers while Table 2-3 contains ag or other non-municipal water suppliers. Monroeville WD falls into the latter category and is included in Table 2-3.
2	Emil Cavagnolo	GGA/OAWD	2				2-3	OAWD's service area is currently just under 30,000 acres	Comment addressed in the GSP section indicated.
3	Emil Cavagnolo	GGA/OAWD	2	2.2.1.1	2-16	4		OAWD's latest WMP I 2020	Comment addressed. The 2020 WMP was used.
4	Emil Cavagnolo	GGA/OAWD	2	2.5.1.2	2-29	1		Colusa Subbasin now Chowchilla	Comment addressed in the GSP section indicated.
5	Emil Cavagnolo	GGA/OAWD	2	2.5.1.3	2-32	5		The public meeting in Orland was at the Glenn County Fairgrounds	Comment acknowledged. There was no meeting held at the fairgrounds, to our knowledge.
6	Emil Cavagnolo	GGA/OAWD	2	2.5.1.3	2-33	6		I do not remember this type of meeting in Glenn County	Comment acknowledged.
7	Emil Cavagnolo	GGA/OAWD	3	3.3.3.3	3-83	last		Agricultural Water Demand is a heading and should be Bold Print	Comment addressed in the GSP section indicated.
8	Leslie Nerli	GGA Board	2	2.1.2	Plan Area	1	2	The obvious and probably already corrected is….primary urban….Colusa & William in Glenn Co…wrongly printed for both counties	Comment addressed in the GSP section indicated.
9	Leslie Nerli	GGA Board	2	2.4	23		3	Water purveyors along TC Canal Re: 0%-100% depending on available water - truly dependent on what Bureau feels to allow each year and is announced very early in year.	Comment acknowledged. The text has been updated to reflect the agency responsible for the allocation volume.
10	Leslie Nerli	GGA Board			32			Areas of sustainability concerns: Glide Water District Please see attached MAP of what I believe to be an excellent area of land to recharge. First off, the land owner of the property has changed hands from Pete Galaya to: RD 45 , LLC , 1380 East Ave, Ste 124, Chico, CA, Parcel number 020-240-0140 There is 41.5 acres of Glide water district in the block of Habitat. Not sure what plain ole Habitat is but definitely good percolation in this area. Of course this is a statement made only by experience and not as a geologist/hydrologist which would have to be confirmed by science. A rice farmer to the west of the proposed property for recharge used almost 10 acre feet one year for his crop. Again, the cost of water and other crop costs combined with returns have forced this farmer to sell part of his land using the sale of his land from many generations in his family to develop orchards so that he can keep some of the remaining 4rth or 5th generation family farm. From what I was told by Mike Alves regarding there are 41.5 acres of glide district land within the 300+/- acres of Habitat. When available from the Bureau, water can be surface water that can be purchased at each year's allocation rate for the only the 41.5, but not more than the allocation for each year. In addition to the glide surface water yearly allocation, any Bureau excess flow water could be captured in the 41.5 acres and remaining property acres as well. So using the Glide	Comment acknowledged. This would make a great addition to the list of "potential PMAs" in Section 6.5 of the GSP, and will be considered for inclusion in the GSP. We also invite everyone to submit suggestions for PMAs through the Colusa Subbasin PMA Submittals portal: https://colusagroundwater.org/projects-and-management-actions-submittals/.

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11	Leslie Nerli	GGA Board			32			in "excess flows available" Of course, they still charge a fee and Glide a fee as well, but usually at a more reasonable price. Because this property lies between the 2 creeks, it does flood during wet years. So, maybe some improvements could be made to capture more of the flood water that flows so quickly away and allow for more time to capture excess flood water to our groundwater storage. Maybe it will be so simple and cost effective as placing Check damns? and/or doesn't need them just some drainage management. I do not know who the RD 45 LLc people are or if they would even consider working with the ground water recharge project. Even to the north of Wilson Creek is land in the habitat. It is a very large piece of property. 300 +/- acres.	Please see the response to comment 10.
12	Mary Fahey	CGA	1	Cover Page	Cover Page	N/A	N/A	1. Title: Change to Colusa Subbasin Groundwater Sustainability Plan. 2.Add logo to page 3.Under "Prepared for", change Colusa GSA and Glenn GSA to: Colusa Groundwater Authority and Glenn Groundwater Authority 4.Make these same changes on the second page	Comment addressed in the GSP section indicated.
13	Mary Fahey	CGA	All Chapters	Entire Document – footer				Change footer to read: Colusa Groundwater Authority and Glenn Groundwater Authority Colusa Subbasin Groundwater Sustainability Plan	Comment addressed in the GSP section indicated.
14	Mary Fahey	CGA	1	1.3.1	1-3	1		Please specify that there are **two** Private Pumper Representatives from the Colusa County Groundwater Commission, **appointed by the Colusa County Board of Supervisors**	Comment addressed in the GSP section indicated.
15	Mary Fahey	CGA	1	1.3.1	1-3	4		Second Sentence, please edit as follows: **Except for the Private Pumper representatives**, Board members are chosen in public meetings by the respective governing boards of the Member Agencies…. **Private Pumper representatives on the CGA Board are recommended by the Colusa County Groundwater Commission and appointed by the Colusa County Board of Supervisors**.	Comment addressed in the GSP section indicated.
16	Mary Fahey	CGA	2	2.1.1	2-1	4		Glenn and Yolo County boundary should be **Colusa** and Yolo County boundary	Comment addressed. The GSP has also been revised to include the new RD 1004 subbasin boundary line.
17	Mary Fahey	CGA	2	2.1.2	2-4	1		Fourth line – Change water pumpers to groundwater pumpers: …and two appointed private groundwater pumpers…	Comment addressed in the GSP section indicated.
18	Mary Fahey	CGA	2	2.1.2	2-4	2		Orland and Willows are in Glenn County. Colusa and Williams are in Colusa County.	Comment addressed in the GSP section indicated.
19	Mary Fahey	CGA	2		2-4		Table 2-2	Grimes water district should be: Colusa County waterworks district #1 – Grimes Also in Colusa County: Colusa County waterworks district #2 - Princeton	Comment addressed. Colusa County Waterworks Districts for Grimes and Princeton have been added to Table 2-2. Del Oro Black Butte District was also added.

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20	Mary Fahey	CGA	2				Fig. 2-3	The map is titled Colusa Subbasin GSA Member Agencies but does not show/list Colusa County or Glenn County Under Note 1: There are two private pumpers from the Colusa County Groundwater Commission on the CGA Board There are no private pumpers on the GGA Board	Comment addressed. Edits were made to the note section that Colusa and Glenn Counties are member agencies but are not shown on the map.
21	Mary Fahey	CGA	2	2.2.1.1	2-15	6		(NSV IRWM) last sentence, add year that the update was adopted. In March, 2021….	Comment addressed in the GSP section indicated.
22	Mary Fahey	CGA	2	2.2.1.1	2-18	2		Second bullet states "The following GSAs have readily available MSRs:" Don't you mean "The following GSA Member agencies…"?	Comment addressed in the GSP section indicated.
23	Mary Fahey	CGA	2	2.2.1.2	2-19	1		I believe CCWD has a SCADA system. There may be other districts as well that are not listed.	Comment acknowledged. USBR funded the project in 2014.
24	Mary Fahey	CGA	3	3.1.7.3.1	3-32	5		Faults: Second to last sentence, Zamora Fault should be listed along with the others that were analyzed.	Comment addressed in the GSP section indicated.
25	Mary Fahey	CGA	3	3.1.10.2	3-42	1		Primary Users, first sentence – can this be re-worded. It sounds like there are only 20 Stakeholders in the basin.	Comment addressed. The text was changed to include the total count of water service agencies within the Colusa Subbasin based on DWR's GIS dataset.
26	Mary Fahey	CGA	3	3.1.11.2.3	3-45	2		– The TNC project is better described as an on-farm multi-benefit managed aquifer recharge and shorebird habitat program. Where it says migratory birds, please specify migratory shorebirds.	Comment addressed. The section title has been changed as suggested.
27	Mary Fahey	CGA	3				3-19	Water source layer missing for Colusa County portion	Comment acknowledged. Water source was not surveyed for water use by DWR in Colusa County during the displayed survey year. Land and water use surveys are constantly being conducted, so more recent information will be included in GSP annual reports and/or periodic GSP evaluations and updates.
28	Mary Fahey	CGA	4	4.1	4-1	1+		Should monitoring for GDEs be mentioned in the discussion about the monitoring networks?	Comment acknowledged. GDEs have been included in the write up as part of the stream-aquifer monitoring.
29	Mary Fahey	CGA	4	4.2.2.2	4-4	1		Will this section be expanded to include more details?	Comment addressed. The monitoring protocols now include protocols that are used by the GSAs.
30	Mary Fahey	CGA	4	4.2.3.3	4-17	1		Suggest spelling out Irrigated Lands Regulatory Program (ILRP) in first sentence	Comment addressed in the GSP section indicated.
31	Mary Fahey	CGA	4					General chapter 4 comment: This Chapter will need to be updated based on recent activities/discussions/decisions, especially regarding monitoring and filling data gaps for stream interactions and GDEs. Also, information about the coordination efforts taking place along basin boundaries between the neighboring subbasin GSAs should be expanded. Overall, this chapter reads light on describing the Colusa Subbasin monitoring network and heavy on listing excerpts from the regulations.	Comment addressed. We have included a section on the representative monitoring networks for groundwater levels and stream-aquifer interaction, of which the latter includes monitoring for surface water depletions and impacts to GDEs. All monitoring protocol sections have been revised to include more information regarding protocols used by the monitoring agencies and not just the requirements listed under SGMA regulations. The requirements listed in the BMPs have been summarized instead of comprehensively listed.
32	Evan Markey/Michael Bolzowski	GGA/Cal Water	2	2.1.2.1	8	4	-	The plan states Willows used 1.6 MGD. Our records show and average of 1.2 MGD for the same time.	Comment addressed. This typo has been corrected. The volume listed in Table 2-2 also equates 1.2 MGD (1,044 AFY = 1.16 MGD).

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33	Evan Markey/Michael Bolzowski	GGA/Cal Water	Appendix	2.7.3	121	-	2-4	Table shows Willows average per capita as 231 Gallons per Capita Per Day from 1990 to 2015. Our current average 2015 to 2020 is much lower, 143 Gallons per Capita Per Day. The model maybe overestimating our demands for the basin.	Comment acknowledged. The C2VSimFG-Colusa model inputs and results are finalized for GSP development. This and other concerns would be addressed in future revisions of the model, and incorporated into GSP annual reports and/or periodic GSP evaluations and updates.
34	Lester Messina	Colusa Glenn Subwatershed Program (SVWQC)	2	2.2.1.2	2-20	2		Recommended Change: Irrigated Lands Regulatory Program The Central Valley Regional Water Quality Control Board (CVRWQB) has adopted waste discharge requirements (WDRs) for discharges from irrigated commercial croplands to protect both surface water and groundwater supplies. When land is in agricultural production it is irrigated and fertilized. It is assumed that portions of the soil amendments, particularly fertilizer, is converted to nitrate which has the potential to percolate into groundwater The ILRP regulates such discharges, growers can minimize the percolation of nitrate to groundwater through the implementation of effective management practices. Commercial irrigated lands, including managed wetlands are required to obtain regulatory coverage.	Comment addressed in the GSP section indicated.
35	Ben King	Land Owner	2	2.1.1				How were the vertical boundaries of the annexed area of the previous West Butte Subbasin determined since the HCM did not cover this area during previous data collection?	Comment acknowledged. The 2016 preliminary hydrogeologic investigation included the entire groundwater aquifer system within Colusa and Glenn Counties, including the portions of the previous West Butte Subbasin and current existing Corning Subbasin. Vertical boundaries of subbasin were defined using the same information regarding depths to relatively impermeable geologic formations, interpretation of geologic formations, and the estimated freshwater-brackish water interface.
36	Ben King	Land Owner	2	2.1.1				The lateral extent is not bounded by the Sacramento River to the east but it is bounded by the western boundary of RD 1004.	Comment addressed in the GSP section indicated.
37	Ben King	Land Owner	2	2.1.2.1				How many wells and what is the volume for Del Oro Arbuckle?	Comment addressed. There are two wells, the second well was installed and operational in October 2015. The average annual volume in 2016-2020 was 48.35 AFY.
38	Ben King	Land Owner	2	2.3				Why is Colusa Drain Mutual Water Company only on the map in Yolo County? All of Colusa County CDMWC is missing from the Map.	Comment acknowledged. Our understanding is that CDMWC/CDWUA has a shared service area with many other water districts and agencies. CDMWC/CDWUA was included on the map, but was drawn "underneath" the other agency boundaries. Figures 2-3 and 2-4 have been revised to better identify the CDMWC/CDWUA service area in those shared locations. Figure 2-3 has been revised to show the CDMWC everywhere that it exists.

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39	Ben King	Land Owner	2		2-9		Table 2-3	There are no entries for Surface Water Supply or Volume Descriptions for CDMWC or RD479. If there is some valid reason for the omission it should be explained in a footnote rather than just omitted.	Comment addressed. Surface water supply available to CDMWC is variable and consists of the Colusa Drain and its tributaries. The major water source available during the irrigation season is return flow or drainage water from districts in the northern part of the Colusa Basin that divert water from the Sacramento River and discharge their return water to the Colusa Drain. RD 479 conveys drain water and relies on the RD 2047 to convey drainage water to the Sacramento River.
40	Ben King	Land Owner	2	2.8	2-21		Table 2-6	Relating to Table 2-3 above there are no diversions cited for Model Input as Diversions attributable to CDMWC acreage. What is the impact of this omission?	Comment acknowledged. Please refer to Figure 3-6 and Table 3-2.
41	Ben King	Land Owner	2		2-21		Table 2-6	The USEPA SDWIS system reports violations and maintains a log of monitoring events. This monitoring data and time line of violations does not seem accessible on the Waterboards site. The EPA link should be included. Why isn't the Drinking Water Open Data Portal referenced as it is in 2.6?	Comment addressed. The EPA SDWIS website has been added to the list as another resource. The California Open Data Portal has also been added to Table 2-6. These different websites contain slightly different, but also duplicate information regarding public drinking water supply requirements and monitoring information.
42	Ben King	Land Owner	2		2-21			The CV Salt information is not online? How do stakeholders access this data. Where can Stakeholders access GAMA data? Where is the Sacramento Valley Water Coalition Data? Where is the groundwater quality data relating to wells used for groundwater substitution accessible? It is part of the Appendix of the Environmental Assessment for Tehama-Colusa Canal Authority In-Basin Water Transfers.	Comment acknowledged and addressed. Stakeholders can obtain data from programs that do not post data online by contacting the responsible agency and requesting the data. In some cases, data from these programs are available on other data repositories, such as USGS or GeoTracker websites. In the case of the SVWQC, data is available via GeoTracker GAMA and from Luhdorff & Scalmanini, their monitoring entity. Websites to the individual programs, through which contact information for all of the agencies and coalitions participating in those programs can be accessed, were added to Table 2-6. Groundwater quality data relating to wells used for groundwater substitution is not currently included in the groundwater monitoring network, other than those wells that are part of other existing monitoring programs. For example, the environmental assessment for the Tehama-Colusa Canal Authority In-Basin Water Transfer Initial Study evaluated groundwater from wells included in the GAMA program, which is already listed in Table 2-6.
43	Ben King	Land Owner	2					According to the City of Colusa Policy PRC –9.2-The City will prepare a Water Resources bi-annual report to the City Council. The Public Works Department will analyze the quality of drinking water in the City. The description of the General Plan is incomplete because it does not mention that water quality is addressed and included in this bi-annual report to the City Council for the City of Colusa.	Comment addressed. Table 3 of Appendix 2A has been reworded to clarify this statement.
44	Ben King	Land Owner	2					The Human Right to Fresh Water should be addressed somewhere in 2.3 or 2.4. Ultimately this will affect the priority of beneficial use, management actions and minimum thresholds to comply with the requirements of this Law.	Comment addressed. Section 2.4, Additional GSP Elements, and Section 2.2.1.3, Groundwater Monitoring and Management, now include references to Water Code Section 106.3 text and related actions taken by the GSAs.

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45	Ben King	Land Owner	2		2-30			Don't understand the reference to Human Right to Water as described. Doesn't this Right apply to all residents in the Colusa Subbasin and all water systems?	Comment acknowledged. The stakeholders listed in Table 2-8 are just a shortlist of sample stakeholders, not a comprehensive list of all stakeholders that apply to that category of interest. The stakeholders listed in Table 2-8 for the "Human Right to Water" topic are those that are most vulnerable to losing access to clean drinking water.
46	Ben King	Land Owner	Table 3-1					What change in Data Sources were used to incorporate the annexed area from the West Butte Basin? What sources were used for Geochemistry and water quality?	Comments acknowledged and addressed. The Colusa Subbasin boundary was revised along its eastern edge to follow the Sacramento River or the western boundary of RD 1004. Basin boundary modifications were redrawn in coordination with CGA and RD 1004 staff and submitted to DWR for approval. A previous basin boundary modification had the eastern edge of the Colusa Subbasin follow the county boundary, regardless of whether it was east of the Sacramento River or not. Digital data sources for mapping the water chemistry have been added to Table 3-1. Table 3-1 is not a full list of all data and information sources, please refer to Chapter 8 References, Chapter 3.2 Groundwater Conditions, and Chapters 2 and 4 for more information regarding the different sources of water quality data and informative reports that were downloaded and used.
47	Ben King	Land Owner	3.1.5		3-7			The Hydrology of the Colusa Subbasin is also influenced by the Geochemistry and underlying Faults. Since the Subbasin water quality is influence by the volcanic rock of the Sutter Buttes and influences from the marine and lacustrine geologic history of the Subbasin – can Hydrology be determined without Geochemistry? Faults are known to influence Geochemistry and water quality since there may be anoxic water upwelling and lateral movement of naturally occurring contaminants via faults like the Willows Fault.	Comment acknowledged. Section 3.1.5 only discusses physical surface hydrology, specifically, surface waters that exist within the Subbasin. The section introduction has been revised to include a statement regarding water chemistry and refers the reader to the groundwater quality discussion sections found later in the chapter.
48	Ben King	Land Owner	3.1.5		3-11		Figure 3-6	Why is part of the CDMWC delivery area included in ColGGWS? The CDMWC on the west side of Colusa Basin Drain south of Hahn Road receives surface water deliveries as the rest of the CDMWC. There are CDMWC subarea components on multiple sides of this area but for some reason this jurisdictional area of the CDMWC is treated differently. This area is also part of the flood zone and receives significant seepage during seasonal winter flows.	Comment acknowledged. The subareas labeled in Figure 3-6 are collections of C2VSimFG-Colusa model elements that approximately represent water supplier service areas based on GIS mapping. CDMWC has a discontinuous service area along the Colusa Drain, and so is represented by several model subareas. The representation of water supplier service areas is limited by the spatial resolution of model elements. Service areas were modeled to capture the best representation of the service area alignment possible, while also simulating a total acreage that is closest to the actual acreage of that service area.
49	Ben King	Land Owner			3-16		Table 3-2	What assumptions are included in Model Diversion ID 113? As mentioned above a portion withing the jurisdictional boundaries of the CDMWC and a CDMWC surface water delivery area is left out of the CDMWC budget subarea.	Please see the response to comment 48. Per Table 3-6, the diversion records (input files) that came with DWR's C2VSimFG Beta2 model were used without adjustment for this diversion in the C2VSimFG-Colusa model.

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50	Ben King	Land Owner	3.1.7				3-3	See Springhorn Page 22 – Table 2.1 and Page 93 Table 3.3, Need to incorporate Turlock Lake Lacustrine influence to document Corcoran like clay components to the Lithology and also need to incorporate the formation of the Sutter Buttes Rampart and Geomorphic influence of the Sutter Buttes volcanic structure. Both Springhorn and Harwood and Helly differentiate the lithology of the Pliocene and Pleistocene periods this way. Water quality and subsidence issues are related to this geologic history. Figure 3-10 is probably the most complete Geologic Map I have seen for the region – excellent!	Comment acknowledged and addressed. The extent of the Turlock Lake Formation is unknown within the Colusa Subbasin west of the Sutter Buttes. Many of the boreholes used by Springhorn southwest of the Sutter Buttes did not encounter the Turlock Lake Formation, though there were some lithologies that may be related to it.
51	Ben King	Land Owner					3.11, 3.14 &3.15	See Springhorn Page 113 Figure 4.4. This Geologic Crossection needs to be incorporated in Cross Section C-C on Figure 3-11. Otherwise the Cross section leaves out the influence of the most unique Geomorphic Unit in the Sacramento Valley which is the Sutter Buttes. Also there is a critical need to address the Cross Section next to the City of Colusa because of the interrelationships of the Willows Fault, Sutter Buttes Rampart, Colusa Dome and Sacramento River. As it now stands Cross Section C-C is not consistent with the robust Geology set out in Figure 3-10 which seems to be a recent update since it references Springhorn. Regarding 3.14 how can you have a 3 Dimensional Model that omits the geology of the Sutter Buttes? Regarding 3.15 – it is important to map the area of the Corcoran like clays deposited by the Turlock Formation to know the potential area of impact for future subsidence.	Comment acknowledged. The 3D HCM representation focuses on the shallow marine and continental sedimentary geologic formations. It excludes the relatively more impermeable underlying plutonic and metamorphic formations. The 3D representation also fits slightly inside of the Colusa Subbasin boundary. Permeable subsurface volcanic formations that far west of the Sutter Buttes are thin at the scale being shown. Intrusive igneous formations related to the Sutter Buttes exist deeper than what the 3D representation shows. It is recommended to include more subsurface mapping of the permeable volcanic deposits and relatively impermeable plutonic formations, and to expand the 3D HCM beyond the subbasin boundaries in future HCM revisions. Cross Section C-C' has been revised a bit to include the Willows Fault zone near Colusa.
52	Ben King	Land Owner	3.1.9.2					See USGS Circular 1358 "Water Quality in Basin-Fill Aquifers of the Southwestern United States: Arizona, California, Colorado, Nevada, New Mexico and Utah, 1993-2009. Thiros,Paul, Bexfield and Anning 2014.(USGS Thiros et al 2014) See Page 56 – it is clear that arsenic contamination occurs and translocates along fault zones like the Willows Fault as is currently is the case in the Middle Rio Grande Basin. The water system for the City of Colusa could have the same fate as the water system for the City of Albuquerque.	Comment acknowledged and addressed.
53	Ben King	Land Owner	3.1.8.2		3-35	2nd and 3rd		The base of freshwater should not include brackish water which is defined by the USGS and others at 1000 ug/L. Water quality definitions should be consistent with the California Human Right to Fresh Water. Brackish water is not potable. The reference to brackish water in the Upper Princeton Valley is inconsistent with the outdated Olmstead and Davis referenced in paragraph 2 . See Springhorn Page 149 for additional references.	Comment acknowledged. The base of fresh water presented in the GSP are based on historical reports, of which many regulatory agencies use differing concentrations to define brackish versus fresh water. Data gaps regarding the lateral base of fresh water mapping or regarding discrete location well depth information for wells with measured water quality issues have been expanded upon in the Section 3.1.12.

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54	Ben King	Land Owner			3.37		3.17	The Base of Freshwater Depths in the annexed area from the old West Butte Basin seem incorrect based on the vertical depths included in Springhorn's Cross Section work. Also the area west of Colusa on Lurline near Roberts Ditch is known to have lower fresh water base levels. Levels are probably in the 300 to 400 ft levels or less in both areas.	Please see the response to comment 53.
55	Ben King	Land Owner	3.1.10.2		3-39			The potential for vertical movement via abandoned gas wells and faults needs to be mention since it most likely will lead to aquifer degradation in areas where the subsurface groundwater have elevated TDS levels and/or anoxic conditions.	Comment acknowledged and addressed.
56	Ben King	Land Owner	3.1.10.3		3-42			Arsenic contamination at the abandoned Del Oro Walnut Ranch well and the well at the CIP site which was cited by SWRCB show arsenic contamination has been found in the Colusa City limits. The USEPA reports also show arsenic contamination in the Princeton water supply system.	Comment acknowledged.
57	Ben King	Land Owner	3.1.12.1		3-50			Additional Areas of Uncertainty: 1. See Springhorn Page 165 Figure 6.1 Areas where subsurface information is needed regarding the area outlined west of the Sutter Buttes, 2. Research regarding the vertical and lateral movement of saline water within and across the Willows Fault as generally described on Page 56 of USGS Thiros et al 2014, 3 The predicted desorption of arsenic from a volcanic structure like the Sutter Buttes in Figure 6-5 of Thiros on Page 58, 3. The breadth and depth of the Corcoran type clays from the Turlock Lake formation highlighting the potential for future subsidence, 4 – the water quality issues near the Freshwater area west of Williams as described in the Colusa County Groundwater Management Plan.	Comment addressed. Descriptions of these issues of concern and existing data gaps have been incorporated into various sections of Chapter 3.1, HCM.
58	Ben King	Land Owner	3.1.12.1				3-5	The C2VSimFG Model has to incorporate the saline and anoxic seawater around and south of the Sutter Buttes. According to the Sutter- Yuba investigations (SWRB Bulletin No. 6, 1952) a TDS level as high as 10,000 was observed near Robbins. Others including the DWR and Curtin have observed TDS levels from 4,000 to 6,000 south of the Sutter Buttes.	Comment acknowledged.
59	Ben King	Land Owner	3.1.12.3				3-51	What are the statutory obligations to address the Human Right to Fresh Water in the HCM?	Comment acknowledged. The Human Right to Water is not specifically addressed in SGMA regulations. SGMA and the Human Right to Water are intrinsically related, however, as the projects and plans proposed and implemented under SGMA aim to directly address the concerns outlined under the Human Right to Water. Section 2.4, Additional GSP Elements, and Section 2.2.1.3, Groundwater Monitoring and Management, include references to Water Code Section 106.3 text and related actions taken by the GSAs.

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60	Ben King	Land Owner	3.2.5				3-64	The worst reported arsenic contamination for any public water system in the Sacramento Valley water supply system is in Grimes. The USEPA has documented arsenic contamination in the Princeton public supply system. There has been two incidences of arsenic contamination in supply wells within the boundaries of the City of Colusa. The wide scope of arsenic contamination around the extent of the Sutter Buttes Rampart and south of the Sutter Buttes in the Colusa Basin needs to be disclosed as an area of grave concern. See Springhorn Page 164 highlighting the need for more research about the need for more work regarding the relationship of arsenic contamination and the health risks from arsenic.	Comment acknowledged. Chapter 3 text has been revised to include data gaps regarding characterizing sources of arsenic near and downgradient of the Sutter Buttes and flow mechanics along the Willows Fault.
61	Ben King	Land Owner	3.2.5.1.1				Figure 3-30	What is the source for this data? Is there a time series? Stakeholders should have access to time series for water quality data and it should be included in the Appendix like the hydrograph data concerning water levels. Arguably water quality data should have a higher level of access and transparency due to the Human Right to Fresh Water.	Comment acknowledged. The TDS concentrations shown on Figure 3-30 are those recorded in GeoTracker and USGS website databases, last downloaded in 2020. The mapped TDS concentrations are the historical high at all groundwater sample locations. Historical EC charts are included in Chapter 5 for the representative groundwater quality monitoring network wells. All data taken from existing monitoring programs and data repositories (e.g., GeoTracker, GeoTracker GAMA, DWR WDL, USGS NWIS, CEDEN, etc.) will be evaluated in future GSP annual reports and periodic GSP evaluations and updates. EC/TDS concentration time series charts for all current active monitored wells will also be considered for inclusion in future GSP annual reports and periodic GSP evaluations and updates.
62	Ben King	Land Owner			3-66			According to the 2020 Tehama-Colusa Canal Water Authority Initial Study/Environmental Assessment there were several wells used for Groundwater Substitution with elevated Specific Conductance. As reported in the Appendix for the report GCID, 7 of the 16 reported wells had a consistent annual reported level of Specific Conductance greater than 1000 ug/L. Three of these wells had levels greater than 1500 and the other 4 were between 1000 and 1500. Are these wells included in the data points of Figure 3-30 and the discussion on page 3-66?	Comment acknowledged. Wells were not included in Figure 3-30 unless their TDS measurements were submitted to GeoTracker or USGS before the datasets were downloaded to generate the map in 2020. These wells do not appear to have been submitted before then. The TCC environmental assessment does not include named well locations or additional well identification information. These wells will be evaluated in relevant future projects, GSP annual reports, and periodic GSP evaluations and updates.

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63	Ben King	Land Owner	3.2.5.2.1		3-67			Where is the location of the well near Grimes with Arsenic at 200 ug/L.? Grimes arsenic levels are reported to be approximately 25 ug/L. The USGS publication by Thiros et al has an extensive discussion of the desorption process of arsenic for volcanic rocks in saline groundwater with PH greater than 8. The USGS predictive model predicts the occurrence of arsenic in basin discharge areas like Robbins and the areas south of Grimes. This USGS publication also highlights how arsenic had moved into the groundwater of Albuquerque via a fault. The Willow fault crosses the Sacramento River at Colusa and runs south towards Grimes and the area where the two arsenic contaminated wells were found at the Del Oro Walnut Ranch site and CIP which is now in the boundary of the City of Colusa. The Sutter GMP includes a Figure showing elevated areas of TDS and Arsenic with levels as high as 370 ug/L. There is discussion of a biotic response that coincides with anoxic groundwater becoming oxidated from soil microbial activity that release arsenic as a bi-product. Arsenic contamination of the Colusa public water supply would be disastrous and a violation of the Human Right to Fresh Water.	Comment acknowledged. The 200 ug/L arsenic concentration near Grimes was a typo and should be 28 ug/L. References and discussion regarding Human Right to Water have been added to Chapters 2 and 3. Groundwater flow along faults is discussed in Chapter 3.
64	Ben King	Land Owner	3.2.6				Figure 3.31	Figure 3.31 should overlay the area of the Corcoran like clays from the Turlock Lake geological formation to show a potential relationship of subsidence and the presence of this clay formation	Comment acknowledged. Data is lacking regarding the lateral extent of the Turlock Lake Formation west of the Sutter Buttes. This has been added to the data gaps section of the HCM and additional commentary has been included in the regional geology discussion.
65	Ben King	Land Owner			3-72			The relationship between the Corcoran like clay formation and the presence of inelastic subsidence should be discussed based off the history in the San Joaquin Valley.	Comment acknowledged. The text has been revised to address the comparison.
66	Ben King	Land Owner	3.3.3	3-80			Table 3-9	Using only 2013 and 2015 water diversion data would lead to a wrong outcome if the diverter did not use surface water available during those years. It is an extremely small and not representative data set. Landowners could have not diverted during those years because they were trying to help other landowners out with their surface water allocations since they had wells or the landowner could have been converting land for orchard development with a new filter system.	Comment acknowledged. The point of the comment is understood; however, use of 2013 and 2015 land use and water supply conditions for all but the historical water budget scenario is driven by the GSP regulations. Those regulations state: "Projected water demand shall utilize the most recent land use...", and "Projected surface water supply shall utilize the most recent water supply information..." Since the historical model runs up through 2015, the "most recent" information would be 2015. However, 2015 (and 2014) was a Shasta Critical year, so for the projections 2015 was used to represent Shasta Critical years, and 2013 was used to represent Shasta Non-Critical years. This assumption was reviewed with several district managers and deemed as reasonable. Note that the 2013 TCCA allocation was 75%, equal to the average 1990-2015 allocation.
67	Ben King	Land Owner		3-81,2				Using Land Use data only for the years of 2003,2009 and 2014 is not representative if there was a conversion from rice to row crops or row crops to orchards. The impact of this narrow assumption set could lead to incorrect Budget Subareas.	Comment acknowledged. These are the years when DWR land use surveys are available. Years in between are interpolated to develop the best historical land use characterization.

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68	Ben King	Land Owner	3-4	3-102				Management Areas should not be set until the GSP is approved and implemented for several years. The history and genesis of the Colusa Groundwater Authority JPS was for collective management of the Subbasin and there is no basis to change the jurisdictional management of the Subbasin in contravention of those principals. Stakeholders and property owners who are paying Prop 218 Assessments must know there is a rational basis for any changes in jurisdictional oversight within the Basin to maintain confidence in the GCA's governance. What should not happen are actions which may lead to a perception that a few powerful members have manipulated the process for their own benefit.	Comment acknowledged. Management Areas were not defined for the Colusa Subbasin.
69	Ben King	Land Owner	4.2.3.3		4-17		Table 4-4	The Monitoring Network is woefully inadequate to protect against groundwater quality degradation and to protect the Human Right to Fresh Water. All wells used for Groundwater Substitution should be used to collect water quality samples and to preserve public accountability against over pumping. There is an incentive for quantity rather than quality and Stakeholders should be entitled to publicly available water quality data from groundwater substitution wells. In order to protect Colusa County Resident's Human Right to Fresh Water Monitoring Wells should be placed in the study area suggested by Springhorn as referenced in the Comments on Section 3. Springhorn raised concerns about high Saline TDS levels and arsenic levels in a large area west and southwest of the Sutter Buttes. Several monitoring wells should be placed in this area. Monitoring wells may also need to be placed around the City of Williams to provide a historical time series to monitor TDS levels over time. If water banking activities start with the development of Sites, this enhanced Monitoring Network and time series will become critical to protect the water supply for the City of Williams.	Comment addressed. The text has been revised to include a better description of the data gaps in the groundwater quality monitoring network.
70	Ben King	Land Owner	4.2.3.4		4-19			Springhorn highlighted a wide area where there are water quality monitoring data gaps. Monitoring wells should be placed in this area in consultation with the DWR and Springhorn's personal input since he highlighted this concern in the first place. Additional monitoring wells may be needed around the City of Williams and any potential water banking sites that could cause degradation of drinking water supplies for on the west side of the Subbasin.	Comment addressed. The text has been revised to include a better description of the data gaps in the groundwater quality monitoring network.

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71	Ben King	Land Owner	4.2.4.4		4-20			One or two Extensometers need to be installed near Arbuckle and Dunnigan. One site should be near the intersection of Bailey Road and Hwy 99 since it is the site of greatest subsidence and because the infrastructure of I-5 is there in addition to the Arbuckle Cemetery and old railroad tracks. The other Extensometer should be installed near Dunnigan working with the Yolo County GSA to choose a site. There are approximately 500 residences in the area and an ever-growing commercial infrastructure.	Comment acknowledged. Colusa County was originally considering installing an extensometer, but has recently been coordinating with DWR (through the CGA) to install a continuous GPS station near Arbuckle instead. We agree that the installation of more real-time monitoring stations both within the heart of current subsidence and along the edges would be beneficial in quantifying the magnitude and rate of subsidence in this area of concern.
72	Donald Bills	GGA-TAC	1	1.2	1.2	2		1.—Sustainable groundwater resources not only preserve, and enhance the economic viability, social well-being and culture of all beneficial uses and users, but also insure the sustainability of water for natural and environmental needs. Especially those of at risk or critical resource value (i.e. springs, wetlands, riparian habitat, and baseflow reached of perennial and/or intermittent streams). I would suggest adding something like this to the stated goal of the Colusa Subbasin GSP. 2.—there is no such thing as sustainable/safe yield. At best the term means planned depletion. I suggest you replace it with sustainable goal.	Comment addressed. The sustainability goal has been updated to precisely match the phrasing adopted by the CGA and GGA, and "sustainable yield" has been changed to "sustainable goal" where it is not text taken directly from DWR or SGMA documentation.
73	Donald Bills	GGA-TAC	1	1.2	1.2	3		1.—Sustainable/safe yield is no longer considered to be a valid term in the context of hydrogeology. The term was originally developed as a legal term to characterize a water budget in balance by relating recharge (from precipitation) with discharge, two terms that are not related. I suggest that you replace it here with sustainable goal.	Please see the response to comment 72.
74	Donald Bills	GGA-TAC	1	1.3	1.2	3		1.—Suggest that you modify Both GSAs in the last sentence to “Both the Colusa and Glenn GSAs…” for clarity.	Comment addressed in the GSP section indicated.
75	Donald Bills	GGA-TAC	1	1.4	1.4	1, bullet 5		1.—Suggest that you add to seawater intrusion, brackish or saline groundwater intrusion. As discussed during TAC meetings, as freshwater is removed from storage in the regional aquifer. The reduced hydraulic head will allow brackish and/or saline water at depth to seep upward into the regional aquifer. Unless monitoring of water quality at depth in the regional is intended to be the monitoring tool for this.	Comment acknowledged. The upwelling or mobilization of brackish or saline connate/deep groundwater is included as part of the "degradation of water quality" undesirable result topic and is monitored via the groundwater quality monitoring program. It is not addressed under the "seawater intrusion" undesirable result topic.
76	Donald Bills	GGA-TAC	1	1.4	4 of 7	Article 5 sub-article 2	1-1, GSP regulation section 354.18, bullet 3	Suggest replacing estimate of sustainable yield with estimate of sustainable goals.	Comment acknowledged. Table 1-1 contains the checklist requirements posted by DWR in 2016. The text and terminology in the "Description" column come directly from that document and were not edited.
77	Donald Bills	GGA-TAC	1	1.4	4 of 7	Article 5 sub-article 2	1-1 GSP regulation section 354.18, surface water supply	Shouldn’t this also include reclaimed water and/or	Comment acknowledged. Table 1-1 contains the checklist requirements posted by DWR in 2016. The text and terminology in the "Description" column come directly from that document and were not edited. Reclaimed water (as "recycled water" or "reused water") is one of the water source types considered under §354.18(b) (as applicable).

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78	Donald Bills	GGA-TAC	1	1.4	6 of 7	Article 5 sub-article 4	1-1, GSP regulation section 354.36, representative monitoring.	Remote-sensing data was discussed as an additional proxy in addition to groundwater elevations for other sustainable indicators. Should it be mentioned here?	Comment acknowledged. Remote sensing is being conducted by DWR. The schedule and flight paths have not yet been determined for the Colusa Subbasin. Chapter 7 includes DWR's planned airborne electromagnetic (AEM) survey as available data to be used for updating the HCM and potentially evaluating groundwater levels, the interface with deeper brackish waters, and lithologies along fault zones. We do not discuss including remote sensing data as an ongoing recurring monitoring program, other than whatever DWR, USGS, and NASA have already planned or implemented. Existing datasets, however, will be evaluated in each GSP annual report and/or periodic evaluation.
79	Donald Bills	GGA-TAC	1	1.4	6 of 7	Article 5 sub-article 4	1-1, GSP reg section 354.36, Assessment and Improvement of Monitoring Network	Again remote-sensing methods and data are another tool that seems suited for filling data gaps by improving monitoring frequency, accuracy, and density of data sites. Discussion of DWR INSAR and gravity data as possibilities.	Comment addressed. All of the satellite surveys, remote sensing surveys, GPS, gravity surveys, SAR/InSAR, etc. are included under the UNAVO umbrella. The text has been updated to specifically call out InSAR as part of the monitoring network for land subsidence and mention other sources of subsidence or displacement data.
80	Donald Bills	GGA-TAC	3	3.1	3-1	1, first sentence		First occurrence of abbrev. Should be spelled out in text. I.E. This section describes the hydrologic conceptual model (HCM) of the Colusa Subbasin.	Comment addressed in the GSP section indicated.
81	Donald Bills	GGA-TAC	3	3.1.3	3-6		3-3. Note in upper left of plot. Second sentence.	There appears to be missing or jumbled text at the start of sentence 2. " at r y ars missing more that 30 days…". Suggest that it be fixed is needed.	Comment addressed in the GSP section indicated.
82	Donald Bills	GGA-TAC		3.1.4	3-8		3-4	Since land surface elevation is color coded on the Topography map, it might help to identify the very light shade of blue as surface water as it can be easily confused with the very light green (greenish-blue?) that is land surface less than 30 ft.	Comment addressed. Edits have been made to Figure 3-4.
83	Donald Bills	GGA-TAC		3.1.5	3-7	Paragraph2, 1st sentence	3-5	"The regional watersheds and natural waterways are shown on Figure 3-5." Figure 3-5 also shows principal water infrastructure. I suggest it be added to the sentence and the fig. 3-5 title.	Comment addressed. Edits have been made to Figure 3-5.
84	Donald Bills	GGA-TAC		3.1.5	3-10	First paragraph, last sentence		"These streams are intermittent and drain the foothills that border the Coast Ranges to the west." Perennial streams are connected to the regional groundwater table and get most of their base flow by groundwater discharge. Intermittent streams are only seasonally connected to the regional groundwater table and flow seasonally or in response to runoff. Ephemeral streams are not connected to the regional groundwater table and only flow in response to seasonal runoff. Are Foothill streams of the Coast range truly intermittent?	Comment acknowledged. The foothill streams are historically a mix of intermittent and ephemeral streams. However, given the many back-to-back, multi-year droughts that the region has been experiencing over the past two decades, these foothill creeks and streams are most likely all ephemeral until they reach the valley floor, where they may have stretches of connectivity with shallow groundwater aquifers.

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85	Donald Bills	GGA-TAC	3	3.1.5.1.1	3-10			Is there no range of flow data for Stony Creek pre-Black Butte Dam (and even Stony Gorge Dam)? This would give some context to the releases from Black Butte Dam since 1996.	Comment acknowledged and addressed. Stony Gorge Reservoir was constructed in 1928. Black Butte Lake was constructed in 1963. Streamflow measurements in Stony Creek downstream of Black Butte Lake are not available prior to 1941. These post-Stony Gorge Reservoir / pre-Black Butte Lake discharges have been summarized in Chapter 3.
86	Donald Bills	GGA-TAC		3.1.5.1.2	3-13			"Sacramento River stream flows measured at the Ord Ferry-Main Channel stream gauge, in the northern part of the Subbasin, varied between 200 and 160,000 cfs during the 1984 to 2020 time period, with extreme low flows measured in the spring of 1990." Why is the time p3.1.5.1.3eriod limited to 1984 to 2020? If the intent here is to describe natural surface waters, there are documented (USGS) periods of extreme flows greater that this range extending back to the 1920 from stream-flow gaging stations in or adjacent to the Colusa subbasin.	Comment acknowledged and addressed. There are limited stream gauges north of the Sutter Buttes with historical discharge data.
87	Donald Bills	GGA-TAC		3.1.5.1.3	3-13			3.1.5.1.4 Glenn Colusa Canal lists acres serviced. Wouldn't it be appropriate to do the same for the Tehama-Colusa Canal? Also the length of the canal and diversions? I watched the Tehama-Colusa Canal being built less that a quarter-mile away from where I grew up on Co. Rd. 21 south of Orland. I even rode my bike in the bottom of the canal once it was cemented in. I noticed at the time there was a line of one-way valves on the bottom of the canal. I later learned they were there to relieve stress on the canal by allow rising groundwater to move into the canal. Is this something you are accounting for in your groundwater models during those wet years when WLS are very close to the surface?	Comment acknowledged. Commentary has been added to the TCC section. The groundwater model does not currently model TCC as a canal. Surface water supplies and agricultural demand are accounted via diversion and place of use information.
88	Donald Bills	GGA-TAC		3.1.5.1.6	3-15	1		"These foothill drainages and their tributaries are classified as part of the Sacramento-Stone Corral Watershed…". I think you mean the Upper Stony Watershed.	Comment acknowledged. Upper Stony Watershed drains into Stony Creek and Stony Gorge Reservoir. The fringe foothills are part of the Sacramento-Stone Corral Watershed. These foothills drain through the ephemeral and intermittent streams.

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89	Donald Bills	GGA-TAC		3.1.5.1.6	3-15	2		"Runoff in these ephemeral and intermittent streams generally begins in late fall when the rainy season starts and may continue until late spring." Intermittent streams suggest some seasonal contact with the regional groundwater table. Probably not true for many of these streams in the north part of the subbasin. I do not know about those in the southern part of the subbasin. Springs are overlooked in this discussion (or elsewhere). Many of these smaller streams have springs at or near their headwaters that issue from either the Tehama (exposures of pre-Paleogene, would have a QW signature), Riverbank or Modesto Formations. Discuss here?... High elevation areas to the west of Orland/Willows. GW contours do not extend that far west. 3.1.11.3 does not address springs. Black butte Lake overlies mostly Tehama formation. Is there ant possibility of Reservoir water seeping into Tehama and showing up in springs to the south? QW signature, spring flow related to lake level not climate, etc.	Comment acknowledged. The foothill streams are historically a mix of intermittent and ephemeral streams. However, given the many back-to-back, multi-year droughts that the region has been experiencing over the past two decades, these foothill creeks and streams are most likely all ephemeral until they reach the valley floor, where they may have stretches of connectivity with shallow groundwater aquifers. Springs are discussed in Section 3.1.11. We decided not to discuss streams in the Hydrology section given the lack of reported information regarding those springs' discharge and source. Some text has been added regarding the historical presence of springs at the headwaters. Groundwater contours are not shown in the northwestern area of the Subbasin due to lack of published data and lack of wells in those upland areas. This indicates either that there is no groundwater in those areas that is economically feasible to access, that the wells in those areas are old and are not included in the DWR well database, and/or that the wells are not currently being monitored and reported. There is a possibility of groundwater in the Tehama Formation to be discharging into Black Butte Lake; however, given the studies conducted by TNC regarding stream-aquifer interactions, available groundwater level data, and a thalweg analysis that has been added to Chapter 3 for Stony Creek, it seems highly unlikely that that is occurring unless it is shallow groundwater or "perched" shallow recharged waters that are not connected to the main freshwater aquifer system.
90	Donald Bills	GGA-TAC	3	3.1.6	3-18		3-9	The color for soil type C and water bodies on fig. 3-9 (light blue) are so similar it is hard to tell them apart. I suggest you consider using more contrasting colors and adding waterbodies to the explanation to make them easier to tell apart.	Comment addressed in the GSP section indicated.
91	Donald Bills	GGA-TAC			3-27		3-16	Top of Cretaceous rocks contours are in meters MSL, and tops of Cretaceous rocks elevation are in feet MSL. Using both metric and SI units makes them a little difficult to compare. Can they both be in the same units? Also, there are places where the contours do not match the elevations (SE of Black Butte, Artois, Princeton, etc.). I assume this is related to structural offsets. I suggest you consider adding the principal structures (faults) to this map to help with the interpretation.	Comment addressed in the GSP section indicated.

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92	Donald Bills	GGA-TAC		3.1.7.2.3	3-31	4		During a review of USGS topographic maps that cover the area west of Orland and Willows, I found about 24 marked springs, a few with actual names. Based on their location, these springs appear to be discharging from either the Tehama, Riverbank or Modesto Formations in the northwest part of the Colusa Subbasin, There is little hydrogeologic information shown on the maps of this report for this area owing to a lack or well data. Springs represent a source of hydrogeologic information that can be used in the absence of well data to extend water level contours and improve understanding of groundwater conditions in the area. Any information about these springs from land owners or site inventories by DWR or the USGS will improve the hydrogeologic characterization of this area of the subbasin. Some mention of spring discharge from the Tehama, Riverbank, and Modesto Formations might be appropriate here, with a more complete discussion in groundwater discharge.	Comment acknowledged. Springs are discussed in Section 3.1.11. We decided not to discuss streams in the Hydrology section given the lack of reported information regarding those springs' discharge and source.
93	Donald Bills	GGA-TAC		3.1.8.2	3-36	2-3		?... Base of the Tehama and Tuscan Formation and (or, and/or?) Base of freshwater excluding those areas where post-Cretaceous sediments contain brackish water. Freshwater is defined as 3,000, 2,000, and 1,000 mg/L depending on which reference is used (USGS, DWR, of C2VSim). Which is it? I would also suggest that you define brackish water here as its related freshwater and the freshwater boundary. The vertical extent of these boundaries shown on fig. 3-11 to 3-13 while approximate do not appear to consistently align with either of these definitions. Perhaps it would be appropriate to add queries ("?") where the degree of uncertainty is highest.	Comment acknowledged. The varying definitions for freshwater versus brackish water are among several issues with defining the base of freshwater. DWR is working on a new base of freshwater study, potentially with a threshold of 1000 mg/L. This threshold concentration is anticipated to be adopted as industry standard for the base of fresh water, and will be used for future versions of the HCM. It is recommended that the model be revised to account to for that. Comment on the cross section mapping has been addressed.
94	Donald Bills	GGA-TAC		3.1.9.2	3-38	1		"These basin faults may act as barriers or conduits to fresh groundwater flows." I think it is also important to mention that, if the faults are deep seated, they can also provide conduits for poorer quality (brackish) water from the marine sediments below to migrate up into the freshwater layer. This is particularly true if the hydraulic head of the freshwater layer is consistently reduced owing to groundwater withdrawal.	Comment addressed. The text has been clarified.
95	Donald Bills	GGA-TAC	3	3.1.10, Principal aquifers	3-39			Some text edits for clarity.	Comment acknowledged. It is unclear what text edits this comment refers to. The entire Chapter 3 has gone through several proofreaders since comments were received and prior to issuance of the public draft GSP.

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96	Donald Bills	GGA-TAC		3.1.10.3, water Quality	3-42	1		Electrical conductivity (EC) is not a measure of the quality of the water. It is a measure of how electrically conductive the water is. As a result, there is a nearly direct relationship between EC and total dissolved solids (TDS) in the water. TDS is one general measure of water quality. The more dissolved solids in the water, the more electrically conductive it is and, as a result, the quality of the water is generally poorer. For this reason, I suggest you delete reference to EC in the first sentence of the paragraph.	Comment addressed in the GSP section indicated.
97	Donald Bills	GGA-TAC		3.1.10.3	3-42			Fire retardant used to be manufactured in Orland and included boron with other chemicals known for both their fire suppression properties and as chemical fertilizer. Currently, fire retardant is a mix of ammonium polyphosphate, diammonium phosphate, diammonium sulfate, monoammonium phosphate, attapulgus clay, guar gum known as Phos Chek. Over time, after a fire, this material gets watered into a watershed and may be a concern for the water quality of an aquifer. It is also highly concentrated where manufactured and distributed (Airports like Orland, Willows, and USFS and CDF fire bases).	Comment acknowledged.
98	Donald Bills	GGA-TAC		3.1.10.3	3-42	3		Most drycleaners use both Trichloroethylene (TCE) and Tetrachloroethylene (PCE) (as did the one in Orland). The studies I have seen on this issue for the Orland area refer mostly to TCE.	Comment acknowledged. Documentation from the Department of Toxic Substance Control and EnviroStor that we have seen indicate that PCE is the constituent of concern for the Orland Dry Cleaner Site.
99	Donald Bills	GGA-TAC		3.1.11, Ground water Inflows and Outflow s	3-42 to 48	1		The section heading is groundwater inflows and outflows. The lead sentence begins “Groundwater underflows between the Colusa Subbasin and neighboring groundwater subbasins…”. Groundwater underflow is a specific type of inflow or underflow. I would suggest that a better use of this introductory paragraph would be to list all the relevant GW inflows and outflows to the Colusa Subbasin as discussed in the following subsections. I would also add the Corning Subbasin in the first sentence in relation to groundwater underflow. As water-level contours indicate (fig. 3-19), Stony Creek is not a barrier to groundwater flow.	Comment acknowledged and addressed. The text has been updated to clarify underflows along the Subbasin boundaries.
100	Donald Bills	GGA-TAC		3.1.11.2. 2, GW banking ?	3-43			Groundwater banking. Not in the glossary of terms and it appears to mean something different here (recharge) as opposed to the most common definition (water management mechanism designed to increase water supply reliability through the buying, selling, and storage of surface water and groundwater rights for later use). I would suggest artificial recharge as a alternate term since the main heading (2.1.11.2) is Groundwater Recharge Areas.	Comment addressed in the GSP section indicated.

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101	Donald Bills	GGA-TAC		3.1.11.3, Ground water discharge areas	3-45	2		I suggest that you consider adding a few sentences about springs in the Colusa Basin to this paragraph. Something like: "Most springs in the Colusa Subbasin occur near the western boundary and discharge from the Tehama, Riverbank, or Modesto Formations and stream channel alluvium. About 25 springs can be identified from USGS topographic maps of the subbasin. A number of these springs have been developed for agricultural use by landowners locally (apparent on satellite imagery). The flow, and water quality of these springs may exist in DWR or USGS databases based on past historical inventories." If properly inventoried these springs would represent significant additional information about the occurrence, movement, and quality of ground water in the regional aquifer of the Colusa Subbasin, especially where this information is poorly defined.	Please see the response to comment 92.
102	Donald Bills	GGA-TAC	3	3.1.11.3	3-48	2, 4th sentence		"There are also many unmetered domestic wells located throughout the study area." I suggest adding unmetered small ag wells also: "…unmetered domestic and small agricultural wells…"	Comment addressed in the GSP section indicated.
103	Donald Bills	GGA-TAC				2, 5th sentence		It might be appropriate to add a sentence or two here to briefly explain how the annual rate of withdrawal from domestic wells was determined (estimated). Average pump capacity of all domestic wells, seasonal domestic water use estimates, or other. Adding small unmetered ag. wells to this total would increase significantly I imagine.	Comment addressed. The methodology used to estimate rural residential (domestic) pumping in the GSP has been added. This is the current, best available approach for quantifying domestic groundwater pumping in the Colusa Subbasin.
104	Donald Bills	GGA-TAC		3.1.11.3	3-48	3		I would also add a comment to this paragraph that during years when surface water deliveries are significantly cut back (drought), agricultural lands rely heavily on wells to make up the difference.	Comment addressed. The suggested text has been added.
105	Donald Bills	GGA-TAC	3	3.1.12.1	3-51	4		other methods or data sources: I'd like to suggest passive seismic. The method uses seismic signals already available in the environment, either anthropogenic (i.e. freeway traffic), or natural (i.e. earthquakes, ocean waves, etc). the seismic signals are processed similar to standard reflection and/or refraction surveys but for much larger areas and depths. Ground-based, non-invasive CSAMT (Controlled Source Audio-frequency Magnetotellurics) and TEM (transient electromagnetic or alternately called time-domain EM (TDEM)) surveys can provide detailed subsurface information on stratigraphy, structure, depth to water and water quality in localized areas of interest. Survey lines that pass over or by existing wells provide ground-truth.	Comment addressed. Thank you for pointing out these alternate methods of subsurface mapping. The text has been revised.

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106	Donald Bills	GGA-TAC	3	3.1.12.1	3-52	1		Different TDS thresholds to define base of freshwater. Part of the problem may also be that water use type has a lot to do with whether water is considered fresh or not. MCL for safe drinking water is 500 mg/L, Livestock can tolerate about 1,500 mg/l. A lot of commercial ag. plants can tolerate 2,000 to 3,000 mg/L. There is also not broad agreement on what constitutes fresh, saline, or brackish water. It seems to me that the standard for what constitutes freshwater should be the same for all subbasins in the Sacramento Valley, if not the entire Central Valley.	Comment acknowledged. Please see the response to comment 92. The idea is to use the upcoming DWR study as the standard TDS threshold for freshwater.
107	Donald Bills	GGA-TAC		3.2.2.1	3-53	2, second sentence		"The most notable recovery period occurred around 1983, which was both a wet year and when water users added more surface water to their supply portfolios." The recovery after the 1987 to 1991 drought seems at least as great if not greater.	Comment addressed. The 1991 recovery is a notable recovery in terms of magnitude while the 1983 recovery is notable in terms of conditions prior to 1983 and after 1983. When surface water supply increased, there was a large rise in water levels.
108	Donald Bills	GGA-TAC			3-53		3-22	It is hard to evaluate temporal trends on this plot referring back to the average annual precipitation plot at the beginning of this chapter. To help understand and evaluate this temporal data it would seem appropriate to add a plot of the annual average precipitation to this graph.	Comment acknowledged. Precipitation was excluded from this hydrograph in the interest of using the two existing vertical axes to show depth to water and elevation. The drought periods are shown on the hydrograph for reference to climatic events. The text has been revised to clarify that the peaks and valleys in the water level hydrograph represent the rainy season and dry season, respectively.
109	Donald Bills	GGA-TAC		3.2.2.1	3-55	1		Besides showing the general direction of flow to the SE, Figure 2 appendix 3-B appears to show Walker Creek to be a gaining stream (i.e. perennial, groundwater contours point up stream) from the NW part of the subbasin to Artois. Comparing land surface contours (fig 3-4) to the groundwater contours for this area seems to indicate that the depth to water is from -10 to -30 ft below the streambed throughout. Is there a discrepancy here that needs to be resolved?	Comment acknowledged. The contours shown are groundwater elevations, not depth to water. The contours point upstream and indicate groundwater flow is in the direction of the drainage. There are a number of potential factors for why it looks like the depth to water is above land surface. These include, but are not limited to, the spatial density of available data, construction of monitored wells, assumptions made during interpolation into contours, and the scale of regional mapping. Many of the multiple completion monitoring wells show an upward gradient within the Subbasin, and most of the monitored wells are constructed in the semi-confined to confined zone of the principal aquifer. It is possible that groundwater is discharging to Walker Creek in this area during the spring of 2006.
110	Donald Bills	GGA-TAC	3	3.2.2.1	3-55	4		"Current groundwater levels are similar to those measured in 2017, indicating that regional groundwater levels have been relatively stable since the end of the previous multiple-year drought." I find this statement a little misleading. What it overlooks is the fact that the combined effect of the 2007-09 and 2012-16 droughts was an average depth to water decline of over 30 ft (fig 3-22) from which the principal aquifer has yet to recover. In addition the 2019 and 2020 was appear to continue trending down, not stable, as cones of depression continue to expand (fig 3-24 and 3-25).	Comment acknowledged. As of the making of the hydrograph, the water levels had somewhat stabilized. Of course, we have entered a period of alternating average and dry or multiple-dry years and this is taking a toll on the aquifer system. In particular, it is taking a toll on the shallow groundwater aquifer system, which is lacking in available water level data. DWR and GSAs have started working to improve monitoring and record-keeping of shallow wells and wells that are going dry, but that has not been evaluated as part of this GSP given the SGMA time constraints. The text has been revised to mention this.

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111	Donald Bills	GGA-TAC		3.2.2.1	3-55	1,3rd sentence		"Impacts due to pumping are the exception to the typical gradients and disrupt both local and regional gradients." I suggest that you add to this sentence or the first sentence of the paragraph a comment on the effects of changing hydraulic parameters on the lateral groundwater gradient.	Comment addressed in the GSP section indicated.
112	Donald Bills	GGA-TAC		3.2.5	2-64	Second		Delete EC. It is not a water quality parameter.	Comment addressed in the GSP section indicated.
113	Donald Bills	GGA-TAC				third		Who monitors and regulates the water quality of municipal supply systems? Worth mentioning here? Regional water quality control boards? Saline connate water? Connate water is water trapped within the pores of sedimentary rocks. For that to happen it would have to be fully confined laterally and vertically and not be faulted or fractured. In the geologic discussion it states that pre-Cretaceous rocks are faulted and fractured. Groundwater is almost always in motion and always flows in response to gravity and/or the hydraulic gradient. The flow rates can be very slow, ft per hundreds to thousands of years or more. The connate water would be in pre-Cretaceous sediments. Has anyone dated the water to see if it is, in fact, greater than 145 million years old, give or take?	Comment acknowledged. The municipal wells are regulated under SWRCB and the Division of Drinking Water. Drinking water quality is submitted to the SWRCB SDWIS Water Watch and GeoTracker systems. This is discussed in Chapter 4, Monitoring Networks.
114	Donald Bills	GGA-TAC		3.2.5.1.1	3-64	1		End of first sentence add "…and/or EC value (EC is a surrogate [estimate of] for TDS because it is more easily measured on site)." There appears to be a discrepancy in the Secondary MCL for TDS; 500mg/L in sentence 2 and 500 mg/L in sentence 4. Fix?	Comment acknowledged. TDS has three MCLs: the recommended limit (500 mg/L), the upper limit (1000 mg/L), and the short-term limit (1500 mg/L). This has been explained in the text.
115	Donald Bills	GGA-TAC		3.2.5.1.1	3-66	1		"Wells screened in the unconfined to semi-confined zone of the aquifer (i.e. in wells less than 200 feet deep) had the highest number of wells with elevated TDS concentrations." I suggest adding "in thew central and southern part of the subbasin" to the end of this sentence.	Comment addressed in the GSP section indicated.
116	Donald Bills	GGA-TAC		3.2.5.1.1	3-66	2		First sentence, …In these areas…. What areas? Suggest replacing with …southwest of Colusa…	Comment addressed in the GSP section indicated.
117	Donald Bills	GGA-TAC		3.2.5.1.2	3-67	1		Anthropogenic source for increasing chloride and sulfide concentrations? Septic systems, landfills, other?	Comment addressed in the GSP section indicated.
118	Donald Bills	GGA-TAC		3.2.5.2.2	3-67	1		Boron. Pre, late 1970's Boron was a component of fire retardant for its fire suppression characteristics. Fire retardant was manufactured in a plant in Orland and stored at firebases (airports) in Glenn and Colusa counties. Is saw wide use in suppressing forest, brush, and grass (at lower elevations) fires in Glenn and Colusa Counties.	Comment addressed.
119	Donald Bills	GGA-TAC		3.2.5.2.3	3-68	1		Known or suspected cause for increases in iron and manganese worth mentioning here? Natural or human caused? Landfill west of Artois? Junk yards? Suggest adding if appropriate.	Comment addressed.
120	Donald Bills	GGA-TAC		3.2.5.2.3	3-68	1		Known or suspected cause for anthropogenic increases in hexavalent chromium worth mentioning here? Landfill west of Artois? Suggest adding if appropriate.	Comment addressed.

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121	Donald Bills	GGA-TAC		3.2.7	3-73	2 and 3 paragraphs		The second paragraph is misleading ("While Stony Creek, Sacramento River, and the Colusa Basin Drain all experience gaining and losing conditions throughout the year,…") and appears to contradict the information provided in the 3rd paragraph. I would suggest deleting the second paragraph entirely and moving the table references to the 3rd paragraph.	Comment addressed in the GSP section indicated.
122	Donald Bills	GGA-TAC		3.2.8	3-74	2nd paragraph	3-34	I do not follow the scoring criteria for GDE. A GDE where groundwater is near the surface has a score of 1; least likely to be GDE when it should be more likely to be a GDE. If a GDE is not near surface water OR crop land it scores a 4; most likely to be a GDE when it should be least likely to be a GDE. How the 30 ft DTW line was derived is explained in paragraph 1 on page 3-75. But I could not find or estimate the 30 ft DTW on any or the other figures in the text or appendix. An approximated 30 ft DTW line for 2006 data on figure 3-19 would run from between Arbuckle and College City, to near the boundary of the subbasin west of Williams, to just west of Artois, ending at Stony Creek just N/NW of Orland. This is nowhere near the line shown on figure 3-35. Using figure 5 in appx 3B I can approximate a 30 ft contour to the 2017 data. But it also does not compare to the 30 ft DTW contour on figure 3-35. The explanation table on figure 3-35 does not reference a time period (2014 to 2018?) for the 30 ft DTW line or any of the other features shown. Finally, there is no reference to springs and the riparian habitat they support at headwater streams in the NW part of the subbasin between Willows and Orland. These would represent some of the most important and species diverse habitat in the subbasin. I would suggest that the entire GDE section be revised so it more clearly and plainly represents GDE's that occur within the subbasin.	Comment addressed. Clarification has been added in the section indicated. The scoring criteria uses an if/then method. If the response to criteria 1 is "yes," then the scoring moves on to criteria 2. If the response to criteria 1 is "no," then that land receives a score of 1 and the scoring ends. GDEs are near shallow groundwater and not near agricultural lands or surface water features.
123	Donald Bills	GGA-TAC	3	3.3 Water budget information	3-77	1		This section describes water budget components in detail but, I did not see a clear statement of what the water budget was for. Water budgets can be used for many things (i.e. GW gains or losses, basin gains or losses, etc). Is there a statement of the purpose of the water budget in the Groundwater Sustainability Plan Emergency Regulations §354.18 that could be added to the introduction here? The name suggests it is to determine groundwater sustainability of the principal aquifer in the subbasin. That implies that all the inflows and outflows are on onside of the equation and +/- change in storage is the result.	Comment addressed. The introduction has been edited to explain the purpose and utility of water budgets.

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124	Donald Bills	GGA-TAC	3	3.3.3	3-80		3-9	What is the Shasta non-critical and Shasta Critical, mentioned on the table? How does it relate to the Colusa Subbasin? I think it is defined two pages later under Land use. But there is still no explanation of what a Shasta critical and Shasta noncritical year is. Reservoir contents? Outflow? Both? Is there a reference for this missing? It would be worth providing a footnote to table 3-9 to define Shasta critical and Shasta non critical.	Comment addressed. An explanatory footnote has been added at the first reference to "Shasta Critical" and "Shasta Non-Critical" years in the text.
125	Donald Bills	GGA-TAC		3.3.3.3	3-83	3, Land Use		"…modified based on planned development according to the Colusa County 2030 General Plan." Is there a 2030 Glenn County General plan worth considering here as well?	Comment acknowledged. The Glenn County General Plan is currently being updated. The current plan is 28 years old, and thus does not have much direct utility for this application.
126	Donald Bills	GGA-TAC	3	3.3.4	3-84	1, bullet 1		Groundwater pumping and stream accretion are described as inflows here. In paragraph 2 second bullet on page 3-85 they are described as outflows. Which is it? I would suggest they are both outflows from the principal aquifer and the text needs to be fixed accordingly.	Comment acknowledged. From the perspective of the surface water system, which is essentially the root zone and surface waterways, groundwater pumping and accretions are inflows. From the perspective of the underlying groundwater system, these same two flow paths are outflows.
127	Donald Bills	GGA-TAC		3.3.4	3-85	3rd bullet of first paragraph (3-84)		Change in Storage is defined as changes in soil moisture storage within the upper several feet of soil in the root zone, as well as changes in storage in surface water bodies within the basin. Neither of these are change in storage. They are either inflows or outflows components that when summed with other inflows or outflows result in a change in storage of the principal aquifer. I would suggest that the text be fixed accordingly.	Comment acknowledged. The volume of water stored in the root zone and surface water bodies (mainly canals and drains) changes over time (seasonally) depending on a variety of factors. But on an annual basis the change from year to year is very small.
128	Donald Bills	GGA-TAC			3- 86 and 3-87		3-10 and 3-11	The tables do a much better job of representing the various SW and GW components of the water budget. Is there some way change the text so it is mere consistent with the tables? Also, In both table 3-10 and 3-11 the column headings for future conditions climate change relate to a specific date (2030 and 2070). It would be useful to the reader if the other columns (historical simulation, current baseline, and future condition no climate change base line) had the time periods they are based on as well. 1990 to 2015, 2015, and 1966 to 2015 respectively.	Comment addressed. The suggested edits have been made.
129	Donald Bills	GGA-TAC		3.3.4.1	3-88	4		I would suggest that ET from the riparian corridor of the Sacramento River as well as evaporation from the rivers surface can also be significant and worth discussing here. Especially during the summer months when ET is at a maximum and daytime temperatures can exceed 100 degrees for weeks at a time. This is important to consider under future climate change scenarios where temperatures and the days per year of excessive heat are predicted to increase.	Comment addressed. A sentence has been added preceding Tables 3-10 and 3-11 noting that Native Vegetation ET includes riparian corridors along streams and rivers.
130	Donald Bills	GGA-TAC		3.3.4.1	3-89		3-38	I would suggest that you add the change in storage (3taf.yr) to the graph. It is not apparent on the graph even though it is color coded in the legend. The columns look equal. In any case it should not be a color-coded box as inflow or outflow. It is the result of both.	Comment addressed in the GSP section indicated.

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131	Donald Bills	GGA-TAC		3.3.4.1	3-90		3-39	The GW change is storage in table 3-12 is shown as a negative number (-27.5 taf/yr, a loss). So, why is it shown as an inflow in this figure? Change in storage is neither an inflow nor a outflow but the result (sum) of both. Showing it this way graphically suggests the inflows and outflows are in balance. They are not. I would suggest that you add the actual change in storage (-27.5 taf/y) to the legend and remove it from the inflow column. I suggest you make similar changes to figures 3-40 to 3-47.	Comment acknowledged. The convention we choose to use is to include change in storage on the chart so the sum of the 2 columns are equal. A negative change in storage results from inflows being less that outflows, so the change in storage gets added to the inflows so that the two columns balance.
132	Donald Bills	GGA-TAC		3.3.4.1.1	3-91	1 and 2	3-12	"The primary sources of surface water in the basin are the Sacramento River and Stony Creek. Surface water supplies are relatively reliable in the basin and represent approximately 74 percent of the total water supplies." Is this statement accurate? How do Shasta critical and non-critical years affect it? I would think that during Shasta critical years SW deliveries would be much and during Shasta non-critical years would be at or near 100 percent. The second paragraph seems to support this.	Comment addressed. We have verified the calculation and the value is 70%. The value has been corrected, and clarification has been added.
133	Donald Bills	GGA-TAC	3	3.3.4.2	3-93	2		Average annual inflows to and outflows from the groundwater system were estimated to be 997 taf/yr during the current conditions baseline simulation period on figure 3-41 are shown as 998 taf/yr not 997. Which is right?	Comment acknowledged. The 1 AFY discrepancy results from rounding. Both numbers as regarded as right, within uncertainty.
134	Donald Bills	GGA-TAC		3.3.4.3.1	3-95	4		"There is negligible change in groundwater storage under the future condition, no climate change baseline water budget." I suggest you add the actual change in parentheses: "…negligible change (+0.6 taf/yr)…"	Comment addressed in the GSP section indicated.
135	Donald Bills	GGA-TAC		3.3.4.3.2	3-97	1		"Average annual inflows to and outflows from the groundwater system were estimated to be 1.0 maf/yr." I suggest you add the type and time period to toe sentence so it is consistent with the title of this section and the figure referenced. "Average annual future conditions 2030 climate change baseline groundwater system inflows to and outflows from the groundwater system were estimated to be 1.0 maf/yr."	Comment addressed in the GSP section indicated.
136	Donald Bills	GGA-TAC		3.3.4.3.2	3-98		3-45	Change in storage is not an inflow as shown…. See previous comments.	Please see the response to comment 131.
137	Donald Bills	GGA-TAC		3.3.4.3.3	3-100		3-47	Change in storage is not an inflow as shown…. See previous comments	Please see the response to comment 131.
138	Donald Bills	GGA-TAC		3.3.5	3-101	1		"Uncertainty refers to a lack of understanding of the basin setting…" Add Water Budget to uncertainty in the first sentence to be consistent with the section title. I.E. "Water budget uncertainty refers to…"	Comment addressed in the GSP section indicated.

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139	Donald Bills	GGA-TAC		3.3.6	3-102	1		"Based on the current conditions and future conditions with no climate change scenarios, which represent long-term average conditions in the subbasin, overdraft conditions are not expected to occur in the Colusa Subbasin." The rest of the paragraph appears to contradict this. I suggest you change not to expected to occur to minor or modest overdraft is expected to occur.	Comment addressed in the GSP section indicated.
140	Donald Bills	GGA-TAC		3.3.7	3-102	1		"As described previously, sustainable yield refers to the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin, and including any temporary surplus that can be withdrawn annually from a groundwater supply without causing an undesirable result." At the beginning of this chapter sustainable yield was also related to a maximum depth below lands surface, 200 ft I believe. I suggest you add that add that condition her also.	Comment acknowledged. Yes, other sustainability indicators need to be brought into the estimate of sustainable yield, particularly streamflow depletion, and effects on GDEs and other beneficial uses and users.
141	Donald Bills	GGA-TAC		3.5, references				I did not attempt to check or verify references…	Comment acknowledged.
142	Donald Bills	GGA-TAC	4	4.2.2.2.1	4-4	1		Groundwater levels should be measured from a pre-established and recorded reference point. — The reference point elevations (RPE) need to have been surveyed to the NAVD 88, feet and shall be accurate to within 0.5 feet, at a minimum (23 CCR §352.4(a)(4). The USGS standard is 0.1 ft. The reasoning is related to the accuracy of GW model results. If the accuracy of GWLs input to GW models are not accurately known, any errors in model results propagate over time through the model runs. As a result, GWL changes and associated changes in inflow, outflow and storage become increasing less certain. In the case of the Colusa subbasin knowing the accuracy of the MP to only 0.5 ft could result in WL changes of +/- 0.5 ft and storage changes of +/- 0.5 ft (100,000s af/y potentially). Also, Accurate to within 0.5 ft at a minimum seems a little ambiguous. Do you mean that 0.5 ft is the least accurate value acceptable but greater values (1.0 ft, 5.0 ft, etc.) are also acceptable? I would suggest you change this phrase to : " accurate to within +/- 0.5 ft (+/- 0.1 ft if you are going to use the more broadly accepted standard). If you make the change here, make it throughout the rest of the text.	Comment addressed. The protocols and requirements have been shortened to include only a summary of the requirements and references for approved protocols. This level of detail is no longer included in Chapter 4.

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143	Donald Bills	GGA-TAC		4.2.2.2.1	4-4	1, bullet 2		"…Equipment should be operated and maintained in accordance with the manufacturer's instructions." The WL measuring equipment should be calibration checked annually to be sure it is still the same as the original manufacture calibration. In addition, if a well probe is stuck in is a well but can be removed. The calibration of the well probe should be verified before the probe is used again.	Comment addressed. Please see the response to comment 142.
144	Donald Bills	GGA-TAC		4.2.2.2.1	4-4	1, bullet 3		Monitoring wells developed in partially confined or confined aquifers can have a pressure gage installed in the well cap as a further indication of potential hydraulic head.	Comment addressed. Please see the response to comment 142.
145	Donald Bills	GGA-TAC		4.2.2.2.1	4-4	1, bullet 4		Near pumping, recently pumping nearby. Nearby stream flowing or not recently following or not, etc.	Comment addressed. Please see the response to comment 142.
146	Donald Bills	GGA-TAC		4.2.2.2.1	4-4	1, bullet 6		Water levels shall be measured to the nearest 0.1 foot, at a minimum (23 CCR §352.4(a)(3). Measurements to the nearest 0.01 feet are preferred and should be used if the equipment allows. — Groundwater elevations (GWE) are calculated as the RPE minus measured depth to water (DTW). See the problem here? It your RPE is only accurate to +/- 0.5 ft, your GWE is now only accurate to +/- 0.6 ft. USGS standard is to measure RPE's to +/- 0.1 ft and WLS to +/- 0.01 ft (depths less than 500 ft) and round to the nearest 0/1 ft. In addition, all depth to water measurements in wells are repeated until you can get three results within 0.1 ft of each other. The average is used.	Comment addressed. Please see the response to comment 142.
147	Donald Bills	GGA-TAC	4	4.2.2.2.1	4-5	2, bullet 5		"Recorded information should include:…" NOTE: The Height of the RPE can and will change over time. That is why it should be checked at least annually, and the new elevation noted if it has changes.	Comment addressed. Please see the response to comment 142.
148	Donald Bills	GGA-TAC		4.2.2.3	4-6		Figure 4-1	Significant cones of depression (GW withdrawal for Ag.) occur to the NW of Orland just south of Stony Creek and to the SW of Orland. Yet, there is only one monitoring well (21N04W12A001-004M) available to evaluate these drawdowns as they develop over time. I would suggest additional monitoring wells be places in these areas. The same is true in the area to the west of Artois and Willows.	Comment addressed. Please see the response to comment 142.
149	Donald Bills	GGA-TAC		4.2.2.3	4-12	2		"Many of the surface waters are near wells included in the current groundwater monitoring network, except for the surface waters within the Colusa National Wildlife Refuge, east of Williams." Suggest you add the following to this: "…east of Williams, N and NW of Orland near Stony Creek, NW of Artois along the middle reaches of Walker Creek, and NW of Willows along the middle reaches of Willow Creek."	Comment addressed. These additional data gap areas are now called out in the GSP.

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150	Donald Bills	GGA-TAC		4.2.2.3	4-12	5		Are the caved-in of casing collapsed wells going to be repaired or replaced?	Comment acknowledged. To the best of our knowledge, there are no plans to repair or replace these damaged wells. The GSP now excludes the damaged wells from the monitoring network and includes recommended replacement wells, as well as recommended locations for new wells to add to the monitoring network.
151	Donald Bills	GGA-TAC		4.2.2.4	4-12	2, item 2		Consider adding: c. Areas of active drawdowns (storage decline) with minimal monitoring well coverage.	Comment addressed in the GSP section indicated.
152	Donald Bills	GGA-TAC	4	4.2.2.5.2	4-14			I would recommend considering adding monitoring wells in the areas mentioned in my comments on page 4-6 and 4.12. Figure 4.2 already shows one well being removed from the network in the areas near Orland mentioned in comments on page 4-6.	Comment addressed. These additional data gap areas are now called out in the GSP.
153	Donald Bills	GGA-TAC		4.2.3	4-14			Irrigated Ag is also known to increase salinity in shallow water-bearing zones as irrigation leaches minerals from the soil. I would also add nitrate as a constituent of concern for the Colusa subbasin. Nitrates resulting from livestock operations and areas with a high density of septic systems are known to also leach in to the subsurface.	Comment acknowledged. The GSAs decided to focus on salinity for their groundwater quality monitoring as nitrate is more heavily regulated, monitored, and required to have management actions if exceedances occur. The GSP annual report and periodic GSP evaluations and updates will evaluate existing nitrate concentrations, but nitrate is not currently a constituent of concern for action from the GSAs.
154	Donald Bills	GGA-TAC		4.2.3.2	4-16	1		Wilde, 2005 has been updated extensively. Newer versions od different chapters of the report were developed in 2008, 2012, 2014, 2018, 2019, 2021 The entire manual is now available online at: https://www.usgs.gov/mission-areas/water-resources/science/national-field-manual-collection-water-quality-data-nfm?qt-science_center_objects=0#qt-science_center_objects 3rd Bullet: Sample integrity, i.e. ppb protocol? Perhaps add a comment about the chain of custody (oops… bullet 14).	Comment addressed. Wilde (2005) is the version recommended in the DWR BMPs. The text was revised to acknowledge this recommendation, but also to allow for more recent versions to be used.
155	Donald Bills	GGA-TAC		4.2.3.2	4-16	2, bullet 2		And the unique identifier should be verified to already exist in the data base so the data has a home and does not end up in a "unknown site" file.	Comment addressed. Please see the response to comment 142.
156	Donald Bills	GGA-TAC		4.2.3.2	4-16	2, bullet 6		During purging of the well field parameters should be monitored until stable to insure the well has been correctly purged. Easy to do with a QW multi meter.	Comment addressed. Please see the response to comment 142.
157	Donald Bills	GGA-TAC		4.2.3.2	4-16	2,bullet 8		Suggest adding dissolved oxygen (DO) to the list of filed parameters. GW typically has low or near zero DO. Water sitting in well casing for a period of time will accumulate concentrations of DO. Represents another good indicator of proper well purge.	Comment addressed. Please see the response to comment 142.

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158	Donald Bills	GGA-TAC		4.2.3.2	4-16	2, bullet 9		Sample labels can be preprinted in the lab with all the appropriate info. Prevents the smearing of hand-written labels using pencil, ink and even waterproof ink (Sharpie). Also be aware that the outside of the sample bottles can "sweat" in coolers or other containers. The result is the label glue will weaken and the labels will come off. Double bag samples is one solution.	Comment addressed. Please see the response to comment 142.
159	Donald Bills	GGA-TAC		4.2.3.2	4-16	2, bullet 10		Field parameter DO is a good indicator of this. Laminar flow may require the use of a variable speed pump so DD is not excessive during collection of the water sample.	Comment addressed. Please see the response to comment 142.
160	Donald Bills	GGA-TAC		4.2.3.2	4-16	2, bullet 11		DQOs? Is this a reference to Quality assurance. If so a number of duplicates, blanks and spike samples will need to be processed either in the lab or on site, depending on the type and number of water samples being collected during an individual field run. Maybe briefly explain here?	Comment acknowledged. The references to DQOs have been removed or reworded, as necessary, as we did not define specific DQOs.
161	Donald Bills	GGA-TAC		4.2.3.2	4-16	2, bullet 12		In this case DQOs appears to be referring to lab detection limits for individual constituents. Correct or no? May need more explanation here.	Comment acknowledged. The references to DQOs have been removed or reworded, as necessary, as we did not define specific DQOs.
162	Donald Bills	GGA-TAC		4.2.3.5	4-19	1		The lead sentence suggesting the existing QW monitoring programs as sufficient contradicts 4.2.3.4 which says they are not sufficient. If the existing monitoring wells are not spatially located enough to address salinity concerns or, not deep enough to detect upwelling of brackish GW from below, they are indeed not sufficient.	Comment acknowledged. The text has been revised to include a more in-depth discussion about the rationale, data gaps, and recommendations for the groundwater quality monitoring network.
163	Donald Bills	GGA-TAC		4,2,3,5	4-19	2		Small diameter monitoring wells pose additional issues for the collection of Value QW samples. Small diameter submersible pumps (less than 2 inches) are few and far in between. Typically, they are limited to lifts of 100 ft or less, and have small pumping rates (~one gpm or less). Bailers (Teflon preferred) are another option and are readily sized to fit in 2-inch monitoring wells. Bailing a well to purge can be difficult depending on the depth. Bailers have to be pre cleaned between each water sample. Bailer sample volumes may be on the order of 1 liter or less meaning several bail volumes to collect a sample. Then there is still the issue if ant of the monitoring wells are deep enough to register upwelling of brackish water from below.	Comment addressed. Please see the response to comment 142.
164	Donald Bills	GGA-TAC		4.2.4.1 lands subsiden ce	4-20	2, bullet 8		Land subsidence should be measured at least as accurately as SWLs if not more accurate. Small changes in land subsidence (tenths of a foot, not half a foot or more) can have a significant impact on the surface and on GW storage. If you are measuring the elevation of ground surface to +/- 0.1 ft and the elevation of your RP to +/- 0.5 ft, again the accuracy of your subsidence measurement is no better than +/- 0.6 ft.	Comment addressed. Please see the response to comment 142.

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165	Donald Bills	GGA-TAC		4.2.5.1	4-24	1, bullet 7		Benchmarks at USGS stream-flow gaging stations are surveyed to the nearest 0.01 ft. One-hundredth foot accuracy is critical to development of a good (+/- 5 percent of the actual flow) or better stage-discharge relationship. If not, you risk losing indications of GW supported base flow and any seasonal signature of gaining or losing flow to/from GW. As an aside, the USGS also requires a minimum of 10-years of continuous (every 15-minutes) record for the data to have any statistical significance.	Comment addressed. Please see the response to comment 142.
166	Donald Bills	GGA-TAC		4.2.5.2	4-24	3		Accuracy of stage data is +/- 0.01 ft (required).	Comment addressed. Please see the response to comment 142.
167	Donald Bills	GGA-TAC		4.2.5.5	4-24	1		Figure 4-4 is land subsidence. I think you mean figure 4-5. The legend for figure 4-5 does not provide adequate explanation of the different stream types shown on the map (perennial, intermittent, ephemeral, canals, or drains). The line widths and colors vary from thick to very thin and light blue to very light blue respectively. It needs to be revised.	Comment addressed. Waters in the maps have been adjusted in coloring, as deemed necessary.
168	Donald Bills	GGA-TAC		4.2.5.5	4-25	2		"Additionally, existing stream and drainage reports will be evaluated for additional information on the timing, stage, and magnitude of flows in ephemeral and intermittent streams in the subbasin, if necessary to fill data gaps or support projects and management actions during GSP implementation." There used to be a stream-flow gaging station on Walker Creek at Artois. Still there? Still active? There also use to be a gage on the Glenn-Colusa Canal where it crosses Stony Creek south of Hamilton City. Still there? Still Active? I imagine there are additional discontinued stream-flow gaging stations scattered across the Colusa subbasin. If the structures for these sites are still there, they can be re-established by installing stage recorders and making periodic discharge measurements to verify the old stage discharge relationships. Besides the Colusa Drain, Willow Creek west of Willows is another intermittent/ephemeral stream that would be worth the effort to gage.	Comment addressed. The text has been revised to include a more in-depth discussion about the rationale, data gaps, and recommendations for surface flow and spring monitoring.
169	Donald Bills	GGA-TAC		4.3 Referenc es	4-27			Add Wilde (2005) or most recent reference(s) available. Reference for California Rice Commission? Reference for California Statewide Groundwater Elevation Monitoring Program (CASGEM)?	Comment addressed. The references are included under the consulting agencies name. Wilde (2005) is the version recommended in the DWR BMPs. The text was revised to acknowledge this recommendation, but also to allow for more recent versions to be used.
170	Holly Reimers		1	1.1	1-1	2		The priority being to halt overdraft and bring basins into balance? This is not even close to being complied with. The overdraft is far greater than the recharge with the ground water tables lowering each year.	Comment acknowledged. Halting overdraft and bringing the subbasin into hydrologic balance is a goal. Achieving this goal will take a lot of effort, collaboration, and give-and-take between all of the affected peoples, communities, industries, and environments.
171	Holly Reimers		1	1.1	1-1		1, 2 & 6	Sounds good but is NOT will not work and is not doable.	Comment acknowledged. This bullet list includes the "undesirable results" as defined by DWR and SGMA.

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172	Holly Reimers		1	1.1	1-1	4		Achieving the groundwater management within 20 years WILL BE TOO LATE.	Comment acknowledged. The 20-year timeframe was decided and established through SGMA, and is simply a deadline for sustainability to be reached or improvements to be shown. Ideally, improvements to groundwater and surface water conditions will occur much sooner than the 20-year deadline.
173	Holly Reimers		1	1.2	1-2	1		SEE ABOVE!	Comment acknowledged. The 20-year timeframe was decided and established through SGMA, and is simply a deadline for sustainability to be reached or improvements to be shown. Ideally, improvements to groundwater and surface water conditions will occur much sooner than the 20-year deadline.
174	Holly Reimers		1	354-10	3 of 7		1-1	The whole process has been totally lacking in "public engagement". Nor has the GGA encouraged any "active involvement". As the times we have given input we have been overridden by counsel.	Comment acknowledged. This concern has been conveyed to the public outreach team.
175	Holly Reimers		2	2.1.2	2-4	2.1.2.1		With the Colusa Subbasin depending on ground water for their potable water the ground water for these wells should be closely watched as the number of wells are going dry or having to be lowered at an alarming rate.	Comment acknowledged. Additional text has been added to Chapter 2 to specify private pumper representation in the GSAs and to Chapter 3 to include a data gap concerning groundwater levels in shallow domestic wells.
176	Holly Reimers		2				2-6	The table shows the density of Ag. wells around Orland. Is anyone reporting the number of domestic wells that are being affected by this?	Comment acknowledged. The density of domestic wells is shown in the middle panel of Figure 2-6. Well densities are based solely on DWR's records and may not reflect all existing wells in the Subbasin. Domestic wells impacted by lowering of groundwater levels are not being tracked in this figure. Additional text has been added to the GSP Chapter 3 to include a data gap concerning groundwater levels in shallow domestic wells.
177	Holly Reimers		2	2.2	2-16	2.2.1.1		"Manage and reduce invasive plant populations" This has been one of my main talking points for many years. The Salt Ceder and the Bamboo are non native and are using more water than any other source. Especially in this dry year these plants need to be eradicated!	Comment acknowledged.
178	Holly Reimers		2	2.2	2-17	2.2.1.1		"Ensure long-term Groundwater Sustainability" At the rate this is going and where it is headed the train has left the station and we in Glenn County will have little or no ground water in the very near future. Domestic and livestock wells MUST be protected.	Comment acknowledged.
179	Holly Reimers		2	2.2	2-17	2.2.1.1		The definition of sustainable: "related to, or being a method of harvesting or using a resource so that the resource is NOT depleted or PERMANENTLY damaged". To date all that I have seen and hear coming from the GGA has been a JOKE!!!	Comment acknowledged.
180	Holly Reimers		2		2-23	2.2.4		With 2021 being one of if not the driest years on record to transfer surface water OUT of the subbasin should be at the very least suspended. To transfer serfice water then pump ground water as a substitute should not be allowed.	Comment acknowledged. Much of the surface water that flows within or through Colusa Subbasin is managed by USBR, a federal agency. Local agencies have little to no power to determine the amount of surface water that is transferred out of the Subbasin.
181	Holly Reimers		2		2-29	2.5.1.2		Chowchilla?????	Comment addressed in the GSP section indicated.

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182	Holly Reimers		3		ALL	ALL		Anyone reading this needs a Masters degree in Geology. Anyone looking for something to put them to sleep at night can try this chapter. Most of what is contained is FAR above most people and especially those here in Northern California. Maybe this chapter is necessary but it is way over the top on so much detail that it loses the normal person. It certainly lost me.	Comment acknowledged. All of the topics are either required by DWR and SGMA or are industry-standard supplemental topics that were deemed to be appropriate for inclusion in this Chapter. The goal of Chapter 3 was to meet DWR/SGMA requirements and provide information to GSAs, residents, and other scientists and engineers that may work on future SGMA-related projects. The Executive Summary contains a simplified version of Chapter 3. Chapter 3 is very technical as it describes the physical, chemical, and climatic history of the area designated as Colusa Subbasin, discusses existing conditions of the subbasin (as of 2020), and introduces future scenario model and water budget calculations based on predictions of future conditions. The techniques and tools to characterize aquifer properties, flow mechanics through a substrate, water budgets, etc. require scientific terminology to accurately convey the necessary information.
183	Holly Reimers		4		ALL	ALL		There is no mention of using those locals that are drillers and or anyone that repairs pump and wells. It should be noted that those working in the "field" just might have a better idea as to what is happening to our groundwater than someone sitting at a computer someplace other then in the field in Glenn County.	Comment acknowledged. Additional testing and local data collection is recommended. Chapters 5, 6, and 7 provide suggestions and recommendations for future technical studies, next steps, water management studies, etc. to reach the sustainability goals.
184	Holly Reimers							After reading through this whole draft. Witch I will have to admit was in many places very boring, I see no offers of solutions. Lots of "we will Keep looking at it" but nothing to address what some are saying is a major overdraft of our ground water. Domestic and stock wells are having to be lowered or are running out of water. The word on the street is that the ground water is dropping by over 1' per year and that was BEFORE the current very dry year. To me this is nothing more than a "make someone feel good" and a waste of time and energy of some that are well meaning but this is NOT getting the job done.	Comment acknowledged. The "we will look into it" is primarily due to lack of available information regarding groundwater flow mechanics. Additional testing and local data collection is recommended. Chapters 5, 6, and 7 provide suggestions and recommendations for future technical studies, next steps, water management studies, etc. to reach the sustainability goals.
185	Jim Wallace		3		3-86	Table 3-10		The table lists diversions only from Stony Creek (SC) and the Sac River (SR), and not the CBD.	Comment acknowledged. The table represents a boundary budget for the Subbasin, so only diversions from boundary waterways outside the Subbasin are reported separately (please refer to the table footnote (a)). In an effort to simplify the number of flow paths shown, inflows to the Colusa Basin Drain are included as part of the total "Sacramento River Inflows." A footnote clarifying this has been added to the table (please refer to table footnote (c)). Diversions from the Colusa Basin Drain are internal to the Subbasin, and are thus not shown in this table.
186	Brooke Davis		6	6.2	5	1	Summary of all PMAs	It is clear what Direct Groundwater recharge is, but not clear what In-Lieu Groundwater recharge is to someone not familiar with it. Is it meaning there is recharge happening simply because there is less ground water used?	Comment addressed. Clarification has been added to Section 6.2 to describe all project types. "In-lieu groundwater recharge" refers to projects that offset groundwater pumping by supplying or otherwise incentivizing use of surface water or other water supplies instead.

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187	Ben King		5.3.1.3		5-6			Last paragraph should include impact of SWRCB water curtailments to TC Contractors. The example just refers to Federal curtailments. Comment should also highlight the fact that TC Member groundwater pumpers will have no alternative but to pump groundwater during curtailments because they need to irrigate their permanent plantings.	Comment addressed. The text in Section 5.3.1.1 has been revised to note that both "federal and state water allocation policies," among other factors, could potentially lead to reductions in available surface water supplies.
188	Ben King		5	5.3.1.4				Comment should address the dewatering of small water systems and domestic wells and the impact on DAC and SDAC households in the affected areas. This is not a hypothetical issue – domestic wells in College City and Arbuckle have run dry. This should be highlighted in the GSP.	Comment addressed. We have added a preface to the GSP to acknowledge the current drought conditions and summarize what is known at this time about the severity of well dewatering experienced by water users, including domestic well users and DAC/SDAC/EDA households. Notably, the majority of the populace in the Colusa Subbasin is classified as a DAC, SDAC, or EDA - just as impacts to groundwater conditions affect these communities, ongoing outreach and implementation of the GSP and PMAs will also benefit them. It is noted that ongoing management of the Colusa Subbasin under the GSP will follow an "adaptive management" strategy that involves active monitoring of Subbasin conditions and addressing any challenges related to maintaining groundwater sustainability by scaling and implementing PMAs in a targeted and proportional manner in accordance with the needs of the Subbasin. Annual reports provide an opportunity each year to evaluate current Subbasin conditions and assess needs for further PMAs. During periodic evaluations, the GSP will be reviewed and revised, as needed, as we learn more about the effects of current and future conditions. At this time, prior to completion and adoption of the GSP, drought response efforts in the Subbasin are the responsibility of the counties, cities, and other local agencies. Counties are currently leading a number of efforts to document and address dewatered wells, including putting programs in place to bring water to those users whose wells are dry. Following adoption of the GSP, those responsibilities may shift to or be coordinated with the GSAs. A strategy for guiding potential coordination between the GSAs, counties, cities, and other local agencies is described in Ch 7. Coordination would ensure preservation of public health and safety (purview of counties/cities) and groundwater sustainability (purview of GSAs).
189	Ben King		5	5.3.1.5				Discussion should include the impact on small water systems and domestic wells. The number of reported domestic wells should be recorded and highlighted. It is my understanding that over 19 domestic wells have already ran dry. The impact on households in SDAC and DAC areas should be highlighted.	Please see the response to comment 188.

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190	Ben King		5	5.3.4.1	5-10			Discussion of the role of the USEPA should be included. The USEPA has cited the small water systems of Grimes and Princeton for arsenic contamination. It is very important that that the discussion includes the degradation of fresh water aquifers caused by upwelling of poor quality water. There is a possibility that over pumping could cause or exasperate this undesired outcome.	Comment addressed. The California Safe Drinking Water Act addresses the regulation and control of public water systems in the State of California, including enforcing provisions of the federal Safe Drinking Water Act. The federal government first granted primary enforcement responsibility to the State in 1978. The State Water Resources Control Board Division of Drinking Water (DDW) is the agency responsible for enforcement in Colusa and Glenn Counties, including the entire Colusa Subbasin. Chapter 5 has been revised to clarify the state and federal regulatory relationship. Grimes and Princeton have had violations of the 10-microgram per liter Primary Maximum Contaminant Level (MCL), which is both the State of California and federal standard. Chapter 3 has been revised to include discussion of arsenic in Grimes and Princeton.
191	Ben King		5	3.4.2	5-11			Impact on SDAC and DAC areas should be identified and discussed by the GSA. Water quality of monitoring wells with multi-completion stages should be documented for each depth stage to identify degraded fresh water aquifers caused by upwelling. We should avoid water quality monitoring cherry picking and record the data for all depth stages and monitor trends over time to identify possible upwelling.	Comment addressed. Chapter 2 has been revised to include discussion and mapping of Disadvantaged Communities (DAC) and Severely Disadvantaged Communities (SDAC). We concur that multiple completion wells should be used for monitoring EC trends when such wells are available. Monitoring and reporting of EC for all completions in multiple completion wells should be included in the monitoring for potential upwelling of brackish or saline water. New monitoring wells used for monitoring upwelling should be multiple completions when feasible.
192	Ben King		5	3.4.3	5-11			If Sites is constructed, water quality may be adversely impacted by the elevation gradient between the elevation of sites and the bowels of wells on the valley flow. This gradient could be 600 to 900 feet of elevation head and may take decades to document. Especially around the Sutter Buttes Rampart we need to monitor for potential effects of a redox reaction when connate water upwells and starts an oxidation process. Arsenic desorption is a predicted outcome when the pH of the connate water is greater than 8. There are also potential biotic outcomes again arsenic related when connate salt water starts the oxidation process. Certain anoxic microbes may add to the arsenic contamination similar to the cause of arsenic contamination in Chesapeake Bay. Earthquake activity could also affect the movement of upwelled contaminants. The west side of the valley has a history of geothermal conditions which could be impacted by earthquakes and earthquakes could also be a catalyst for upwelling via active faults.	Comment acknowledged. The stage of Sites Reservoir will be higher than the intakes of wells in the Colusa Subbasin, and an elevation gradient will exist between the reservoir stage and groundwater levels in wells in the Colusa Subbasin. The reservoir is located in the Coast Range adjacent to the groundwater subbasin. Most of the reservoir will be separated from the Subbasin by at least two miles of Coast Range rocks. Seepage from the reservoir to the groundwater subbasin is expected to be very low because of the low permeability of the Coast Range rocks. Because seepage rates are anticipated to be very low, no significant impact to the pH of groundwater in the subbasin is expected. As documented in Chapter 3, arsenic concentrations are known to be elevated in the vicinity of the Sutter Buttes. The elevated arsenic concentrations are a consequence of the geologic materials comprising the aquifer and the geochemistry of the aquifer and groundwater. The geology and current groundwater geochemistry, along with geothermal activity, earthquake activity and the potential for movement of connate water constitute the existing conditions in the Subbasin.

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193	Ben King		5	3.4.4.	5-12			How about birth defects, mother health and other arsenic contamination related outcomes Rather than adverse effect to property values – loss homeowner values and loss of housing if a domestic well becomes contaminated.	Comment addressed. Section 5.3.4.4 has been revised to reference public health concerns as "Potential Effects of Undesirable Results" associated with degraded water quality.
194	Ben King		5	3.4.5	5.12			USEPA and SWRCB Citations should be evaluated.	Comment addressed. Chapter 3 has been revised to provide additional information on exceedances of drinking water standards. Please see also the responses to comments 190 and 193.
195	Ben King		5	4.1	5-16			The stakeholder input regarding the 80 pct level should be documented and recorded for future public comment. As you may know there has been over 20 domestic wells reported dry with several in the College City area. The domestic well threshold should be an area of future discussion and stakeholder input as the drought progresses. The advocates of the 80 pct threshold should be documented and disclosed and the issue of domestic wells should have a future public discourse. Was there a GSA vote on the 80 percent level?	Comment acknowledged. The SMC were presented to the public and discussed at Joint TAC meetings. Joint TAC meetings were held approximately monthly, with a total of 13 meetings held between May 8, 2020, and June 11, 2021. SMC were addressed at nine of the 13 meetings, and at all seven meetings held between January 8, 2021, and June 11, 2021. TAC members engaged in a very thorough, thoughtful, and constructive manner, giving consideration to all interests in the Subbasin involved with or affected by groundwater use and management. SMC were ultimately vetted and approved by both the CGA and GGA Boards at open Board meetings. Public notice was given in advance of those meetings. The decision records for the SMC are documented in Appendix 5A, and referenced in Section 5.3 of the GSP.
196	Ben King		5	5.4.1.1.1				The adverse degradation from the redox process for connate salt water will most likely be permanent. Significant lowering of groundwater near Grimes and the East Side of the Sacramento River could be the most vulnerable are for redox and potential adverse biotic outcomes. On the west side where there is natural geothermal pressures the lowering of groundwater levels could affect the hydrologic balance of groundwater and result in more upwelling. Again another reason to measure all water quality at all observable depths.	Comment acknowledged. Please see responses to comments 192 and 234.
197	Ben King		5	5.4.4.1				There should be a Minimum Threshold for Arsenic Contamination. There are two small water supply systems in Colusa County with USEPA Citations, two abandoned wells at the southern part of the City of Colusa and a reported observation of 200 ug/L near Grimes. Trends in arsenic contamination should be monitored over time due to the potential for continued redox of connate salt water and potential movement via faults which could be adversely aggravated by future tectonic activity.	Comment acknowledged. Please see responses to comments 190, 192, 193, 194 and 234.

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198	Ben King		5	5.4.4.2				The Measurable Objective for arsenic should be the USEPA MCL of 10 ug/L	Comment acknowledged. Please see responses to comments 190, 192, 193, and 194. The State Water Resources Control Board Division of Drinking Water (DDW) requires drinking water service providers to issue Consumer Confidence Reports (CCRs) to the public on an annual basis. The CCRs must report on detected contaminants on state and federal lists and contaminants exceeding their California Public Health Goals (PHGs) and Primary and Secondary Maximum Contaminant Levels (MCLs). PHGs are non-enforceable goals established by the California EPA's Office of Environmental Health Hazard Assessment (OEHHA). The law requires that where OEHHA has not adopted a PHG for a constituent, the water service providers are to use the federal Maximum Contaminant Level Goal (MCLG). PHGs and MCLGs are health-based standards, which are typically much lower than MCLs. For example, the California PHG and MCL for arsenic are 0.004 micrograms per liter (µg/L) and 10 µg/L, respectively. The regulations also require water service providers to include specific language on the health effects of arsenic in the CCRs if the arsenic concentration is above 5 µg/L, but below or equal to 10 µg/L. Violations must be documented, including an explanation of the violation including, duration of the violation, potential adverse health effects, and actions taken to address the violation. DDW may refer enforcement to the United States Environmental Protection Agency.
199	Ben King		5	5.4.4.4				The Interim Milestone discussion should include the GSA's role in working with the State of California to guarantee the Human Right to Fresh Water to the residents of the Colusa Subbasin. The State has the responsibility to uphold this Human Right and the GSA will likely have to work with the State on targeted solutions or mitigation efforts.	Comment addressed. A specific reference to the Human Right to Fresh Water is now added to Section 5.4.4.4. Additional discussion of the Human Right to Water and its relationship to the GSAs and the GSP is provided in Chapter 2.

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200	Ben King		Appendix 6A		1			The potential for In-Lieu Recharge within the service are of the Tehama-Colusa Canal needs to be evaluated on a month by month or week by week basis and at incremental delivery points on the Canal itself. The physical capacity of the Canal and the physical limitations of all the component irrigation systems that use delivered water will constrain the potential for In-Lieu Recharge. Additionally, there is no discussion about how the use of the Canal for groundwater conveyance under the Warren Act. To the extent the Canal infrastructure is used to store groundwater or convey groundwater from one irrigation system to another (potentially against the flow of the Canal) the potential for the use of In-Lieu deliveries will be constrained.	Comment acknowledged and addressed. Considering historical canal operations, Jeffrey Sutton (General Manager, Tehama-Colusa Canal Authority) has expressed his (caveated) opinion that it is likely that conveyance capacity is available to facilitate the in-lieu projects proposed, subject to certain conditions. The exact communication with Jeffrey Sutton is included in a new attachment to Appendix 6A, and footnoted on the reference to the TCC. A monthly, weekly, or daily operations model of the TCC was not readily available, and creation of such was not in the scope or budget for GSP development work at this time.
201	Ben King		Appendix 6A					It was not clear from the analysis if any of these constraints were considered or analyzed in the potential for the target In-Lieu deliveries. Additional constraints may be relevant once the seasonality of water demand is considered and whether or not the cumulative capacity of the connected irrigation systems is considered since it is likely that both groundwater and surface water would be a required supply during peak ET demand periods.	Please see the response to comment 200.
202	Ben King		Appendix 6A					Is there a model for monthly or weekly water availability at the various delivery points down the Canal infrastructure and monthly or weekly cumulative ET demand for the service area as the water flows southward. Currently water available for the CCWD has to traverse all the northern user service areas and also be of sufficient supplies to meet the needs of Dunnigan Irrigation District. If Sites is constructed, the water flows across both CCWD and DID service area will have be of sufficient volume to meet the delivery needs of the TC – Colusa Basin Drain interconnect pipeline.	Please see the response to comment 200.

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203	Ben King		Appendix 6B	Introduction				These demand actions are not "backstops" and should not be implemented without full and transparent support the Cities of Colusa, Williams, Willows and Orland and the Board of Supervisors of Glenn and Colusa Counties. If there is a need to implement this type of action it should be done by a member irrigation company and fully paid by the local irrigation company since there are substantial property rights at issue. Rather than a "back stop" the proposed demand actions should be considered the last and least desired option and should only be done extensive public discourse and public meetings. . As discussed on Page 10, any such Demand Action "..should include consideration of legal, economic, engineering, hydrogeologic, and political considerations".	Comment acknowledged. The demand management action is described as a backstop option because it is viewed as an option that would be considered after other available options. This is stated in the second paragraph of Section 6.5.2.3. As summarized in Table 6-47 of the same section, the management action would be considered in consultation with stakeholders and all local governing agencies, including the GSAs.
204	Ben King			Sponsor				There should be a sponsor disclosed for the two proposed demand actions. Grant Davies mentioned that Mary Fahey and Lisa Hunter were the sponsors which is obviously not correct because they are County Employees.	Comment acknowledged. It was the decision of the CGA and GGA to include demand management in the list of potential PMAs. The CGA and GGA are listed as the proponents of these management actions in Table 6-2. The responsibility for implementing specific components of demand management would depend on the precise action selected. However, we reiterate that demand management is viewed as an option that would be considered after other available options (per Section 6.5.2.3).

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205	Ben King						Table 1	What Does Rice Milling encompass? There are Tree Nut Farming and a Vegetable and Melon Farming, Grain Farming but no Rice Farming. Is Rice Farming part of Rice Milling or Grain Farming. Rice farming and related local jobs should be identified separately since some rice farmers already fallow ground as necessary for organic rice production and/or sell surface water. The data seems to be from 2014 and only one year which happens to be a drought year. Since it is 7 year old data if could be irrelevant and/or unrepresentative because it reflects the economic impact of the last drought. Has this data been assessed against more recent year's data? What kind of volatility is there in the IMPLAN data set? There should be more recent data presented and presented over a multiple year period. It is interesting to note that 3750 or approx. 31% of the 12,255 FTE jobs are local government. The dependent economic relationship between local government jobs and the local economy should be discussed and analyzed. Fallowed land and out of basin water sales and transfers take away local jobs and dimmish the tax base necessary for local government jobs. There is no discussion about seasonal employment and the positive add on revenue derived from unemployment benefits, fringe benefits and retirement/government payments that come with seasonal employment. Many seasonal employees are women and mothers of low to middle income household units that depend on the marginal income, unemployment insurance and other government payments that comes with seasonal employment. This is a critical and necessary component for any economic costs benefit analysis for a program that will lead to fallowing farmable acreage	Comment acknowledged and addressed. IMPLAN sectors for the economy are based on an aggregation of North American Industry Classification System (NAICS) codes. Rice milling includes NAICS 311212. This includes a number of businesses related to the milling of rice. It does not include rice farming. Rice farming is under the Grain Farming IMPLAN model sector. This includes NAICS 111130, 111140, 111150, 111160, 111191, and 111199. It includes rice in addition to other grains. All values shown in the GSP represent current dollars, not 2014 dollars. The 2014 IMPLAN "multipliers" are used to calculate the total value of the industry based on current industry values. Multipliers capture the relationship between a dollar spent in different sectors of the economy. This relationship is generally stable over time. The results of the analysis are sensitive to changes in the value of the crops produced over time, and less so to the use of base IMPLAN data for industry multipliers. Therefore, the values as reported in the GSP reflect current conditions. Comments regarding the number of jobs and different types of employment are noted and would be considered in a benefit-cost assessment. The purpose of the analysis summarized in Table 1, as described in that section, is to demonstrate the economic contribution of agriculture to Colusa/Glenn counties. It is summarizing the value of the current industry. It is not a benefit-cost analysis of a specific or hypothetical demand management program. That would require a different analysis framework that was not developed here. It may be appropriate to develop additional analysis under future GSP implementation that would include these considerations. A sentence was added to clarify that "This section describes the current contribution of agriculture to the Colusa Subbasin economies."

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206	Ben King				3	Demand Management Costs		There is no reason to assume that Net Groundwater Pumping reduction assumed would actually provide a physical benefit to the stressed aquafers in the Colusa Subbasin. This type of program may work within irrigation districts but it needs to be applied within the sphere of adjacent wells or at least within an irrigation system. Paying a rice farmer not to plant a rice field near Grimes is not going to mitigate the pumping depletion caused by pumping groundwater to irrigate a tomato field on the west side of I-5. Perhaps this will with the accounting of a water budget but in reality do nothing to mitigate the short term or long term impact of dropping water levels in stressed parts of the aquifers. The most likely outcome of this type of Demand Action would be to pit certain ag industry vs ag industry. Many tomato farmers are tenant farmers who make substantial investment in buried drip lines. Many rice farmers are settlement contractors who can make money selling water especially during critically dry years and some of which are organic rice farmers who need to idle production fields for a growing season and who would have great incentive to idle and receive payment.	Comment acknowledged. The hydrogeologic conditions of the Subbasin affect outcomes for PMAs in different parts of the Subbasin. These would be assessed as part of PMA implementation. As described under Section 6.5.2.4, a demand management program could be targeted to specific areas within the Subbasin. Similarly, other PMAs would be targeted to areas of need so that specific benefits occur in these regions. Broader benefits would accrue to the entire subbasin because the subbasin is viewed as a single unit for groundwater sustainability.

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207	Ben King						Figure 3	There is no transparency regarding the methodology, source or assumptions made for the water costs presented.	Comment acknowledged and addressed. The method is briefly summarized on Pages 4 and 5, prior to Figure 2. The section title on Page 4 was changed to "Methods." The paragraphs within that section were edited and two technical references were added. The figure formatting was also corrected so that figures are referenced within the correct sections. The revised paragraphs are: "An economic model of the Colusa Subbasin was applied to evaluate the supply and demand for water and establish the cost of demand management. It reflects the local water supplies and uses, financial data on returns to farming, and current crop market conditions for Sacramento Valley crops. This includes current crop prices and yields. Production costs are representative averages based on University of California Cooperative Extension crop budgets. It The model is calibrated to the GSP water budget (applied water and evapotranspiration of applied water) and geospatial land use data described in Chapter 3 of the GSP. A technical description of the economic calibration method is beyond the scope of this technical appendix. The method applied is a standard, peer-reviewed economic analysis approach that is widely applied for valuation of water supply and water supply projects in California [refs footnote]. This same technical approach was applied for calibration of an economic optimization model of the Colusa Subbasin. The model quantifies the effect of changes in water supply availability and cost on farm income (e.g., net income and gross farm revenues) and simulates how the agricultural sector would respond to changes in water availability and cost. Responses include switching to higher value and/or lower water use crops, adjusting input use, and idling land. The decision to switch crops and/or idle land depends on agricultural market conditions simulated by the model under increasing levels of a range of (hypothetical) demand management. The economic analysis quantifies the direct economic cost of changing crops and idling land under implementation of demand reduction. For this technical appendix, costs are expressed on a per acre-foot basis for comparability to other PMAs in the GSP. " References added to the footnotes include: Department of Water Resources. Water Plan Update. 2009. Data and Tools Technical Appendix. Economic Modeling of Agriculture and Water in California using the Statewide Agricultural Production Model. U.S. Bureau of Reclamation. 2019. CVP Long Term Operations EIS. Appendix 12A: Statewide Agricultural Production Model (SWAP) Documentation.

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208	Ben King				8			It is true that a specific allocation " would require careful analysis of the legal, hydrogeologic, economic and engineering implications, and would require vigorous and informed discussion with stakeholders." The Colusa Subbasin stakeholders should first have the opportunity to be informed and then have the vigorous discussion before considering these Demand Actions.	Comment acknowledged. Demand management is a backstop to other PMAs that would only be implemented if determined necessary after analysis of legal, hydrogeologic, economic and engineering implications, and would require vigorous and informed discussion with stakeholders.
209	Ben King				11			The following statemen as it applies to California is false : " Most GSA's in the state….use.. wellhead meters , to track and enforce allocations." Is it really true that the use of crop type and/or ET calculations are less common than wellhead metering. The DWR has spent extensive resources with the LandIQ crop mapping and many water budgets and irrigation systems are built on CIMIS ET Data and crop coefficients. Ultimately drip lines only have so much capacity so a lot can be done without metering especially when there is only one source of irrigation water. Metering for private pumpers with only source of water would seem like an unnecessary burden and regulatory overreach.	Comment acknowledged and addressed. The full statement reads "Most GSAs in the state and groundwater management entities outside the state use some form of measurement, usually wellhead meters, to track and enforce allocations. There are also examples of allocations that use crop type and/or ET calculations to estimate water use and groundwater pumping, but this approach is less common. Estimation versus measurement is a GSA policy decision that can have important effects on the cost and its ability to manage the allocation effectively." The meaning was not to imply all GSAs use meters. Edited for additional clarity as follows: "Most groundwater management entities outside the state use some form of measurement, including wellhead metering, to track allocations. In California, many GSAs are proposing or considering direct measurement or using crop type and/or ET calculations to estimate water use and groundwater pumping. Estimation versus measurement is a GSA policy decision that can have important effects on the cost and its ability to manage the allocation effectively."
210	Ben King				11			Secondary economic impacts SHOULD be considered BEFORE "future iterations" and more importantly any further consideration of the implantation or adoption of the Demand Management PMAs proposed in this Appendix.	Comment addressed. The text has been revised to indicate that these impacts "should be considered" in future iterations of this analysis.
211	Ben King		Appendix 6D					Please consider my comments from Appendix 6A regarding the assumptions for Modeling Parameters as it relates to projects relying on surface water deliveries from the Tehama - Colusa Canal and Colusa County Water District in particular.	Please see the response to comment 200.

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212	Holly Dawley	GCID	5	5.1	5 1	N/A		The Sustainability Terminology could use some context. It might be helpful at the end of 5.1 before 5.1.1 to reiterate what the MTs and MOs are and how they relate.	Comment addressed. Additional clarification of terminology has been added to Section 5.1.
213	Holly Dawley	GCID	5	5.1.1	5 2	2nd bullet list		Would be helpful to carry symbols through to the bullet list indicating the five sustainability indicators that are relevant to the GSP	Comment addressed. Symbols have been added to the bullet list in Section 5.1.1.
214	Holly Dawley	GCID	5	5.1	Not specific			Since it has come up, it might be helpful to address that there is a layer of Ancient Seawater but why that does not trigger the indicator.	Comment acknowledged. Connate water and the base of the freshwater are discussed in Chapter 3 of the GSP.
215	Holly Dawley	GCID	5	5.1	5 2	1st after 2 bullet lists		Suggest add sentence after the 1st sentence quickly explaining why those 2 indicators are using proxies.	Comment addressed. A sentence has been added to explain the correlation between groundwater levels and groundwater storage and depletions of interconnected surface water, allowing groundwater levels to serve as a proxy for those sustainability indicators.
216	Holly Dawley	GCID	5	5.2.1	5 3	3rd paragraph		Why are “planned projects” in quotes? This is a title/name not a nickname.	Comment addressed. The quotation marks have been removed.
217	Holly Dawley	GCID	5	5.3.1.1	5 5	2nd		What is “foreseeable?”	Comment addressed. "Foreseeable" has been revised to reference the projected water budget analysis period (2016-2065), both in Section 5.3.1.1 and Section 5.3.2.1.
218	Holly Dawley	GCID	5	5.3.1.3	5 6	Last paragraph in 5.3.1.3		Suggest add “or state” after federal in 1st sentence. Water use in the CVP can be dictated by State, too.	Comment addressed. The text in Section 5.3.1.1 has been revised to note that both "federal and state water allocation policies," among other factors, could potentially lead to reductions in available surface water supplies.
219	Holly Dawley	GCID	5	5.3.4	5 10			Consistency: Add indicator symbols as in other sub-task titles.	Comment addressed in the GSP section indicated.
220	Holly Dawley	GCID	5	5.3.4.1	5 10	3rd paragraph		Suggest clarify “existing regulatory programs.”	Comment addressed. The existing regulatory programs are described in the paragraphs following the referenced paragraph. The following text was added: "The California Safe Drinking Water Act addresses the regulation and control of public water systems in the State of California, including enforcing provisions of the federal Safe Drinking Water Act. The federal government first granted primary enforcement responsibility to the State in 1978. The State Water Resources Control Board Division of Drinking Water (DDW) is the agency responsible for enforcement in Colusa and Glenn Counties, including the entire Colusa Subbasin."

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221	Holly Dawley	GCID	5	Global				Suggest putting together a summary table to show indicators and thresholds and perhaps MOs, MTs for more visual/condensed readers. It's a lot of text with no easy summary or cross walk.	Comment addressed. A table has been added to the beginning of Section 5.4 that summarizes the sustainability thresholds for all applicable sustainability indicators.
222	Holly Dawley	GCID	6	6.1	6 2		Table 6-1	Units need to be better identified	Comment addressed. The units have been clarified (average annual volumes; taf/yr).
223	Holly Dawley	GCID	6	6.1	6 2			Changed storage is so small…it is within the error of the model?	Comment addressed. Yes, the change in groundwater storage (-0.8%) is considered to be within the uncertainty of the groundwater model analysis. Commentary on this has been added to the water budget uncertainty and model uncertainty (Ch. 3 and Appendix 3D), and indicated in a footnote.
224	Holly Dawley	GCID	6		6 7		Table 6-2	GCID In-Basin Project: This is only potentially available in Shasta Non-Critical Years.	Comment addressed. Clarification has been added to Table 6-2 and to the project description in Section 6.4.1.4.
225	Holly Dawley	GCID	6		6 8		Table 6-2	Delevan Pipeline Project. Might need to ground truth with Sites or Bill Vanderwaal. The way it is written up indicates an older understanding of the proposed Delevan	Comment acknowledged. The GSP Technical team will review this information and confirm the current details of the proposed Delevan Pipeline.

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226	Ben King		5A		2	Outreach		Since the majority of the Outreach and Public Involvement Process was done before the severity of the current drought was known the outreach process does not reflect the impact on domestic well users nor does have domestic well users had the opportunity to give their input. The reported number of domestic well problems should be documented and there should be a concerted outreach program to get their input on the Minimum Thresholds and mitigation measures. The GSA has an opportunity to truly understand the impact on domestic wells from lowered groundwater levels and act in a proactive manner to help manage and mitigate adverse outcomes for the future. The current Memorandum does not reflect input from domestic well users.	Comment acknowledged. We have added a preface to the GSP to acknowledge the current drought conditions and summarize what is known at this time about the severity of well dewatering experienced by water users in the Subbasin, including domestic well users. As stated in Appendix 5A, "Members of the public were welcome to attend the Joint TAC and open Board meetings and were encouraged to express their opinions, and suggestions, and comments on the SMCs, as well as other aspects of the GSP. Members of the public attended and participated in most Joint TAC meetings, including those in which SMCs were discussed." It is noted that GSP development has occurred over several years, with continued public outreach and consideration of the most sufficient and credible information and data available for the decisions being made and the time frame available for making those decisions. Ongoing management of the Colusa Subbasin under the GSP will follow an “adaptive management” strategy that involves active monitoring of Subbasin conditions and ongoing public outreach. Data, information, and input from the public will be evaluated, reported, and used to guide GSP implementation. GSP annual reports provide an opportunity each year to check in and evaluate current Subbasin conditions and assess needs for additional PMAs. The first annual report, due April 2022, will evaluate groundwater conditions in the Colusa Subbasin since 2015. During the periodic (five-year) evaluations, the GSP will also be reviewed and revised, as needed, to address new understanding of Subbasin conditions. Please note that Appendix 5A has been changed to Appendix 5B for the final GSP.
227	Ben King		5A			Hydrographs		The hydrograph for 14N02W22A002 does not have any data on the two pages it is presented.	Comment acknowledged. Well 14N02W22A002 is newly constructed and has not yet been monitored. This well is included in the Colusa Subbasin groundwater monitoring network and will be monitored in the future. Please note that Appendix 5A has been changed to Appendix 5B in the final GSP.

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228	Ben King		5B		1			The statement " This appendix describes an economic analysis of MT's that was developed and presented to the TAC at the May 13,2021 Meeting" is false. While it is clear that the economic analysis was included in the presentation there is no indication that the economic analysis was presented or discussed at the meeting. The Minutes of the May 13, 2021 TAC Meeting do not reflect any discussion of the ERA proposal and states on Page 8 of the Minutes in Agenda Item 4.b Projects and Management Actions (PMAs) - " This Agenda item was not discussed during the TAC meeting due to time constraints"	Comment addressed. The presentation was given at the next TAC meeting on June 11, 2021. The text was edited to reflect this date. ERA Economics was asked by the GSAs to develop a description of general demand management programs and prepare economic analysis to illustrate initial concepts for the TAC and public. The demand management program is not a PMA proposal developed by ERA. All PMAs were proposed and defined, and will ultimately be implemented, by the GSAs and stakeholders (which includes the TAC and all local entities). Please note that Appendix 5B has been changed to Appendix 5C in the final GSP.
229	Ben King		5B		2			What are the assumed capital cost for refurbishing potentially dewatered domestic wells? What are the assumptions for energy costs caused by additional pumping? What rate schedule? As you probably are aware there are many critical assumptions depending on season and time of use.	Comment addressed. The following sub-paragraphs have been added to summarize cost assumptions: "1.a.The capital cost of well replacement is set at $40,000 per well based on costs for domestic well replacement used in other GSPs . These costs generally include drilling at $40 per foot, a sanitary seal for a $2,500, and a pump for $5,000. This does not include permit costs. Actual costs will vary based on the costs of materials and supply and demand for well drilling services. " "2.a.Agricultural pumping energy cost depends on lift, pump efficiency, and the power rate which varies by time of use and size of load. For purposes here, the analysis used an average over several 2021 PG&E agricultural power rates to get a total variable pumping cost of about $0.52 per acre-foot per foot of lift." Please note that Appendix 5B has been changed to Appendix 5C for the final GSP.
230	Ben King		5B		4		Figure 2	What does the Table Crop and Acres mean? There is not explanation for the inclusion of this table of the documentation for and reference source.	Comment addressed. The following statement has been added to clarify the acreage shown in the figure: "The irrigated acreage within the Thiessen polygon is also shown in the figure. The mix of crops grown affects the cost of demand management. The example polygon is predominantly planted to permanent crops (almonds and olives), which are costly to idle due to higher net return relative to other annual crops and the substantial capital investment required to establish orchards." Please note that Appendix 5B has been changed to Appendix 5C for the final GSP.

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231	Ben King		5B		2			Why does the economic analysis assume that demand management would be adopted by the GSA? The economic analysis in Chapter 6 appears to be highly speculative and is difficult to assess since the assumptions for the analysis have not been disclosed.	Comment addressed. Appendix 5B uses demand management as an example only, and does not imply it would be implemented. The following sentence was added to make this clearer to the reader: "It is noted that demand management is not a planned PMA in the Colusa Subbasin, and these costs are used as a proxy for the costs of other projects." Two paragraphs were added to the appendix to describe the costs for well drilling and replacement. Please see also the response to comment 229. Please note that Appendix 5B has been changed to Appendix 5C for the final GSP.
232	Ben King		5B		All	General Comment		Regarding the costs of replacing the domestic well it is hard to assess whether or not the analysis is based on representative costs because the assumptions were not disclosed. The analysis seems to make rudimentary assumptions and not real life assumptions. In the crisis of a drought, local drilling capacity and well repair services are very limited and usually focused on serving the biggest and best customers. Domestic well owners are likely to have to wait until the growing season is over and pay for the costs to maintain their personal health and livelihood during the loss of the well. Some domestic well owners may not have access to the capital they need to make the repairs and most would not be able to secure 20 year financing unless they had equity in their houses and could refinance. Having a well run dry and being ablet to get an appraisal for refinancing is probably near impossible and ultimately the loss of a well may mean substantial loss of market value of their house. To make this a meaningful analysis, there is a timely opportunity to contact the County administrators and survey the domestic well users that have lost their wells during the current drought and ask them about direct and consequential economic costs and costs due to loss of income due to their well depletions. There are more than 20 such dry domestic wells in Colusa County alone.	Comment addressed. Two paragraphs were added to clarify the underlying costs applied to the analysis (see response to comment 229). The analysis is developed to support long-run planning for MTs/MOs. The short-run costs listed in the comment are important to consider in severe drought emergencies, such as 2021. The following paragraph was added to the discussion section of the appendix: "The analysis is developed to support long-run planning for setting MTs. PMAs needed to support higher MTs require time to develop and implement and cannot be implemented rapidly in response to severe, unprecedented drought. The short-run costs of wells running dry during severe drought events can include other cost factors that were not explicitly analyzed. For example, in the crisis of a severe drought, local drilling capacity and well repair services can be limited, which can result in higher cost or increased wait times. This can place additional financial stress on households with domestic wells." An expanded analysis working with local well drillers and other parties in the county could be considered as part of GSP implementation. The additional costs of domestic well replacement during a drought emergency are noted.

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233	Ben King		5C	General				Arsenic levels should be included for Grimes and Princeton since the USEPA has continuously reported that observed levels are above the USEPA MCL. Arsenic should also be reported for all the wells for the Colusa Supply system since there has been the Del Oro Walnut Ranch well abandonment and the CIP enforcement action. Also the well near Grimes with the 200 ug/L observation should be included and reported for each observable depth if it is a multi-completion well.	Comment acknowledged and addressed. Public drinking water systems in the Colusa Subbasin are regulated by the State Water Resources Control Board Division of Drinking Water (DDW), and the regulated public systems have the responsibility for monitoring and reporting on drinking water quality for regulated constituents and unregulated constituents requiring monitoring and reporting. As described in Chapter 5, the GSAs will coordinate with the public systems to address water quality issues in the basin but are focusing GSP monitoring efforts on upwelling of brackish or saline water, which is not explicitly addressed under other existing monitoring and reporting programs. Chapter 3 has been revised to include additional discussion of arsenic impairments in the subbasin. The appendix has been updated to include EC plots for Grimes and Princeton. Please note that Appendix 5C has been changed to Appendix 5D for the final GSP.
234	Ben King		5C	General				All of the reported locations should have EC observations for each observable stage if any of the reported locations are multi-completion wells. The new well drilled by the County of Darrin Williams property should be included in the appendix and water quality observations should be tracked for each observable depth. Mr. Williams reported upwelling near the 1000 foot depth and the water quality from the upwelling aquifer should be observed and tracked.	Comment acknowledged. We concur that multiple completion wells should be used for monitoring EC trends when such wells are available. Monitoring and reporting of EC for all completions in multiple completion wells should be included in the monitoring for potential upwelling of brackish or saline water. New monitoring wells used for monitoring upwelling should be multiple completions when feasible. Please note that Appendix 5C has been changed to Appendix 5D for the final GSP.
235	Ben King		5C	General				Overall the Appendix needs to incorporate the wells discussed in Section 3.2.5.11. There is a multicompletion well near Maxwell with 4 stages and TDS levels as high as 1640 mg/L. There is a shallow well west of Grimes with a measurement of 2,040 mg/L. Wells near College City with TDS concentrations greater than 1000 should be of immediate concern since domestic wells are running dry and bowls are being lowered. Where are the measurements for the shallow wells west of Colusa with TDS levels greater than 2000 mg/L.	Comment acknowledged. The appendix provides EC plots for the subset of wells comprising the water quality representative monitoring network. Other water quality monitoring wells exist in the Subbasin. The historical water quality results are discussed in Chapter 3, and water quality results from existing wells and monitoring programs will be evaluated by the GSAs in coordination with the regulated entities during implementation of the GSP. Please note that Appendix 5C has been changed to Appendix 5D for the final GSP.
236	Ben King		5C	General				Generally we should have up to date observations for all reported wells. The data for the Maxwell public supply system ends before 2013. The data for the Princeton public supply system ends before 2014 Arbuckle only has 3 observations ending in 2016. Since the Williams supply system has elevated EC levels, all the supply wells for Williams should be reported so as to avoid cherry picking and also to monitor any adverse trends.	Comment acknowledged. Some of the drinking water compliance sampling is conducted on a two to three year cycle for a given well. The data presented is the latest data available through the State Water Resources Control Board Division of Drinking Water (DDW), as of June 29, 2021. The data, as available from DDW, will be updated annually during implementation of the GSP. Please note that Appendix 5C has been changed to Appendix 5D for the final GSP.
237	Mary Fahey	Colusa County/CGA	5	Intro	5 - 1	1		Second sentence, instead of “Colusa GSAs”, please use either “Colusa Subbasin GSAs” or “Colusa Groundwater Authority and Glenn Groundwater Authority”	Comment addressed. The text has been revised to "Colusa Groundwater Authority and Glenn Groundwater Authority."
238	Mary Fahey	Colusa County/CGA	5	5.3.1.3	5 - 6	3		Type-o, line 3, pumping would have to increase…	Comment addressed. The text has been corrected.
239	Mary Fahey	Colusa County/CGA	5	5.3.4.1	5 - 11	1,2nd bullet		Type-o, increase in the number of...	Comment addressed. The text has been corrected.

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240	Mary Fahey	Colusa County/CGA	5	5.4.1	5 - 16	1		Is "Section 0" correct?	Comment addressed. The text has been corrected.
241	Mary Fahey	Colusa County/CGA	5	5.4.7	5 - 33	5		Type-o, Stony Creek	Comment addressed. The text has been corrected.
242	Mary Fahey	Colusa County/CGA	5	5.4.7	5 - 32			If you feel it's appropriate, this is a good opportunity to mention here that the CGA, GGA and neighboring GSAs have been coordinating throughout GSP development and will continue to coordinate and share technical data during GSP implementation.	Comment addressed. This point has been added to Section 5.4.7 with reference to additional coordination activities described in Chapter 7.
243	Mary Fahey	Colusa County/CGA	Appx 5A		2	1-3		It should be noted that the SMC were also vetted and approved by both the CGA and GGA Boards at open, publicly noticed meetings.	Comment addressed. The text has been revised to note this. The SMC decision records have also been added as a new appendix to Chapter 5 (Appendix 5A).
244	Mary Fahey	Colusa County/CGA	Appx 5A		2	3		Members of the public were welcome to attend all of these meetings and were encouraged to express their opinions and suggestions. There was very good stakeholder attendance and participation at these meetings.	Comment addressed. Clarification has been added to reinforce this.
245	Mary Fahey	Colusa County/CGA	6	Section 6 -1	6-4			2nd bullet: Suggest removing the second sentence regarding demand management. This type of PMA is a last resort and should not be highlighted.	Comment addressed. This reference to demand management has been removed.
246	Mary Fahey	Colusa County/CGA	6		6-6		Table 6-2	First project: Colusa Subbasin Multi-Benefit Groundwater Recharge (TNC). This project concludes in the spring of 2021, not 2020.	Comment addressed. The text has been corrected.
247	Mary Fahey	Colusa County/CGA	6	6.3.3.1	6-29			Add a program benefit – Groundwater conditions (via groundwater Recharge)	Comment addressed. This benefit has been added.
248	Mary Fahey	Colusa County/CGA	6	6.3.3.1	6-29			Pilot program concludes in 2021. The program evaluated flooding that would provide habitat benefits for migrating shorebirds, and groundwater recharge. Both (habitat and recharge) are equal goals of the project.	Comment addressed. The text has been revised to clarify these equal goals.
249	Mary Fahey	Colusa County/CGA	6	6.3.3.1	6-30			While the current project is limited to SDAC communities due to grant funding requirements, ongoing, the project would not be limited to benefitting water levels in DACs.	Comment addressed. Clarification has been added to not that other communities may also benefit depending on where the project is implemented.
250	Mary Fahey	Colusa County/CGA	6	6.3.3.2	6-32			Pilot program runs from 2018-2021. Also update dates in Table 6-13.	Comment addressed. The text has been corrected.
251	Mary Fahey	Colusa County/CGA	6	6.3.3.4	6-32			Depending on the farm, there may be installation of monitoring equipment required (flow meters, groundwater level monitoring devices)	Comment addressed. The text has been revised and additional context has been given for potential infrastructure/equipment needs, depending on the field.
252	Mary Fahey	Colusa County/CGA	6	6.3.3.6	6-32			Program completed in 2021	Comment addressed. The text has been corrected.
253	Mary Fahey	Colusa County/CGA	6	6.3.3.6	6-33			Last three bullets should be indented further	Comment addressed. The text has been corrected.
254	Mary Fahey	Colusa County/CGA	6	6.3.3.7	6-33			Could the CGA and GGA also serve permitting roles?	Comment addressed. The CGA and GGA have been added to the list of agencies with potential permitting roles.
255	Mary Fahey	Colusa County/CGA	6	General				General comment – excellent work on this chapter. This is a great set of tools that the GSAs can pull from as they implement SGMA in the Colusa Subbasin.	Comment acknowledged.
256	Zac Dickens	GCID	6	6.2	pg 6-11	N/A	6 - 3	For chapter consistency, in the "Planned" section on the "In-lieu Groundwater Recharge" row, please move "GCID In-lieu Groundwater Recharge" to the "Potential" section on the "In-leu Groundwater Recharge" row.	Comment addressed. The text has been corrected.

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257	Zac Dickens	GCID	6 and associated appendix items	Through out				Minor formatting request. Please use Word's find and replace for all instances of "Glenn Colusa Irrigation District" and substitute with "Glenn-Colusa Irrigation District".	Comment addressed in the GSP section indicated.
258	Holly Reimers	West Side Landowner	6	Section 6.1,	Page 6-3			It should be noted that in the past 15 to 20 years the number of orchards has greatly increased while the number of flood irrigated acres had been greatly reduced. Flood irrigation aids in the recharging of the ground water. The number of acres that has been moved from flood irrigation to drip irrigation is quite substantial with the overall drop of the ground water levels. I have seen this personally when my neighbor changed his irrigated pastures to trees and drip irrigation. On property I own to the East of his now drip irrigated fields the old Oak trees started to suffer then die. These trees were in some cases well over 300 years old but had grown accustomed to the supply of water from the surface. When this water was reduced or eliminated they were unable to survive. Also the water level of my domestic well to the East dropped.	Comment addressed. A sentence has been added to Section 6.1 to acknowledge the shift in irrigation practices.
259	Holly Reimers	West Side Landowner		Section 6.2	Page 6-8			Orland Unit Water Users Flood Water Conveyance. I would note that the conveyance is already in place to be able to run any flood waters from the South Canal into the "Low Line Ditch" then into Hambright Creek, just North of the Graves Cemetery. There is also the option to flood acres at the Black Butte Ranch to provide for additional groundwater recharge. Being on the upper end of the water recharge system it has been noted that when there is no surface irrigation waters applied to the grounds at the Black Butte Ranch the ground water levels in the areas to the East start to drop.	Comment addressed. These details have been added to the project description in Section 6.5.1.5 as an example of potential project configurations.
260	Holly Reimers	West Side Landowner			Page 6-9		Table 6-2	There is no mention of Walker Creek of Hambright. Both of these creeks help in the ground water recharge.	Comment addressed. Section 6.5.1.2 has been revised to acknowledge the potential recharge benefits and opportunities along other streams and creeks, including Walker Creek and Hambright Creek. However, it is noted that the westside streams diversion project analysis was confined to the six streams listed because of the availability of monthly flow estimates.
261	Holly Reimers	West Side Landowner			Page 6-10		Table 6-2	OH one of my favorite points. Invasive species and the Eradication of such!! Arundo & Tamarisk, also known as Bamboo and Salt Cedar. Non-native and VERY invasive. Stony Creek has the largest overgrown population of Bamboo in the WHOLE state of California. I'm not sure that the Salt Cedar has been inventoried but it is just as invasive and a major user of ground/surface water. To anyone that is worried about the "riparian" habitat I would suggest they take a drive up 1-5 or drive Hwy. 32 between Orland and Chico. It takes water to make "riparian" habitat at this time there is NO WATER. **These no-native invasive plants need to be destroyed and eradicated.**	Comment acknowledged.

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262	Holly Reimers	West Side Landowner		Section 6.3.2.10			Table 6-11	Why is there even a conversation about water transfers. Especially when that water could be used to recharge our deleted groundwater basin? When there is conversations about putting meters on wells why would water be transferred out of the basin?	Comment acknowledged. Table 6-11 establishes the cost of within basin transfers and is used to support the Planned PMA cost estimates. No water transfers outside of the basin are considered or included in this GSP.
263	Holly Reimers	West Side Landowner		Section 6.5.1.2			Figure 6-10	Should also list Hambright Creek and Walker Creek	Please see the response to comment 260.
264	Holly Reimers	West Side Landowner		Section 6.5.1.5	Page 6-69		Table 6-33	Cost: There should be little cost to this as the conveyance system is already in place the proper gates just need to be opened.	Comment acknowledged. The anticipated costs of this project have yet to be determined and would be reported in GSP annual reports and five-year updates when known
265	Emily Reinhart	Davis Ranches/Sycamore Mutual Water Company	6	5.1.7	6-70	1 (above Table 6-35)		Question: What do you mean by "newly formed water storage district"? We are already within an existing water district (Sycamore Mutual Water Company). Davis Ranches is the participating Landowner within the district that will be hosting the recharge site.	Comment addressed. The text has been revised to correct these details.
266	Emily Reinhart	Davis Ranches/Sycamore Mutual Water Company	6	5.1.7	6-70	1 (above Table 6-35)		Water would be sources from Sacramento River during high flows in the system. Currently, Sycamore Mutual Water Company (a Sacramento River Settlement Contractor). We will be looking to rely on our Riparian water rights in order to do winter flooding (beneficial use). We will not have 215 water from the Colusa Drain. Should project start before Nov. 1, we would use some of our settlement contract water to recharge.	Comment addressed. The text has been revised to correct these details.
267	Emily Reinhart	Davis Ranches/Sycamore Mutual Water Company	6	5.1.7	6-70	1 (above Table 6-35)		Habitat benefits also include winter floodplain habitat for migrating shorebirds/waterfowl as we pulse flood the field	Comment addressed. The text has been revised to correct these details.
268	Emily Reinhart	Davis Ranches/Sycamore Mutual Water Company	6	5.1.7	6-71	Table 6-35	Water Source & Reliability	Source is Sacramento River. Reliability is good, but still unknown at this time.	Comment addressed. The text has been revised to correct these details.
269	Emily Reinhart	Davis Ranches/Sycamore Mutual Water Company	6	3.5.1	6-42	1		30 – 45 days during fall/winter. We aren't tied to a specific start date. There is flexibility built into the project to allow for water availability, etc. The target is Fall/Winter for the habitat benefits as well as availability of water in the system. Settlement contract waters would be used if the project starts before Nov. 1.	Comment addressed. The text has been revised to correct these details.
270	Emily Reinhart	Davis Ranches/Sycamore Mutual Water Company	6	3.5.1	6-42	2		We do not have contract for 215 water. We do have riparian rights that we would be exercising for this project for beneficial use (habitat).	Comment addressed. The text has been revised to correct these details.
271	Emily Reinhart	Davis Ranches/Sycamore Mutual Water Company	6	3.5.1	6-42	2		5,000 acre feet over 10-years is our goal.	Comment addressed. The text has been revised to correct these details.
272	Emily Reinhart	Davis Ranches/Sycamore Mutual Water Company	6	3.5.5	6-44	1		No 215 water.	Comment addressed. The text has been revised to correct these details.

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273	Emily Reinhart	Davis Ranches/Sycamore Mutual Water Company	6	3.5.7	6-45	2		No 215 water.	Comment addressed. The text has been revised to correct these details.
274	Emily Reinhart	Davis Ranches/Sycamore Mutual Water Company	6		6-8		Table 6-2	Diversion of winter flows from Sacramento River (riparian) or settlement contract flows (should project start before Nov.1).	Comment addressed. The text has been revised to correct these details.
275	Donald Bills	GGA/CGA TAC Member	5	5.2.1	5.3	1		Nothing in chapter 6 refers to sustainable yield. Should this be a reference to chapter 1 section 1.2? As I mentioned in my review comments there, sustainable/safe yield has not been considered a valid term by the hydrologic community for close to 20 years now (USGS Circular 1186, 1999 Alley and others., USGS SIR 2013-5079, The journey from safe yield to sustainability, Leake and Alley, 2005, A critical review of the Water-budget myth and safe yield, Zhou, 2009, Groundwater depletion in the U.S. 1900 to 2008), Konikow, 2013, The myth of safe yield Kathleen Ferris and Sarah Porter, May 2021, Kyl Center for Water Policy, . It would be better to confine this discussion in terms of the sustainable goal(s). This year proves the point. Estimates of sustainable yield based on historical records are being broken almost everywhere in the subbasin this year.	Comment addressed. The title of the subsection has been revised to, "Sustainable Operation of the Subbasin". The text of the subsection has been revised and no longer refers to sustainable yield. It now refers to sustainable operation of the subbasin. Sustainable yield must be reported and described, per the GSP regulations. See § 354.18(b)(7) and § 354.18(c)(2)(C)). This requirement is addressed in Chapter 3 of the GSP.

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276	Donald Bills	GGA/CGA TAC Member	5	5.2.1	5.3	2		"…it is uncertain that undesirable results will develop in the future." They are occurring now with wells drying up through the basin.	Comment acknowledged. We have added a preface to the GSP to acknowledge the current drought conditions and summarize what is known at this time about the severity of well dewatering experienced by water users in the Subbasin, including domestic well users and DAC/SDAC/EDA households. It is noted that development of the GSP has occurred over several years utilizing the best available science and tools, with the most sufficient and credible information and data available for the decisions being made and the time frame available for making those decisions. Current and historical groundwater conditions and water budgets have been evaluated for the Subbasin in alignment with the GSP regulations, using the most recent and complete hydrologic, water supply, water demand, and land use data available at the time GSP development began. Unfortunately, drought conditions in 2020-2021 have coincided with development of the GSP, a timing that has not permitted complete evaluation and inclusion of data from these years in the GSP at this time. It is noted that ongoing management of the Colusa Subbasin under the GSP will follow an "adaptive management" strategy that involves active monitoring of Subbasin conditions and addressing any challenges related to maintaining groundwater sustainability by scaling and implementing PMAs in a targeted and proportional manner in accordance with the needs of the Subbasin. Data and information collected through ongoing monitoring will be evaluated, reported, and used to guide GSP implementation. GSP annual reports provide an opportunity each year to evaluate current Subbasin conditions and assess needs for additional PMAs. The first annual report, due April 2022, will evaluate groundwater conditions in the Colusa Subbasin since 2015. During the periodic (five-year) evaluations, the GSP will also be reviewed and SMC will be revised, as needed, as we learn more about the effects of current and future conditions.
277	Donald Bills	GGA/CGA TAC Member	5	5.2.2	5.3			"As discussed above, the Colusa Subbasin does not currently have undesirable results, which shows that the Subbasin is being managed sustainably." As of 2021 this is no longer true. It might be reasonable to add a second footnote here to indicate that extreme dry and heat in 2020 and 2021(not seen in the last 1,200 years) has exacerbated the already dry conditions pushing the basin into undesirable results.	Please see the response to comment 276.

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278	Donald Bills	GGA/CGA TAC Member	5	5.3.1.1	5.5	2		"…and are not currently occurring. Per the projected water budget (Chapter 3), these effects are not likely to occur in the foreseeable future." I would suggest amending this text possibly by adding reference to the proposed footnote 2 to account for the existing 2020/21 conditions that clearly have exceeded the undesirable result ("…sustained groundwater levels are too low to reasonably satisfy beneficial uses within the Subbasin").	Please see the response to comment 276.
279	Donald Bills	GGA/CGA TAC Member	5	5.3.1.2	5.5	2		"…impact that would potentially harm the "long-term viability" of affected beneficial uses and users in the Subbasin." It may be necessary to re-evaluate this undesirable result given the current conditions in the subbasin. A significant number of domestic wells and shallow irrigation wells are currently dry or close to being dry while the required amount of representative monitoring wells does not appear to show chronic lowering of groundwater levels.	Please see the response to comment 276.
280	Donald Bills	GGA/CGA TAC Member	5	5.3.1.3	5.6			Suggest replacing sustainable yield with sustainable goals as mentioned earlier. I would also suggest adding a third bulleted Cause: Decrease in the annual precipitation and increase in maximin temperature days (above 100 degrees) related to the changing climate ("Climate Crisis").	Comment addressed. The text of the subsection has been revised and no longer refers to sustainable yield. Sustainable yield must be reported and described, per the GSP regulations. See § 354.18(b)(7) and § 354.18(c)(2)(C)). This requirement is addressed in Chapter 3 of the GSP.
281	Donald Bills	GGA/CGA TAC Member	5	5.3.1.4	5.6			I would suggest adding two additional bulleted items here: Permanent loss of crops due to lack of water (farm failure?). Hauling of water to meet minimum household needs.	Comment addressed. These suggested potential effects have been added to Section 5.3.1.4.

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282	Donald Bills	GGA/CGA TAC Member	5	5.3.2.2	5.7/5.8			"…provided the GSP demonstrates that there is a significant correlation between groundwater levels and the other metrics." The Freshwater zone of the aquifer extends from near the surface to as much as 2,200 ft below the surface with storage estimates of 26 to 140 maf, almost a full order of magnitude difference (chapter 3, section 3.2.3). But most domestic and shallow wells are located within the first 200 ft below the surface where storage is estimated at only about 13 maf. If all these wells were dewatered there would still be significant water in storage (1/2 to 9/10?) not to warrant an undesirable result for GW storage. The 48 monitoring wells represent storage of 1.4 to 7.7 maf… 5 percent of total estimated GW volumes. So, while GW storage is unlikely to see an undesirable result, most of the water wells can go dry anyway affecting beneficial uses and inflicting significant damage to the economy (as we are currently seeing; 2020/21). I realize it is too late in the game to change undesirable results, MTs and MOs now. But I would suggest that consideration for their revision be modified or changed when appropriate to reflect the differences between the unconfined (first 200ft) and confined/ semi-confined (2,000 ft) of the aquifer and more directly link then to climate impacts5.	Comment acknowledged. The referenced subsection has been revised to include the following statement, "As discussed in Section 5.2.1, implementation of the GSP will be based on adaptive management, as required to adapt to changing climatic conditions. The SMCs for groundwater levels and storage will continue to be evaluated and updated as new information about groundwater conditions is acquired and data gaps are filled."
283	Donald Bills	GGA/CGA TAC Member	5	5.3.2.2	5.7/5.8	2		It is unreasonable to use "…groundwater levels ranging from historical lows…". As the current drought and heat crisis is showing us historic ranges can be misleading (e.g. the Colorado River compact based on only 20 years of record) if not used in context.	Comment acknowledged. The sentence reading, "Based on the estimated range of current storage volume in the Colusa Subbasin (Chapter 3) and the small percentage changes in storage estimated to occur over groundwater levels ranging from historical lows to the groundwater levels minimum thresholds, it is anticipated that an undesirable result related to the chronic lowering of groundwater levels would occur before the Subbasin would experience significant and unreasonable effects related to reduction of groundwater storage," has been revised to read, "Based on the estimated range of current storage volume in the Colusa Subbasin (Chapter 3) and the small percentage changes in storage estimated to occur over groundwater levels ranging from current levels to the groundwater levels minimum thresholds, it is anticipated that an undesirable result related to the chronic lowering of groundwater levels would occur before the Subbasin would experience significant and unreasonable effects related to reduction of groundwater storage". Also, please see to the response to comment 282.

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284	Donald Bills	GGA/CGA TAC Member	5	5.3.2.3	5.8	1		"Additional justification and information supporting the criteria used to define when and where the effects of the groundwater conditions cause undesirable results is provided in Appendix 5A." And from Appendix 5, footnote 1 under MTs, "The lack of shallow groundwater data is identified as a data gap and will be addressed along with other data gaps during plan implementation" …And already too late to identify a undesirable condition for 2020/21.	Comment acknowledged. Please see the response to comment 282.
285	Donald Bills	GGA/CGA TAC Member	5	5.3.2.3	5.8	2		"These criteria were determined based on the evaluation of best available data pertaining to the Subbasin's specific conditions and characteristics, as described in the Plan Area and Basin Setting sections of this GSP (Chapter 2 and Chapter 3, respectively),…" Based on 2020/21 conditions it would seem wise to consider adding an interim evaluation to the 5-year period. Suggest every 2 years.	Comment acknowledged. Please see the response to comment 282.
286	Donald Bills	GGA/CGA TAC Member	5	5.3.5.2	5.12	1		As I have commented before and backed up with references from the San Joaquin Valley and Salt River and Tucson Basins in Arizona, 0.5 to 0.6 ft (half a foot…) in a couple months much less 24 is too much to be able to stop or remediate.	Comment acknowledged. The subsidence SMC are being reviewed and will potentially be revised in the final GSP. Additional clarification has also been added to Section 5.3.5.5 to note that: "[...]recognizing that there is uncertainty in Subbasin conditions and that data gaps exist, the GSAs will continue to monitor groundwater levels to identify potential undesirable results as part of GSP annual reports and five-year updates, and adapt GSP implementation, as needed, to avoid undesirable results." Ongoing monitoring and data collection will inform potential updates to sustainable management criteria (including the minimum thresholds, as needed). Potential updates to the GSP will occur during the periodic evaluation process to ensure that the Subbasin is on track to achieve the sustainability goal. Annual reports also provide an opportunity to reassess Subbasin conditions in the interim, and identify whether more urgent evaluation of the GSP is needed.
287	Donald Bills	GGA/CGA TAC Member	5	5.3.5.3	5.13	2		I would suggest adding another potential cause of undesirable result to the list: "decrease in hydraulic conductivity and the resultant increase in well M&O costs."	Comment addressed. These considerations have been clarified in Section 5.3.5.4, as these are viewed more as potential effects of undesirable results.
288	Donald Bills	GGA/CGA TAC Member	5	5.3.6.1	5.13	1		I would suggest adding "Significant and unreasonable impacts to springs".	Comment addressed. The suggested text has been added.
289	Donald Bills	GGA/CGA TAC Member	6	6.2	page 6-12		Table 6.3	"Westside Streams Diversion for Direct or In-lieu Groundwater Recharge…" This type of GW recharge should help mitigate Land subsidence. Suggest you add an "X" to that column.	Comment addressed. The table has been revised to indicate that benefits are expected for land subsidence.

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290	Donald Bills	GGA/CGA TAC Member	6	6.5	Page 6-58		Figure 6.9	I would strongly suggest/recommend adding Walker Creek to the map and this section a one of the Westside larger Streams Diversion for Direct or In-lieu Groundwater Recharge. The Walker Creek Watershed drains an area at least as big as the Willow Creek watershed and bigger than either the Logan or Hunter Creek watersheds. In addition, the Walker Creek watershed contains a number of, as yet characterized springs that would be a source of potential recharge.	Comment addressed. Section 6.5.1.2 has been revised to acknowledge the potential recharge benefits and opportunities along other streams and creeks, including Walker Creek and Hambright Creek. However, it is noted that the westside streams diversion project analysis was confined to the six streams listed because of the availability of monthly flow estimates.
291	Donald Bills	GGA/CGA TAC Member	6	6.5.1.2	page 6-61	1	Figure 6.9	Suggest/recommend adding Walker Creek to the list here. See reasons above.	Please see the response to comment 290.
292	Donald Bills	GGA/CGA TAC Member	6	6.5.1.2	page 6-62		Figure 6-10	Suggest/recommend adding Walker Creek to the map.	Please see the response to comment 290.
293	Donald Bills	GGA/CGA TAC Member	6	6.5.1.2	page 6-63		Table 6-29	Water source and reliability: Add Walker Creek.	Please see the response to comment 290.
294	Ben King		1	1.2				This is a question for the DWR. Since the DWR formally adopted a Human Right to Water ("HRTW) Policy in its Department Administrative Manual during April 2021 – does it want to state that it will be including HRTW considerations in the DWR's decision making, program activities and public engagement in SGMA and the GSP development. Wont this statement promote HRTW engagement?	Comment acknowledged. Please note that the Colusa Subbasin GSP does reference the Human Right to Water policy and how that has been factored into GSP development and SGMA-related processes. Please refer to Sections 2.6.1, Human Right to Water, and Sections 2.7.1.2 and 5.4.4.4 of the GSP.
295				1.3.1				Typo for Private Pumpers – appointed by Colusa Groundwater BOS ? Did you mean to say recommended by the Commission and appointed by the BOS? Were there public meetings for the appointment by the Board Members by GSA's? It would be great to know that the GSA's have public meetings. Do they have websites and interested party lists? Please confirm that each GSA has websites and posts notice of meetings at a minimum.	Comment addressed. The description of the Private Pumper Representatives has been corrected as suggested. As described in Section 1.3.1 (in the paragraph following the bulleted list of GGA representatives): "Board members are chosen in public meetings by the respective governing boards of the Member Agencies. Alternates for each Board member are chosen in the same manner by the same Member Agencies." To clarify, member agencies of the CGA and GGA are not GSAs and are not individually held to the requirements of GSAs, but the member agencies do hold public meetings. As described in Section 2.7.3, the CGA and GGA (GSAs) do maintain interested party lists, and do maintain websites that provide notice of meetings, as well as other information and materials related to GSP development. Those websites are: https://colusagroundwater.org/ https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority

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296	Ben King			1.3.3				Are these costs for the Basin as a whole? It would be good to break these costs on a per acre basis and discuss how the costs are allocated to Cities and small water systems. For example – what does the CGA expect the City of Williams to pay going forward? Voters in the Cities need to know. What will the County of Glenn and the County of Colusa be expected to contribute?	Comment addressed. Yes, the costs summarized in Table 1-1 are the total estimated annual GSP implementation costs for the Colusa Subbasin as whole. This clarification has been added to the text in Section 1.3.1. Specific financing plans and cost-allocation approaches are not yet determined, but will be identified and determined with stakeholder involvement following GSP adoption. Those decisions are expected to be made in the coming year. As described in the last paragraph of Section 1.3.1, "The Colusa Subbasin GSAs will develop a financing plan for the overall implementation of the GSP that will specify funding sources and cost-allocation approaches across entities for the different GSP implementation activities (see Chapter 7 and Appendix 7A for a description of existing options)."
297	Ben King		2	2.1			Table 2-3	Table 2-3 is misleading in that it does not reflect the loss in surface supply due to water transfers. There needs to be a table that reflects the historical amount of water transfers for every water purveyor and how much of the water remains in Basin and out of Basin. Without this stakeholders can not assess the available water supply for the Basin.	Comment acknowledged. It is noted that Tables 2-2 and 2-3 are within the Plan Area section of the GSP, and are intended to summarize general information about water purveyors and agencies with water management responsibilities in the Colusa Subbasin (per 23 CCR §354.8). The historical volume of surface water that has remained in the Subbasin is summarized in the water budget (Section 3.3, per 23 CCR §354.18). Please also see the response to comment 298.
298	Ben King		2	2 generally				The Colusa County GMP does a good job discussing water transfers but the GSP is silent on it. Stakeholders need transparency and understanding how water transfers work and how ground water substitution and fallowing work into the available water supply. The transparency and discussion regarding water transfers, fallowing and groundwater substitution also have potential negative DEI and HRTW outcomes because water transferred out of basin and fallowed acreage means less jobs and ground water pumped for ground water substitution could lead to aquifer degradation if the groundwater pumped is pool quality.	Comment addressed. Clarification has been added to Section 3.3.3 (Water Budget Assumptions) to explain how water transfers were factored into the Subbasin water budget. In the historical water budget, surface water supplies were configured to implicitly reflect historical surface water transfers and any effects of transfers on historical groundwater pumping. In the current conditions and future conditions water budgets, it would be highly speculative to characterize possible future water transfers. The approach we used to specify projected surface water supply is consistent with 23 CCR §354.18(c)(3)(C). The uncertainty of future conditions related to surface water supplies is one of many reasons that GSP implementation will be based on adaptive management. As described throughout the GSP, the GSAs are committed to ongoing monitoring and implementation of projects and management actions to respond to changing Subbasin conditions.

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299	Ben King		2					Again there needs to be discussion about surface water transfers and a Table listing the number of acre feet pumped for groundwater substitution and the acres fallowed by each Settlement Contractor. Stakeholders need to know this for HRTW and DEI concerns and also for the general sustainability of economic health of the Subbasin.	Comment acknowledged. Please see the responses to comments 297-298.
300	Ben King		2	2.3.2				There needs to be a discussion regarding groundwater trading markets and how this would impact the potential water demands. The California Water Commission are holding hearings regarding groundwater trading and it is very relevant to the effects on water demands and the economic feasibility and sustainability for the subbasin. To not include any discussion is misleading and could lead stakeholders to misallocate resources or make material economic decisions without full knowledge of a likely outcome. The CWC appears to quite committed to groundwater trading and the PPIC has come out strongly in favor of water markets. It is misleading not to discuss this likelihood especially when there is such a focus on recharge in the PMAs. It would seem that some PMAs may not be economically efficient if water could be traded instead. In June of 2021, Steven Springhorn , Acting Director of SGMA discussed the framework for Water Trading for SGMA Implementation – it seems ingenious to go through this process and not discuss what the Acting Director of SGMA is presenting to the California Water Commission.	Comment acknowledged. The concept of a water market is addressed in the GSP under Section 6.5.2.3, Long-Term Demand Management Action. The market-based concept of financial incentives to encourage the reallocation of groundwater is also a core component of the PMA described in Section 6.5.2.4, Strategic Temporary Land Idling for Drought and Localized Short-Term Groundwater Management. The concept of groundwater markets is further explored in Appendix 6.B, Economic Analysis of Demand Management and Conceptual Allocation Approaches. Page 11 of Appendix 6.B. notes that groundwater trading is a potential option for the subbasin and that other GSAs across the state are currently exploring such options. Appendix 6.B. also presents an economic analysis of potential demand management actions in the Colusa Subbasin. This provides a basis for establishing whether projects are cost-effective relative to other demand management actions, such as a limit on groundwater extractions and a groundwater trading market. However, that type of analysis would be completed as part of future GSP implementation. The GSP acknowledges the potential benefits of a market for improving flexibility for stakeholders that would face limits on groundwater pumping. However, it also acknowledges that developing a market is a substantial undertaking that is beyond the scope of initial GSP development. A market is an institution that would allow willing buyers and sellers of water to make voluntary exchanges. It requires defining property rights to groundwater (e.g., allocation), market and trading rules, administration, and monitoring and enforcement. These may be considered in the future if it is determined to be of interest to the subbasin stakeholders. Any evaluations would be conducted in a public, stakeholder-driven process.

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301	Ben King		2	2.3.2				There needs to be reference to the ERA Demand Management Actions if they remain in the GSP. If implemented these Management Actions will have the intended effect which is to limited Demand. These PMAs are DEMAND Management Actions and should be referenced and discussed in this section.	Comment addressed. A reference has been added in Section 2.3.2 to indicate that potential demand management actions are discussed in Section 6.5.2.
302	Ben King		2	2.5.1				Discussion about water quality testing, determination of appropriate well depth and what happens if the driller finds poor water quality. I think the answer is that this information is not captured or disclosed and therefore it is a concern for water quality and HRTW issues.	Comment addressed. Section 2.5 provides an overview of coordination of the GSAs' management efforts with existing county and state programs, including county well permitting programs. The following has been added to Section 2.5. "The State recognizes the Human Right to Water pursuant to Water Code Section 106.3, which states, “every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes.” The human right to water extends to all Californians, including disadvantaged individuals and groups and communities in rural and urban areas (State Water Resource Control Board [State Board], 2021). The GSAs will seek to work with their respective counties, State Board staff and stakeholders in support the State Board’s efforts, “to develop new systems or enhance existing systems to collect data and identify and track communities that do not have, or are at risk of not having, safe, clean, affordable, and accessible water for drinking, cooking, and sanitary purposes (State Board, 2021)."

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303	Ben King		2	2.6.1				The following was taken verbatim from the DWR's recent Drought Memo. This is from a footnote: DWR formally adopted the Human Right to Water (HRTW) Policy in its Departmental Administrative Manual which outlines how the HRTW should be included in DWR decision-making, program activities, and public engagement. The Water Board adopted a HRTW Resolution, recognizing HRTW as a core value and directing its implementation across programs and activities. The Water Board is also currently drafting a Racial Equity Resolution. There should be a reference to the emerging HRTW and Racial Equity actions by the DRWR and the SWRCB since it is central to Stakeholder HRTW and Diversity Equity and Inclusion (DEI) concerns regarding the GSP and its future implementation.	Comment addressed. Commentary has been added to the existing discussion in Section 2.6.1, Human Right to Water, to reference these emerging efforts.
304	Ben King							I strongly disagree with the statement that the GSA supported and allowed for effective engagement of all stakeholders regarding HRTW and DEI issues. I would urger the DWR to expressing prohibit GSAs taking any action against a stakeholder unless a mediator is brought in especially regarding situations where there are HRTW and DEI or potentially negative racial outcomes.	Comment acknowledged. It is noted that the GSAs created and followed a Communication and Engagement Plan (Appendix 2E) and sponsored, publicized, and conducted numerous engagement opportunities for stakeholders in the Subbasin (Section 2.7.2), including more than 236 separate meetings and workshops. Meetings and workshops have touched on all aspects of GSP development and decision-making, including issues relevant to HRTW and DEI. Meetings and workshops have been open to the public, and meeting notes, materials, and/or recordings have been available to the public. Communication and outreach for these meetings and for GSP development (Appendix 2C) has reached stakeholders of varied backgrounds. All comments related to the GSP have been logged and addressed appropriately (Appendix 2B). The GSAs have made clear and consistent efforts to respectfully engage with stakeholders through robust discussion.

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305	Ben King			Public Engagement 2.7.3.6				The Stakeholder Engagement Process was materially flawed because there was no discussion about the California Water Commissions initiatives around groundwater water trading. It is unreasonable to have no public engagement and submit a GSP without any public discussion of an issue that the DWR Acting Deputy Director of SGMA is presenting at the California Water Commission. As I said, we are spending a lot of time and money considering and debating potential PMAs when we have spent no time regarding the water trading policies being considered by the California Water Commission. Water Trading will have many intended consequences on the allocation of resources and many unintended consequences – some of which could be extremely detrimental to the long term sustainability of the fresh water aquifers of the Sacramento Valley. It seems like the PMA considerations may be a real waste of time – I just found out about the Water Trading discussions of the CWC yesterday which happens to be the last business day for the comment period for this GSP. Where are the GSAs websites. There is a lot of discussion regarding the CGA website but is there any other website. Do they exists for each Member GSA ? If not – why and how can stakeholders gain transparency. Does each Member GSA have an interested person list?	Comment acknowledged. The GSAs have engaged in extensive public engagement, please see the response to comment 304 for additional information. As described in Section 2.7.3, the CGA and GGA (GSAs) do maintain interested party lists, and do maintain websites that provide notice of meetings. Please see the response to comment 295 for more information. The concept of groundwater markets is noted in the GSP. As described under Comment Response 300, the concept of a water market is addressed in the GSP under Section 6.5.2.3, Long-Term Demand Management Action, market-based concept of financial incentives to encourage the reallocation of groundwater under Section 6.5.2.4, Strategic Temporary Land Idling for Drought and Localized Short-Term Groundwater Management, and Appendix 6.B., Economic Analysis of Demand Management and Conceptual Allocation Approaches. It is noted that these groundwater trading discussions have occurred since GSP development began, and draft recommendations for groundwater trading policies will not be available from the California Water Commission until 2022, after GSP adoption. There are various uncertain factors that could affect future water supplies, but would be speculative to define now. The uncertainty of future conditions related to water supplies and potential water trading policies are among the many reasons that GSP implementation will be based on adaptive management. As described throughout the GSP, the GSAs are committed to ongoing monitoring and implementation of projects and management actions to respond to changes in Subbasin conditions. The GSP is a "living document" that the GSAs will review and revise as more information about the basin setting becomes available (per 23 CCR §356.4).

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306	DEPARTMENT OF FISH AND WILDLIFE			3.2.7; starting page 3-77):				The GSP does not include sufficient detail describing the timing of depletions of interconnected surface water (ISW). a. Issue: Though the GSP discusses annual gains and losses from interconnected surface waters in the subbasin and summarizes net gains by water year type (Table 3-6, page 3-79), the GSP does not include sufficient detail on the timing of depletions as required by 23 CCR § 354.16(f). In order to adequately assess ISW that may be gaining or losing at different times of the year, it is preferential to present net gain/loss values by month, rather than by year. Quantifying depletions by month for each reach will facilitate evaluation of impacts or benefits to environmental beneficial users that rely on surface waters during specific portions of the year. b. Recommendation: The Department recommends including net gains or losses to interconnected surface waters by month, rather than by year.	Comment addressed. A summary of average monthly net gains/losses has been added to Appendix 3G, in addition to the existing summary of annual and average annual net gains/losses. It is noted that these results are summarized from the C2VSimFG-Colusa groundwater model, and therefore carry significant uncertainty. However, at the time of GSP development the model results are considered to be the best available data to describe streamflow depletion. The GSAs have proposed studies to improve model calibration and close data gaps related to depletions of interconnected surface water (please refer to Chapter 7 of the GSP).
307	DEPARTMENT OF FISH AND WILDLIFE			3.2.8; starting page 3-82				Groundwater dependent ecosystem (GDE) identification, required by 23 CCR § 354.16(g), is based on methods that risk exclusion of ecosystems that may depend on groundwater. a. Issues: i. GDE Scoring Criteria: The GSP assigns a rank of '1' (less likely to be a GDE) to '4' (more likely to be a GDE) to potential GDE areas within the Natural Communities Commonly Associated with Groundwater dataset. It is unclear how the rankings are utilized throughout the remainder of the GSP to assess monitoring networks, management criteria, or potential projects. Accordingly, the ranking system has no apparent actionable groundwater management relevance.	Comment addressed. The text in Section 3.2.8 has been revised to clarify that preliminary screening of the potential GDEs within the Colusa Subbasin was conducted to help prioritize areas for further mapping, evaluation and monitoring of GDEs during implementation of the Colusa Subbasin GSP. The preliminary screening supported the assessment of data gaps, evaluation of existing monitoring networks, which could potentially be used for GDE monitoring, and development of PMAs. The GSAs will seek to work with resource agencies, stakeholders, beneficial users and the public to refine the understanding of GDEs in the Colusa Subbasin, fill data gaps and develop PMAs with consideration of GDEs.

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308	DEPARTMENT OF FISH AND WILDLIFE			3.2.8; starting page 3-82				ii. Depth to Groundwater Threshold: The GSP relies on a groundwater level threshold of 30-feet below the ground surface (bgs) to screen potential GDEs within the subbasin. However, mature Valley Oak (Quercus lobata) can access groundwater up to 80 feet bgs (Howard 1992, Lewis & Burgy 1964). The use of a 30-foot threshold may incorrectly result in Valley Oak communities receiving a GSP-imposed score of '1,' indicating that they are least likely to be a GDE.	Comment acknowledged. The GDEs analysis will be refined during GSP implementation. Additional clarification has been added to the GSP Chapter 3 to acknowledge that significant data gaps exist for the precise locations and characteristics of GDEs in the Colusa Subbasin. It is noted that the prioritization, or "scoring," of GDEs is intended as a step toward identifying GDEs using the information available at the time of GSP development. This "scoring" is not seen as a final call on the classification of GDEs, but rather a prioritization for future work to better identify and expand monitoring of potential GDEs. Section 4.2.5.4 has been revised to state that the ISW monitoring network wells may be useful for monitoring groundwater levels near GDEs; however, a dedicated network of shallow monitoring wells will be developed specifically for GDE monitoring during implementation of the GSP. As described in the GSP Chapter 7, the GSAs have proposed a study to investigate expansion of the shallow groundwater level monitoring network for GDEs during GSP implementation. Among other goals, this study is planned to help close data gaps related to identification of GDEs. The prioritization will be refined in this study, and will be factored into decisions for the placement of new monitoring sites to improve the understanding and protection of GDEs.
309	DEPARTMENT OF FISH AND WILDLIFE			3.2.8; starting page 3-82				iii. GDEs Near Surface Water: The GSP assesses whether potential GDE areas are located near surface waters or irrigated cropland, or both. The GSP considers potential GDE areas within 150 feet of surface waters, within 150 feet of irrigated rice paddies, and within 50 feet of other irrigated croplands to have access to surface water; and therefore, the GSP assigns these areas a score of '2' or '3,' indicating they are less likely to be groundwater dependent. The GSP states that "GDEs include vegetation and habitat that are wholly dependent on groundwater" (line 9, page 3-83); however, this narrow definition of a GDE disregards a GDE's adaptability and opportunistic approach to accessing water in which vegetation and ISW may rely on both surface water and groundwater across seasons and years. Furthermore, this GDE definition contradicts an earlier description of GDEs within the GSP, in which the plan states that "a GDE's dependence on groundwater refers to reliance of GDE species and/or communities on groundwater for all or a portion of their water needs" (line 3, page 3-82). Particularly as the GDE areas receiving scores of '2' or '3' have already been determined to be located in areas with depths to groundwater of less than 30 feet, proximity to potential surface waters is insufficient evidence to categorize them as 'less likely' to be GDEs.	Comment acknowledged. Please see the response to comment 308. It is noted that the GDE "scoring" is not seen as a final call on the classification of GDEs, but rather a prioritization for future work to better identify and expand monitoring of potential GDEs. The prioritization will be refined during GSP implementation and will be factored into decisions for the placement of new monitoring sites to improve the understanding and protection of GDEs (see GSP Chapter 7).

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310	DEPARTMENT OF FISH AND WILDLIFE			3.2.8; starting page 3-82				iv. Data Gaps: The GSP states that there is potential for GDEs to be present in the uplands west of Orland and west of Arbuckle, but that groundwater level data is lacking in these areas and there is insufficient information "to determine their existence" (line 26, page 3-83). Rather than waiting an indeterminate amount of time to gather data to prove groundwater dependence of potential GDE areas and leaving the potential GDEs unclassified in the interim, the GSP should conservatively consider these areas to be GDEs until sufficient data is collected that proves otherwise.	Comment acknowledged. Please see the response to comment 308. It is noted that the GDE "scoring" is not seen as a final call on the classification of GDEs, but rather a prioritization for future work to better identify and expand monitoring of potential GDEs. The GSAs are not discounting that these western areas are GDEs. During GSP implementation, the GSAs are planning to refine the GDE assessment, and have proposed studies to investigate the western boundary of the Subbasin and expand shallow groundwater monitoring to close data gaps in areas where potential GDEs exist. Please see Section 7.1.2 for additional information about these studies.
311	DEPARTMENT OF FISH AND WILDLIFE			3.2.8; starting page 3-82				v. Special Status Species: SGMA defines GDEs as ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface [23 CCR § 351 (m)]. The GSP does not identify or discuss species that may be present within the subbasin that rely on groundwater, groundwater dependent ecosystems, or interconnected surface waters.	Comment addressed. A reference to TNC's analysis of freshwater species located in the Colusa Subbasin has been added to Section 3.2.8 of the GSP (based on analysis of the California Freshwater Species Database version 2.0.9 within the Subbasin boundary). We have also added more text to acknowledge data gaps regarding which of these species are found within GDEs, and references to GSP studies in Chapter 7 to help close those data gaps and expand understanding of GDEs in the Subbasin.
312	DEPARTMENT OF FISH AND WILDLIFE			4.2.5.4; starting page 4-33				The GSP should include additional details related to the plans to improve the monitoring network for GDEs and ISW within the subbasin. a. Issue: The GSP states that the ISW representative monitoring network will also be used to monitor GDEs. The GSP does not present any information or figures to support its assertion that the ISW monitoring sites are located sufficiently near to GDEs to assess shallow groundwater levels in those areas. While the Department appreciates the GSP's acknowledgement of data gaps related to the characterization of GDEs and ISW within the subbasin and the GSP's proposed plan to install up to an additional 10 shallow monitoring wells, the GSP does not provide details on planned locations or timelines for installation of these additional monitoring locations. b. Recommendation: The GSP should include additional detail related to the anticipated timeline for installation of additional wells to further refine ISW and GDE characterization and management. The Department recommends that the GSP assess the locations of special status species within the subbasin to determine which GDE areas likely provide priority habitat. GDE areas and ISW that support special status species or are most at risk of negative impacts due to groundwater pumping should be prioritized for monitoring to inform management actions (See Comment #2(v)).	Comment addressed. Section 4.2.5.4 has been revised to state that the ISW monitoring network wells may be useful for monitoring groundwater levels near GDEs; however, a dedicated network of shallow monitoring wells will be developed specifically for GDE monitoring during implementation of the GSP. The development of a dedicated groundwater dependent ecosystem monitoring network consisting of shallow monitoring wells is discussed in Chapter 6.5.2.9 Potential Management Actions and Chapter 7.1.2.1 GSP Studies. Although the GSAs used the best available scientific data and information to assess potential GDEs within the Colusa Subbasin, significant data gaps exist in the understanding of the GDEs and the associated species. The GSAs will seek to work with resource agencies, stakeholders, beneficial users and the public to refine the understanding of GDEs in the Colusa Subbasin, fill data gaps and develop PMAs with consideration of GDEs.

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313	DEPARTMENT OF FISH AND WILDLIFE			5.3.6, 5.4.6 ; starting pages 5-15 and 5-30				Interconnected surface water sustainable management criteria (SMC) may not protect against undesirable results for fish and wildlife beneficial uses and users. a. Issues: i. Minimum Thresholds: Minimum thresholds (MTs) for ISW are set at 10 feet below the measured historical low for each representative monitoring well. The GSP states that establishing MTs below the historic lows is necessary to provide a sufficient margin of operational flexibility during GSP implementation, and that no undesirable results were observed at the historic low; however, the GSP does not include sufficient analysis or discussion to support this claim. In 2015, the second of back-to-back critically dry water years in the Sacramento Valley which resulted in recent historical low groundwater levels, vegetated and aquatic GDEs experienced adverse impacts including stressed or dying riparian vegetation, poor instream habitat availability, and increased water temperatures (DFW 2019). It is unclear what, if any, studies or analyses were completed to assess whether environmental users within the subbasin experienced undesirable results at the historical low groundwater levels, or what metrics the GSP would evaluate to determine the presence of an undesirable result for GDEs or ISW in the event of additional groundwater decline beyond the historic low as the MTs allow. The ISW SMC are also referenced as protective of GDE beneficial users of	Comment acknowledged. The sustainable management criteria for depletion of interconnected surface water were established with the GSAs' understanding that significant data gaps exist in the understanding of stream aquifer interactions in the Colusa Subbasin. Additional studies, more refined numerical models, and additional monitoring will be needed to address these data gaps and uncertainties. Additionally, the GSAs acknowledge that the sustainability thresholds will need to be reviewed and evaluated, and potentially refined, as additional data and information becomes available. The GSAs will seek to work with stakeholders, beneficial users, the public and GSAs representing adjacent subbasins during this process.

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313 cont'd								groundwater according to the GSP, but the supporting discussion focuses on groundwater gradients and associated depletions. No analysis is presented that characterizes whether the established MTs are sufficient to maintain water levels that have historically been shallow enough to support GDEs, or if the MTs would permit groundwater levels to fall below root zones, removing groundwater as an available water source to some GDEs. If MTs are not protective of GDE access to groundwater supplies, significant impacts to environmental beneficial users of groundwater will likely be experienced before MTs are reached. Furthermore, the GSP reports annual net values for streamflow depletion from the modeled baseline conditions, baseline conditions with climate change, and baseline conditions with climate change and project scenarios. However, the annual analysis does not provide sufficient detail on the timing of depletions to adequately assess potential impacts to environmental users (See Comment #1). The GSP compares modeled annual depletions to total annual flow in these river systems, and uses this annual normalization to characterize groundwater contributions to ISW as nominal. This coarse annual comparison does not take into account how groundwater contributions to river base flows are often proportionately greater in dry years or during annual low-flow seasons, or how groundwater contributions play a key role in maintaining water quality and temperatures. Properly contextualizing groundwater contributions to surface water is especially important to understanding potential impacts of groundwater depletion on surface waters and their ecosystems, particularly when the GSP states that streamflow accretion is expected to decrease by 38.3% with climate change impacts (line 9, page 6-2). The Department recommends the GSP reselect minimum thresholds that would better protect environmental uses and users of groundwater, rather than enabling declines in groundwater levels over the implementation horizon beyond the historic low. Additional analyses of the specific impacts of the established thresholds on GDE and ISW beneficial users of groundwater should be included.	

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314	DEPARTMENT OF FISH AND WILDLIFE			5.3.6, 5.4.6 ; starting pages 5-15 and 5-30				ii. Undesirable Results: The GSP requires 25% of ISW representative monitoring wells in the subbasin to fall below their MTs for 24 consecutive months before identifying an undesirable result to GDEs or ISW. While environmental users are adapted to sustain short-term lowering of groundwater levels during dry periods, environmental users may not be able to sustain extended periods of reduced groundwater access that would result from allowing groundwater levels to fall to historic lows for 24 months. By the time an undesirable result is declared, and management actions are triggered in response to the undesirable result, environmental groundwater users will have already experienced significant stress and potentially irreversible mortality. The Department recommends the GSP reconsider the 24-month duration of groundwater levels below MTs required to constitute an undesirable result, recognizing that extended durations of groundwater inaccessibility for environmental users will likely lead to adverse impacts that cannot be easily reversed when groundwater levels recover. At a minimum, the Department recommends identifying physical triggers (e.g., declining Normalized Difference Vegetation Index signals) and associated management actions (e.g., demand reduction) to enable the GSAs to identify and mitigate localized patterns of lowering groundwater or depleted ISW and associated negative impacts before the second year of MT exceedances yields more	Comment acknowledged. The GSAs will conduct local management of the Colusa Subbasin based on measurable objectives and interim milestones with the goal of avoiding exceedances of minimum thresholds and triggering of undesirable results. The GSAs will conduct this local management with consideration of all beneficial users and will seek to work with resource agencies, stakeholders, beneficial users, the public and GSAs representing adjacent subbasins to avoid exceeding minimum thresholds and incurring undesirable results.

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314 cont'd								significant and undesirable impacts. These interim action triggers will help preempt irreversible losses and undesirable results for environmental users. Undesirable Results: The Department recommends the GSP reconsider the 24-month duration of groundwater levels below MTs required to constitute an undesirable result, recognizing that extended durations of groundwater inaccessibility for environmental users will likely lead to adverse impacts that cannot be easily reversed when groundwater levels recover. At a minimum, the Department recommends identifying physical triggers (e.g., declining Normalized Difference Vegetation Index signals) and associated management actions (e.g., demand reduction) to enable the GSAs to identify and mitigate localized patterns of lowering groundwater or depleted ISW and associated negative impacts before the second year of MT exceedances yields more significant and undesirable impacts. These interim action triggers will help preempt irreversible losses and undesirable results for environmental users.	

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315	DEPARTMENT OF FISH AND WILDLIFE			6.5.2.3, 6.5.2.4; starting page 6-84				The GSP should include additional metrics and timelines related to the implementation of demand management within the subbasin. a. Issue: The Department appreciates the GSP's identification of both shortand long-term demand management actions that will serve as a "backstop" to the other identified PMAs. As the other PMAs focus largely on implementing recharge projects that may be costly, rely on securing additional surface water supplies, and/or require potentially lengthy permitting processes, demand management may be necessary in instances where a quick response to undesirable results within the subbasin is needed. Though the GSP identifies various demand management strategies, the GSP states that these management actions are in the "early conceptual stage" and as such, no timelines have been determined. b. Recommendation: The Department recommends detailing specific timelines and metrics that would trigger the implementation of the identified demand management scenarios should recharge projects encounter delays or fail to produce the anticipated groundwater benefits to the subbasin.	Comment acknowledged. It is noted that the decisions pertaining to demand management involve major public policy questions that will require evaluations of conditions in a public, stakeholder-driven process. The GSP acknowledges a non-exhaustive list of events that may trigger demand management in Section 6.5.2.3. The precise decisions for whether and how demand management would be applied will be determined by the GSA boards through a stakeholder-driven process during GSP implementation. If demand management is pursued, the establishment of implementation metrics and timelines should be considered.
316	Holly Reimers			ES-14				What happened to the wells between 200' and 2,000'?	Comment acknowledged. The criteria for selecting interconnected surface water monitoring wells are that the wells must be less than 200 feet deep and the wells must be located between 2,000 feet and 5 miles from the surface waters being monitored. Wells that are deeper than 200 feet do not meet the criteria for monitoring interconnected surface waters.
317	Holly Reimers			ES-16		ES-16		Wells falling below their MT should be monitored more often than every 24 months. Every two years allows for a severe lowering of the ground water level that might not be recoverable. Any well falling below it's MT should be checked at least twice a year. Any land subsidence should not be acceptable. This is not something that is recoverable.	Comment acknowledged. As described in Section 4.2.1.3, groundwater level measurements will be collected twice annually, at a minimum, to ensure seasonal trends are well accounted for (23 CCR §354.34(c)(1)(B)). Manual measurements for all network wells should be collected in the spring and fall, at a minimum, unless more frequent measurements are required to characterize changes in groundwater levels.

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318	Holly Reimers			ES-17 12-15				" .. not currently occurring ... " WHAT?? Has anyone noted the number of dry and going dry wells in Glenn County? Granting that this is an usually dry year and that Stony Creek has not run all year it is almost amazing that there have not been more dry wells. Yet there are those around the County that continue to pump great amounts of ground water from their deep wells. Sort of like putting a straw on a glass and sucking. The top part of the glass will go dry first as the water is pulling from the bottom.	Comment acknowledged. We have added a preface to the GSP to acknowledge the current drought conditions and summarize what is known at this time about the severity of well dewatering experienced by water users in the Subbasin, including domestic well users and DAC/SDAC/EDA households. It is noted that GSP development - including work to define undesirable results and establish the Sustainable Management Criteria - has occurred over several years utilizing the best available science and tools, with the most sufficient and credible information and data available for the decisions being made and the time frame available for making those decisions. Current and historical groundwater conditions and water budgets have been evaluated for the Subbasin in alignment with the GSP regulations, using the most recent and complete hydrologic, water supply, water demand, and land use data available at the time GSP development began. Unfortunately, drought conditions in 2020-2021 have coincided with development of the GSP, a timing that has not permitted complete evaluation and inclusion of data from these years in the GSP at this time. Ongoing management of the Colusa Subbasin under the GSP will follow an “adaptive management” strategy that involves active monitoring of Subbasin conditions and addressing any challenges related to maintaining groundwater sustainability by scaling and implementing PMAs in a targeted and proportional manner in accordance with the needs of the Subbasin. Data and information collected through ongoing monitoring will be evaluated, reported, and used to guide GSP implementation. GSP annual reports provide an opportunity each year to evaluate current Subbasin conditions and assess needs for additional PMAs. The first annual report, due April 2022, will evaluate groundwater conditions in the Colusa Subbasin since 2015. During periodic GSP evaluations, the GSP will also be reviewed and SMC will be revised, as needed, as we learn more about the effects of current and future conditions.

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319	Holly Reimers			Ch 2-1				The basin boundaries should be redrawn to exclude those lands that do not have access to groundwater primarily those lands in the western portion of the basin. Not only is there little to no groundwater these lands are receiving no benifit from being in the basin, only an expense.	Comment acknowledged. There are currently no specific plans for submitting a basin boundary modification request to exclude the lands indicated in this comment. At this time, there is insufficient information to determine whether those areas are hydrogeologically disconnected from the Colusa Subbasin. In Section 7.1.2.3 of the GSP, the GSAs have proposed the Colusa Subbasin Western Boundary Investigation to fill data gaps and better define the western fringes of the Subbasin. Also, specific financing plans and cost-allocation approaches are not yet determined, but will be identified and determined with stakeholder involvement following GSP adoption. Please see the response to comment 321.
320	Holly Reimers			3-15 3.1.5.16				Why is Hambright creek not mentioned? When running it is a major source of groundwater recharge.	Comment addressed. Hambright Creek has been added to the list of streams and creeks in Section 3.1.5.1.6.
321	Holly Reimers			6.5.1				The OUWUA is acknowledged as direct Groundwater Recharge. The land owners in the OUWUA should also be acknowledged as having the ability to assist in the ground water recharge. Those that apply only surface water should be given credit and not charges as they are helping the recharge when ever they apply surface water.	Comment addressed. An acknowledgement to participating landowners has been added to the project description in Section 6.5.1.5. Specific financing plans and cost-allocation approaches are not yet determined, but will be identified and determined with stakeholder involvement following GSP adoption. As described in Section 1.3.1, "The Colusa Subbasin GSAs will develop a financing plan for the overall implementation of the GSP that will specify funding sources and cost-allocation approaches across entities for the different GSP implementation activities (see Chapter 7 and Appendix 7A for a description of existing options)."
322	Holly Reimers			7.6	8-23			Charging the landowners on the west side of the basin, with no groundwater, the same amounts as those that have the water under their ground and are pumping for their perennial crops is unfair. Paying a "tax" or "fee" when there is no benefit to the landowner, there should be some benefit but so far we on the west side are seeing none. To place this additional burden on these land owners may force them to look at other uses of their ground to be able to "pay" for your additional fees.	Comment acknowledged. Specific financing plans and cost-allocation approaches are not yet determined, but will be identified and determined with stakeholder involvement following GSP adoption. As described in Section 1.3.1, "The Colusa Subbasin GSAs will develop a financing plan for the overall implementation of the GSP that will specify funding sources and cost-allocation approaches across entities for the different GSP implementation activities (see Chapter 7 and Appendix 7A for a description of existing options)." These considerations will be folded into the financing plan development and discussions.
323	Holly Reimers			Appendix 7A			Table 1	All "fees" should be passed only by a majority approval vote. Any "vote" should be conducted on a per/acre basis and should take into consideration what benefit there is to the landowner(s). You can call it is "fee" BUT if it looks like a duck, quacks like a duck IT IS A DUCK! A "fee" by any other name is still a tax on our property.	Please see the response to comment 322.

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324	Holly Reimers		General Comments					It has been said that there are outside groups purchasing ground in the basin with the only purpose of mining the ground water. This is not a supportable option for the basin to be able to sustain its self. NO GROUND WATER SHOULD BE EXPORTED FROM THE BASIN -EVER! Chapters 3, 4 & 5 one needs to have a Doctorate Degree in Hydrology, Geology and Engineering to even start to understand any of this. This should be written so that the general public and landowners would have some kind of understanding as to what some of these proposals are and how they as landowners will be effected. Or at least put in a summary that the landowner can understand, it may be included I might have missed it in all the other "stuff'.	Comment acknowledged. All of the topics are either required by DWR and SGMA or are industry-standard supplemental topics that were deemed to be appropriate for inclusion in these chapters. The goal of Chapters 3 through 5 was to meet DWR/SGMA requirements and provide information to GSAs, residents, and other scientists and engineers that may work on future SGMA-related projects. The techniques and tools to characterize aquifer properties, flow mechanics through a substrate, water budgets, and monitoring require scientific terminology to accurately convey the necessary information. The Executive Summary contains a simplified version of these chapters.
325	Lisa Hunter	GGA	Executive Summary	N/A	ES-1	19-Dec		This is a general discussion on SGMA- suggest changing "subbasin(s)" to "basin(s)"	Comment addressed in the GSP section indicated.
326	Lisa Hunter	GGA	Executive Summary	N/A	ES-3		Figure ES-1	In the legend, remove "(Colusa Subbasin)" following "Colusa Groundwater Authority GSA"	Comment addressed in the GSP section indicated.
327	Lisa Hunter	GGA	Executive Summary	N/A	ES-5		Figure ES-2	The background color makes it difficult to read the cities and see the boundary on the fence diagram- consider changing the color of the background or the boundary & city names	Comment addressed in the GSP section indicated.
328	Lisa Hunter	GGA	Executive Summary	N/A	ES-14	12		Change "twelve" to "12" to be more consistent with the format in the prior paragraph	Comment addressed in the GSP section indicated.
329	Lisa Hunter	GGA	Executive Summary	N/A	ES-21		Table ES-5	Consider using thousands rather than millions in the 5th column so there are fewer decimals. It may be easier to ready.	Comment addressed. The suggested edits have been incorporated into the indicated table in the Executive Summary and in Chapter 6.
330	Lisa Hunter	GGA	1	1.1	1-1	11		adopt Groundwater Sustainability Plans (GSPs) for non-critically overdrafted medium- and high-priority groundwater basins	Comment addressed in the GSP section indicated.
331	Lisa Hunter	GGA	1	1.3	1-2	26		~~Colusa and Glenn GSAs~~ CGA and GGA	Comment addressed in the GSP section indicated.
332	Lisa Hunter	GGA	1	1.3.1	1-3	18-19		Please add details similar to what is included for the CGA. The GGA was formed 6/20/2017 as a JPA with 9 member agencies (8 Director seats). The JPA was amended 10/14/19 to add a 10th member and one additional Director seat for a total of 9 Director seats. The GGA is the exclusive GSA for the Glenn County portion of the Colusa Subbasin.	Comment addressed in the GSP section indicated.
333	Lisa Hunter	GGA	1	1.3.1	1-3	19		The GGA has nine Director seats (this change is also suggested in the comment above)	Comment addressed in the GSP section indicated.
334	Lisa Hunter	GGA	1	1.3.1	1-4	1		Update GGA contact information: Glenn Groundwater Authority: Lisa Hunter, Water Resources Coordinator (530) 934-6501 (530) 934-6540 720 North Colusa Street 225 North Tehama Street Willows, CA 95988 lhunter@countyofglenn.net	Comment addressed in the GSP section indicated.
335	Lisa Hunter	GGA	1	1.3.2	1-4	15		with preparing the GSP and coordination activities in	Comment addressed in the GSP section indicated.
336	Lisa Hunter	GGA	1	1.3.3	1-5	4		under separate rate studies	Comment addressed in the GSP section indicated.

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337	Lisa Hunter	GGA	2	2.1.1	2-1			It might be helpful to note that no basins/subbasins border the western portion of the Colusa Subbasin.	Comment addressed in the GSP section indicated.
338	Lisa Hunter	GGA	2	2.1.1	2-2		Table 2-1	~~Corning Subbasin GSA~~ ~~Corning Sub-basin GSA~~	Comment acknowledged. The GSAs in the Corning Subbasin have been checked to confirm their alignment with the GSAs listed on the SGMA Portal and in the Corning Subbasin GSP (https://www.corningsubbasingsp.org/).
339	Lisa Hunter	GGA	2	2.1.2	2-4	8		water/irrigation districts	Comment addressed in the GSP section indicated.
340	Lisa Hunter	GGA	2	2.1.2	2.-4	11		Butte City is in the Butte Subbasin and should not be included here.	Comment addressed. The reference to Butte City is now removed.
341	Lisa Hunter	GGA	2	2.1.2.1	2-4	18-19		"Municipal water users in the Colusa Subbasin depend on groundwater." This sentence seems to be more appropriate in the next paragraph under "Municipal Water Purveyors"	Comment addressed. The reference to municipal water users has now been moved to the suggested section.
342	Lisa Hunter	GGA	2	2.1.2.1			Figure 2-2	Remove "Colusa Subbasin" after Colusa Groundwater Authority GSA in the legend	Comment addressed in the GSP section indicated.
343	Lisa Hunter	GGA	2	2.1.2.1				Are small water systems discussed?	Comment addressed in the GSP section indicated. State small water systems are defined in Chapter 2.1.2.1.
344	Lisa Hunter	GGA	2	2.1.2.1			Table 2-3	The page number appears as 2-11 (and should be 2-10)	Comment addressed in the GSP section indicated.
345	Lisa Hunter	GGA	2	2.2.1.1	2-17	16-18		Add "tribes"	Comment addressed in the GSP section indicated.
346	Lisa Hunter	GGA	2	2.2.1.1	2-17	33		The NSV IRWM Plan was revised March 2020	Comment addressed in the GSP section indicated.
347	Lisa Hunter	GGA	2	2.2.1.1	2-19	18-30		The Glenn County Groundwater Management Plan was adopted in 2000 (Ordinance 1115), revised in 2012 (Ordinance 1237). Incorporation of the Preliminary Plan and the Export Water Transfer Guidelines in Ordinance 1237 was very important.	Comment addressed in the GSP section indicated.
348	Lisa Hunter	GGA	2	2.2.1.1	2-20	11		~~A Counties'~~ Local Agency Formation Commissions (LAFCO) in each County conducts reviews of municipal	Comment addressed in the GSP section indicated.
349	Lisa Hunter	GGA	2	2.2.1.2	2-22	31		When land is in agricultural production it is generally irrigated and fertilized.	Comment addressed in the GSP section indicated.
350	Lisa Hunter	GGA	2	2.2.3	2-26	4-Jan		Exhibit C also contains Export Water Transfer Guidelines	Comment addressed in the GSP section indicated.
351	Lisa Hunter	GGA	2	2.5	2-31	29		The GSAs in the Colusa Subbasin will seek to work with Colusa and Glenn Counties	Comment addressed in the GSP section indicated.
352	Lisa Hunter	GGA	2	2.7.1	2-34	28		To guide and facilitate beneficial user engagement in the ~~GSA~~ GSP process,	Comment addressed in the GSP section indicated.

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#	Commenter Name (if available)	Commenter Organization (if applicable)	Chapter	Section	Page Number	Paragraph Number (from top of page)	Figure/ Table Number (If Applicable)	Comment	Response
353	Lisa Hunter	GGA	2	2.7.1	2-35	5-Apr		"Reflecting its "living document" role as a compilation / repository reflecting various engagement activities implemented or planned to be implemented by the GSAs." This sentence does not appear to be complete. Consider revising.	Comment addressed in the GSP section indicated.
354	Lisa Hunter	GGA	2	2.7.1.1	2-35	25		Were the mandates adopted by the counties? Is that the appropriate word? Please double-check.	Comment addressed in the GSP section indicated.
355	Lisa Hunter	GGA	2	2.7.1.2	2-37		Table 2-8	In the Tribes row, it notes "consult". Consult has a very specific meaning here. It that the appropriate word. Would it be more accurate to note collaborate? Consult if requested?	Comment acknowledged. "Consult" is considered the appropriate word in this context.
356	Lisa Hunter	GGA	2	2.7.1.3	2-38	2		~~SMGA~~ SGMA	Comment addressed in the GSP section indicated.
357	Lisa Hunter	GGA	2	2.7.1.3	2-38	9-12		Consider revising to be clear that all boards/committees requiring Brown Act compliance were conducted in such a manner and an effort was made to be inclusive. (There are ad hoc committees that did not require Brown Act compliance)	Comment addressed in the GSP section indicated.
358	Lisa Hunter	GGA	2	2.7.1.3	2-38	9-12		the GSAs have adopted a comprehensive table-based GSP comment	Comment addressed in the GSP section indicated.
359	Lisa Hunter	GGA	2	2.7.1.3	2-38	29		~~weekly by GSA staff~~ on a regular basis by facilitation staff and is then included in the agenda packet for each ~~GSP~~ GSA Board meeting beginning in XX (Date)	Comment addressed in the GSP section indicated.
360	Lisa Hunter	GGA	2	2.7.1.3	2-38	32-34		each Board agenda defines said decision as a formal action ~~and further includes an agendized item for~~ which could include discussion by each Board about associated public input recorded in the comments tables that might inform their decision-making.	Comment addressed in the GSP section indicated.
361	Lisa Hunter	GGA	2	2.7.1.3	2-38	41		• ~~Final public comment period prior to adjournment of each meeting.~~ Final public comment is not agendized on Board or TAC meeting agendas- Member comments are. While frequently, final public comments are taken at that time, I suggest removing the general statement because it may not be accurate.	Comment addressed in the GSP section indicated.
362	Lisa Hunter	GGA	2	2.7.2.1	2-39	3-4		thereafter ~~to present~~ September 2021, the parties that make up the CGA and GGA have collectively sponsored, publicized and conducted over 236 separate It may be helpful to note in this section, the meetings referenced were the meetings that are open to the public. Additional ad hoc meetings were held (some of which members of the public attended)	Comment addressed in the GSP section indicated.
363	Lisa Hunter	GGA	2	2.7.2.1	2-39	22-23		Committee and Subcommittee meetings) requiring compliance with the Brown Act, agendas ~~and associated background information~~ are posted no less than 72 hours before a meeting and all materials presented in said meetings. Background material is made available once prepared and distributed to the board.	Comment addressed in the GSP section indicated.
364	Lisa Hunter	GGA	2	2.7.2.1	2-39	29-30		All public outreach meetings were similarly publicized through Facebook and Twitter.	Comment addressed in the GSP section indicated.

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365	Lisa Hunter	GGA	2	2.7.2.1	4-40	15-17		On a regular ~~and publicly noticed~~ basis, inter-basin meetings of representatives from the Colusa Subbasin met with representatives from the adjacent Corning, Butte, Sutter and Yolo Subbasins (and other non-adjacent subbasin representatives) to discuss interconnected	Comment addressed in the GSP section indicated.
366	Lisa Hunter	GGA	2	2.7.2.1	4-40	28		As described above, ~~in~~ in the initial stages of GSA	Comment addressed in the GSP section indicated.
367	Lisa Hunter	GGA	2	2.7.2.1	4-40	35+		There were also 3 meetings in 2015 with general SGMA information co-sponsored by the Glenn County WAC, Glenn County Farm Bureau, and the UC Cooperative Extension.	Comment addressed in the GSP section indicated.
368	Lisa Hunter	GGA	2	2.7.2.2	2-42		Table 2-9	Include the Preface in the Public Draft Review	Comment addressed in the GSP section indicated.
369	Lisa Hunter	GGA	2	2.7.3.1	2-42	15-17		~~Confidentiality~~ sensitive information, actual contact information of interested parties is not appropriate to publish as part of this GSP). Any interested member of the public could be added to the lists by signing up via ~~respective~~ online entry options located on the CGA ~~respective GSA's~~ website~~s~~ and through email sign up options or requesting by phone for each GSA.	Comment addressed in the GSP section indicated.
370	Lisa Hunter	GGA	2	2.7.3.1	2-42	18+		Did we connect with Cortina?	Comment addressed. Clarifications have been added to the GSP.
371	Lisa Hunter	GGA	2	2.7.3.5	4-43	33		to view all outreach events from late 2020 through (ADD DATE) and including public review and subsequent GSA	Comment addressed in the GSP section indicated.
372	Lisa Hunter	GGA	2	2.7.3.6	2-44	9		(when available after ~~Match~~ March 2020)	Comment addressed in the GSP section indicated.
373	Lisa Hunter	GGA	2	2.7.3.6	2-44	22		GSP background documents ~~including Drought Preparedness and Response~~	Comment addressed in the GSP section indicated.
374	Lisa Hunter	GGA	2	2.7				General comment: It would be helpful to define "public meeting". It is referenced frequently and may confusion between Board and/or committee meetings which are open to the public and public outreach meetings which follow a different process, including the outreach done to advertise public outreach meetings (for instance board meetings are not publicized in the social media and via press release, whereas public outreach meetings were)	Comment acknowledged. The general distinction is: "public meetings" are open to the public and allow comments and feedback from the public, but are not exclusively held for that purpose (e.g., Board meetings, TAC meetings), whereas "public outreach meetings/workshops" are open to the public and are primarily designed to engage with the public and stakeholders to solicit their opinions and feedback. This has been clarified in Section 2.7.2
375	Lisa Hunter	GGA	3	3.1.3	3-4	6-May		with periods ~~of~~ exceeding 100-degree Fahrenheit temperatures.	Comment addressed in the GSP section indicated.
376	Lisa Hunter	GGA	3	3.1.5.1.1			Figure 3-7	This comment refers to this figure and other similar figures. The small inset graphic is useful to see the trends; however, the x and y axis labels are not legible- can the labels be clearer? Perhaps darker to facilitate reading them?	Comment addressed in the GSP section indicated.
377	Lisa Hunter	GGA	3	3.1.5.1.3	3-13	21		Missing a "." after Subbasin	Comment addressed in the GSP section indicated.
378	Lisa Hunter	GGA	3	3.1.7.2.1	3-30	33-34		Is the sentence referencing the average yield in the West Butte Subbasin relevant here? If so, should it reference the Butte Subbasin instead? If not, I suggest removing.	Comment addressed in the GSP section indicated.
379	Lisa Hunter	GGA	3	3.7.8.1	3-35	39-40		Also reference the CCWD jurisdictional boundary	Comment addressed in the GSP section indicated.

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380	Lisa Hunter	GGA	3	3.1.8.2	3-36	6		Is the Corning Subbasin intended to be referenced in the text or was this a carryover from prior work?	Comment addressed in the GSP section indicated.
381	Lisa Hunter	GGA	3	3.1.11.1	3-43	17-18		, along Stony Creek. ~~Stony Creek is~~ Groundwater underflow may occur…	Comment addressed in the GSP section indicated.
382	Lisa Hunter	GGA	3				Figure 3-18	Why is there no soils color shading in the vicinity of Orland?	Comment acknowledged. The underlying dataset used to evaluate the soil agricultural groundwater banking index (SAGBI) potential is the Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) which does not include soil survey mapping for the city of Orland urban center. The soil survey dataset does not specify why certain areas were not surveyed.
383	Lisa Hunter	GGA	3	3.1.11.3	3-46	11		or through discharge to ponds, springs, wetlands,	Comment addressed in the GSP section indicated.
384	Lisa Hunter	GGA	3				Figure 3-19	The labels appear to be missing.	Comment addressed in the GSP section indicated.
385	Lisa Hunter	GGA	3				Figure 3-21	Figure 3-21 is referenced but appears to be missing. Instead Figure 3-23 is inserted two times (once after page 3-49 and once after page 3-58)	Comment addressed in the GSP section indicated.
386	Lisa Hunter	GGA	3	3.1.11.3	3-49	25		It may be useful to note that the well extraction information includes more that just the Colusa County portion of the Colusa Subbasin- if I understand, it includes all of Colusa County.	Comment addressed in the GSP section indicated.
387	Lisa Hunter	GGA	3	3.1.12.4	3-54	31		Glenn County is also mapping and recording reports of dry wells. See regular updates at: https://arcg.is/10nmyT2 Colusa may also be tracking.	Comment addressed in the GSP section indicated.
388	Lisa Hunter	GGA	3	3.1.12.5	3-55	1		delineation of groundwater dependent ecosystems	Comment addressed in the GSP section indicated.
389	Lisa Hunter	GGA	3	3.2.2	3-55	29		Add the conditions to 2020 to be consistent with the rest of the sentence.	Comment addressed in the GSP section indicated.
390	Lisa Hunter	GGA	3	3.2.2	3-55	32		Consider adding potential environmental impacts	Comment addressed in the GSP section indicated.
391	Lisa Hunter	GGA	3	3.2.5.1	3-67	38		Is “Eh” a typo? Should it be EC? If so, please correct. If not, please add to the acronym list.	Comment addressed in the GSP section indicated.
392	Lisa Hunter	GGA	3	3.2.5.2	3-70	35		Is this intended to be Colusa County’s wells of Colusa Subbasin wells?	Comment addressed in the GSP section indicated.
393	Lisa Hunter	GGA	3	3.2.6	3-73	38		near Zamora in Yolo County (outside of the Colusa Subbasin), at 12N1E34Q1	Comment addressed in the GSP section indicated.
394	Lisa Hunter	GGA	3				Figure 3-32	It would be helpful to add the cities points layer with labels similar to the other figures.	Comment addressed in the GSP section indicated.
395	Lisa Hunter	GGA	3	3.2.7.1	3-78	16		For clarity please note if the net gain is to groundwater or to the stream. (I assume the gain is to groundwater.)	Comment addressed in the GSP section indicated.
396	Lisa Hunter	GGA	3				Figure 3-34	Suggest adding Stony Creek to the title “Stony Creek Thalweg Analysis”	Comment addressed in the GSP section indicated.

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397	Lisa Hunter	GGA	3				Figure 3-36	In this figure, it is difficult to understand where the final "potential GDEs" or likelihood of GDEs exist. The legend is a bit difficult to follow as well. It may be useful to have a final figure without the extra layers to clearly denote the potential GDEs and likelihood scores.	Comment acknowledged. The figure will be updated during future updates to the Colusa Subbasin GSP.
398	Lisa Hunter	GGA	3	3.3.1	3-86	8		This references a 26-year period. Page 3-98 states a 25-year period. Please reconcile throughout.	Comment addressed in the GSP section indicated.
399	Lisa Hunter	GGA	3	3.3.1	3-86	30		Capitalize Subbasin	Comment addressed in the GSP section indicated.
400	Lisa Hunter	GGA	3	3.3.3.1	3-89	37-42		Was the Glenn County General Plan used? If not, please specify how the information was interpolated, similar to how it was done under the Urban and Industrial Water Demand section on page 3-93	Comment addressed in the GSP section indicated.
401	Lisa Hunter	GGA	3	3.3.3.3	3-92	37-39		Was the Glenn County General Plan used? If not, please specify how the information was interpolated, similar to how it was done under the Urban and Industrial Water Demand section on page 3-93	Comment addressed in the GSP section indicated.
402	Lisa Hunter	GGA	3	3.3.4.1.1	3-101	14-15		Diversion agreements/reductions are specifically called out for Sac River Settlement Contractors. Would it be useful to also note other supply cutbacks such as the TCC Districts?	Comment acknowledged. Reduced allocations to Tehama Colusa Canal CVP contractors in certain years and Stony Creek water shortages experienced by the OUWUA are noted in Section 3.3.4.1.1.
403	Lisa Hunter	GGA	3	3.3.4.1.2	3-101	36		Change basin to Subbasin.	Comment addressed in the GSP section indicated.
404	Lisa Hunter	GGA	3	3.3.4.3.1	3-105-3-106	21-22	Figure 3-44	The text indicates +0.6 taf/yr while the figure indicates 1 TAF per year (I assume to figure is rounding). This may be helpful to reconcile.	Comment addressed in the GSP section indicated.
405	Lisa Hunter	GGA	3	3.3.4.3.2	3-107-3-108	13-Dec	Figure 3-46	The text indicates -2.7 taf/yr while the figure indicates -3 TAF per year (I assume to figure is rounding). This may be helpful to reconcile	Comment addressed in the GSP section indicated.
406	Lisa Hunter	GGA	3	3.3.4.3.3	3-109-3-110	14-15	Figure 3-48	The text indicates -7.3 taf/yr while the figure indicates -7 TAF per year (I assume to figure is rounding). This may be helpful to reconcile	Comment addressed in the GSP section indicated.
407	Lisa Hunter	GGA	4				Table 4-2	Footnote d- SWL should be SWD	Comment addressed in the GSP section indicated.
408	Lisa Hunter	GGA	4	4.2.4.5	4-29	29		The ~~Colusa and Glenn~~ Colusa Subbasin GSAs are	Comment addressed in the GSP section indicated.
409	Lisa Hunter	GGA	4	4.2.4.5	4-29	34		Remove the "s" from Willows. Should be Willow Creek.	Comment addressed in the GSP section indicated.
410	Lisa Hunter	GGA	4	4.2.4.5	4-30	7		the ~~Colusa and Glenn~~ Colusa Subbasin GSAs	Comment addressed in the GSP section indicated.
411	Lisa Hunter	GGA	4	4.2.5.4	4-33	31		monitoring sites for groundwater dependent ecosystems.	Comment addressed in the GSP section indicated.

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412	Lisa Hunter	GGA	5	5.2.1	5-3	28		Might be useful to indicate the PMAs could be implemented by other partners (not just the GSAs).	Comment addressed in the GSP section indicated.
413	Lisa Hunter	GGA	5	5.3.1.4	5-7			Include stock water impacts (hauling water, selling livestock, etc)	Comment addressed in the GSP section indicated.
414	Lisa Hunter	GGA	5	5.3.2.5	5-10			Include stock water impacts (hauling water, selling livestock, etc)	Comment addressed in the GSP section indicated.
415	Lisa Hunter	GGA	5	5.3.2.6	5-10	27		Updates should not be capitalized	Comment addressed in the GSP section indicated.
416	Lisa Hunter	GGA	5	5.3.4.1	5-12	9		Irrigation or stock water supply	Comment addressed in the GSP section indicated.
417	Lisa Hunter	GGA	5	5.3.6.2	5-15	31		Use GGA and CGA instead of spelling out	Comment addressed in the GSP section indicated.
418	Lisa Hunter	GGA	5	5.3.6.2	5-15	33		will occur utilizing a subset of wells in the Subbasin's groundwater elevation monitoring network selected for	Comment addressed in the GSP section indicated.
419	Lisa Hunter	GGA	5	5.4.1.1	5-19	Not present		In the Minimum Thresholds section #1- when discussing domestic wells, it may be appropriate to reference the Human Right to Water. It may also be useful to note in the section (when discussing that very shallow wells likely do not meet current health standards. At the end of #1, add "contained in the DWR database" after protect 80 percent of domestic wells.	Comment addressed in the GSP section indicated.
420	Lisa Hunter	GGA	5				Figure 5-1 and similar	It would be useful to add which method was used to determine the MT. Could be added on the right hand side under Minimum Threshold: XX ft	Comment addressed in GSP. This only applies to Figure 5-1, as Figures 5-2 and 5-3 represent wells included in the interconnected surface water monitoring network. The method used to determine the MT for the interconnected surface waters is different from the two alternative methods used for the groundwater levels.
421	Lisa Hunter	GGA	5				Table 5-2	It would be helpful to add a column to denote which method was used to determine the MT. It could be simply 1 or 2 with explanation in the footnote section.	Comment addressed in the GSP section indicated.
422	Lisa Hunter	GGA	5	5.4.5.1	5-29	10-Mar		Based on discussion, evaluating infrastructure sensitivity may be a good project for the GSP.	Comment addressed. A proposed study of infrastructure sensitivity to land subsidence has been added to Chapter 7, and is referenced in Section 5.4.5.1.
423	Lisa Hunter	GGA	5	5.4.5.1	5-29	17		Glenn County has data from 2004.	Comment addressed in the GSP section indicated.
424	Lisa Hunter	GGA	5				Figure 5-2 and similar	Minimum Threshold should be ft bgs not ft	Comment addressed in the GSP section indicated.
425	Lisa Hunter	GGA	5	5.4.6.1	5-34	4		better represented local conditions at that time rather than adding an additional 10 feet (in order to be more protective).	Comment addressed in the GSP section indicated.

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426	Lisa Hunter	GGA	5	5.4.7	5-36			Should water quality and subsidence be mentioned in this section?	Comment addressed. Section 5.4.7 of the GSP was revised as follows: "The Colusa Subbasin GSAs and the GSAs in the adjacent subbasins coordinated their approach to developing sustainable management criteria during development of their respective GSPs and will continue to coordinate their efforts during plan implementation. The Colusa Subbasin GSAs and the GSAs in the adjacent subbasins developed similar sustainable management criteria for degraded water quality and inelastic land subsidence. Because of the similarity in these sustainable management criteria across the subbasins, and the ongoing interbasin coordination efforts, it is anticipated that the minimum thresholds established in the Colusa Subbasin for degraded water quality and inelastic land subsidence will help avoid undesirable results for the Colusa Subbasin and the adjacent subbasins. GSP Section 7.1.2 describes implementation activities focused on interbasin coordination for degraded water quality, inelastic land subsidence and other sustainability indicators."
427	Lisa Hunter	GGA	6					This chapter should discuss the PMA submittal process including the online submittal forms to gather stakeholder ideas and ongoing nature of including PMAs in the GSP.	Comment addressed. Additional information has been added to Section 6.1.3 to describe the PMA submittal process.
428	Lisa Hunter	GGA	6				Figure 6-1	The title "Colusa Subbasin PMA" does not seem appropriate for the image and may be unnecessary. The legend indicates blue lines for "Groundwater Basins"- is that correct? It seems to be streams. The legend does not include water districts or what I assume are wells. Those may be helpful to include. Generally, this is quite a busy figure for the purpose. Consider simplifying.	Comment addressed. Map has been simplified and updated as suggested.
429	Lisa Hunter	GGA	6	6.1	6-4	6		Planned PMAs ~~that will~~ are expected to be implemented to primarily address current,	Comment addressed in the GSP section indicated.
430	Lisa Hunter	GGA	6	6.1	6-4	34		Add "The PMAs are not ranked."	Comment addressed in the GSP section indicated.

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431	Lisa Hunter	GGA	6	6.2.1	6-6	24-28		Note that not all projects are the responsibility of the GSAs, but rather a partnership or sometimes the GSAs will have a supporting role.	Comment addressed in the GSP section indicated.
432	Lisa Hunter	GGA	6	6.2.1	6-6	34		GSAs, ~~and~~ districts, and other partners in the Colusa Subbasin will further develop	Comment addressed in the GSP section indicated.
433	Lisa Hunter	GGA	6				Table 6-2	DWR is also a partner in the Colusa Subbasin Multi-Benefit Groundwater Recharge moving into the expanded program. In the Sycamore Slough Groundwater Recharge Pilot Project- "from" should not be capitalized. "would be available From settlement contract" The Sites Reservoir Project says "The Sites Project is a new off-stream storage…" It might be helpful to clarify this is in development, not that the project has completed a new storage facility. The well abandonment outreach and funding program should specify this would be accomplished by working with well permitting agencies. Review of County Well Permitting Ordinances should specify the GSAs would work with the counties to review and suggest revisions to ordinances (these are outside of the jurisdiction of the GSAs)	Comment addressed in the GSP section indicated.
434	Lisa Hunter	GGA	6	6.3.1.3	6-19	5		~~County~~ LAFCO	Comment addressed in the GSP section indicated.
435	Lisa Hunter	GGA	6	6.3.3.1	6-29			See comments on Table 6-2 relating to this project.	Comment addressed. Applicable edits have been added to Section 6.3.3.1.
436	Lisa Hunter	GGA	6	6.3.3.1	6-30	3		Should this reference waterbirds or shorebirds?	Comment addressed in the GSP section indicated.
437	Lisa Hunter	GGA	6	6.3.3.4	6-32	11		recharge sites	Comment addressed in the GSP section indicated.
438	Lisa Hunter	GGA	6	6.3.3.4	6-32	13		~~winter~~ specific months	Comment addressed in the GSP section indicated.
439	Lisa Hunter	GGA	6	6.3.3.5	6-32	24-25		The program is summer/early fall and/or spring (July 15-October 15 and/or March 15-April 15). Please adjust references to timing, here and in other sections relating to this project.	Comment addressed. References to the timing of the Colusa Subbasin Multi-Benefit Recharge project have been revised to include the spring period.
440	Lisa Hunter	GGA	6	6.3.3.6	6-32	29		Add a sentence to provide an update on 2021. Due to dry conaditions in 2021, the project implementation was delayed.	Comment addressed in the GSP section indicated.
441	Lisa Hunter	GGA	6	6.3.3.6	6-33	3		Clarify the availability of **surface** water rights	Comment addressed in the GSP section indicated.
442	Lisa Hunter	GGA	6	6.3.3.6	6-33	4		Missing bullet point	Comment addressed in the GSP section indicated.
443	Lisa Hunter	GGA	6	6.3.3.6	6-33	21		Indicates the project is not expected to terminate. Please note this is a pilot project that could be continued if deemed appropriate.	Comment addressed in the GSP section indicated.
444	Lisa Hunter	GGA	6	6.3.4.2	6-37		Table 6-15	Glenn County LAFCO should be changed to Glenn LAFCO	Comment addressed in the GSP section indicated.

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445	Lisa Hunter	GGA	6	6.3.4.3	6-37	13		Glenn County LAFCO should be changed to Glenn LAFCO	Comment addressed in the GSP section indicated.
446	Lisa Hunter	GGA	6	6.3.4.6	6-38	20		Glenn County LAFCO should be changed to Glenn LAFCO	Comment addressed in the GSP section indicated.
447	Lisa Hunter	GGA	6	6.4.1	6-46	14		This section ~~described~~ describes ongoing	Comment addressed in the GSP section indicated.
448	Lisa Hunter	GGA	6	6.5.1	6-58	2		If determined to be necessary or desirable under	Comment addressed in the GSP section indicated.
449	Lisa Hunter	GGA	6				Table 6-34	Reference to migratory waterfowl be changed to migratory birds (could be waterfowl or shorebirds?)	Comment addressed in the GSP section indicated.
450	Lisa Hunter	GGA	6	6.5.1.7	6-69	11		shorebirds/waterfowl as ~~we pulse flood the field~~ the field is pulse flooded, or	Comment addressed in the GSP section indicated.
451	Lisa Hunter	GGA	6				Table 6-35	One period after Sycamore Slough in the implementation description. In the benefits and benefit evaluation methodology, it notes waterfowl. Will it also include shorebirds?	Comment addressed in the GSP section indicated. Yes, this project may benefit migratory waterfowl or shorebirds, so the text has been modified to "migratory birds".
452	Lisa Hunter	GGA	6				Table 6-36	In the implementation description, it may be useful to add a sentence indicating that this concept could be applied throughout the Colusa Subbasin.	Comment addressed in the GSP section indicated.
453	Lisa Hunter	GGA	6	6.5.2.3	6-84	6		Remove “or MO”	Comment addressed in the GSP section indicated.
454	Lisa Hunter	GGA	6	6.5.2.3	6-86	1		action ~~will only~~ could be triggered	Comment addressed in the GSP section indicated.
455	Lisa Hunter	GGA	6	6.5.2.3	6-86	13		Add “for domestic purposed only” when describing de minimis use	Comment addressed in the GSP section indicated.
456	Lisa Hunter	GGA	6	6.5.2.7	6-91	1		would review and ~~revise~~ suggest revisions to the county	Comment addressed in the GSP section indicated.
457	Lisa Hunter	GGA	6	6.5.2.7	6-91	11-12		Replace “better” with “appropriate” It might also be useful to note requiring depths to be deeper than MTs.	Comment addressed in the GSP section indicated.
458	Lisa Hunter	GGA	6				Table 6-51	In the implementation description, it should not the action would be to review and **suggest revisions** to the county well permitting	Comment addressed in the GSP section indicated.
459	Lisa Hunter	GGA	6				Table 6-52	In the implementation description, it may be useful to include that this action could be done in coordination with neighboring GSAs, especially along Stony Creek.	Comment addressed in the GSP section indicated.
460	Lisa Hunter	GGA	7				Table 7-1	There are two Table 7-1 (page 7-3 and 7-4) In the second table, in the well inventory program description: Add that the program would seek to identify wells that are no longer active In the well registration program- remove the reference to voluntary. This could be voluntary or not.	Comment addressed in the GSP section indicated. It is noted that there is only one Table 7-1, the table on page 7-4 is a continuation of the same table on the prior page.
461	Lisa Hunter	GGA	7	7.1.2.8	7-9			Add that the program would seek to identify wells that are no lo	Comment addressed in the GSP section indicated.

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462	Lisa Hunter	GGA	7	7.1.2.9	7-10	2		Remove reference to voluntary.	Comment addressed in the GSP section indicated.
463	Lisa Hunter	GGA	7	7.2	7-16			It might be appropriate to add that some details on the cost allocation between the GSAs remain to be finalized.	Comment addressed in the GSP section indicated.
464	Lisa Hunter	GGA	7	7.6	7-22	24		GSAs are ~~pursuing~~ considering a combined approach…	Comment addressed in the GSP section indicated.
465	Pamela Plemmons		Executive Summary			22-2		(Executive summary-Line 22-27 and corresponding sections in the text) I believe that the foundational assumptions with the water budgets do not reflect the reality of future climate change and the assumptions of data used as the baseline were not indicative of drought years. In addition, the idea that using a central tendency for climate change is short sighted at best. It seems to me that a "critical' tendency for climate change should also be included in the analysis—one that looks at a serious increase in overall earth temperature above 2.5*C. Otherwise, we are just putting our heads in the sand with regard to future water/crop issues. What mitigation factors could be planned for? How is water distributed equitably in times like that? What future cropping patterns might be considered? (maybe more annual crops when water is available..)	Comment acknowledged. As the commenter acknowledges, there is significant uncertainty in future conditions related to climate, water supplies, and other factors that will impact groundwater conditions and sustainability in the Colusa Subbasin. The uncertainty of future conditions is one of many reasons that GSP implementation will be based on adaptive management. The GSAs' adaptive management strategy for GSP implementation is described extensively in Chapter 6. The GSAs are committed to ongoing monitoring and implementation of projects and management actions to respond to changing Subbasin conditions. Additionally, the GSP is considered a "living document," and will be revised over time, as needed, once more is known about the basin setting through monitoring (Chapter 4) and GSP studies (Chapter 7). It is also noted that use of the 2070CT climate change scenario is consistent with GSP regulations, and assumes that 2070CT climate change effects will occur immediately and continue over the entire projected period. In reality, climate change effects will occur gradually with uncertain interannual changes.
466	Pamela Plemmons		Executive Summary			17-21		(Executive summary-Line 17-21 and corresponding sections in the text)) I also would like to add that the assumptions of surface water use and a reduction in irrigated acreage from Shasta in critical years would be less is actually inaccurate. Since much of the irrigated agriculture in the Glenn and Colusa area are permanent crops (almonds and walnuts), they need to be irrigated no matter what…what it does trigger is a significant increase in ground water use.	Comment acknowledged. Please see the response to comment 465.
467	Pamela Plemmons		Additional Comment					Finally, what I find distinctly disturbing is that in the entire plan there is no individual accountability for ground water use by individual growers, no monitoring of private wells or individuals who are excessive consumers of our precious and shared resource. For example, I am aghast at the practice of almond farmers extensively irrigating to "fatten up" the nuts just prior to harvest. Seriously!!! What a waste of water!!! The extra moisture has to be dried out using more energy in the drying process. Why is there no individual accountability for each well and that each grower pay the price for water just like most consumers have to do? I believe this is something that truly needs to be included in the plan.	Comment acknowledged and addressed. Specific plans for determining accountability and cost-allocation approaches are not yet determined. Cost-allocation approaches and related accountability measures will be identified and determined by the GSA Boards through a stakeholder-driven process following GSP adoption. Those decisions are expected to be made in the coming year. In Chapter 7, GSP studies are also proposed to expand monitoring, which may help to inform these decisions.

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468	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	6	6.5.2	6-81			*(Summary of Comment A.1)* The Draft GSP has a lot of words but little action, except recharge projects. In Chapter 6, the GSP describes an adaptive management approach and projects and management actions that the GSAs **could** implement to ensure that the Colusa Subbasin is operated sustainably (i.e., to avoid undesirable results). The management actions given in Chapter 6 are all "Potential Management Actions", and all are currently in the early conceptual stage, so there is no understanding of the benefits, costs, the funding sources, or specifics about how the actions will maintain sustainable groundwater levels.	Comment acknowledged. As described in Section 6.1, the GSAs recognize that there are data gaps and uncertainties in future conditions (per 23 CCR §354.44(d)), and have planned an adaptive management strategy for PMA development and implementation. The adaptive management strategy involves active monitoring of Subbasin conditions (as described in Chapter 4) and addressing any challenges related to maintaining groundwater sustainability by scaling and implementing PMAs in a targeted and proportional manner in accordance with the needs of the Subbasin. The adaptive management approach is consistent with SGMA (CWC §10728.2, §10733.8), consistent with DWR recommendations, and consistent with GSPs that have been approved by DWR. Notably, the GSAs have proposed several "planned PMAs" (described in detail in Section 6.3) that do provide more specific information, as available, about project benefits, costs, and funding. As described in Section 6.2.2, the "planned PMAs" are expected to provide more than 80 TAF/yr in gross average annual benefits that will offset groundwater pumping and support groundwater sustainability in the Colusa Subbasin. These benefits are expected to address sustainability concerns in the projected future water budget, even under the effects of 2070CT climate change (Table 6-1). The GSAs expect that the planned PMAs will achieve the sustainability goal for the Colusa Subbasin and avoid reaching the minimum thresholds defined in this GSP under future, changing conditions. Nevertheless, recognizing the uncertainty in future conditions, the GSAs have proposed numerous "potential PMAs" that could be implemented if conditions change unexpectedly from the projected future water budgets. These potential PMAs are an essential part of the adaptive management approach, offering the GSAs options to address uncertain future conditions that may be selected and developed further, as needed.

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469	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	6	6.1	6-2		Table 6-1	*(Summary of Comment A.2, part 1)* Section 6.1 of the draft GSP talks about climate change and then gives a selection of water budget values with and without climate change (2070 central tendency). According to Table 6-1, water users will pump 13% more groundwater to make up for evapotranspiration (ET) increase due to climate change, and stream accretion (groundwater that discharges to the steams) will remain positive but will decrease by 48,000 acre-feet / year with climate change, approximately 38% from the future conditions without climate change and approximately 0.5% of the Sacramento River flow.	Comment acknowledged. Clarification has been added to Section 6.1. As indicated in its title, Table 6-1 summarizes key water budget parameters that were evaluated to formulate PMAs. Table 6-1 does not include the benefits of planned PMAs, nor does it summarize the GSAs' plans for future management of the Subbasin. As described in Section 6.2.2 (and clarified in Section 6.1), the "planned PMAs" are expected to provide more than 80 TAF/yr in gross average annual benefits that will offset groundwater pumping and support groundwater sustainability in the Colusa Subbasin. These benefits are expected to address potential sustainability concerns in the projected future water budget (Table 6-1), especially for areas of localized groundwater declines in the Orland and Arbuckle areas.
470	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						*(Summary of Comment A.2, part 2)* It isn't clear how the stream depletion monitoring program will interact with the stream accretion assumptions. The stream depletion monitoring program only monitors groundwater levels, but it should also include monitoring of stream flow changes, i.e., seepage and accretion changes, to validate the assumptions about climate change and sustainability	Comment acknowledged. The CGA and GGA are coordinating with GSAs in other subbasins through the Northern California Water Association (NCWA). NCWA is leading a Sacramento Valley-wide effort for improved and coordinated streamflow measurement, which will continue during GSP implementation. However, the GSAs' plans for monitoring shallow groundwater levels as a proxy for stream depletion monitoring are consistent with GSP regulations and consistent with recommendations of the Environmental Defense Fund (EDF, 2018). It is also noted that if the GSAs were to measure stream flow changes, as suggested, it is expected that measurement accuracy would limit the ability to differentiate the estimated +/-0.5% of streamflow change in the Sacramento River discussed in previous comments.
471	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	5-6					*(Summary of Comment A.3, part 1)* The groundwater monitoring for sustainability focuses on domestic wells and stream depletion, but not much on subsidence.	Comment acknowledged. Land subsidence in the Colusa Subbasin will not be monitored using the groundwater level monitoring network or wells. As described in Section 4.2.3.2 of the Colusa Subbasin GSP: "The Colusa Subbasin land subsidence monitoring network is comprised of survey benchmarks, benchmarks, continuous GPS stations, extensometers, and remote sensing data."
472	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	5	5.4.1	5-19:5-21			*(Summary of Comment A.3, part 2)* The MTs for domestic well sustainability are developed by taking the greater depth of either the depth where 20% of the domestic wells within the Thiessen polygon around each of the 48 RMN monitoring wells are shallower, or the depth at 50% of the historical range below the deepest groundwater level prior to January 1, 2015 (and sometimes 2016). These GSP standards for the MTs effectively means that domestic wells in the Colusa subbasin can experience groundwater levels deeper than historical levels and still be considered sustainable.	Comment acknowledged. The CGA and GGA Boards made decisions to set the Sustainable Management Criteria for all sustainability indicators through a transparent process in public meetings with extensive stakeholder engagement. The decisions are documented in Appendix 5.A. All decisions were made in meetings open to the public, following technical presentations and discussions, also held in meetings open to the public.

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473	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	5				Tables 5-1 through 5-3	*(Summary of Comment A.4)* The draft GSP establishes different MTs for each monitoring site (except for subsidence benchmarks) and evaluates MTs in sub-groups of sites with a minimum size and minimum duration. The draft GSP requires that all monitoring sites in a sub-group must exceed their respective MTs together before an undesirable result can occur. This requirement implies that the monitoring site with the greatest MT depth will likely control the occurrence of an undesirable result.	Comment acknowledged. The minimum thresholds are applied at each individual monitoring location within the representative monitoring network for each sustainability indicator. There is no predetermined grouping of locations for the purpose of determining whether undesirable results are occurring in the Colusa Subbasin. The occurrence of an undesirable result for each applicable sustainability indicator in the Colusa Subbasin is determined when a defined percentage of the monitoring locations in the corresponding representative monitoring network exceeds minimum thresholds, regardless of where the monitoring locations are within the basin. The undesirable result is judged to occur based on the percentage of locations exceeding their minimum thresholds, not on the magnitude of the minimum thresholds or the magnitude by which the minimum thresholds are exceeded.
474	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	App. 5C					*(Summary of Comment A.5, part 1)* Are there any facts to document that domestic wells in the WCR database are no longer in use or previously dewatered? DWR has a web site where people can volunteer that their well went dry (https://mydrywell.water.ca.gov/report/). The assumption that the wells previously went dry when groundwater was at the lowest pre-2015 point, allows the GSP to reason that an MT that allow loss of up to 20% percent of the shallow domestic wells is cost-effective, and an acceptable balance between avoiding significant and unreasonable impacts to domestic (and other shallow) wells and allowing sufficient flexibility for conjunctive management of Subbasin surface and groundwater supplies. We ask, cost effective to whom?	Comment addressed. The GSP covers the entire Colusa Subbasin, and measures of cost-effectiveness are consequently from that perspective, as is standard practice. The benefit-cost analysis of PMAs and potential dewatered well impacts is additionally defined at the monitoring well Thiessen polygon level. As described in Appendix 5C, it is important to emphasize that groundwater levels in the Subbasin will be managed for MOs, which are generally set substantially above MTs that the economic analysis is based on. Historical low water levels below the total domestic well depth being an indicator for wells that may have been previously dewatered was deemed to be a reasonable assumption, given the data available and data gaps identified in the GSP. The following paragraph was added to the introduction section of Appendix 5C so that assumptions, data limitations, and other potential GSP PMAs are clear to the reader. "The reconnaissance-level economic analysis was based on the data available for GSP development and the simplifying assumptions described in the sections below. Important assumptions include: (i) the analysis was developed for MTs, not MOs that the Subbasin will be managed for and are substantially higher than MTs, (ii) only a subset of costs and benefits (pumping cost, well replacement cost, PMA avoided costs) associated with PMA implementation dewatered domestic were considered, and (iii) the example PMA considered was demand management (reducing pumping). The analysis can be refined and expanded as

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474 cont'd									GSP data gaps are addressed and additional information becomes available. It is also noted that the GSP includes additional potential actions for monitoring potential impacts to domestic wells, as described in Section 6.5.2.1, Domestic Well Mitigation Program." As documented in Appendices 5B and 5C, for the Subbasin as a whole, approximately 46 percent of the domestic wells in the WCR database are shallower than the pre-2015 historical groundwater levels as defined by the groundwater level representative monitoring network. Many of these shallow wells may no longer be used, or they may have been deepened because they would have otherwise been dry at times prior to 2015. Nevertheless, all wells in the WCR database were considered in the calculation of the groundwater level minimum thresholds. Including these shallow, potentially unused or deepened wells in the analysis of well completions depths resulted in groundwater level minimum thresholds that are shallower than they would have been if the wells had been excluded, and is viewed as a conservative approach to avoiding undesirable results for all users, considering data gaps.
475	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	App. 5C					*(Summary of Comment A.5, part 2)* The economic analysis concludes that groundwater levels will be managed to the higher MOs levels and therefore no harm will occur to domestic wells; but if harm occurs, then the GSAs should develop a domestic well mitigation program (see Chapter 6) that would provide a safety net to potentially compensate for impacts to domestic wells. It appears to AquAlliance that the GSP has decided that the shallow domestic wells can go dry, and the GSAs might find a way to help the well owners, but they aren't ready to commit to the compensation portion.	Comment acknowledged. Please note that the GSAs have revised the MTs for chronic lowering of groundwater levels at several RMS sites, particularly around the Orland area. These revisions have created shallower MTs that are more protective of the 20th percentile depths of domestic wells. The GSAs still propose a potential domestic well mitigation program, though the precise policies, funding, and other factors underlying that program will need to be determined by the GSAs through a public, stakeholder-driven evaluation and decision-making process during GSP implementation. The GSAs also reiterate that they are planning an adaptive management strategy for GSP implementation. Please see the response to comment 468.

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476	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	4-5				Table 5-1	(Summary of Comment A.6) A 50% range, or Margin of Operational Flexibility (MOF), has been established at each monitoring well to accomodate seasonal fluctuations in groundwater levels. Is the MOF about the MT depth not considered an undesirable result? Isn't the period, presumably summer months, when groundwater drops below the MT an unreasonable result? What happens if the seasonal decline is greater than the 50% range? How many of the domestic wells in the well 22N03W24E001 Thiessen polygon will go dry with groundwater at a depth of 349+ feet?	Comment acknowledged. The minimum threshold for groundwater level declines is based on the lower of 1) the 20th percentile of shallowest domestic well depths in each representative monitoring well's Thiessen polygon, or 2) 50 percent of range below the historical low groundwater elevation measured in each representative monitoring network well. The measurable objective is the mean of most recent five years of available groundwater elevation measurements up to March 2020 in each representative monitoring network well. The margin of operational flexibility is the difference between the measurable objective and the minimum threshold. The GSAs will conduct local management of the Colusa Subbasin based on measurable objectives with the goal of avoiding exceedances of minimum thresholds and triggering of undesirable results. The GSAs will conduct this local management with consideration of all beneficial users and will seek to work with resource agencies, stakeholders, beneficial users, the public and GSAs representing adjacent subbasins to avoid exceeding minimum thresholds and incurring undesirable results.
477	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	5				Table 5-1	(Summary of Comment A.7) The draft GSP appears to plan for subsidence throughout the subbasin to be as much as 10 feet over the next 40 years with a subsidence MO set at 0.25 feet per year for each of 63 survey benchmarks. The subsidence benchmark MTs are set at 0.50 to 0.60 feet per year or as much as 20 to 24 feet over the next 40 years, depending on the current rate of subsidence. There doesn't appear to be any Management Actions other than recharge to mitigate subsidence, and no proposal to create a subsidence mitigation program. Clarification is needed on the maximum rate of subsidence at any point that will trigger an undesirable results and the duration for averaging.	Comment acknowledged and addressed. The CGA and GGA Boards made decisions to reduce the MT and MO land subsidence rates to lower values, consistent with other GSPs in the Sacramento Valley. These revisions are incorporated throughout Chapter 5. The revised MT is 0.5 feet per five years for all sites, and the revised MO is 0.25 feet per five years for all sites. The criteria that an undesirable result is considered to occur is when the Minimum Threshold is exceeded at 20 percent of the land subsidence monitoring benchmarks.

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478	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network					Figures 3-23, 3-31, 3-32	(Summary of Comment A.8) The draft GSP requirement to consider monitoring sites as a group when determining whether the MTs have been exceeded may create areas where the number of sites are too small to allow for the groups to encompass all monitoring sites, and/or create scientifically logical groups. The draft GSP should give the boundaries of the subsidence and groundwater monitoring well groups.	Comment acknowledged and addressed. Clarification has been added to Chapter 5 to explain the monitoring site subsets. For each monitoring network the subset of locations is not predetermined; rather, it is delineated only as sites collectively exceed their minimum threshold values. The subset of sites may be any combination of monitoring sites subbasin-wide, and do not necessarily need to be located in the same region.
479	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	4-5					(Summary of Comment A.9) The draft GSP should give the boundaries of the Thiessen polygons for the monitoring wells that are used to measure groundwater levels for either domestic wells or stream depletion, and provide a table of the number and depths, with cumulative frequency for domestic wells in each polygon.	Comment acknowledged. Thiessen polygons were not used to develop sustainable management criteria for surface water depletions.
480	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	4					(Summary of Comment A.10, part 1) The depth of the screens for some of the 48 RMN groundwater monitoring wells in Table 5-2 are given in Table 4-2. The draft GSP doesn't explain why the deep screened monitoring wells are selected to monitor shallower aquifers used by domestic wells even, when there is often a shallow monitoring well at the same location.	Comment acknowledged and addressed. Some of the monitoring wells in the representative monitoring network for lowering of groundwater levels are multiple completion monitoring wells, meaning that they have multiple discretely screened intervals at different depths within the aquifer. The completion depths, and therefore the measurable objectives and minimum thresholds, for the multiple completion monitoring wells in the representative monitoring network were misidentified as the deepest completion intervals in Table 5-2 of the public draft GSP. The completions selected for the representative groundwater level monitoring network have been updated to reflect the completions that best represent the median depth of nearby domestic wells. Thresholds, tables, and hydrographs in Chapters 4 and 5, including Table 5-2 and corresponding appendices, have been updated to reflect these changes.

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481	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	5				Tables 5-2 and 5-3	(Summary of Comment A.10, part 2) Seven of the wells in the domestic well monitoring network are shallow and are also part of the 12-well stream depletion monitoring network. While the MOs for the stream depletion network in the seven shallow wells are nearly equal to the MOs for the domestic well network, the MTs are very different and much deeper. The draft GSP doesn't clearly explain the differences in any Management Actions needed to maintain the sustainability of domestic wells and interconnected surface waters that result from the different MTs at these same shallow monitoring wells.	Comment acknowledged. There are 48 well locations used as representative monitoring locations for groundwater levels and 12 well locations used as representative monitoring locations for interconnected surface waters. The minimum threshold for assessing impacts to chronic lowering of groundwater levels were calculated using the deeper value of either (1) the 20th percentile of shallowest domestic well depths in the monitoring well's Thiessen polygon, or (2) 50% of range below the historical low groundwater elevation at the monitoring location. The minimum thresholds in the representative monitoring network for assessing depletions of interconnected surface waters were calculated by using the historical fall 2015 groundwater elevations and adding 10 feet to that depth. Appendix 5B provides a detailed discussion of the relationship between the sustainable management criteria for groundwater levels and surface water depletions. For locations in which both groundwater level and surface water depletion monitoring network wells exist, along with their well-specific sustainable management criteria, the management of the Colusa Subbasin will be based on the more conservative monitoring well and its associated sustainable management criteria. Sustainable management criteria for depletion of interconnected surface waters allow for the least reduction in groundwater levels, and management actions related to this sustainability indicator will be based on the surface water depletion monitoring network wells.

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482	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Summary of Comment A.11) The draft GSP proposes to investigate the possibility of compensating domestic well owners for impacts from groundwater production. What is the recommendation in the GSP for how the well owner should determine the depth for the new well? What assurances does the GSP give to the domestic well owner that the depth for the new well will be sufficient to ensure a future domestic water supply? Can the well owner assume that if they follow the GSP's recommended depth procedures for a new domestic well, they will receive compensation if the depth to groundwater is ever exceeded?	Comment acknowledged. It is noted that the domestic well mitigation program proposed in the GSP (described in Section 6.5.2.1) does not state that well owners would receive direct compensation. Funds may be directed toward projects designed to secure reliable water sources for affected domestic well owners (through, for example, public water system consolidations funded by state or federal programs). The precise policies, funding, and other factors underlying that program will need to be determined by the GSAs through a public, stakeholder-driven evaluation and decision-making process during GSP implementation.
483	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Summary of Comment A.12) Will the GSP also include a subsidence mitigation program that financially compensates homeowners and landowners for damage from subsidence? Will there be funds to repair infrastructures such as roads, bridges, levees, stormwater drainage, pipelines, home and building foundations, walls and roofs, domestic, municipal, industrial, and agricultural wells? What are the possible sources of subsidence mitigation funding, a consumption tax, a property tax, a flat tax per well Will the subsidence fund be designed to anticipate the cost of mitigation repairs over the full 40 years, that is, mitigate the planned 10 to 20+ feet of subsidence?	Comment acknowledged. Please see the response to comment 482 regarding the GSP's discussion of how mitigation program funds may be directed. Regarding subsidence, it is noted that the CGA and GGA Boards made decisions to reduce the MT and MO land subsidence rates to lower values, consistent with other GSPs in the Sacramento Valley. Please see the response to comment 477. Additionally, the GSAs have proposed a study of infrastructure sensitivity to land subsidence in Section 7.1.2.15. This study will help to fill data gaps related to infrastructure sensitivity to subsidence and address questions related to needs for subsidence mitigation. If needed, specific mitigation provisions will be developed by the GSA Boards through a public, stakeholder-driven process during GSP implementation.

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484	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	4				Table 4-2	(Summary of Comment A.13) Table 4-2 lists the characteristics of the monitoring wells in the GSP network, a total of 104 completions wells. However, only 48 completions are used for the domestic well network and another 5 for the stream depletion network. Only those 53 domestic and stream depletion wells have sustainability criteria, MOs and MTs. Why weren't MOs and MT calculated for the remaining 51 monitoring wells? Why are the other 51 wells included in the "groundwater monitoring network"? How will measurements in these other 51 wells be used in the groundwater monitoring program?	Comment acknowledged. There are 48 well locations used as representative monitoring locations for groundwater levels and 12 well locations used as representative monitoring locations for interconnected surface waters. The representative monitoring network wells (see Chapter 5) are a subset of wells used for establishing and monitoring sustainable management criteria. Sustainability thresholds such as the MT, MO, and interim milestones are defined at these representative monitoring network sites. Measurements at the representative sites are used to evaluate plan implementation. Measurements from the other monitoring locations are used to support evaluation of the plan implementation and support future decision making regarding sustainability thresholds, projects, and monitoring. The other groundwater monitoring well completions (totaling 104 completions, including the representative monitoring network) will be used to monitor overall groundwater level conditions in the Subbasin. The monitoring sites will be used to demonstrating progress towards during plan implementation, monitoring impacts to beneficial uses and users, monitoring changes in groundwater conditions, and quantifying annual changes in the water budget components (CCR § 354.34).
485	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	App. 5B					(Summary of Comment A.14) The hydrographs in Attachment A of Appendix 5B give the values of the MO and MT and graphically show their implications. Of interest are those wells where the MT based on the 20% shallower wells depth is below the 50% range depth. This occurs at 30 of the 48 wells.	Comment acknowledged. As described in Section 5.4.1.1, the MT is calculated as the deeper value of the 20th percentile of shallowest domestic well depths in the monitoring well's Thiessen polygon, or 50% of range below the historical low groundwater elevation. Also, it is noted that the GSAs have revised the MTs for chronic lowering of groundwater levels at several representative monitoring network sites. These revisions have resulted in shallower MTs that are more protective of domestic wells. See the response to comment 485.
486	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	App. 5B					(Summary of Comment A.15) The selection of the MO and lowest point for the MT appears to use groundwater levels after January 1, 2015 when it produces a lower elevation than measurement before the SGMA Benchmark date. The use of all historical data to calculate the 50% range appears to be continuing the pre-SGMA impacts into the GSP management actions. This seems to invert the concept that the GSP doesn't have to remedy pre-2015 impacts by making the GSP continue the pre-2015 impacts in the determination of sustainability criteria.	Comment acknowledged. The measurable objective is the mean of most recent five years of available groundwater elevation measurements up to March 2020 in each representative monitoring network well. The minimum threshold for groundwater level declines is based on the lower of 1) the 20th percentile of shallowest domestic well depths in each representative monitoring well's Thiessen polygon, or 2) 50 percent of range below the historical low groundwater elevation measured in each representative monitoring well.

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487	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	App. 5C					(Summary of Comment A.16) In Appendix 5C, the economic analysis argues that the maximum number of domestic wells that would go dry at the MT threshold is 12%, but excludes wells with depths shallower than the pre-January 2015 low because it was assumed those wells went dry with the lowest groundwater level and/or are no longer used. The economic analysis doesn't address if these wells recovered, nor document that these wells actually went dry. To evaluate the groundwater level in domestic wells, you need to use a wells screened at the depth of the domestic wells, for example the stream depletion monitoring wells.	Comment acknowledged. The analysis is based on the information available in the WCR database. Data gaps will be addressed in subsequent GSP updates, as described in Chapter 4 of the GSP. In addition, ss noted in the GSP, additional studies of potential domestic well impacts and for development of a program to mitigate for any well impacts is described under Section 6.5.2.1, Domestic Well Mitigation Program.
488	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	App. 5C					(Summary of Comment A.17, part 1) Appendix 5C says that the portion of the wells shallower than the proposed MT is in aggregate 12% of the domestic wells, not 20%. Histograms of RMN and domestic well depths, and cumulative frequency depth statistics are needed to understand the validity and significance of this economic analysis.	Comment acknowledged. We were unable to find a statement in Appendix 5C that says or implies that "the proposed MT is in aggregate 12% of the domestic wells, not 20%." The MTs are based on the lower of 50% below the historical low groundwater level or 20th percentile of domestic well depths, so it is anticipated that the aggregate share of domestic wells shallower than the MT would be less than 20%.
489	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	App. 5C				Table 1	(Summary of Comment A.17, part 2) A review of the statistics in Appendix 5C (Table 1) finds a large range in the percentage of wells that are shallower than the historical low before January 2015, ranging from zero to 97% across the 48 RMN wells. The aggregate for these dry wells is 46%. Does this average give the GSP's estimated future reduction in domestic well reliability within each RMN well polygon? How does the 12% aggregate for 20% shallower dry wells relate to the 46% well shallower than the lowest pre-January 2015 groundwater level? What are the depths, percentiles and the number of wells that could possibly go dry for each of the RMN well polygons where the MTs are based on the 50% range below the historical low, and/or based on the 20% shallower depth?	Comment unclear. The MTs are based on the lower of 50% below the historical low groundwater level or 20th percentile of domestic well depths, so it is anticipated that the aggregate share of domestic wells shallower than the MT would be less than 20%. Table 1 summarizes the available well data for each polygon. As described in Chapter 4 of the GSP, data gaps will be addressed in future GSP updates. The MT set is an input to the analysis described in Appendix 5C. That is, the economic analysis did not set the MT, it evaluated the costs and benefits (as identified in Appendix 5C) of the proposed MT.

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490	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	App. 5C					(Summary of Comment A.18) Obviously, the future cumulative average of dry wells under the GSP will be greater than the 46% of total wells. When 50% of the historical range is subtracted from the lowest pre-January 2015 groundwater level to calculate the MT, it creates a lower-than-the-lowest sustainable threshold. By this logic, the number of wells listed in Appendix 5C (Table 1) will go dry, at minimum, whenever groundwater levels go below the lowest historical elevation, and possibly more when groundwater levels reach the +50% depth threshold. For areas around the monitoring wells where the MT was set at the 20% shallower wells threshold (because that depth was greater than the lowest +50% depth), Appendix 5C (Table 1) shows a "share" less than 20% (0.20). Does this mean that additional wells will go dry in the future if groundwater levels reach the MT?	Comment unclear. We are not able to follow the logic in the comment and the comment appears to reference information that is not in Appendix 5C (e.g., the MT and selection criteria). In general, the MTs are based on the lower of 50% below the historical low groundwater level or 20th percentile of domestic well depths. This calculation is completed for each polygon individually to establish the MT, not for the entire Subbasin in aggregate. The MT were an input to the economic analysis described in Appendix 5C. That is, the economic analysis did not set the MT, it evaluated the costs and benefits (as identified in Appendix 5C) of the proposed MT.
491	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	App. 5C					(Summary of Comment A.19, part 1) Does the Table 1 in Appendix 5C total of 2,925 wells being shallower than the historic low groundwater level before January 2015 agree with the statistics on dry or no longer used wells collected by DWR or any government agency?	Comment acknowledged. The analysis described in Appendix 5C is based on Well Completion Report data published by DWR.
492	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	App. 5C					(Summary of Comment A.19, part 2) Table 1 of Appendix 5C shows that for the RMN well 22N03W24E001 near Orland, 1,589 out of a total of 1,677 wells are shallower than the historic low before January 2015, or 97%. This monitoring well is the closest RMN well to the City of Orland. Did 97% of the domestic wells around Orland go dry at least once sometime before 2015, and/or have they been abandoned? If yes, what is the source of this data?	Comment acknowledged. The economic analysis described in Appendix 5C excluded domestic wells that were shallower than the historic low groundwater level in each polygon. These data are from the DWR WCRs. As described in Chapter 4 of the GSP, data gaps will be addressed in future GSP updates, and this analysis may be refined with new information.
493	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	3, 6	3.3			Tables 3-11, 3-12, 6-1	(Summary of Comment A.20) The draft GSP provides a general background discussion on the surface water and groundwater budgets in Section 3.3. Tables 3-11 and 3-12 provide the average annual values for the surface water and groundwater budget components for all five analysis periods, respectively (pages 3-96 and 3-97). The water budget analysis selected as representative of conditions in the next 50 years is the projected Future Condition with the 2070 Central Tendency Climate Change provided by DWR.	Comment acknowledged.

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494	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	3	3.3			Tables 3-11, 3-12	(Summary of Comment A.21) Unfortunately, there appears to be a calculation error in the 2070 Future Conditions outflow, the right-hand column of Table 3-12. The three groundwaterpumping components, Agricultural, Urban and Industrial and Managed Wetlands, have future 2070 values of 548,000, 10,000 and 35,000 AFY, respectively. The sum of these three groundwater components equals 593,000 AFY, not the 559,000 AFY shown. This results in a Change in Storage (Inflow – Outflow) value of -42,000 AFY, not the -7,000 AFY shown. The values of the three groundwater components listed as inflow components in the surface water budget, Table 3-11, have different future 2070 values that sum to 558,000 AFY. This error in the Groundwater Pumping components needs to be corrected.	Comment acknowledged and addressed. We appreciate your identification of this potential issue. Upon review, it was found that the total groundwater pumping and urban groundwater pumping in Table 3-12 are correct, and that the error was an issue with the summary of agricultural and managed wetlands pumping. These two values have been corrected, and now align with the values in Table 3-11. The total Change in Storage (Inflow - Outflow) of -7 taf/yr corresponds to the model results, and is unchanged.
495	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	6				Table 6-1	(Summary of Comment A.22, part 1) In Table 6-1, the change in annual average groundwater storage with the 2070 climate change is a negative 7,900 AFY. This value differs from the -7,000 AFY value shown in Table 3-11, but this may be the result of round-off error in the Table 3-11 values. Note that the error in the total Groundwater Pumping in Table 3-12 could significantly change the rate of groundwater storage in Table 6-1, so it needs to be corrected.	Comment acknowledged. The difference is due to rounding, and has now been noted in Table 6-1. The concern with the change in groundwater storage has been corrected, please see the response to comment 494.
496	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	6				Table 6-1	(Summary of Comment A.22, part 2) Table 6-1 shows that there will be an annual average decrease in Stream Accretion of 48,000 AFY, or 38.3%, in the Net Stream Accretion in the future with the 2070 climate change scenario. The sums listed in Table 6-1 for future without climate change, 125,000 AFY and for 2070 with climate change, 77,000 AFY, don't appear to agree with the sums that would be obtained using values listed in Table 3-11, but the difference is the same - 48,000 AFY.	Comment acknowledged. The difference is due to rounding and slight changes in how values are summarized from the C2VSimFG-Colusa model results between the two summary tables; however, as noted the difference remains the same. This has now been noted in Table 6-1.
497	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	3					(Summary of Comment A.23, part 1) The increase in Groundwater Pumping and the decrease in Net Stream Accretion in the future with the 2070 climate change scenario suggest that the assumptions being made regarding loss of surface water flows during a groundwater substitution transfer are flawed. The decrease in Net Stream Accretion with future Groundwater Pumping suggests that the overall percentage of groundwater being pumped that will be recharged from the streams in the Colusa Subbasin, i.e., stream depletion, with any future pumping increase is significantly greater than the DWR/BOR assumed 13% stream flow loss from a groundwater substitution transfer.	Comment acknowledged. Please see the response to comment 298.

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498	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	3					(Summary of Comment A.23, part 2) The groundwater budget in draft GSP Table 3-12 shows that more surface water will infiltrate into the groundwater basin to the detriment of the streams, and that the future increase in groundwater pumping will decrease the discharge of groundwater to streams. Under the existing conditions streams gain more water from the groundwater system than they give. With the 2070 climate change scenario, streams will continue to gain more from the groundwater system, but the gain will be less. The decline in Net Stream Accretion with future increased Groundwater Pumping that changes the streams for gaining to losing suggesting that the subbasin maybe at a tipping point where the impacts from future pumping increases are amplified and cause significantly more harm than just the existing condition.	Comment acknowledged. Please see the response to comment 465.
499	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	3					(Summary of Comment A.24) Figures 3-29 and 3-49 graph the cumulative change in groundwater storage across the water budget scenarios. In 2015 the cumulative change in groundwater storage since 1990 is approximately a negative 600,000 AF, lower than in than any time prior to the start of SGMA. This should be the starting point for going forward in an evaluation of the subbasin's groundwater sustainability. If the anticipated future loss in groundwater storage under the 2070 climate change scenario is added to existing loss in groundwater storage, the cumulative loss is groundwater storage for the Colusa Subbasin in 2065 is approximately 1,000,000 AF. The authors of the draft GSP may know this, and that's maybe why many of the groundwater monitoring well MTs are set at 50% of the historical range below the historical low to allow for an additional 400,000 AF of loss in groundwater storage predicted by the 2070 climate change scenario without triggering an undesirable result.	Comment acknowledged. 23 CCR § 354.18(c)(3) requires that a 50-year period of historical data be used as a baseline for estimating future hydrology. The selected, SGMA-required 50-year period is 1966-2015, which includes the effects of the 2014-2015 critical years. However, it would not be correct to start with those conditions and add those years to the record. The basic assumption is that hydrologic patterns will repeat themselves with adjustments made to the records per DWR guidelines to reflect the effects of climate change. It is noted that GSP regulations do require that GSAs use the most recent land use, evapotranspiration, crop coefficients, and surface water supply information as a baseline for estimating future water demand and surface water supply. As described in Section 3.3.3, the Colusa Subbasin GSP does use data from the most appropriate recent years as a baseline for estimating future water demand and surface water supply.

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500	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Summary of Comment A.25) The existing groundwater contours in the Butte and Colusa subbasins suggest that the current flow of groundwater in the aquifers shallower than 700 feet flow towards the center of the valley with the flow generally north to south aligned with the Sacramento River. There are several sets of monitoring wells that are approximately opposite each other along the north-south boundary between the subbasins. After comparing MTs for sets of west-to-east monitoring well matches, it was found that the MT elevations in the Butte Subbasin are higher in all but one of the 10 sets. This may create a condition where the Butte Subbasin is providing more interbasin groundwater flow to the west in the future. The implications from setting the MT values in the Colusa Subbasin at elevation lower than the MTs in the Butte Subbasin should be analyzed and management action(s) should be included in the GSPs for each other subbasin to maintain sustainable interbasin groundwater flow.	Comment acknowledged. The GSAs coordinated with the GSAs in the adjacent basins during development of sustainable management criteria, including sustainable management criteria for chronic lowering of groundwater levels and depletions of interconnected surface waters. The GSAs will continue to coordinate with the GSAs in the adjacent basins during implementation of the GSP. Groundwater levels in the Colusa Subbasin near the boundary with the Butte Subbasin will be managed to limit potential increases in surface water depletions, meaning that the minimum thresholds for groundwater levels will be superseded by the minimum thresholds for surface water depletions in the Colusa Subbasin near the Butte Subbasin boundary. Appendix 5B provides a detailed discussion of the relationship between the sustainable management criteria for groundwater levels and surface water depletions. For locations in which both groundwater level and surface water depletion monitoring network wells exist, along with their well-specific sustainable management criteria, the management of the Colusa Subbasin will be based on the more conservative monitoring well and its associated sustainable management criteria. Surface water depletion sustainable management criteria allow for the least reduction in groundwater levels, and management actions related to this sustainability indicator will be based on the surface water depletion monitoring network wells. Projects and management actions will be undertaken by the GSAs, agencies and stakeholders in the Colusa Subbasin.
501	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	3-4					(Summary of Comment A.26) The GSP should specifically state that the water quality MOs and MTs for the Colusa Subbasin will follow the requirements of the CVVRWQCB's Sacramento River Basin Plan. In addition, the GSP should maintain the subbasin's water quality so that it meets all required health protective drinking water standards at levels below the Maximum Contaminant Levels (MCLs) for public water systems, and below the public health goals (PHGs). The GSP should specify Management Actions that will maintain and/or improve the subbasin water quality with an emphasis on the known problems.	Comment acknowledged.

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502	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network	7					(Comment A.27) Is voter approval necessary for any fees or taxes levied to raise funding for any of the Mitigation Actions? Who are the actual voters? Are they all landowners in the Colusa Subbasin, only landowners in a GSA, or all citizens of the Colusa subbasin? The GSP actions may need to fund mitigations to municipal or small water systems, so how are these systems represented in the funding decisions? Will the de minimus extractors, a person who extracts, for domestic purposes, two acre-feet or less of groundwater per year, be allowed a vote? How many votes does each eligible voter get? Will the number of votes be based on the acres owned, number of wells owned, volume of groundwater pumped, or some combination of factors? What happens if the economic burden to fund the management actions falls disproportionately on one group, to whom can they appeal? Will mitigation funds go to the de minimus extractor because their wells can go dry like anyone else's, but they are otherwise exempt from SGMA? Are there any statutes that govern how government agencies determine the per capita or per centum rate of a tax or fee?	Comment acknowledged. Developing a finance plan for the Subbasin will be part of GSP implementation and is not part of initial GSP development. As described on page 1 of Appendix 7A, there are a series of activities that the GSAs will need to undertake to continue to fund and finance GSP implementation activities.
503	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Comment A.28) Do the stream depletion MOs and MTs take precedence over the domestic well MOs and MTs when the monitoring well are adjacent? How should the domestic well owner utilize the stream depletion thresholds?	Comment acknowledged. Appendix 5B provides a detailed discussion of the relationship between the sustainable management criteria for groundwater levels and surface water depletions. For locations in which both groundwater level and surface water depletion monitoring network wells exist, along with their well-specific sustainable management criteria, the management of the Colusa Subbasin will be based on the more conservative monitoring well and its associated sustainable management criteria. Surface water depletion sustainable management criteria allow for the least reduction in groundwater levels, and management actions related to this sustainability indicator will be based on the surface water depletion monitoring network wells. Projects and management actions will be undertaken by the GSAs, agencies and stakeholders in the Colusa Subbasin.
504	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Comment A.28) What is the lateral extent that the stream depletion MO and MT applies? Up to 5 miles from the well? Only in the area where the 5 miles zone intersects a stream? Only in the area between the monitoring well and the stream?	Comment acknowledged. Sustainable management criteria (e.g., measurable objectives and minimum thresholds) for depletions of interconnected streams were assigned to each monitoring well in the representative monitoring network based on the historical groundwater levels at that specific monitoring well. During implementation of the Colusa Subbasin GSP, groundwater levels in each monitoring well in the representative monitoring network will be evaluated in comparison to the well-specific measurable objectives and minimum thresholds. Undesirable results will be judged to have occurred when 25 percent of the representative monitoring network wells exceed their well-specific minimum thresholds.

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505	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Comment A.28) Is there a map of the 48 Representative Monitoring Network (RMN) Thiessen polygon boundaries? What is the area of each polygon? How many domestic wells are in each polygon?	Comment acknowledged. The density of domestic wells is portrayed in Chapter 2 of the GSP. The GSAs will consider including a map of the Thiessen polygons during future updates to the Colusa Subbasin.
506	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Comment A.28) Do the MO and MT apply to all domestic wells within that well's polygon? How does the requirement to evaluate undesirable results using 12 RMN wells affect the MO and MT at a specific domestic well? Should a domestic well owner be prepared to have a dry well if depth of their well is shallower than the MT in their polygon, or if the depth is shallower than the deepest MT in the group of 12 RMN wells?	Comment acknowledged. Sustainable management criteria (e.g., measurable objectives and minimum thresholds) do not apply to individual domestic wells, only wells in the representative monitoring network for the applicable sustainability indicators. Sustainable management criteria for depletions of interconnected streams were assigned to each monitoring well in the representative monitoring network based on the historical groundwater levels at that specific monitoring well. During implementation of the Colusa Subbasin GSP, groundwater levels in each monitoring well in the representative monitoring network will be evaluated in comparison to the well-specific measurable objectives and minimum thresholds. Undesirable results will be judged to have occurred when a percentage of the representative monitoring network wells exceed their well-specific minimum thresholds. Sustainable management criteria and the corresponding representative monitoring networks for the sustainability indicators applicable to the Colusa Subbasin are designed for sustainable management of the Subbasin as a whole. Groundwater conditions at specific domestic wells are subject to local and well-specific influences, which are uncertain. Domestic well owners are urged to participate with the GSAs, their respective Counties and stakeholders to address domestic well concerns during implementation of the Colusa Subbasin GSP.

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507	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Comment A.28) If a domestic well is being installed or replaced, can the well owner rely on the MO and MT depths in their polygon to determine a minimum depth of their new well? Does the GSP offer any advice on the sustainability criteria for the minimum depth of a new well or replacement well? Should the new well be at least the depth of the old well's polygon MT, or the 12-well group MT, to ensure that the well doesn't go dry in the future?	Comment acknowledged. Sustainable management criteria (e.g., measurable objectives and minimum thresholds) do not apply to individual domestic wells, only wells in the representative monitoring network for the applicable sustainability indicators. Sustainable management criteria for depletions of interconnected streams were assigned to each monitoring well in the representative monitoring network based on the historical groundwater levels at that specific monitoring well. During implementation of the Colusa Subbasin GSP, groundwater levels in each monitoring well in the representative monitoring network will be evaluated in comparison to the well-specific measurable objectives and minimum thresholds. Undesirable results will be judged to have occurred when a percentage of the representative monitoring network wells exceed their well-specific minimum thresholds. Sustainable management criteria and the corresponding representative monitoring networks for the sustainability indicators applicable to the Colusa Subbasin are designed for sustainable management of the Subbasin as a whole. Groundwater conditions at specific domestic wells are subject to local and well-specific influences, which are uncertain. Domestic well owners are urged to participate with the GSAs, their respective Counties and stakeholders to address domestic well concerns during implementation of the Colusa Subbasin GSP.
508	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Comment A.28) What advice does the GSP give on how a domestic well owner should interpret the MO and MT values when their well is near the polygon boundary? For example, if a domestic well is installed or replaced in the 22N02W30H002 polygon that's close to the boundary with the 22N03W24E001 polygon, should the depth of the new well be at the deeper MT of the 22N03W24E001 polygon or the shallower 22N02W30H002 polygon?	Comment acknowledged. Sustainable management criteria (e.g., measurable objectives and minimum thresholds) do not apply to individual domestic wells, only wells in the representative monitoring network for the applicable sustainability indicators. Sustainable management criteria for depletions of interconnected streams were assigned to each monitoring well in the representative monitoring network based on the historical groundwater levels at that specific monitoring well. During implementation of the Colusa Subbasin GSP, groundwater levels in each monitoring well in the representative monitoring network will be evaluated in comparison to the well-specific measurable objectives and minimum thresholds. Undesirable results will be judged to have occurred when a percentage of the representative monitoring network wells exceed their well-specific minimum thresholds. Sustainable management criteria and the corresponding representative monitoring networks for the sustainability indicators applicable to the Colusa Subbasin are designed for sustainable management of the Subbasin as a whole. Groundwater conditions at specific domestic wells are subject to local and well-specific influences, which are uncertain. Domestic well owners are urged to participate with the GSAs and their respective Counties to address domestic well concerns during implementation of the Colusa Subbasin GSP.

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509	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Comment A.28) Will monitoring the RMN wells only 2 to 3 times each year effectively capture the fluctuations in groundwater level? In particular, the periods of maximum decline which have significant influence over domestic wells and stream depletion?	Comment acknowledged. Most of the wells within the Colusa Subbasin groundwater monitoring network are monitored by DWR staff 2 or 3 times per year, usually in the spring and fall to account for seasonal fluctuations. Monitoring twice per year is acceptable per CCR § 354.34. Increased monitoring frequency may be requested or conducted, as needed for plan implementation.
510	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Comment A.28) What is the distribution of the depths of domestic wells associated with each RMN monitoring well? How many of the 20% shallower wells will go dry with each increment of groundwater level decline? Histograms of wells depth and cumulative frequency of depth statistics are needed to understand the validity and significance of the 20% shallower threshold.	Comment acknowledged. The density of domestic wells is portrayed in Chapter 2 of the GSP (Figure 2-7). The GSAs may consider including a map of the Thiessen polygons with domestic well depth statistics during plan and project implementation, or future updates to the Colusa Subbasin GSP.
511	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Comment A.28) Will the construction of deeper domestic wells in the future influence the MO and MT values? If so, how will the MO and MT change, when will the change occur and what measures should a domestic well owner take when and if this change occurs?	Comment acknowledged. Construction of deeper domestic wells in the future may result in changes in the sustainable management criteria for chronic lowering of groundwater levels. The GSAs will evaluate sustainable management criteria during implementation of the GSP, including during periodic updates of the GSP. The GSAs will consider beneficial uses and users during plan implementation and will coordinate with stakeholders, and the GSAs representing the adjacent subbasins during this public process.

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512	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Comment A.28) Will the use of 50% range values in deep aquifers to set the domestic well MTs cause more the wells to go dry and/or for longer periods than if the range in shallower aquifers were used? In other words, will the use of MT developed on deeper data delay actions needed to maintain the sustainability of the domestic wells because they allow greater declines in groundwater level before an undesirable result is acknowledged?	Comment acknowledged and addressed. Some of the monitoring wells in the representative monitoring network for chronic lowering of groundwater levels are multiple completion monitoring wells, meaning that they have multiple discretely screened intervals at different depths within the aquifer. The completion depths, and therefore the measurable objectives and minimum thresholds, for the multiple completion monitoring wells in the representative monitoring network were misidentified as the deepest completion intervals in Table 5-2 of the public draft GSP. The completions selected for the representative groundwater level monitoring network have been updated to reflect the completion that best represents the median depth of nearby domestic wells. Sustainable management criteria and hydrographs in Chapters 4 and 5, including Table 5-2 and corresponding appendices have been updated to reflect these changes. Also, the GSAs will implement the Colusa Subbasin GSP using a public process that includes domestic well owners and other beneficial users with the goal of implementing projects and management actions geared towards achieving and maintaining measurable objectives, and avoiding reaching minimum thresholds.
513	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Comment A.28) Where in SGMA is the standard that 20% dry wells can be determined to be acceptable and non-significant, and therefore not an undesirable result? Where in SGMA does it give the standards for the economic analysis to determine the cost-effectiveness and the acceptable balance between avoiding significant and unreasonable impacts to domestic and other shallow wells in determining the MTs? Is the GSP's sacrifice of a 20% shallower well considered a taking? Does there need to be compensation? What is the value of the compensation, replacement costs of a deeper well, the original cost of the well, the value of the water at the time it goes dry or the change in water quality makes the water unusable, or all of the above.	Comment acknowledged. Please note that the GSAs have revised the MTs for chronic lowering of groundwater levels at several RMN sites. These revisions have resulted in shallower MTs that are more protective of the 20th percentile depths of domestic wells. The GSAs still propose a potential domestic well mitigation program, though the precise policies, funding, and other factors underlying that program will need to be determined by the GSAs through a public, stakeholder-driven evaluation and decision-making process during GSP implementation. Please see the response to comment 482 regarding the GSP's discussion of how mitigation program funds may be directed.

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514	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network		6.5.2.1				(Comment A.28) The Management Action for the Domestic Well Mitigation Program states that the GSP (GSA) is in the early conceptual stage. SGMA exempts the GSP from CEQA (WC 10728.6), but requires implementation projects to undergo CEQA review. All eight of the Management Actions given in GSP Chapter 6.5.2 are in early conceptual stage. If the GSP is adopted with this language and no specifics are provided about what actions will be taken, does that mean that any future projects or actions to implement the GPS Management Actions are still CEQA exempt?	Comment acknowledged. Please see the response to comment 482.
515	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						*(Summary of Comment B, part 1)* The Plan as proposed will degrade the groundwater basin and harm groundwater users who are not involved in conjunctive use, water transfers, or water banking but are reliant on the same groundwater basin.	Comment acknowledged.
516	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						*(Summary of Comment B, part 2)* The public and SGMA governing bodies and committees have been excluded from NorthState inter-basin discussions. When participants in the Vina Stakeholder Advisory Committee asked staff if discrepancies in inter-basin flow volumes/direction that are estimated in the various GSA Basin Settings had been deliberated within the Inter-Basin Coordinating Committee, they answered that they are too busy, but would examine the issue after the GSPs are submitted in 2022.	Comment acknowledged. Interbasin coordination has occurred throughout GSP development and will continue during plan implementation. The CGA and GGA have engaged in robust interbasin coordination through NCWA and participation in GSP planning meetings in adjacent subbasins. Staff, representatives, and consultants from the Colusa Subbasin and neighboring basins have coordinated for consistency between GSPs, including at meetings open to the public. The GSP process recognizes that data gaps exist, and has built in a structured monitoring and annual/periodic review process to develop clearer understanding of subbasin conditions and progress toward sustainability over time. The GSP is a "living document" that the GSAs will review and revise as more information about the basin setting becomes available (per 23 CCR §356.4).
517	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						*(Summary of Comment B, part 3)* Achieving sustainability requires local agencies, stakeholders, and water users to make many difficult and potentially contentious decisions. These decisions are prone to conflict, particularly when pumping restrictions are viewed as infringing on property rights or when fees are charged to support local management. The Colusa GSP is not complete without a detailed process and funding to resolve conflicts that arise both within and external to the GSA boundaries.	Comment acknowledged. The GSAs have made clear and consistent efforts to respectfully engage with all stakeholders through robust discussion. Public outreach and engagement is described in the response to comment 304, and is documented in Chapter 2 and associated appendices. The GSAs have also engaged in a transparent and public decision-making process through numerous GSA Board meetings and TAC meetings, documented in Appendix 5A. The GSAs are not searching for conflict, but are prepared to address it if it arises.

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518	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Summary of Comment C, part 1) The Colusa GSP must not assume that local ordinances will in any way protect the population and environment of Glenn and Colusa counties from any transfers and expanded conjunctive use. Water transfers are not protective of the public or the environment, and Think tanks are already encouraging the California Legislature to override local ordinances: "If counties with restrictive groundwater export ordinances fail to amend their laws to conform to SGMA, the legislature should consider preempting local laws that discriminate against out-of-county uses or place undue burdens on groundwater and groundwater-substitution transfers that would not jeopardize sustainable groundwater management of the source aquifer." (comment provides some other examples)	Comment acknowledged.
519	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Summary of Comment C, part 2) Sustainability is not found in the Colusa GSP, let alone equitable sustainability for all residents, farms, businesses, and the environment. The Colusa and Butte GSAs are dominated by large, non-residential landowners, many of whom have sought to play in the lucrative water market already to the detriment of their neighbors, streams, rivers, and species.	Comment acknowledged. The GSAs have made clear and consistent efforts to respectfully engage with all stakeholders through robust discussion. Public outreach and engagement is described in the response to comment 304, and is documented in Chapter 2 and associated appendices.
520	Barbara Vlamis, Jim Brobeck, Bill Jennings, Carolee Krieger	AquAlliance, California Sportfishing Protection Alliance, California Water Impact Network						(Summary of Comment C, part 3) In addition to exports, it is foreseeable that a future GSA will encourage drawdown of the aquifer (based on Los Angeles v. San Fernando) to satisfy massive crop thirst as the drought continues, which will then create extra storage space for imported waters to “recharge” the Basin.	Comment acknowledged. This comment appears to suggest that intentional overdraft will occur because of SGMA. The GSP does not plan for intentional overdraft. The GSP plans for projects and management actions and adaptive management to achieve and maintain sustainability and respond to unforeseen future conditions that may impact sustainable operation of the Subbasin (see Chapter 6). The GSP does not authorize or encourage exports out of the Basin.
521	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	2					(Summary of Comment 1.A, Disadvantaged Communities, Drinking Water Users, and Tribes) The plan fails to clearly document the population of each DAC and the population dependent on groundwater as their source of drinking water in the subbasin. The plan should provide the population of each identified DAC, and identify the sources of drinking water for DAC members, including an estimate of how many people rely on groundwater (e.g., domestic wells, state small water systems, and public water systems).	Comment acknowledged and addressed. We have added additional clarification in Section 2.1.2.1, Water Purveyors, to indicate that municipal and rural domestic water supplies in the Colusa Subbasin largely serve DACs, SDACs, and EDAs, and thus the water sources (groundwater) used to meet all urban (including rural domestic) water needs in the Subbasin are those used by DAC/SDAC/EDA populations.

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522	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	2					(Summary of Comment 1.A, Disadvantaged Communities, Drinking Water Users, and Tribes) The GSP fails to provide depth of domestic wells (such as minimum well depth, average well depth, or depth range) within the subbasin. The plan should include a map showing domestic well locations and average well depth across the subbasin (i.e., a map similar to Figure 2-7 showing average well depth per square mile).	Comment acknowledged. Domestic well densities per one square mile throughout the Colusa Subbasin are discussed in Chapter 2. The GSAs may consider additional evaluations of domestic well depths during GSP implementation, including in the implementation of projects and management actions and during periodic updates of the GSP.
523	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	Appendix 3G					(Summary of Comment 1.A, Interconnected Surface Waters) The identification of Interconnected Surface Waters (ISWs) is insufficient, due to lack of a comprehensive map of ISWs in the subbasin. The plan should provide a map showing all the stream reaches in the subbasin, with reaches clearly labeled as interconnected (gaining and losing) or disconnected. Consider any segments with data gaps as potential ISWs and clearly mark them as such on maps provided in the GSP.	Comment acknowledged. The C2VSim-ColusaFG numerical model was used to determine a subbasin-wide aggregate gain/loss within interconnected surface waters. The model is not currently scaled to determine gains and losses along every ephemeral, intermittent, and perennial stream or canal reach within the Subbasin, but has recently been updated to include a finer timestep. The Stony Creek thalweg analysis discussed in Chapter 3 explores the potential for using groundwater level measurements within shallow wells as a means to determine if stream reaches are connected or not. The thalweg analysis results were compared to the results of the Interconnected Surface Water in California's Central Valley (ICONS) study (TNC, 2021). The results between the two analyses were consistent, but also confirmed data gaps regarding availability of reliable data to evaluate for stream-aquifer connectivity. The GSAs will seek to work with resource agencies, stakeholders, beneficial users and the public to refine the understanding of interconnected surface waters in the Colusa Subbasin, fill data gaps, and develop PMAs with consideration of interconnected surface waters. Future model refinement may be considered to support understanding and quantification of surface water and groundwater connectivity. Additional mapping of surface water connectivity may be included in plan and project implementation reports or future updates to the GSP.

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524	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	Appendix 3G					(Summary of Comment 1.A, Interconnected Surface Waters) While the GSP presents a thorough, comprehensive evaluation of ISWs using the C2VSimFG-Colusa model (Appendix 3G), the plan should confirm those results by overlaying the stream reaches with depth-to-groundwater contour maps and should also discuss stream reaches in the interior of the subbasin (e.g., whether they were included in the groundwater model; their relevant depth to groundwater; whether they are considered to be disconnected, and what data was utilized to support that conclusion).	Comment acknowledged. The GSP includes groundwater elevation contour maps and hydrographs with depth to water in Chapter 3. Depth to water contour maps are not included in this initial Colusa Subbasin GSP but may be included in future revisions or projects completed during plan implementation.
525	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	3					(Summary of Comment 1.A, Groundwater Dependent Ecosystems) The identification of Groundwater Dependent Ecosystems (GDEs) is insufficient. The GSP identified and mapped GDEs using the NC dataset, but incorrectly removed NC dataset polygons in areas adjacent to irrigated fields or due to the presence of surface water supplies. NC dataset polygons adjacent to irrigated land or surface water supplies can still potentially be reliant on shallow groundwater aquifers, and therefore should not be removed solely based on their proximity to irrigated fields or surface water supplies. The plan should provide a comprehensive set of maps for the subbasin's GDEs (e.g., map the NC dataset and label polygons retained, removed, or added to/from the dataset) and discuss how local groundwater data was used to verify whether polygons in the NC Dataset are supported by groundwater in an aquifer.	Comment acknowledged and addressed. The preliminary screening of the potential GDEs within the Colusa Subbasin was conducted to help prioritize areas for further mapping, evaluation and monitoring of GDEs during implementation of the Colusa Subbasin GSP. The preliminary screening supported the assessment of data gaps, evaluation of existing monitoring networks, which could potentially be used for GDE monitoring, and development of PMAs. The GSAs will seek to work with resource agencies, stakeholders, beneficial users and the public to refine the understanding of GDEs in the Colusa Subbasin, fill data gaps and develop PMAs with consideration of GDEs. The GDEs analysis will be refined during GSP implementation. Additional clarification has been added to the GSP Chapter 3 to acknowledge that significant data gaps exist for the precise locations and characteristics of GDEs in the Colusa Subbasin. It is noted that the prioritization, or "scoring," of GDEs is intended as a step toward identifying GDEs using the information available at the time of GSP development. This "scoring" is not seen as a final call on the classification of GDEs, but rather a prioritization for future work to better identify and expand monitoring of potential GDEs.

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527	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	3					(Summary of Comment 1.A, Groundwater Dependent Ecosystems) The GSP does not provide an inventory of the flora or fauna species present in the subbasin's GDEs, except to discuss the four most prevalent vegetation species. The plan should include an inventory of the fauna and flora present within the subbasin's GDEs (Attachment C of this letter lists freshwater species located in the Colusa Subbasin), and note any threatened or endangered species.	Comment acknowledged and addressed. A reference to TNC's analysis of freshwater species located in the Colusa Subbasin has been added to Section 3.2.8 of the GSP (based on analysis of the California Freshwater Species Database version 2.0.9 within the Subbasin boundary). We have also added more text to acknowledge data gaps regarding which of these species are found within GDEs, and references to GSP studies in Chapter 7 to help close those data gaps and expand understanding of GDEs in the Subbasin.
528	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	3					(Summary of Comment 1.A, Groundwater Dependent Ecosystems) The GSP should provide depth-to-groundwater contour maps.	Comment acknowledged. Several depth to groundwater contour maps are included in Chapter 3 (see Figure 3-19, 3-20). It is noted that GSP regulations require groundwater elevation contour maps (§354.16(a)(1)), which are also included in Chapter 3 and Appendix 3B.

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530	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	3					(Summary of Comment 1.A, Native Vegetation and Managed Wetlands) The integration of native vegetation and managed wetlands into the water budget is sufficient because the GSP included the groundwater demands of native vegetation and managed wetlands in the historical, current, and projected water budgets.	Comment acknowledged.

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531	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	Appendix 2E					(Summary of Comment 1.B, Stakeholder Engagement during GSP Development) Stakeholder engagement during GSP development is insufficient. SGMA's requirement for public notice and engagement of stakeholders is not fully met by the description in the Stakeholder Communication and Engagement Plan (Appendix 2E). The opportunities for public involvement and engagement with DACs, drinking water users, tribes, and environmental stakeholders are described in very general terms. They include technical and informational workshops and meetings open to the public. No specific outreach targeted to DACs, drinking water users, tribes, or environmental stakeholders is described in the GSP.	Comment acknowledged. It is noted that the GSAs have made clear and consistent efforts to respectfully engage with all stakeholders and interested parties through robust discussion. As described in Section 2.7.2, the CGA and GGA sponsored, publicized, and conducted numerous public engagement opportunities for stakeholders and interested parties in the Subbasin, including more than 236 separate meetings and workshops. Meetings and workshops have been consistently advertised and open to the public, and meeting notes, materials, and/or recordings have been available to the public. Other specific communication and outreach activities are described in Section 2.7.3, including tribal engagement. Communication and outreach has reached stakeholders and interested parties of varied backgrounds, including DACs, drinking water users, tribes, and environmental stakeholders. The GSAs have made clear efforts to reach and engage with all stakeholders and interested parties in the Colusa Subbasin. Notably, the majority of the populace in the Colusa Subbasin is classified as a DAC, SDAC, or EDA (see Section 2.1.2.3). Outreach and communication with communities in the Colusa Subbasin is intrinsically communication with DACs, SDACs, and EDAs.
532	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	Appendix 2E					(Summary of Comment 1.B, Stakeholder Engagement during GSP Development) The Stakeholder Communication and Engagement Plan does not include a plan for continual opportunities for engagement through the implementation phase of the GSP for DACs, domestic well owners, tribes, and environmental stakeholders. The plan should describe efforts to consult and engage with these stakeholders, and should utilize DWR's tribal engagement guidance to comprehensively address all tribes and tribal interests in the subbasin within the GSP.	Comment acknowledged. Engagement strategies listed throughout Appendix 2.E are nearly all expected to be used during GSP "development (or planning) and implementation," which is explicitly stated in several locations. Those engagement strategies apply to GSP implementation. Additionally, Section 2.7.3 of the GSP specifically describes the GSAs' consistent tribal engagement during GSP development. The GSAs are prepared to continue tribal engagement during GSP implementation. Table 4 in Appendix 2.E presents "Educational and Reference Documents for SGMA Implementation" and was used to inform the Communication and Engagement Plan. That list includes DWR's SGMA Engagement With Tribal Governments, thus, said guidance was and continues to be used. Finally, all PMA descriptions in Chapter 6 describe plans for "Notice to Public and other Agencies," summarizing plans for outreach related to implementation of that PMA. As described in Section 2.7.1, the GSAs are committed to periodically update the C&E Plan as conditions warrant, including but not limited to any necessary and beneficial conditions associated with the transition from GSP development to GSP implementation.

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533	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	5					(Summary of Comment 1.C, Disadvantaged Communities and Drinking Water Users) The GSP does not sufficiently describe or analyze direct or indirect impacts on DACs or tribes when defining undesirable results, nor does it describe how the groundwater levels minimum threshold will avoid significant and unreasonable impacts on beneficial users beyond 2015 and be consistent with Human Right to Water policy. The plan should describe direct and indirect impacts on drinking water users, DACs, and tribes when describing undesirable results and defining minimum thresholds for chronic lowering of groundwater levels.	Comment acknowledged and addressed. Section 5.3.1 has been revised to include the following, "As described in Chapter 2, most of the Subbasin is classified as an Economically Disadvantaged Area and has a high proportion of Disadvantaged Communities (DACs), and Small Disadvantaged Communities (SDACs). These beneficial users, along with members of California Native American Tribes (Tribes), including the federally recognized Cachil Dehe Band of Wintun Indians and the Cortina Indian Rancheria of Wintun Indians of California, typically rely on groundwater to meet their drinking water needs. As expressed in California Water Code Section 106.3, "every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes." The human right to water extends to all Californians, including disadvantaged individuals and groups and communities in rural and urban areas (SWRCB, 2021). Undesirable results caused by chronic lowering of groundwater levels could affect the Human Right to Water by limiting the ability of drinking water beneficial users, including DACs, SDACs and Tribes, to access safe, clean, and affordable water for human consumption, cooking, and sanitary purposes. These drinking water beneficial users could experience cumulative effects of undesirable results caused by chronic lowering of groundwater levels and degraded water quality." Also in Section 5.3.1, the listing of the potential effects of the undesirable results caused by chronic lowering of groundwater levels was revised to include decreased access to safe, clean and affordable drinking water, and additional references to projects and management actions and implementation activities focused on maintaining groundwater levels and mitigating drought impacts to drinking water beneficial users was added. Section 5.4.1 was revised to discuss the Human Right to Water in the context of minimum thresholds for chronic lowering of groundwater levels.

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535	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	5					(Summary of Comment 1.C, Disadvantaged Communities and Drinking Water Users) The plan should evaluate the cumulative or indirect impacts of proposed minimum thresholds for degraded water quality on drinking water users, DACs, and tribes.	Comment acknowledged and addressed. See responses to comments 533 and 534.

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536	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	5					(Summary of Comment 1.C, Disadvantaged Communities and Drinking Water Users) The plan should provide a summary table for EC that presents the pre-2015 historical maximums, the salinity objective from the Basin Plan, the SMCL, and the resulting minimum thresholds. Ensure that the minimum thresholds do not exceed the salinity objective in the Basin Plan.	Comment acknowledged. Historical salinity, as total dissolved solids, is discussed in Chapter 3. Historical maximum total dissolved solids concentrations, as reported to State and federal agencies, are depicted on Figure 3-30. Historical salinity, as electrical conductance, for the representative groundwater quality monitoring network (public water supply wells) are shown in Appendix 5D and discussed in Chapter 5. The historical electrical conductance measured in the representative groundwater quality monitoring network was used to determine the sustainability thresholds. Existing regulatory programs are currently monitoring and will be addressing salinity concerns in shallow wells throughout the subbasin. The CGA and GGA will coordinate with these programs, the lead regulatory agencies, and the regulated community within the Colusa Subbasin during implementation of this GSP, including during development and implementation of projects and management actions.
537	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	5					(Summary of Comment 1.C, Disadvantaged Communities and Drinking Water Users) The plan should set minimum thresholds and measurable objectives for all water quality constituents within the subbasin that can be impacted and/or exacerbated as a result of groundwater use or groundwater management. Ensure they align with drinking water standards.	Comment acknowledged. MCL exceedances are managed by individual water supply agencies.
538	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	5					(Summary of Comment 1.C, Groundwater Dependent Ecosystems and Interconnected Surface Waters) Sustainable management criteria for chronic lowering of groundwater levels provided in the GSP do not consider potential impacts to environmental beneficial users. When defining undesirable results for chronic lowering of groundwater levels, provide specifics on what biological responses (e.g., extent of habitat, growth, recruitment rates) would best characterize a significant and unreasonable impact to GDEs. Potential impacts on environmental beneficial uses and users need to be considered when defining undesirable results in the subbasin. Defining undesirable results is the crucial first step before the minimum thresholds can be determined.	Comment acknowledged. The development of a dedicated groundwater dependent ecosystem monitoring network consisting of shallow monitoring wells is discussed in Chapter 6.5.2.9 Potential Management Actions, and Chapter 7.1.2.1 GSP Studies. Although the GSAs used the best available scientific data and information to assess potential GDEs within the Colusa Subbasin, significant data gaps exist in the understanding of the GDEs and the associated species. These data gaps include potential undesirable results impacting environmental beneficial users. The GSAs will seek to work with resource agencies, stakeholders, beneficial users and the public to refine the understanding of GDEs in the Colusa Subbasin, fill data gaps, re-evaluate sustainability thresholds, and develop PMAs with consideration of GDEs.

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539	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	5					(Summary of Comment 1.C, Groundwater Dependent Ecosystems and Interconnected Surface Waters) The GSP does not explain how the chosen minimum thresholds and measurable objectives avoid significant and unreasonable effects on surface water beneficial users in the subbasin, such as increased mortality and inability to perform key life processes (e.g., reproduction, migration). When establishing SMC for the subbasin, consider that the SGMA statute [Water Code §10727.4(l)] specifically calls out that GSPs shall include "impacts on groundwater dependent ecosystems".	See response to comment 538.
540	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	5					(Summary of Comment 1.C, Groundwater Dependent Ecosystems and Interconnected Surface Waters) When defining undesirable results for depletion of interconnected surface water, include a description of potential impacts on instream habitats within ISWs when minimum thresholds in the subbasin are reached. The GSP should confirm that minimum thresholds for ISWs avoid adverse impacts to environmental beneficial users. These recommendations apply especially to environmental beneficial users that are already protected under pre-existing state or federal law.	Comment acknowledged and addressed. Section 4.2.5.4 has been revised to state that the ISW monitoring network wells may be useful for monitoring groundwater levels near GDEs; however, a dedicated network of shallow monitoring wells will be developed specifically for GDE monitoring during implementation of the GSP. The development of a dedicated GDE monitoring network consisting of shallow monitoring wells is discussed in Chapter 6.5.2.9 Potential Management Actions and Chapter 7.1.2.1 GSP Studies. Although the GSAs used the best available scientific data and information to assess potential GDEs within the Colusa Subbasin, significant data gaps exist in the understanding of the GDEs and the associated species. These data gaps include potential undesirable results impacting environmental beneficial users and in-stream habitat. The GSAs will seek to work with resource agencies, stakeholders, beneficial users and the public to refine the understanding of GDEs in the Colusa Subbasin, fill data gaps, re-evaluate sustainability thresholds, and develop PMAs with consideration of GDEs.
541	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	3					(Summary of Comment 2, Climate Change) The integration of climate change into the projected water budget is insufficient. The GSP incorporates climate change into the projected water budget using DWR change factors for 2030 and 2070. However, the plan does not consider multiple climate scenarios (e.g., the 2070 extremely wet and extremely dry climate scenarios) in the projected water budget. While these extreme scenarios may have a lower likelihood of occurring, their consequences could be significant and their inclusion can help identify important vulnerabilities in the subbasin's approach to groundwater management.	Comment acknowledged. The GSAs have chosen to evaluate future scenarios of hydrologic uncertainty associated with projections of climate change using the 2030CT and 2070CT scenarios, consistent with GSP requirements (§354.18(c)(3)(A)). However, the GSAs acknowledge that there is significant uncertainty in future conditions related to climate change and other factors that will impact groundwater conditions and sustainability in the Colusa Subbasin. The uncertainty of future conditions is one of many reasons that GSP implementation will be based on adaptive management, described extensively in Chapter 6. It is also noted that the 2030CT and 2070CT climate change effects are simulated over the entire projected period. In reality, climate change effects will occur gradually with uncertain interannual changes.

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542	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	3					(Summary of Comment 2, Climate Change) Imported water should be adjusted for climate change and incorporated into the surface water flow inputs of the projected water budget. The sustainable yield is calculated based on the projected water budget with climate change incorporated. However, if the water budgets are incomplete, then there is increased uncertainty in virtually every subsequent calculation used to plan for projects, derive measurable objectives, and set minimum thresholds.	Comment acknowledged. As indicated in Table 3-9, surface water supplies in the future conditions 2030 and 2070 climate change scenarios were adjusted for climate change with reductions to simulate drought periods. However, the uncertainty of future conditions related to surface water supplies is one of many reasons that GSP implementation will be based on adaptive management. As described throughout the GSP (especially Chapter 6), the GSAs are committed to ongoing monitoring and implementation of projects and management actions to respond to changing Subbasin conditions.
543	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	3, 6					(Summary of Comment 2, Climate Change) The plan should incorporate climate change scenarios into projects and management actions.	Comment acknowledged. As described in Chapter 6 (Section 6.1), PMAs were developed with consideration for the 2070CT climate change scenario. Select planned PMAs were also simulated in the 2070CT climate change scenario to evaluate depletions of interconnected surface water along major waterways in the Colusa Subbasin (see Appendix 3G).

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544	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	4, 7					(Summary of Comment 3, Data Gaps) The consideration of beneficial users when establishing monitoring networks is insufficient, due to lack of specific plans to increase the Representative Monitoring Sites (RMSs) in the monitoring network that represent water quality conditions and shallow groundwater elevations around DACs, domestic wells, tribes, GDEs, and ISWs in the subbasin. The GSP should ensure that groundwater elevation and water quality RMSs are monitoring groundwater conditions spatially and at the correct depth for all beneficial users, and should plan to increase the number of RMSs in the shallow aquifer across the subbasin as needed to adequately monitor all groundwater condition indicators across the subbasin and at appropriate depths for *all* beneficial users. Monitoring should prioritize proximity to DACs, domestic wells, tribes, and GDEs.	Comment acknowledged and addressed. The GSAs have reviewed and selected new representative completions for several RMN well locations in the groundwater level monitoring network. Completions have been selected to be more representative of domestic well users, including DACs and tribes. Revisions have also created shallower MTs that are more protective of the 20th percentile depths of domestic wells. Section 4.2.5.4 has been revised to state that the ISW monitoring network wells may be useful for monitoring groundwater levels near GDEs; however, a dedicated network of shallow monitoring wells will be developed specifically for GDE monitoring during implementation of the GSP. Although the GSAs used the best available scientific data and information to assess potential GDEs and ISWs within the Colusa Subbasin, significant data gaps exist in the understanding of ISWs, GDEs, and associated species. As described in Sections 6.5 and 7.1.2, the GSAs will seek to work with resource agencies, stakeholders, beneficial users and the public to refine the understanding of GDEs and ISWs in the Colusa Subbasin, fill data gaps, and develop PMAs with consideration of these beneficial users. Plans for expanding the water quality monitoring network (Section 7.1.2.2) have also been revised to clarify that consideration of these beneficial users will be considered in
545	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	4, 7					(Summary of Comment 3, Data Gaps) The GSP should provide maps that overlay current and proposed monitoring well locations with the locations of DACs, domestic wells, tribes, GDEs, and ISWs to clearly identify potentially impacted areas.	Comment acknowledged. Maps of the DACs, tribal lands, GDEs, and surface waters are provided in Chapters 2 and 3. Surface waters are shown on maps in Chapter 4 with the interconnected surface waters and groundwater level monitoring network locations. As more information becomes available during plan implementation, the capability and appropriateness of monitoring sites to accurately and reliably monitoring conditions relative to specific areas of concern may be evaluated and addressed in future reports.

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546	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	4					(Summary of Comment 3, Data Gaps) The GSP should describe biological monitoring that can be used to assess the potential for significant and unreasonable impacts to GDEs or ISWs due to groundwater conditions in the subbasin.	Comment acknowledged and addressed. Although the GSAs used the best available scientific data and information to assess potential GDEs and ISWs within the Colusa Subbasin, significant data gaps exist in the understanding of ISWs, GDEs, and associated species. As described in Sections 6.5 and 7.1.2, the GSAs will seek to work with resource agencies, stakeholders, beneficial users and the public to refine the understanding of GDEs and ISWs in the Colusa Subbasin, fill data gaps, and develop PMAs with consideration of these beneficial users. Section 6.5 described opportunities for evaluating and planning biological monitoring.
547	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	6					(Summary of Comment 4, Addressing Beneficial Users in Projects and Management Actions) The GSP should clarify the planning horizon of the described domestic well mitigation program to ensure that it will proactively monitor and protect drinking water wells through GSP implementation.	Comment acknowledged. It is noted that Glenn and Colusa Counties both track and monitor well problems through a voluntary reporting program (described in the Preface). Additionally, it is noted that the GSAs have revised the MTs for chronic lowering of groundwater levels at several RMS sites, particularly around the Orland area. These revisions have created shallower MTs that are more protective of the 20th percentile depths of domestic wells. The GSAs still propose a potential domestic well mitigation program, though the precise policies, funding, and other factors underlying that program will need to be determined by the GSAs through a public, stakeholder-driven evaluation and decision-making process during GSP implementation. Mitigation could involve actions designed to secure reliable water sources for affected domestic well owners (through, for example, public water system consolidations funded by the GSA).
548	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	6					(Summary of Comment 4, Addressing Beneficial Users in Projects and Management Actions) For DACs and domestic well owners, the GSP should include a discussion of whether potential impacts to water quality from projects and management actions could occur and how the GSAs plans to mitigate such impacts.	Comment acknowledged. Additional text has been added to Section 6.2.2 to describe the anticipated effects of planned PMAs on water quality, including that experienced by domestic well users and DACs.

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549	Ngodoo Atume, Samantha Arthur, E.J. Remson, Amy Merrill, J. Pablo Ortiz-Partida, Danielle V. Dolan, Melissa M. Rohde, Kristan Culbert	Clean Water Action/Clean Water Fund, Audubon California, The Nature Conservancy, American Rivers, Union of Concerned Scientists, Local Government Commission	6					(Summary of Comment 4, Addressing Beneficial Users in Projects and Management Actions) The GSP should develop management actions that incorporate climate and water delivery uncertainties to address future water demand and prevent future undesirable results.	Comment acknowledged. As described in Chapter 6 (Section 6.1), PMAs were developed with consideration for the 2070CT climate change scenario. Select planned PMAs were also simulated in the 2070CT climate change scenario to evaluate depletions of interconnected surface water along major waterways in the Colusa Subbasin (see Appendix 3G). As the comment indicates, there is significant uncertainty in future conditions related to climate, water supplies, and other factors that will impact groundwater conditions and sustainability in the Colusa Subbasin. The uncertainty of future conditions is one of many reasons that GSP implementation will be based on adaptive management. The GSAs' adaptive management strategy for GSP implementation is described extensively in Chapter 6.
550	Samantha Arthur	Audubon California	3					Audubon appreciates that the GSA has identified and specifically included managed wetlands in maps and water budgets, specifically the three primary refuges: Sacramento National Wildlife Refuge, Delevan National Wildlife Refuge, and Colusa National Wildlife Refuge.	Comment acknowledged.
551	Samantha Arthur	Audubon California	3					The future condition water budgets should reflect CVPIA Full Level 4 water supplies being available and delivered to each of the three national wildlife refuges. The use of 2013 to represent unconstrained delivery conditions (e.g. see GSP Table 3-9, page 3-88) reflects deliveries to these refuges that are less than the CVPIA Full Level 4 mandated quantities. Annual Full Level 4 water supplies during unconstrained conditions are as follows: a. Sacramento NWR = 50,000 acre-feet, b. Delevan NWR = 30,000 acre-feet, and c. Colusa NWR = 25,000 acre-feet. During constrained conditions, these same refuges generally are provided 75% of this quantity, as stipulated in their water delivery agreements with the U.S. Bureau of Reclamation.	Comment acknowledged. Table 2-3 has been edited to acknowledge the expected availability of CVPIA Full Level 4 water supplies to the national wildlife refuges. A footnote has been added stating that although CVPIA Full Level 4 supply quantities are known, they were not used in the projected water budgets due to the uncertainty in those quantities actually being provided. In light of these uncertainties, simulating constrained surface water supplies was considered a more conservative approach to GSP planning, as more surface water supply availability would increase groundwater recharge and likely decrease groundwater pumping. It is noted that the GSP is a "living document," and will be revised over time, as needed, once more is known about actual future water supplies. It is expected that the C2VSimFG-Colusa model and water budgets will be updated periodically during GSP implementation to incorporate new information and revised assumptions as we learn more about conditions in the Colusa Subbasin.
552	Samantha Arthur	Audubon California	6				Table 6-2	Audubon appreciates that several of the listed projects included in Table 6-2 include identified opportunities for multi-benefit projects that provide water supply and wildlife habitat benefits.	Comment acknowledged.

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553	Samantha Arthur	Audubon California	2				Figure 2-8	Suggest modifying the color scheme or naming for the category "native" to distinguish the refuges from other "native" areas as the refuges are distinctly different land uses than the traditional native upland areas, for instance, in the southwestern portion of the subbasin. Private managed wetlands and managed wetlands in U.S. Fish and Wildlife Service Management Areas that have federal easements are currently not identified in land use or jurisdictional maps.	Comment acknowledged and addressed.
554	Samantha Arthur	Audubon California	2		page 2-11		Table 2-3	Since the three national wildlife refuges are mandated to receive stipulated quantities (though have yet to achieve them), this table should also list the CVPIA Full Level 4 quantities of: Sacramento NWR = 50,000 acre-feet, Delevan NWR = 30,000 acre-feet, and Colusa NWR = 25,000 acre-feet. While the historic average deliveries are useful for baseline understanding, modeling of future conditions should include the full water supplies for these three refuges.	Comment acknowledged and addressed. Please see the response to comment 551.
555	Samantha Arthur	Audubon California	3		Page 3-13	line 32/33		The term "land" should be added to the end of the sentence to result in "federal wildlife land."	Comment addressed in the GSP section indicated.
556	Samantha Arthur	Audubon California	3		Page 3-88		Table 3-9	The future condition water supplies for the three national wildlife refuges should reflect the CVPIA Full Level 4 water supply. Deliveries in 2013, represented as a Shasta Non-critical year, did not result in Full Level 4 deliveries to these refuges. The CVPIA Full Level 4 quantities include a portion that is labeled "Level 2" that reflects delivery of CVP project water, and a portion labeled "Incremental Level 4" (the difference between Full Level 4 and Level 2) that can come from other sources. The GSP will need to make reasonable assumptions whether the Incremental Level 2 supply will be derived from other surface water sources or from groundwater, though either is possible.	Comment acknowledged. Please see the response to comment 551.
557	Samantha Arthur	Audubon California	3	Section 3.3.3.1 Historical (Water Budget)	Page 3-89			Under "Agricultural Water Demand" the following sentence is included: "For ponded land uses (rice and managed wetlands), pond depths and pond drainage are also considered to simulate demands." Under the "Current Conditions" (Section 3.3.3.2) and "Future Conditions Scenarios" (Section 3.3.3.3) water budget discussions, this same language is missing. Did these budgets recognize managed wetlands in a similar fashion as described for the historical budget? If so, we suggest adding the same sentence to each of the other water budget descriptions for clarity.	Comment acknowledged and addressed. Clarification has been added to Sections 3.3.3.2 and 3.3.3.3 to verify that, yes, the current and future conditions water budgets did recognize managed wetlands in a similar fashion as described for the historical budget.

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558	Samantha Arthur	Audubon California	3		Page 3-96		Table 3-11	As a result of including the CVPIA Full Level 4 water supplies for the national wildlife refuges, the values for the various future conditions for "Sacramento River Diversions" and "Groundwater Pumping – Managed Wetlands" as well as the "Evapotranspiration – Managed Wetlands" may all change. The table should be updated accordingly.	Comment acknowledged. Please see the response to comment 551. It is also noted that adding CVPIA Level 4 supplies to the water budget will increase total surface supply to the subbasin and reduce estimated future groundwater pumping, so the approach used in the GSP water budgets represents a relatively worse case scenario for groundwater sustainability planning purposes.
559	Samantha Arthur	Audubon California	3		Page 3-97		Table 3-12	Similar to the prior comment, values in this table for the future conditions would be expected to change when the CVPIA Full Level 4 water supply quantities are incorporated	Comment acknowledged, please see the response to comment 558.
560	Samantha Arthur	Audubon California	6	Section 6.5.2.3	Page 6-84 to 6-86			Several demand reduction concepts are initially outlined in this section. Audubon suggests the following be considered associated with each suggested method: 1. Allocation: Use of groundwater by managed wetlands should not be restricted without adequate replacement with surface water sources, especially the national wildlife refuges. Managed wetlands in the Colusa subbasin provide invaluable benefits to the Pacific Flyway. 2. Allocation with a market: If a market is created and managed wetlands are assigned an allocation, such parcels should be able to participate in a market to optimize the use of their allocations for achieving habitat objectives, but managed wetlands should not be required to participate in a market to secure the water they need. 3. Land repurposing: Strategic siting of where irrigated lands are retired and others are kept in production should consider the potential benefits to wildlife. Areas surrounding protected areas, such as the Sacramento, Delevan and Colusa National Wildlife Refuges, should be prioritized habitat benefits. 4. Financial incentives: Public beneficial uses such as managed wetlands should not be subject to financial conditions that lesson the public benefit otherwise achieved on the lands.	Comment acknowledged. The following statements were added to Chapter 6, Section 6.5.2.3: "Allocation design may include specific considerations for managed wetlands and other habitat benefits uses of water." "Other market rules might consider habitat and ecosystem service benefits." "Other land repurposing program considerations might consider strategic location of repurposed lands considering proximity to protected areas (e.g., National Wildlife Refuges)." and "Financial incentives could consider public benefits (e.g., habitat) separately from private benefits (e.g., irrigation) of water use."
561		City of Orland	5					Chapter 5 states that the subbasin in is currently being managed sustainably without undesirable result despite over 150 domestic wells going dry this summer alone as 2021 data is not yet included in plan development. It is notable that a key partner in the draft plan explained at the October 13th public meeting. "The current actual drought is more compelling than modeled future sustainability challenges."	Comment acknowledged. Please see the response to comment 318.

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562		City of Orland						The plan's allowance for up to 20% of domestic wells going dry may be understandable in light of the age and depths of most of the wells. However, depletion of up to 5% of groundwater storage (over 5 years) and inelastic subsidence of up to½ foot per year were also considered acceptable in the July version of the draft plan, apparently due to an estimate that we still have 26-140 million AF (acre feet) of water in the aquifer. Consultants to the GGA suggest that 26M AF is reliably established, but the estimate of upwards of 140M AF is more of a projection. We are concerned about any reliance on the 140M AF estimate, and suggest that the subbasin should be more conservatively managed to an assumption of 26M AF.	Comment acknowledged. Please note that the GSAs have since revised the MTs and MOs for subsidence at all RMS benchmarks (please see the response to comment 477) and have updated the MTs for groundwater levels at several RMS wells, including those around Orland (please see the response to comment 564). Change in groundwater storage is monitored and managed in proxy through management of groundwater levels according to these revised SMC. However, recognizing the data gaps in the basin setting and the uncertainty of future conditions, GSP implementation will be based on adaptive management (see the response to comment 468). The GSAs have also proposed a number of studies to close data gaps during GSP implementation (see Chapter 7), including a study of infrastructure sensitivity to land subsidence.
563		City of Orland						We welcome the recent consultant proposal, adopted by the Board October 11th to revise the plan with an amendment tightening the measurable objectives (MO) and minimum thresholds (MT) for inelastic subsidence, as the draft plan's original allowance for excessive subsidence would have exposed municipal services like water, wastewater and storm drainage to unacceptable risk of severe disruption.	Comment acknowledged.
564		City of Orland						City of Orland observes that the draft plan as written does not appear to adequately protect the integrity of domestic and municipal drinking water wells. With most said wells being less han 200' deep, more than 20% would be dry by the time well depth MO were reached and almost all would be dry by the point MT were reached. It would seem that the MO and MT for well depths should be reconsidered and revised to a more conservative and protective standard.	Comment acknowledged. Please note that the GSAs have revised the MTs for chronic lowering of groundwater levels at several RMS sites, particularly around the Orland area. These revisions have created shallower MTs that are more protective of the 20th percentile depths of domestic wells, considering historical groundwater levels since the mid-2000s. The GSP also plans to manage groundwater levels to the higher MO levels, which are shallower than 200 ft bgs at all wells and considerably shallower at most. If harm does occur to domestic wells, the GSAs propose implementing a domestic well mitigation program, though the precise policies, funding, and other factors underlying that program will need to be determined by the GSAs through a public, stakeholder-driven evaluation and decision-making process during GSP implementation. The GSAs also reiterate that they are planning an adaptive management strategy for GSP implementation. Please see the response to comment 468.

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565		City of Orland						Finally, we commend the GGA Board for its many projects in progress, planned and contemplated, as laid forth in Chapter 6. However, there do not yet appear to be real "triggers" that would commit the GGA to certain substantive actions when passing MO and approaching MT. We hope the GGA works with the State and consultants in coming years to develop and specify such triggers as a backstop to recharge projects in order to truly protect the precious drinking water resources on which the people of Orland and Glenn County rely.	Comment acknowledged. The GSAs plan to select and implement PMAs to effectively address the specific concerns that arise in the Subbasin, with regard for the specific sustainability concern and relative costs and benefits. The uncertainty of future conditions is one of many reasons that GSP implementation will be based on adaptive management (see the response to comment 468). Planned PMAs (with a timeline and plans for action) alone are expected to address sustainability concerns over the projected future period (see Sections 6.1 through 6.3); however, other potential PMAs are available as needed. Implementation of many potential PMAs, including demand management, involve major public policy questions that will require evaluations of conditions in a public, stakeholder-driven process. The precise decisions for whether and how potential PMAs would be initiated will be determined by the GSA boards through a stakeholder-driven process during GSP implementation.

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2B-2. Letters

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AQUALLIANCE
DEFENDING NORTHERN CALIFORNIA WATERS

October 31, 2021

Lisa Hunter, Program Manager
Glenn Groundwater Authority
lhunter@countyofglenn.net

Mary Fahey, Program Manager
Colusa Groundwater Authority
mfahey@countyofcolusa.com

Re: Draft Colusa Subbasin Groundwater Sustainability Plan

Dear Ms. Hunter and Ms. Fahey:

AquAlliance, the California Sportfishing Protection Alliance, and the California Water Impact Network (hereinafter AquAlliance) submit the following comments and questions on the draft Colusa Subbasin Groundwater Sustainability Plan ("Colusa GSP" or "Plan"). There are serious weaknesses in the Plan that require significant changes to the document, without which the public and policymakers are truly left in the dark and dangerous consequences are obfuscated.

The information and analysis provided in Section A discuss the future changes described in the draft GSP for the Colusa Subbasin groundwater system and the overlying surface waters, and the implications of the proposed sustainability objectives and minimum thresholds. The draft Colusa GSP presents a rosy scenario suggesting that future precipitation, evapotranspiration, and surface water supplies will adjust to the 2070 Central Tendency climate change scenario provided by DWR and keep groundwater levels stable. However, elsewhere in the Plan is material that indicates the proposed GSP management of the subbasin under the 2070 Central Tendency scenario will cause detrimental changes to both surface waters and groundwater. The 2070 scenario sustainable management of subbasin assumes that annual average groundwater pumping will increase approximately 13%, while allowing declines in groundwater below the historical lows. The groundwater storage will be partially sustained by increases in seepage from overlying streams and a reduction in groundwater accretion to the streams.

Section B demonstrates the serious deficiencies in definitions of and plans to resolve conflicts. This failure will lead to escalating costs to residents, farms, and businesses to protect access to groundwater by deepening wells or drilling a replacement, plus likely legal expenses. Adam Keats and Chelsea Tu discussed this at length in 2016: "[i]f a medium or highpriority [sic] groundwater basin becomes a multi-use basin that includes imported water rights, overlying rights, and interconnected instream rights, the relationship between those rights, and the priority given to each of the rights-holders, remains unresolved by the Act. The responsibility for

identifying and addressing the foreseeable legal and use conflicts between imported water, overlying use, and/or in-stream use where groundwater interconnects with surface water is thus left to the GSAs, or ultimately, the courts."[1]

Section C provides historic information on some of the destructive planning and practices that have transpired in the Sacramento Valley that have caused groundwater basins elsewhere in California to become private assets as opposed to public commons. It is a tragedy in the making to have local government, the cities of Colusa, Orland, Williams, and Willows and the counties of Colusa and Glenn, promote a Plan that accepts the failure of 20 percent of the domestic wells and the loss of almost 1,000,000 AF of groundwater storage by 2070.

A. Sustainability objective and threshold for undesirable results

1. The Draft GSP has a lot of words but little action, except recharge projects. The sustainable operation of the subbasin is described as [*p]rojects and management actions that the GSAs **could** implement to ensure that the Colusa Subbasin is operated sustainably (i.e., to avoid undesirable results) are described in Chapter 6. The Introduction to Chapter 6 describes an adaptive management approach for implementing projects and management actions that will be informed by monitoring of groundwater conditions and will lead to implementation of **additional projects if Measurable Objectives (MOs) are not being maintained and Minimum Thresholds (MTs) are being approached** (emphasis added).*

   > *An adaptive management approach **recognizes that undesirable results do not currently exist in the Subbasin**, and it is **uncertain that undesirable results will develop in the future** (emphasis added).* Section 5.2.1, pages 5-3 and 5-4.

   The sustainability management actions given in Chapter 6 are all "**Potential Management Actions**" (Section 6.5.2, page 6-81), and all are ***currently in the early conceptual stage***, so there is no understanding of the benefits, costs, the funding sources, or specifics about how the actions will maintain sustainable groundwater levels (emphasis added).

2. Section 6.1 on Project and Management Actions Development Approach gives the true goal: **pumping more groundwater, 13% more, to make up for evapotranspiration (ET) increase due to climate change**. The draft GSP talks about climate change and then gives a selection of water budget values with and without climate change, Table 6-1 (page 6-2). See page 1 of AquAlliance Exhibit A. The draft GSP assumes that rainfall will increase with the 2070 climate change scenario to meet 74% of the addition ET from climate change, (75 taf/yr / 102 taf/yr = 0.735). The draft GSP says that stream accretion (groundwater that discharges to the steams) will remain positive with and without climate change, but with the 2070 climate change it decreases 48,000 acre-feet / year (AFY) approximately 38% from the future conditions without climate change. That's a lot of decrease, but that's only 0.5% of the Sacramento River flow, so a cynic might ask, why worry (page 6-2)? It isn't clear how the stream depletion monitoring program will interact with the stream accretion assumptions.

[1] Keats, Adam et al., 2016. *Not All Water Stored Underground is Groundwater: Aquifer Privatization and California's 2014 Groundwater Sustainable Management Act*. p. 98.

The stream depletion monitoring program only monitors groundwater levels, but it ***should*** also include monitoring of stream flow changes, i.e., seepage and accretion changes, to validate the assumptions about climate change and sustainability (emphasis added).

3. The groundwater monitoring for sustainability focuses on domestic wells and stream depletion, but not much on subsidence. The MOs and MTs for domestic well sustainability use point data of historical groundwater depth and hydrographs for 48 Representative Monitoring Network (RMN) wells out of the 104 monitoring wells identified in the subbasin, listed on Table 5-2 and 4-1, respectively. The MOs are defined at the middle of the historical range of groundwater levels. (See pdf pages 56 through 67, and 105 through 116 in Appendix 5B for graphic presentation of MOs and MTs with values from Table 5-2.) The MTs are developed by taking the greater depth of either the depth where 20% of the domestic wells within the Thiessen polygon around each of the 48 RMN monitoring wells are shallower, or the depth at 50% of the historical range below the deepest groundwater level prior to January 1, 2015 (and sometimes 2016) (Section 5.4.1, pages 5-19 through 5-21). These GSP standards for the MTs effectively means that ***domestic wells in the Colusa subbasin can experience groundwater levels deeper than historical levels and still be considered sustainable***.

4. The draft GSP requires that the determination of when an MT is exceeded and creates an ***undesirable result*** for domestic wells, stream depletion, water quality, or subsidence, that the monitoring sites, at either monitoring wells or survey benchmarks, must be evaluated in sub-groups of a minimum size and minimum duration, see Table 5-1 (see page 2 of AquAlliance Exhibit A), and all monitoring sites must **exceed their respective MTs together** before an ***undesirable result*** can occur. The draft GSP identifies the monitoring wells, but doesn't identify the monitoring well groups, or define criteria for the making the groups other than state the minimum number needed in a group. The draft GSP does say that once formed the groupings can't change. Except for subsidence, the MTs for each monitoring site are different, Tables 5-2 and 5-3. See pages 3 through 5 of AquAlliance Exhibit A. The requirement that all monitoring sites must **exceed the MTs together** implies that the monitoring site with the greatest MT depth will likely control the occurrence of an ***undesirable results***. In other words, until the deepest or greatest MT value is exceeded, the group hasn't exceeded the collective MT and therefore no ***undesirable result*** has occurred (emphasis added).

   For example, a group of 12 monitoring wells in the northern portion of the Colusa subbasin surrounding Orland, the last 12 wells listed in Table 5-2, have MTs depths that range from 90 to 356 feet, or elevations from 71 to -108 feet amsl. (See pages 5 and 6 of AquAlliance Exhibit A) The MT listed in column 5 is the greatest value of either of the right two columns in Table 5-2. Note that the MT depth selected for these 12 wells are all at or greater than the depth of the 20th percentile of domestic wells. This means that if these 12 wells are a domestic well monitoring group, then an ***undesirable result*** can't occur until the depth to groundwater at the well with the greatest MT depth, well 21N04W12A004, exceeds 356 feet, or an elevation lower than -108 feet (columns 4 and 5 in Table 5-2) for 24 consecutive months. This maximum depth is significantly greater than the 20th percentile depth for the surrounding domestic wells, column 4 versus column 11.

The ***all-or-none*** requirement makes it possible that the depth to groundwater in the other 11 wells could decline far below their MTs, perhaps even exceed a depth of 356 feet, yet not trigger an ***undesirable result***. In fact, the groundwater elevation contour maps for spring and fall 2020, Figures 3-24 and 3-25 (see pages 8 and 9 of AquAlliance Exhibit A) show that the elevations decline beneath Orland from a high point on the northwest side of the town at approximately 240 to 220 feet in spring and fall 2020, respectively. The groundwater well 21N04W12A004 with the lowest MT elevation, -108 feet, is in southwest of Orland. See page 8 of AquAlliance Exhibit A. The requirement that all 12 RMN wells in the group exceed their MTs before an ***undesirable result*** occurs, seems to allow for the low southwest of Orland to either expand laterally, deepen significantly (decline approximately 190 ft or greater, from current elevation of approximately +80 ft down to the MT of -108 ft) before the MT at well 21N04W12A004 is exceeded when mitigation action(s) would be required. It is possible that another well in the group of 12 will be the last to exceed its MT, but the concept is still the same. The depth to groundwater can exceed the MT depths at 11 out of the 12 RMN wells in a group, and still the groundwater is considered sustainable, regardless of the maximum depth to groundwater in the group's Thiessen polygons (emphasis added).

5. The draft GSP has an economic analysis in Appendix 5C (pdf pages 144 through 155) to apparently reason why the MTs are set at the lowest level of either allowing the shallowest 20% of the domestic wells to go dry and/or 50% of the historical water level range below the lowest depth before January 2015 (or 2016). The GSP states that …*[t]he purpose of the analysis was to establish what share of domestic wells in the WCR database may have been* ***previously dewatered and/or are no longer used***. (see page 3 in Appendix 5C). Are there any facts to document that these wells are no longer in use or previously dewatered? DWR has a web site where people can volunteer that their well went dry (https://mydrywell.water.ca.gov/report/). There are 1,589 wells out of a total of 1,677 wells in the Orland area that are assumed to have gone dry according to Table 1 in Appendix 5C near monitoring well 22N03W24E001 – ***95% of the wells.*** See page 3 of AquAlliance Exhibit A for well locations. The assumption that the wells previously went dry when groundwater was at the lowest pre-2015 point, allows the GSP to reason that an MT that allow loss of up to 20% percent of the shallow domestic wells is ***cost-effective***, and ***an acceptable balance between avoiding significant and unreasonable impacts to domestic (and other shallow) wells and allowing sufficient flexibility for conjunctive management of Subbasin surface and groundwater supplies*** (page 9 in Appendix 5C). The economic analysis concludes on page 9 of Appendix 5C that: (1) MT groundwater levels shouldn't be raised because it's not cost effective. We ask, cost effective to whom?; (2) the groundwater levels will be managed to the higher MOs levels and therefore no harm will occur to domestic wells; but (3) if harm occurs, then the **potential** management action that the GSAs **should** develop a domestic well mitigation program (see Chapter 6) would provide a safety net to **potentially** compensate for impacts to domestic wells. It appears to AquAlliance that the GSP has decided that the shallow domestic wells can go dry, and the GSAs **might** find a way to help the well owners, but they aren't ready to commit to the compensation portion (emphasis added).

6. The *undesirable results* for domestic wells protection are only triggered when the groundwater levels in 25% (12 of the 48 network wells) are continuously below their MTs for 24 consecutive months, Table 5-1. Because groundwater levels naturally fluctuation with season, the 50% range has been established at each monitoring well, this standard seems to also say that the seasonal fluctuation about the MT depth, i.e., the GSP Margin of Operational Flexibility (MOF), is not considered an *undesirable result*? For example, well 22N03W24E001, the closest well to Orland (see Figure 4-2, page 3 of AquAlliance Exhibit A), has a MOF of 79 feet with an MT of 273 feet. See page 5 of AquAlliance Exhibit A.

   Answers to the following questions are crucial for the public, policy makers, and AquAlliance members:
   - If the depth to groundwater seasonally fluctuates for years about say 270 feet, from a depth of 191 to depth of 349 feet, isn't the period, presumably summer months, when groundwater drops to 349 feet an *unreasonable result*? Especially because the 20% domestic well depth is only 90 feet, 259 feet higher than this potential seasonal drop in groundwater.
   - What happens if the seasonal decline is greater than the 50% range?
   - How many of the domestic wells in the well 22N03W24E001 Thiessen polygon will go dry with groundwater at a depth of 349+ feet?

7. The draft GSP appears to plan for subsidence throughout the subbasin to be as much as 10 feet over the next 40 years with a subsidence MO set at 0.25 feet per year for each of 63 survey benchmarks. The subsidence benchmark MTs are set at 0.50 to 0.60 feet per year or as much as 20 to 24 feet over the next 40 years, depending on the current rate of subsidence, Table 5-1. See page 2 of AquAlliance Exhibit A. The subsidence MTs imply that groundwater levels are considered "sustainably" managed until subsidence exceeding 20+ feet over an area of at least 15% of the benchmarks, 9 out of 63 benchmarks. The benchmarks seem uniformly distributed across the subbasin, Figure 3-31(page 10 of AquAlliance Exhibit A), so the area subsidence will likely need to be at least 15% of the total basin area or approximately 138,000 acres (the total subbasin area is 918,380 acres – DWR B118). Section 5.4.5 says that the 9 of 63 benchmarks *must be the same subset of locations not any combination of nine locations*. This seems to say that a large area of subsidence needs to develop before any "action" to stop subsidence will be taken. As with the other network groups, the GSP doesn't identify which benchmark belong to each group of 9.

   The Management Actions in Chapter 6 that affect subsidence include In-Lieu recharge or direct surface water recharge, and reviewing the County well ordinances, see Table 6-3 (page 6-12). The In-Lieu and direct surface water recharge assume that this surface water for recharge is available to divert from the rivers. This assumption needs to be verified given all the other requirements on the river flows. There doesn't appear to be any Management Actions other than recharge to mitigate subsidence, no proposal to **possibly** create a subsidence mitigation program like the **possible** domestic well compensation program. The draft GSP also doesn't appear to be concerned about damage from subsidence to infrastructure, homes, stormwater flood control, or levees that might be impacted by 10+ feet of subsidence. As with domestic wells, the trigger required for an ***undesirable result*** is the ***all-or-none*** monitoring group exceedance of the MT for a group of least 9 benchmarks. This

ignores that fact that subsidence often occurs around a lowest point that then spreads outwards. The draft GSP doesn't give a maximum rate or depth of subsidence allowed for the subsidence group of 9 benchmarks or between the benchmarks, just an annual average. With the advent of InSAR radar to measure changes in ground elevation, Figure 3-32, the subsidence in between benchmarks can now be measured. See page 11 of AquAlliance Exhibit A. The draft GSP doesn't indicate whether the subsidence rate for determining whether an **undesirable result** has occurred will be normalized over the years since 2015, over all 40 years of the GSP plan, over every 5 years with GSP updates, or considered as a separate annual value. Clarification is needed on the maximum rate of subsidence at any point that will trigger an **undesirable results** and the duration for averaging (emphasis added).

8. The draft GSP requirement to consider monitoring sites as a group when determining whether the MTs have been exceeded may create areas where the number of sites are too small to allow for the groups to encompass all monitoring sites, and/or create scientifically logical groups. For example, try creating groups of 9 or more from the subsidence benchmarks in Figure 3-31 that encompass the two known areas of subsidence around Arbuckle and Artois, see Figure 3-32. See pages 10 and 11 of AquAlliance Exhibit A. Now, fill in the rest of the Colusa subbasin with groups of 9+ subsidence benchmarks. Do the shapes of these other subsidence groups make sense? Except for the two around the known high subsidence areas, the other groups are likely very irregular in shape and may not properly encompass the other areas of greatest groundwater pumping, or the other areas with the greatest potential for subsidence, see Figure 3-23 (see page 12 of AquAlliance Exhibit A). To have the necessary minimum numbers to form a subsidence group, more distant and unrelated benchmarks would likely have to be combined. The requirement for a minimum of 9 benchmarks in a group along with the irregular shape of the groups could result an area of subsidence having to be monitored by two or more groups. The draft GSP should give the boundaries of the subsidence and groundwater monitoring well groups to show that this group monitoring scheme to determine a trigger of **undesirable results** is practical and show that it will work (emphasis added).

9. The domestic well monitoring program assigns to each monitoring well a portion of the subarea based on a Thiessen polygon network. The draft GSP doesn't appear to have a map of the shapes of these polygons or list the area of each polygon. The Table 1 in economic analysis of Appendix 5C does lists the total number of domestic wells associated with each monitoring well and the number of domestic wells that are shallower than the depth to the lowest groundwater level before January 2015 (or 2016). There is an assumption that these domestic wells are in the associated monitoring well's polygon, but the spatial distribution of the domestic wells is unspecified. The draft GSP doesn't give a distribution of the depths of these domestic wells for each polygon, such as a histogram or frequency table by depth, so the impact of an incremental decline in groundwater in each polygon as it goes towards the MT, or lower, is unknown. The draft GSP should give the boundaries of the Thiessen polygons for the monitoring wells that are used to measure groundwater levels for either domestic wells or stream depletion, and provide a table of the number and depths, with cumulative frequency for domestic wells in each polygon.

10. The draft GPS assumes and plans to allow domestic wells to go dry even when the MOs and MTs are achieved. The draft GSP says that managing to the MOs through actions yet to be determined, will minimize the number of wells that dewater, i.e., go dry, see Chapter 6.5.2.1 (page 6-81). The depth of the screens for some of the 48 RMN groundwater monitoring wells in Table 5-2 are given in Table 4-2, Chapter 4 pages 7 through 10. Eighteen of the RMN wells are screened deeper than 700 feet below the ground surface (bgs), 15 are screened from 250 to 700 feet bgs, and 15 are screen shallower than 20 feet bgs. ***The draft GSP doesn't explain why the deep screened monitoring wells are selected to monitor shallower aquifers used by domestic wells*** even, when there is often a shallow monitoring well at the same location, see Figures 4-2 and Figure 4-8. See pages 3 and 6 of AquAlliance Exhibit A. Seven of the wells in the domestic well monitoring network are shallow and are also part of the 12-well stream depletion monitoring network, Table 5-3. See page 7 of AquAlliance Exhibit A. The remaining 5 shallow wells in the stream depletion monitoring network appear to have deeper companion wells that are part of the 48 RMN network. While the MOs for the stream depletion network in these seven shallow wells are nearly equal to the MOs for the domestic well network, the MTs are very different and much deeper, (compare values in Table 5-2 to Table 5-3). The draft GSP doesn't clearly explain the differences in any Management Actions needed to maintain the sustainability of domestic wells and interconnected surface waters that result from the different MTs at these same shallow monitoring wells. Perhaps, because the Management Actions are ***currently in the early conceptual stage (emphasis added).***

11. The draft GSP proposes to investigate the **possibility** of compensating domestic well owners for impacts from groundwater production. Whether this compensation program is ever created, a well owner that needs to replace a dry or broken well will need to know the depth for that new well, so that it won't go dry again under the GSP. That depth should be related to the MT of the polygon where the new well will be constructed. However, as discussed above in comment 4, the MT for the well's polygon may not be the maximum future "sustainable" depth of groundwater. It will likely be deeper because of the monitoring group ***all-or-none*** requirement to trigger an ***undesirable result***.

    - So, what is the recommendation in the GSP for how the well owner should determine the depth for the new well?
    - What assurances does the GPS give to the domestic well owner that the depth for the new well will be sufficient to ensure a future domestic water supply?
    - Can the well owner assume that if they follow the GSP's recommended depth procedures for a new domestic well, they will receive compensation if the depth to groundwater is ever exceeded? (emphasis added)

12. The Management Action for the Domestic Well Mitigation Program, Section 6.5.2.1, states that the GSP (GSA) will ***investigate implementing a domestic well mitigation program*** with funding to mitigate dewatered well (based on yet undefined eligibility) (emphasis added).

    - Will the GSP also include a subsidence mitigation program that financially compensates homeowners and landowners for damage from subsidence?

- Will there be funds to repair infrastructures such as roads, bridges, levees, stormwater drainage, pipelines, home and building foundations, walls and roofs, domestic, municipal, industrial, and agricultural wells?
- What are the possible sources of subsidence mitigation funding, a consumption tax, a property tax, a flat tax per well?
- Will the subsidence fund be designed to anticipate the cost of mitigation repairs over the full 40 years, that is, mitigate the planned 10 to 20+ feet of subsidence?

13. Table 4-2 lists the characteristics of the monitoring wells in the GSP network, a total of 104 completions wells (page 4-3). However, only 48 completions are used for the domestic well network and another 5 for the stream depletion network. Only those 53 domestic and stream depletion wells have sustainability criteria, MOs and MTs.

    Answers to the following questions are crucial for the public, policy makers, and AquAlliance members:
    - Why weren't MOs and MT calculated for the remaining 51 monitoring wells?
    - Why are the other 51 wells included in the "groundwater monitoring network?"
    - How will measurements in these other 51 wells be used in the groundwater monitoring program?

14. Attachment A of Appendix 5B shows on 48 hydrographs how the groundwater level thresholds are developed and includes the numbers given in Table 5-2. The hydrographs in Attachment A of Appendix 5B gives the values of the MO and MT and graphically show their implications. Of interest are those wells where the MT based on the 20% shallower wells depth is below the 50% range depth. This occurs at 30 of the 48 wells. ***This seems to say that "sustainability" includes dewatering, drying up, 20% of the domestic wells.***

15. The selection of the MO and lowest point for the MT appears to use groundwater levels after January 1, 2015 when it produces a lower elevation than measurement before the SGMA Benchmark date. For example, monitoring well 21N02W36A002 (hydrograph on pdf page 61 in Appendix 5B; see page 13 of AquAlliance Exhibit A) has significant declines in groundwater elevation during 2015, but the other years have minor seasonal variation. The MO is set as the "average" that appears to include the over pumping in 2015, which doesn't reflect the historical groundwater condition. The 50% range also appears to include the 2015 pumping decline and the lowest point appears to be in 2015, after January 1, 2015. The use of the 2015 overdraft seems to make the post-January 2015 conditions the acceptable standard, rather than require them to be corrected. But even if the proper MO and MT were selected for this well, the 20% shallower groundwater level at 81 feet is approximately 50 feet lower than the seasonal average would be if following the GSP's requirement to take the lowest MT depth. How many of the MTs in the 30 out of the 48 Representative Monitoring Network (RMN) (see page 4 of Appendix 5B) wells are calculated using a post-January 1, 2015 historical low can't be determined because the GSP doesn't clearly tabulate the elevations of the lows used for the MT calculation. In addition, the MT calculation use the entire historical range of groundwater levels rather than the most recent 5 years as is done with the MOs, see Table 5-1. The use of the entire historical record brings the pre-2015 historical decline in groundwater level into the calculation of 50% range, which doesn't represent the actual

current post-January 2015 conditions, see the hydrograph for well 20N03W07E007on pdf page 56 in Appendix 5B, as an example. See page 14 of AquAlliance Exhibit A. The use of all historical data to calculate the 50% range appears to be continuing the pre-SGMA impacts into the GSP management actions. **This seems to invert the concept that the GSP doesn't have to remedy pre-2015 impacts by making the GSP continue the pre-2015 impacts in the determination of sustainability criteria (emphasis added).**

16. MT thresholds assume that the definition of "sustainable" means that up to 20% of the domestic wells can go dry. They make arguments that this number will be less, 12% (see pages 4 and 5 in Appendix 5B). But the economic analysis on page 3 in Appendix 5C apparently removed wells with depth shallower than the pre-January 2015 low (or maybe the analysis included the 2015 low, see comment 15) because it assumes these wells went **dry with the lowest groundwater level and/or are no longer used**. The economic analysis doesn't address if these wells recovered, nor document that these wells actually went dry. Remembering that the 20% depth is taken in a deep well, not a shallow water table well. To evaluate the groundwater level in domestic wells, you need to use a wells screened at the depth of the domestic wells, for example the stream depletion monitoring wells, Table 5-3. Table 1 in Appendix 5C says the subbasin average for wells with total depths shallower than the lowest groundwater level before January 2015 is a "share" of 46%. The "share" around each monitoring well varies widely in Table 1 of Appendix 5C, from zero to as much as 97%.

17. The economic analysis in Appendix 5C also says that the portion of the wells shallower than the proposed MT is in aggregate 12% of the domestic wells, not 20% (see pages 4 and 5). This calculation is apparently saying that the number of wells with total depths greater than the pre-January 2015 low (or maybe pre-2016 low), but less than the maximum of the selected MT depth, is lower if either the 20% shallower depth or the historical low plus 50% range depth. This is 8% fewer wells than when the 20% shallower criteria was used by itself. Histograms of RMN and domestic well depths, and cumulative frequency depth statistics are needed to understand the validity and significance of this economic analysis.

    The rationale for setting the MTs acknowledges that for 30 of the 48 RMN wells there is a possibility that more than 20% or the domestic wells will be shallower and be at risk for dewatering (going dry) (page 4 in Appendix 5B). But then the GSP says that wells shallower than the historical low before January 1, 2015 were removed from the analysis, which then resulted in an "aggregate" of approximately 12 percent of the wells potentially go dry. The GSP states that this is much better than 20% going dry and is viewed as an … *acceptable balance between avoiding significant and unreasonable impacts to domestic (and other shallow) wells and allowing sufficient flexibility for conjunctive management of Subbasin surface and groundwater supplies.* A review of the statistics in Table 1 of Appendix 5C for wells associated with each of 48 RMN wells finds a large range in the percentage of wells that are shallower than the historical low before January 2015, ranging from zero to 97%. The aggregate for these dry wells in Table1 is 46%. Does this average give the GSP's estimated future reduction in domestic well reliability within each RMN well polygon? How does the 12% aggregate for 20% shallower dry wells relate to the 46% well shallower than the lowest pre-January 2015 groundwater level? What are the depths, percentiles and the

number of wells that could possibly go dry for each of the RMN well polygons where the MTs are based on the 50% range below the historical low, and/or based on the 20% shallower depth?

18. When 50% of the historical range is subtracted from the lowest pre-January 2015 groundwater level (maybe pre-2016) to calculate the MT, method selected for 30 out of 48 RMN wells, it creates a ***lower-than-the-lowest*** sustainable threshold. Domestic wells could now experience groundwater levels below the historical lowest depth, and the GSP would still find this condition sustainable, **not an undesirable result**. By this logic, the GSP seems to say that at least the number of wells listed in Table 1 of Appendix 5C will go dry whenever groundwater levels go below the lowest historical elevation and possibly more when the 50% threshold depth sets the MT. As if this isn't enough, the MT levels in 18 of the 48 wells are set at the 20% shallower wells threshold whenever that depth was greater than the lowest+50% depth (see page 4 in Appendix 5B). Does this mean that in those areas around the monitoring wells listed in Table 1of Appendix 5C that have a "share" less than 20% (0.20) and may have additional wells dry whenever the 20% shallower depth is used to set the MT? Obviously, the future cumulative average of dry wells under the GSP will be **greater than the 46% of the total wells** (emphasis added).

19. Does the Table 1 in Appendix 5C total of 2,925 wells being shallower than the historic low groundwater level before January 2015 agree with the statistics on dry or no longer used wells collected by DWR or any government agency? DWR does have a website where dry wells can be reported, which appears to list far fewer dry wells in the area around Orland. As an example, Table 1 shows that for well the RMN well 22N03W24E001 near Orland, 1,589 out of a total of 1,677 wells are shallower than the historic low before January 2015, or 97%. This monitoring well is the closest RMN well to the City of Orland. Did 97% of the domestic wells around Orland go dry at least once sometime before 2015, and/or have they been abandoned? If yes, what is the source of this data?

20. The draft GSP provides a general background discussion on the surface water and groundwater budgets in Section 3.3 (pages 3-85 to 3-97). The water budget analysis uses a 26-year Historical period from 1990 to 2015, a Current Conditions period from 2016 to 2065, and three Future Conditions periods from 2016 to 2065. The hydrology baseline used for the Current and Future conditions is the historical data from 1966 to 2015, see Table 3-9. Tables 3-11 and 3-12 provide the average annual values for the surface water and groundwater budget components for all five analysis periods, respectively (pages 3-96 and 3-97). See pages 15 and 16 of AquAlliance Exhibit A. Table 6-1 (page 6-2) provides a summary of the key water budget parameters that influenced the development of the project and management actions. See page 18 of AquAlliance Exhibit A. The water budget analysis selected as representative of conditions in the next 50 years is the projected Future Condition with the 2070 Central Tendency Climate Change provided by DWR (page 3-92).

21. The groundwater water budget in Table 3-12 shows that during the Historical 26-years from 1990 to 2015 there was an average annual deficit of 28,000 acre-feet per year (AFY). Note that units in Tables 3-11 and 3-12 are thousands of acre-feet per year (taf/yr). With the 2070 Future scenario the deficit is reduced, but there is still a loss of storage of 7,000 AFY.

Unfortunately, there appears to be a calculation error in the 2070 Future Conditions outflow, the right-hand column of Table 3-12.

The sum of the Groundwater Pumping components in Table 3-12 is given as 559,000 AFY. See page 17 AquAlliance Exhibit A. The three groundwater components, Agricultural, Urban and Industrial and Managed Wetlands, have future 2070 values of 548,000, 10,000 and 35,000 AFY, respectively. The sum of these three groundwater components equals 593,000 AFY, not the 559,000 AFY shown. If the 593,000 AFY values is used in calculating the outflows, then the ***total groundwater outflow is now 1,063,000 AFY***. This results in a Change in Storage (Inflow – Outflow) value of -42,000 AFY, not the -7,000 AFY shown. This is a 50% increase in the change in storage from the Historical condition, and essentially a 100% increase from the 1966-2015 Current condition.

The values of the three groundwater components listed as inflow components in the surface water budget, Table 3-11, Agricultural, Urban and Industrial and Managed Wetlands, have future 2070 values or 516,000, 10,000 and 32,000 AFY, respectively (see page 15 AquAlliance Exhibit A). The sum of these values is 558,000 AFY, almost equal to the 559,000 AFY sum listed in both Table 3-11 and 3-12. This error in the Groundwater Pumping components needs to be corrected.

22. Table 6-1 provides the differences in the average annual projections for six key water budgets parameters. These parameters appear to be from Table 3-11 and some of the values are the same in both tables, while others have to be calculated from separate component values listed in Table 3-11. See page 18 of AquAlliance Exhibit A. Note that units in Tables 3-11, 3-12 and 6-1 are thousands of acre-feet per year (taf/yr).

    Table 6-1 shows that with the 2070 climate change scenario groundwater pumping will increase 58,000 AFY, or 12.7%. during the next 50 years. Precipitation and Evapotranspiration (ET) is also expected to increase 75,000 AFY and 102,000 AFY, or 6.3% and 6.8%, respectively. The change in annual average groundwater storage with the 2070 climate change is a negative 7,900 AFY. This value differs from the -7,000 AFY value shown in Table 3-11, but this may be the result of round-off error in the Table 3-11 values. Note that the error in the total Groundwater Pumping in Table 3-12 could significantly change the rate of groundwater storage in Table 6-1, so it needs to be corrected.

    Table 6-1 shows that there will be no change in the average annual total of the Sacramento River and Stoney Creek Diversions to the Colusa Subbasin in the future with the 2070 climate change scenario. Table 3-11 shows that there will likely be a small increase in diversions from the Sacramento River, 4,000 AFY, that's balanced by a 4,000 AFY decrease in Stony Creek diversions. Table 3-11 also shows that the sum of these two diversions will increase approximately 119,000 AFY, or 10.2%, when compared to the 1990-2015 Historical baseline diversion of 116,800 AFY. See page 15 of AquAlliance Exhibit A.

    Table 6-1 shows that there will be an annual average decrease of 48,000 AFY, or 38.3%, in the *Net Stream Accretion* in the future with the 2070 climate change scenario. The *Net Stream Accretion* is the sum of the *Stream Gains from Groundwater (Accretion)* inflow

minus the *Stream Seepage* outflow in Table 3-11. See page 15 of AquAlliance Exhibit A. The sums listed in Table 6-1 for future without climate change, 125,000 AFY and for 2070 with climate change, 77,000 AFY, don't appear to agree with the sums that would be obtained using values listed in Table 3-11, but the difference is the same -48,000 AFY. Note that if a comparison is made between the 1990-2015 *Historical Net Stream Accretion*, 160,000 AFY from Table 3-11 values (366,000 AFY – 206,000 AFY = 160,000 AFY), and the future 2070 climate change of 70,000 AFY from Table 3-11 values (323,000 AFY – 253,000 AFY = 70,000 AFY), the future change in *Net Stream Accretion* is -90,000 AFY, or a 56.3% decline (70,000 AFY - 160,000 AFY = -90,000 AFY; -90,000 AFY / 160,000 AFY = 0.563). See page 19 of AquAlliance Exhibit A.

23. The increase in *Groundwater Pumping* and the decrease in *Net Stream Accretion* in the future with the 2070 climate change scenario suggest that the assumptions being made regarding loss of surface water flows during a groundwater substitution transfer are flawed. The change from any of the baseline water budgets in the *Net Steam Gains from Groundwater (Accretion)* (see page 20 of AquAlliance Exhibit A) that occurs with the increase in groundwater production during the next 50-year with the 2070 climate change scenario is much greater than the DWR/BOR assumed *stream depletion factor* of 13 percent[2]

    The groundwater budget in draft GSP Table 3-12 shows that with the future increase in groundwater pumping under the 2070 climate change scenario, there is an increase in seepage from surface waters to the groundwater ranging from 22,000 AFY to 47,000 AFY with the Historical and Current baseline, respectively. See page 20 of AquAlliance Exhibit A. In other words, more surface water will infiltrate into the groundwater basin to the detriment of the streams.

    The groundwater budget in draft GSP Table 3-12 also shows that with the future increase in groundwater pumping the discharge of groundwater to streams, the *Stream Gains from Groundwater (Accretion)* during the next 50 years will decrease from 366,000 AFY and 349,000 AFY, with the Historical and Current baselines, down to 323,000 AFY under the 2070 climate change scenario. A reduction in Stream Accretion of 48,000 AFY (-11,7%) and 26,000 AFY (-7.4%) from the Historical and Current baseline, respectively (see page 20 of AquAlliance Exhibit A).

    The combined loss of stream flow, or net change, over the next 50 years with climate change from the increased seepage and reduced accretion ranges from 48,000 AFY to as much as 90,000 AFY, from the Table 3-12 Current or Historical baselines, respectively. See page 20 of AquAlliance Exhibit A. This loss of stream flow occurs while groundwater pumping is increasing from 94,000 AFY to 91,000 AFY, Current or Historical baselines, respectively. This is a ratio of the change in *Net Stream Accretion* to the change in *Groundwater Pumping* that ranges from approximately negative 51% to as much as a negative 99%, Current or Historical baselines, respectively (see page 20 of AquAlliance Exhibit A.

[2] https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/State-Water-Project/Management/Water-Transfers/Files/Draft_WTWhitePaper_20191203.pdf

The change in the ratio of *Net Stream Accretion* to *Groundwater Pumping* during the 1990-2015 Historical and Current baseline conditions are positive ranging from positive 31.9% to 23.6%, respectively. In other words, under the existing conditions streams gain more water from the groundwater system than they give. With the 2070 climate change scenario, streams will continue to gain more from the groundwater system, but the gain will be less (see page 20 of AquAlliance Exhibit A).

The decrease in *Net Stream Accretion* with future *Groundwater Pumping* suggests that the overall percentage of groundwater being pumped that will be recharged from the streams in the Colusa Subbasin, i.e., stream depletion, with any future pumping increase is significantly greater than the DWR/BOR assumed 13% stream flow loss from a groundwater substitution transfer. ***In fact, with the Historical baseline, the loss is essentially equal to the volume of groundwater being pumped, which is consistent with stream depletion literature.[3] The decline in Net Stream Accretion with future increased Groundwater Pumping that changes the streams for gaining to losing suggesting that the subbasin maybe at a tipping point where the impacts from future pumping increases are amplified and cause significantly more harm than just the existing condition.***

24. The draft GSP's Figure 3-29 (page 3-66) graphs the cumulative change in groundwater storage from 1990 to 2015 for the Historical condition where the average annual change in groundwater storage was a negative 28,000 AFY. See page 21 of AquAlliance Exhibit A. The figure shows that in 2015 the cumulative change in groundwater storage since 1990 is approximately a negative 600,000 AF.

    The draft GSP gives in Figure 3-49 (page 3-111) graphs of the cumulative change in groundwater storage from 1966 to 2015 for the Current condition and the three future 50-year scenarios. See page 22 of AquAlliance Exhibit A. The figure shows that in 2065 under the 2070 climate change scenario the cumulative change in groundwater storage from the present will be approximately a negative 400,000 AF, which is consistent with the annual average decline of -7,300 AFY given in Table 6-1 (-7,300 AFY x 50 years = -365,000 AF) (see page 18 of AquAlliance Exhibit A).

    If the anticipated future loss in groundwater storage under the 2070 climate change scenario is added to existing loss in groundwater storage, ***the cumulative loss is groundwater storage for the Colusa Subbasin in 2065 is approximately 1,000,000 AF*** (-365,00 AF + -600,000 AF = -965,000 AF).

    The use of the past 50-year Current scenario as the input for the hypothetical future scenarios is reasonable. Repeat the past with the climate changes applied to see what happens. However, the starting point for going forward in an evaluation of the subbasin's groundwater

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[3] Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion by wells—Understanding and managing the effects of groundwater pumping on streamflow: U.S. Geological Survey Circular 1376, 84 p.
(Also available at *http://pubs.usgs.gov/circ/1376/*.)

sustainability should be at today's conditions, not the average of the past 50 years. The volume of storage at the SGMA benchmark date of January 1, 2015 was near -500,000 AF, which is lower than in than any time prior to the start of SGMA. The additional decline in groundwater storage from the 2070 climate change scenario should be started at the -500,000 AF value of the SGMA Benchmark date, not the zero of 1966. The authors of the draft GSP may know this, and that's maybe why many of the groundwater monitoring well MTs are set at 50% of the historical range below the historical low. The GSP authors want to allow for an additional 400,000 AF of loss in groundwater storage predicted by the 2070 climate change scenario, for a total of 900,000 since the 1990, without triggering an *undesirable result*. The draft GSP doesn't actually say that it's planning to have this amount of groundwater storage loss, but the water balance calculations suggest that it is likely.

25. While this GSP is being developed for the Colusa Subbasin, a GSP is being developed for the Butte Subbasin to the east. A draft GSP for Butte Subbasin was released for public review. The Butte draft GSP also provides MOs and MT for monitoring wells across the subbasin. The monitoring well network for the Butte Subbasin is divided into a Primary Aquifer, wells less than 700 feet depth, and a Very Deep Aquifer, wells greater than 700 feet depth. There are 41 Primary Aquifer monitoring wells in the Butte Subbasin GSP. See pages 23 and 24 of AquAlliance Exhibit A. The MOs and MT for the Colusa Subbasin are given in Table 5-2, pages 4 and 5 of AquAlliance Exhibit A.

    The existing groundwater contours in the two subbasins suggest that the current flow of groundwater in the aquifers shallower than 700 feet flow towards the center of the valley with the flow generally north to south aligned with the Sacramento River (see pages 8, 9, 25, and 26 of AquAlliance Exhibit A). There are several sets of monitoring wells that are approximately opposite each other along the north-south boundary between the subbasins. See page 3 and 24 of AquAlliance Exhibit A. If the MT elevations for these west-to-east sets of wells are compared, knowledge might be gained on how the management of the groundwater in these basins will affect each other. A table is provided on page 27 of AquAlliance Exhibit A that lists the state well numbers and the MT elevations for monitoring wells in the Colusa GSP along with their nearest eastern counterpart monitoring well(s) in the Butte GSP with the MT elevations. Note that sometimes multiple wells are listed for a single well. This is done whenever there is more than one well that aligns along a general west-to-east orientation.

    The right-hand column of the table gives the difference between the Butte GSP well(s) and the Colusa GSP well(s). A positive value indicates that the MT elevation in the Butte Subbasin is higher than the corresponding MT value in the Colusa Subbasin. In all but one of the 10 sets of west-to-east monitoring wells matches, the MT elevations in the Butte Subbasin are higher.

    This suggests that the groundwater elevations in the Colusa Subbasin will be allowed to be deeper under the Colusa Subbasin GSP than in the Butte Subbasin before an undesirable result is declared. This may create a condition where the Butte Subbasin is providing more interbasin groundwater flow to the west in the future. The implications from setting the MT values in the Colusa Subbasin at elevation lower than the MTs in the Butte Subbasin should

be analyzed and management action(s) should be included in the GSPs for each other subbasin to maintain sustainable interbasin groundwater flow.

26. The Draft GSP states that the primary groundwater quality constituent of concern within the Colusa Subbasin is salinity, specifically the upwelling of brackish connate water into the principal aquifer (page 4-15). The water quality sustainable thresholds listed in Table 5-1 only sets MO and MT values for salinity using electrical conductivity (EC). The MO is 700 µS/cm, and the MT is set at the higher of 900 µS/cm or the measured historical high, whichever is greater (Table 5-1 on page 5-18; page 4 in Appendix 5A). In the basin setting discussion, the plan significantly expands on the water quality issues in the Colusa Subbasin noting in Section 3.1.10.3 on pages 3-42 and 3-43 that:

- *Historical groundwater quality concerns within the Subbasin include locally elevated levels of salinity, TDS, adjusted sodium absorption ratio, boron, nitrate, and manganese (DWR, 2006a; Wood Rodgers, 2008) (page 3-42).*
- *Recent groundwater quality concerns within the Colusa Subbasin include salinity, boron, nitrate, heavy metals, including arsenic, and hexavalent chromium. High concentrations of sodium, chloride, and sulfate, all of which are related to salinity have been observed south of Maxwell (CH2MHILL, 2016a; RD 108, 2008) and could negatively impact agricultural applications.*
- *Elevated salinity levels throughout much of Colusa County, nitrates near Orland and Willows, arsenic near Grimes, and iron and manganese near Williams and Colusa are of concern with respect to drinking water MCLs (CH2MHILL, 2016a).*
- *Arsenic, especially, has been a constituent of concern for Grimes, Colusa, and the surrounding area. Local agencies have been working to mitigate arsenic contamination in groundwater in this area.*
- *Drinking water supply wells near Willows, Glenn County, have experienced high concentrations of hexavalent chromium (California Water Service, 2016).*
- *There are also several active groundwater contamination cleanup sites in the Subbasin. These primarily include leaky storage tanks and unauthorized releases of contaminants such as petroleum hydrocarbons, nitrate, pesticides and herbicides including dicamba, and solvents. Most of these cleanup sites impact the unconfined portion of the principal aquifer, but there is a risk that the contamination could migrate into the deeper, more heavily pumped portions of the aquifer.*
- *The largest contamination site is the Orland Dry Cleaner site, a tetrachloroethylene (PCE) plume that extends approximately two miles southeast of the source location in Orland, Glenn County (Department of Toxic Substances Control [DTSC], 2020; SWRCB, 2020b). In 2007, PCE contamination was recorded at depths of 127 feet bgs (DTSC, 2020).*

More details regarding existing and historical groundwater quality issues and trends is provided in Section 3.2. The Draft GSP acknowledges that the *[g]roundwater quality data collected under existing regulatory programs may not be sufficient for SGMA compliance* (page 4-20). The plan indicates that:

- *The GSAs will continue to coordinate and collaborate with other agencies regarding their monitoring programs, including changes to monitoring sites, monitoring protocols or frequencies, and management actions. Data acquisition is not anticipated to be an issue. If necessary, the GSAs **will consider** implementing their own monitoring programs to address concerns over undesirable results, data gaps in the monitoring networks, or GSP project needs* (page 4-15) (emphasis added).
- *The Colusa and Glenn GSAs **will consider** coordinating with the SVWQC, Northern California Water Association (NCWA), and the California Rice Commission in the establishment and ongoing evaluation of these groundwater quality monitoring network sites with the goal of using data collected under the ILRP for SGMA compliance* (page 4-20) (emphasis added).
- *Annual reports and future revisions to the GSP will provide updates on actions taken to address data gaps over the reporting period* (page 4-20).

Although the Draft GSP acknowledges that there are other agencies with water quality monitoring programs with water quality standards, the plan doesn't set or identify any standards for the water quality constituents that are known to impact the subbasin. Water quality standard already exist for the Colusa Subbasin in the Central Valley Regional Water Quality Control Board's (CVRWQCB) Water Quality Control Plan (Basin Plan) for the Sacramento River Basin and the San Joaquin River Basin.[4] The GSP should specifically state that the water quality MOs and MTs for the Colusa Subbasin will follow the requirements of the CVVRWQCB's Sacramento River Basin Plan. In addition, the GSP should maintain the subbasin's water quality so that it meets all required health protective drinking water standards at levels below the Maximum Contaminant Levels (MCLs) for public water systems, and below the public health goals (PHGs).[5,6] The GSP should specify Management Actions that will maintain and/or improve the subbasin water quality with an emphasis on the known problems.

27. Section 7.6 Financing

Is voter approval necessary for any fees or taxes levied to raise funding for any of the Mitigation Actions? Who are the actual voters? Are they all landowners in the Colusa subbasin, only landowners in a GSA, or all citizens of the Colusa subbasin? The GSP actions may need to fund mitigations to municipal or small water systems, so how are these systems represented in the funding decisions? Will the de minimus extractors, a person who extracts, for domestic purposes, two acre-feet or less of groundwater per year, be allowed a vote? How many votes does each eligible voter get? Will the number of votes be based on the acres owned, number of wells owned, volume of groundwater pumped, or some combination of factors? What happens if the economic burden to fund the management actions falls disproportionately on one group, to whom can they appeal? Will mitigation funds go to the de minimus extractor because their wells can go dry like anyone else's, but they are

[4] https://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/sacsjr_201805.pdf
[5] https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/MCLsandPHGs.html
[6] https://www.waterboards.ca.gov/laws_regulations/docs/drinking_water_code_2021.pdf

otherwise exempt from SGMA? Are there any statutes that govern how government agencies determine the per capita or per centum rate of a tax or fee?

28. The following are additional questions about the management actions and procedures in the draft GSP:

- Do the stream depletion MOs and MTs take precedence over the domestic well MOs and MTs when the monitoring well are adjacent? How should the domestic well owner utilize the stream depletion thresholds?

- What is the lateral extent that the stream depletion MO and MT applies? Up to 5 miles from the well? Only in the area where the 5 miles zone intersects a stream? Only in the area between the monitoring well and the stream?
- Is there a map of the 48 Representative Monitoring Network (RMN) Thiessen polygon boundaries? What is the area of each polygon? How many domestic wells are in each polygon?

- Do the MO and MT apply to all domestic wells within that well's polygon? How does the requirement to evaluate *undesirable results* using 12 RMN wells affect the MO and MT at a specific domestic well? Should a domestic well owner be prepared to have a dry well if depth of their well is shallower than the MT in their polygon, or if the depth is shallower than the deepest MT in the group of 12 RMN wells?

- If a domestic well is being installed or replaced, can the well owner rely on the MO and MT depths in their polygon to determine a minimum depth of their new well? Does the GSP offer any advice on the sustainability criteria for the minimum depth of a new well or replacement well? Should the new well be at least the depth of the old well's polygon MT, or the 12-well group MT, to ensure that the well doesn't go dry in the future?

- What advised does the GSP give on how a domestic well owner should interpret the MO and MT values when their well is near the polygon boundary? For example, the MO for well 22N02W30H002 is 104 feet bgs, and the MT at 175 feet, while the MO of the adjacent well 22N03W24E001 is 194 feet bgs and the MT is 273 feet bgs. If a domestic well is installed or replaced in the 22N02W30H002 polygon that's close to the boundary with the 22N03W24E001 polygon, should the depth of the new well be at the deeper MT of the 22N03W24E001 polygon or the shallower 22N02W30H002 polygon?

- Will monitoring the RMN wells only 2 to 3 times each year effectively capture the fluctuations in groundwater level? In particular, the periods of maximum decline which have significant influence over domestic wells and stream depletion?

- What is the distribution of the depths of domestic wells associated with each RMN monitoring well? How many of the 20% shallower wells will go dry with each increment of groundwater level decline? Histograms of wells depth and cumulative frequency of depth statistics are needed to understand the validity and significance of the 20% shallower threshold.

- Will the construction of deeper domestic wells in the future influence the MO and MT values? If so, how will the MO and MT change, when will the change occur and what measures should a domestic well owner take when and if this change occurs?

- Will the use of 50% range values in deep aquifers to set the domestic well MTs cause more the wells to go dry and/or for longer periods than if the range in shallower aquifers were used? In other words, will the use of MT developed on deeper data delay actions needed to maintain the sustainability of the domestic wells because they allow greater declines in groundwater level before an *undesirable result* is acknowledged?

- Where in SGMA is the standard that 20% dry wells can be determined to be acceptable and non-significant, and therefore not an *undesirable result?* Where in SGMA does it give the standards for the economic analysis to determine the *cost-effectiveness* and the *acceptable balance between avoiding significant and unreasonable impacts to domestic and other shallow wells* in determining the MTs? AquAlliance believes that the domestic landowner, or agricultural landowner, that losses a well due to declining groundwater levels might see any loss of a well as *significant and unreasonable*, and disagree with the GSP's criteria for which wells can be sacrificed for the "greater good." This is analogous to a developer directing the stormwater runoff onto adjacent lands without regard to the flooding it might cause, because it's for the economic good of a community to have more homes. This is not allowed in most of California. Is the GSP's sacrifice of a 20% shallower well considered a **taking**? Does there need to be compensation? What is the value of the compensation, replacement costs of a deeper well, the original cost of the well, the value of the water at the time it goes dry or the change in water quality makes the water unusable, or all of the above?

- The Management Action for the Domestic Well Mitigation Program, Section 6.5.2.1, state that the GSP (GSA) will *investigate implementing a domestic well mitigation program* with funding to mitigate dewatered well (based on yet undefined eligibility). This Management Action along with the others is … ***in the early conceptual stage***. SGMA exempts the GSP from CEQA (WC 10728.6, see below), but requires implementation projects to undergo CEQA review. All eight of the Management Actions given in GSP Chapter 6.5.2 are ***in early conceptual stage***. If the GSP is adopted with this language and no specifics are provided about what actions will be taken, does that mean that any future projects or actions to implement the GPS Management Actions are still CEQA exempt?

  WC 10728.6 - Division 13 (commencing with Section 21000) of the Public Resources Code does not apply to the preparation and adoption of plans pursuant to this chapter. Nothing in this part shall be interpreted as exempting from Division 13 (commencing with Section 21000) of the Public Resources Code a project that would implement actions taken pursuant to a plan adopted pursuant to this chapter.

B. Conflict Resolution

State and federal agencies have long viewed the Northern Sacramento Valley as a source of "surplus" water that will one day serve the accelerating water market through conjunctive-use and water banking (more in Section C). Sadly, the Colusa GSP reflects the willingness of the participants[7] to create a destruction model, emulating the demise of the Owens and San Joaquin valleys. As discussed in Section A, the Plan as proposed will degrade the groundwater basin and harm groundwater users who are not involved in conjunctive use, water transfers, or water banking but are reliant on the same groundwater basin.

It is easy to see that newly formed GSAs have layers of potential conflict. Questions regarding authority, streamlined legal and regulatory timelines, a lack of existing precedents, and the need to represent agency and constituent interests have the potential to exacerbate regional conflicts under SGMA. In some cases, where authoritative interpretations of legal authority and truly sustainable limits have not been established yet, litigation may be necessary and warranted.

The public and SGMA governing bodies and committees have been excluded from NorthState inter-basin discussions. Moreover, when participants in the Vina Stakeholder Advisory Committee asked staff if discrepancies in inter-basin flow volumes/direction that are estimated in the various GSA Basin Settings had been deliberated within the Inter-Basin Coordinating Committee, they answered that they are too busy, but would examine the issue after the GSPs are submitted in 2022.

The drama surrounding the nascent Tuscan Water District and highly questionable Minimum Objectives and Minimum Thresholds in this and other plans are examples of "issues" that have already emerged. Achieving sustainability requires local agencies, stakeholders, and water users to make many difficult and potentially contentious decisions. These decisions are prone to conflict, particularly when pumping restrictions are viewed as infringing on property rights or when fees are charged to support local management.

The Colusa GSP is not complete without a detailed process and funding to resolve conflicts that arise both within and external to the GSA boundaries.

C. Water Transfers and Conjunctive Use

The Colusa GSP must not assume that local ordinances will in any way protect the population and environment of Glenn and Colusa counties from any transfers and expanded conjunctive use. Historic facts and current proposals by DWR funded think tanks belie this:

- Water transfers are not protective of the public or the environment. Transfers implement the dreams of the California's Department of Water Resources, the U.S. Bureau of Reclamation, and State Water Project and Central Valley Project water sellers who have

[7] County of Colusa, City of Colusa, City of Williams, Glenn-Colusa Irrigation District, Maxwell Irrigation District, Westside Water District, Princeton-Codora-Glenn Irrigation District, Provident Irrigation District, Colusa County Water District, Reclamation District 108, Reclamation District 479, Colusa Drain Mutual Water Company, Two representatives of private groundwater pumpers. City of Orland, City of Willows, County of Glenn, Glenn-Colusa Irrigation District, Glide Water District, Kanawha Water District, Monroeville Water District, Orland-Artois Water District, Princeton-Codora-Glenn Irrigation District, Provident Irrigation District.

demonstrated over decades that their interests are not the same as the public's interest. Once the state recognized that they were considerably short on water after former Governor and President Ronald Reagan protected North Coast rivers with Wild and Scenic status, it began trolling for other water sources.

- Some of the Butte GSA entities in Butte County sold surface water from Oroville Reservoir to the 1994 Drought Water Bank.[8] This led to an increase in groundwater withdrawals used for irrigating rice, called groundwater substitution transfers. Until the time of the water transfers, groundwater levels had sustained the normal demands of domestic and agricultural users in the region. The 1994 extractions, however, caused the water levels to suddenly fall in shallow domestic wells, water quality to deteriorate in the wells serving the town of Durham, irrigation wells to fail on several orchards, and one farm to enter bankruptcy because it didn't recover from the loss of its crop. Harmed farmers and residents were told to, "Go hire an attorney."
- State and federal water agencies kept exploring how to manipulate groundwater systems during the 1990s to set up conjunctive use programs. CalFed was one such effort. **"**Potential projects at Stony Creek, Butte Basin, and the Cache-Putah Basin (Conaway Ranch) were eliminated because these aquifers are generally full. *Using these aquifers conjunctively would require initial extraction followed by active or passive recharge*. These may prove to be attractive projects in the future if potential third-party impacts are addressed adequately."[9] **(emphasis added)**
- Additional CalFed material recognized that conjunctive use will require an extra 100 feet of aquifer drawdown and "may be an issue." [10]
- Glenn Colusa ID received close to $3,000,000 of public money to study the Stony Creek Fan Conjunctive Water Management Program and Regional Integration of the Lower Tuscan Groundwater formation project.
- Glenn Colusa ID, Western Canal WD, and Richvale ID actively planned to implement conjunctive use schemes: "Ultimately the project evaluated the effects of exercising both the northern Sacramento Valley's deep aquifer system, which is presently relatively undeveloped, and the shallower, regional aquifer, which is more heavily pumped for both domestic and agricultural needs."[11]

- Think tanks are already encouraging the California Legislature to override local ordinances. "Once GSAs establish sustainability plans that address undesirable impacts of

[8] Thomas, Gregory, 2001. Designing Successful Groundwater Banking Programs in the Central Valley: Lessons From Experience. "The Butte County/Basin districts that increased groundwater pumping during the 1991 State Drought Water Bank included: Western Canal Water District, the Joint Water Districts Board (Richvale Irrigation District, Biggs-West Gridley Water District, Butte Water District, and Sutter Extension Water District) Ramirez Water District, Cordua Irrigation District, Hallwood Irrigation Company, and Browns Valley Irrigation District." p. 30.
"Participants in the 1994 State Drought Water Bank were Richvale Irrigation District, Western Canal Water District, Browns Valley Irrigation District, Cordua Irrigation District, and Ramirez Water District." p. 30.
[9] CalFed Bay Delta Program, 1999. *Conjunctive Use Assessment*. p. 6.
[10] CalFed Bay Delta Program. Groundwater Storage Attribute Matrices, Appendix B. p. B-5.
[11] Glenn Colusa ID, et al, 2012. *Feasibility Investigation of Re-Operation of Shasta and Oroville Reservoirs in Conjunction with Sacramento Valley Groundwater Systems to Augment Water Supply and Environmental Flows in the Sacramento and Feather Rivers*. p. ii.

> pumping, it should be possible to ease the coarser restrictions on this practice found in most county ordinances—which effectively preclude trades if they entail water leaving the county. If counties with restrictive groundwater export ordinances fail to amend their laws to conform to SGMA*, the legislature should consider preempting local laws that discriminate against out-of-county uses or place undue burdens on groundwater and groundwater-substitution transfers* that would not jeopardize sustainable groundwater management of the source aquifer."[12] (emphasis added)

Sustainability is not found in the Colusa GSP, let alone *equitable* sustainability for all residents, farms, businesses, and the environment. The Colusa and Butte GSAs are dominated by large, non-residential landowners, many of whom have sought to play in the lucrative water market already to the detriment of their neighbors, streams, rivers, and species. Sadly, SGMA opened this door further: "Non-residential landowners and future banking partners may find it in their common interest to interpret the legislative intent (74)[13] and lax definitions of safe yield and overdraft provided in the Act (75)[14] based on the opinion in *Los Angeles v. San Fernando*, which encourages drawing down basins to create additional storage space and prevent water "wasting."(76)[15] Thus, in addition to exports, it is foreseeable that a future GSA will encourage drawdown of the aquifer to satisfy massive crop thirst as the drought continues, which will then create extra storage space for imported waters to "recharge" the Basin. As a result of future water exchanges and banking, local residents will bear the additional cost of digging deeper wells just to maintain their straws in the aquifer, and will increasingly compete with each other over a diminishing percolated supply while banked supplies increase."

B. Conclusion

By its own admission, the Colusa GSP is bent on pursuing long-held plans to expand conjunctive use through groundwater manipulation, artificial recharge, and potential dam reoperation that will harm the people and environment of the GSA and surrounding region. The draft Plan will not lead to sustainability as required by SGMA, but will allow major groundwater fluctuations,

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[12] Ayres, Andrew, et al., 2021. *Improving California's Water Market: How Water Trading and Banking Can Support Groundwater Management*. p. 34.

[13] Keats, Adam et al., 2016. *Not All Water Stored Underground is Groundwater: Aquifer Privatization and California's 2014 Groundwater Sustainable Management Act*. Footnote: *2014 Act, § 10720.1(g) (It is the intent of the Legislature "[t]o increase groundwater storage and remove impediments to recharge.").* p. 106.

[14] *Id. Footnote: 2014 ACT, § 10721(v) ("Sustainable yield" is defined as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result."); 2014 ACT, § 10735(a) ("Condition of long-term overdraft" means the condition of a groundwater basin where the average annual amount of water extracted for a long-term period, generally 10 years or more, exceeds the long term average annual supply of water to the basin, plus any temporary surplus. Overdraft during a period of drought is not sufficient to establish a condition of long-term overdraft if extractions and recharge are managed as necessary to ensure that reductions in groundwater levels or storage during a period of drought are offset by increases in groundwater levels or storage during other periods.").*

[15] *Id. Los Angeles v. San Fernando 14 Cal. 3d 199, 280 (1975) ("We agree with plaintiff that if a ground basin's lack of storage space will cause a limitation of extractions to safe yield to result in a probable waste of water, the amount of water which if withdrawn would create the storage space necessary to avoid the waste and not adversely affect the basin's safe yield is a temporary surplus available for appropriation to beneficial use. Accordingly, overdraft occurs only if extractions from the basin exceed its safe yield plus any such temporary surplus.").*

significant well losses, and cost burdens on harmed groundwater dependent farms, homes, and businesses. This was predicted in 2016: "This potential conflict will become acute in the likely scenario where artificial recharge inhibits natural recharge so that it is difficult, if not impossible, to determine the relative quantity of each. Given explicit provisions in the Act and statewide policy favoring storing surface water underground it is not difficult to envision a privately-controlled GSA systematically drawing down percolated groundwater to create storage space in the basin, and then replenishing the basin with imported water, with little consideration of the ability for overlying users to access the basin or the long-term health of the surrounding ecosystem." [16]

Due to the inequity of the Plan for all groundwater dependent residents, farms, and the environment, the deficient presentation of the consequences in the text (see Section A above), and the unacceptable impacts to both ground and surface waters, it should be rejected by the Colusa Subbasin governing body.

Respectfully submitted,



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[16] *Id.* pp. 98-99.

Table 6-1. Summary of Key Colusa Subbasin Water Budget Parameters Influencing Formulation of Projects and Management Actions (average annual volumes, taf/yr)

Water Budget Parameter	Projected Future Conditions without Climate Change	Projected Future Conditions with 2070 Central Tendency Climate Change	Difference (Projected future with 2070 Central Tendency climate change minus without climate change)	Percent Difference[(a)]
Avg. Agricultural Evapotranspiration	1,494	1,596	102.0	6.8%
Precipitation	1,183	1,258	75.0	6.3%
Agricultural Pumping	458	516	58.0	12.7%
Avg. Rate of Change in Groundwater Storage, af/yr	0.6	-7.3	-7.9	-0.8%
Sacramento River and Stony Creek Diversions to Colusa Subbasin	1,287.0	1,287.0	0.0	0.0%
Net Steam Accretion	125	77	-48.0	-38.3%

(a) Calculated as the difference in the fourth column divided by the Projected Future Condition without Climate Change quantity in the second column, except for Avg. Rate of Change in Groundwater Storage, for which the percent difference is based on the approximately 1 million acre-feet that flow into and out of the Colusa Subbasin on an average annual basis. Water budget uncertainty is discussed in Chapter 3, Basin Setting, and model uncertainty is discussed in Appendix 3D. The average change in groundwater storage is considered to be within standard modeling error for this type of groundwater model analysis.

Under projected future conditions without climate change, groundwater storage is forecast to increase modestly, at an average rate of 0.6 taf/yr. With 2070 CT climate change and the associated increase in groundwater pumping to meet increased irrigation demands, groundwater storage is projected to decrease at a rate of 7.3 taf/yr. This net change of -7.9 taf/yr is 0.8 percent of the approximately one million acre-feet that flow into and out of the Colusa Subbasin groundwater system annually.

Under projected future conditions without climate change, net stream accretion (stream accretion minus stream depletion) is projected to be 125 taf/yr on average. This aggregate net stream accretion is for the Sacramento River, Stony Creek, and the Colusa Drain combined[2]. With 2070 CT climate change, net stream accretion is projected to remain positive but to decrease by about 48 taf/yr, or by 38 percent, with respect to the without climate change condition. However, viewed in relation to the average Sacramento River flow above the Feather River confluence of approximately 11.7 million acre-feet per year (af/yr) the projected change is roughly one half of one percent.

The aggregate changes in groundwater storage, 0.8 percent, and net stream accretion, 0.5 percent of the average Sacramento River Flow, are considered to be within standard modeling error for this type of analysis. The GSAs will continue to evaluate and review all Subbasin water budget parameters, including net

[2] A more detailed assessment of projected streamflow accretion-depletion is presented in Appendix 3G. The analysis considers the Sacramento River, Stony Creek, and the Colusa Drain individually and collectively, and evaluates temporal accretion-depletion patterns over the 50-year simulation period.

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Table 5-1. Summary of Sustainability Thresholds for All Sustainability Indicators Applicable to the Colusa Subbasin

Sustainability Indicator	Monitoring Network	Undesirable Result	Minimum Threshold (MT)	Measurable Objective (MO)
Chronic Lowering of Groundwater Levels	48 Representative Monitoring Network (RMN) wells monitored at least 2-3 times annually by DWR	25% (12 of 48) RMN wells fall continuously below their MT for 24 consecutive months	The lower of 50% of measured historical groundwater elevation range below the historical measured low elevation and the elevation corresponding to the 20th percentile of domestic well depths in the RMN well's Thiessen polygon, subject to interbasin coordination and consistency to ensure operational compatibility	Mean of last 5 years available groundwater elevation measurements subject to interbasin coordination and consistency to ensure operational compatibility. A fixed value, not a rolling average.
Reduction in Groundwater Storage	48 RMN wells monitored at least 2-3 times annually by DWR (same as Groundwater Level monitoring network)	Use groundwater levels as proxy	Use groundwater levels as proxy	Use groundwater levels as proxy
Seawater Intrusion	Not applicable	Not applicable	Not applicable	Not applicable
Degraded Groundwater Quality	25 RMN wells monitored by others at variable intervals under existing State of California regulatory programs.	Electrical conductivity (EC) in 25 % (6 of 23) of the RMN wells exceeds the MT for two (2) consecutive years.	The higher of EC of 900 microSiemens per centimeter (µS/cm) (the recommended California Secondary Maximum Contaminant Level) OR the pre-2015 historical maximum measured EC.	EC of 700 µS/cm (corresponding to an agricultural water quality objective providing for no yield reduction for crops commonly grown in the Colusa Subbasin).
Land Subsidence[(a)]	Existing Sacramento Valley Height Modernization Project (SVHMP) benchmarks (63 sites)	15% or more (9 of 63) monitoring sites (benchmarks) experience subsidence rates above the MT	Benchmarks with greater than 1 foot historical subsidence (measured between 2008 and 2017): set MT at 0.60 foot/year. Benchmarks with less than 1 foot historical subsidence (measured between 2008 and 2017): set MT at 0.50 foot/year.	Benchmarks with greater than 1 foot historical subsidence (measured between 2008 and 2017): set MO at 0.25 foot/year. Benchmarks with less than 1 foot historical subsidence (measured between 2008 and 2017): set MO at 0.25 foot/year.
Depletions of Interconnected Surface Waters	12 RMN wells less than 200 feet deep and between 2,000 feet and five miles of interconnected stream (Sacramento River, Colusa Basin Drain, Stony Creek)	25% (3 of 12) RMN wells fall below their MT for 24 consecutive months.	Ten (10) feet below the observed fall 2015 groundwater level. (Fall 2015 level is the measured elevation recorded on the date closest to Oct 15.)	Mean of last 5 years available groundwater elevation measurements subject to interbasin coordination and consistency to ensure operational compatibility. A fixed value, not a rolling average.

(a) Sustainable management criteria for inelastic land subsidence are under review and may be revised after publication of this draft GSP.

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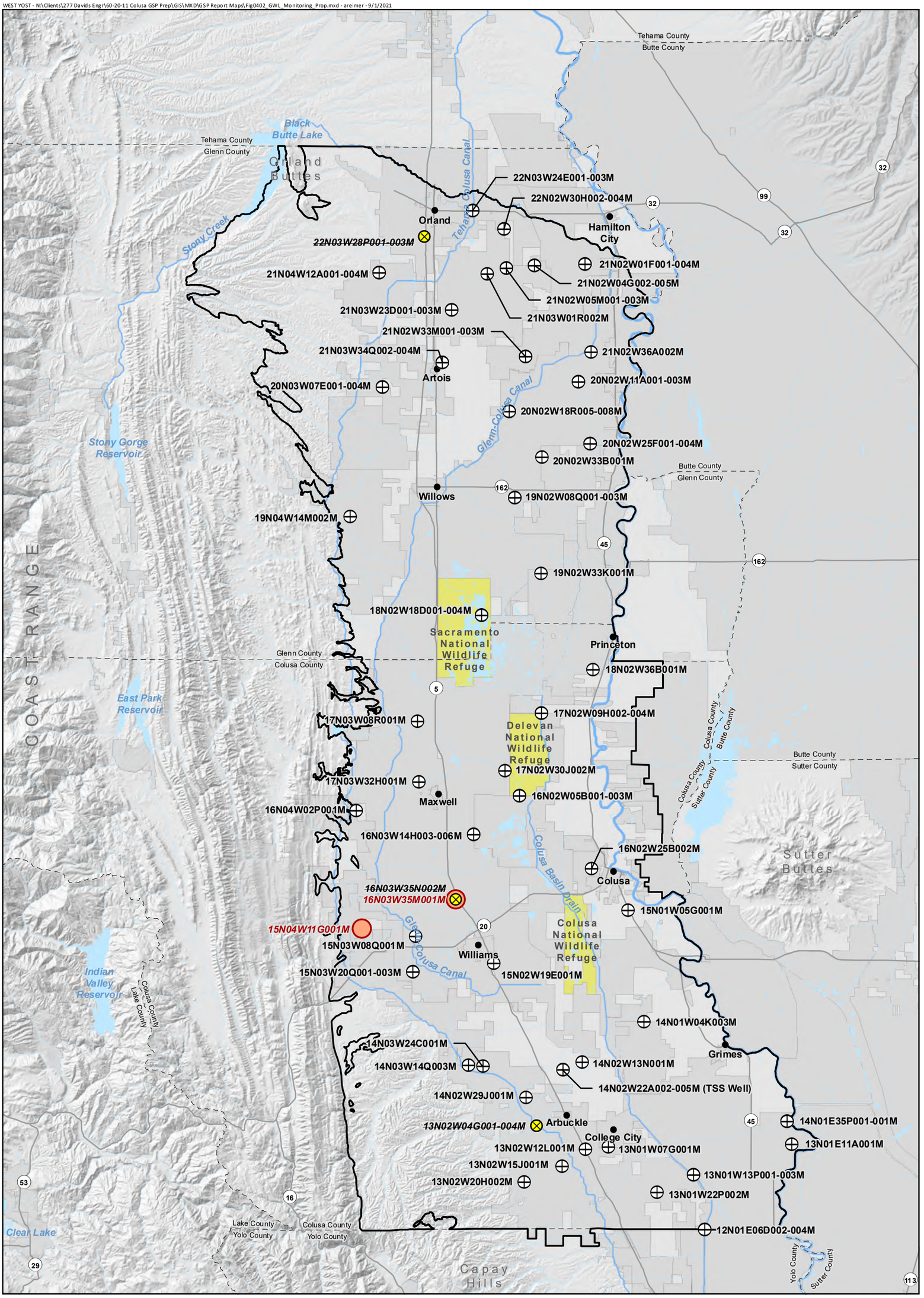

Groundwater Monitoring Network Well

Well Removed from Groundwater Monitoring Network due to Damage or Destruction

Existing Well to Potentially Add to the Groundwater Monitoring Network

Colusa Subbasin

Water Agencies

U.S. Fish and Wildlife Refuge

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

N

0 2.5 5

Scale in Miles

DRAFT **Figure 4-2**

Proposed Groundwater Monitoring Network Wells

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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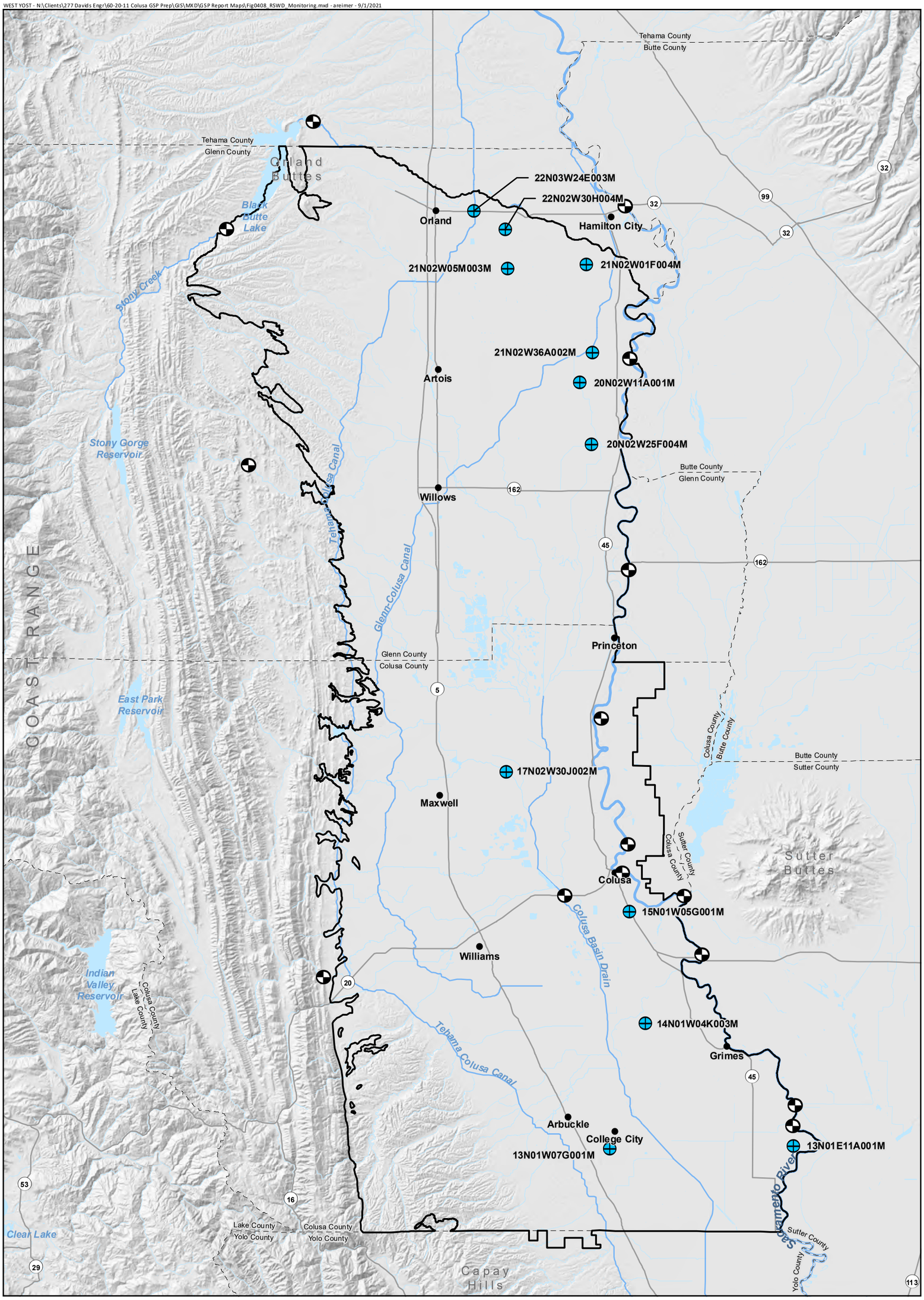
Table 5-2. Groundwater Level Representative Monitoring Network and Sustainability Criteria

SWN	CASGEM ID	Ground Surface Elevation, ft	Minimum Threshold GWE, ft amsl	Minimum Threshold DTW, ft bgs	Measurable Objective GWE , ft amsl	Measurable Objective DTW, ft bgs	Interim Milestone GWE ft amsl	Interim Milestone DTW ft bgs	Margin of Operational Flexibility, ft	20th Percentile Domestic Wells, ft bgs	50% of Range Below Historical Low, ft bgs
12N01E06D004	16331	28	-108	136	-1	29	-1	29	107	136	94
13N01E11A001	18534	32	-75	106	22	10	22	10	96	106	28
13N01W07G001	36246	90	-106	196	-9	99	-9	99	97	153	196
13N01W13P001	18549	32	-88	120	-2	34	-2	34	86	120	89
13N01W22P002	16357	60	-124	184	26	34	26	34	150	184	116
13N02W12L001	31899	135	-72	208	9	126	9	126	82	200	208
13N02W15J001	39884	213	-62	274	61	152	61	152	122	215	274
13N02W20H002	25005	343	95	248	174	169	174	169	79	248	201
14N01E35P001	38718	47	-118	165	18	29	18	29	136	165	48
14N01W04K003	18554	37	-86	124	12	25	12	25	99	124	44
14N02W13N001	18563	62	-80	142	24	38	24	38	104	142	78
14N02W22A002	54756	84	-126	210	84	0	84	0	210	210	0
14N02W29J001	18566	163	-86	248	22	141	22	141	107	216	248
14N03W14Q003	32324	173	-89	261	-13	186	-13	186	75	115	261
14N03W24C001	16691	173	-5	178	38	135	38	135	43	138	178
15N01W05G001	14309	47	-54	101	28	19	28	19	82	101	51
15N02W19E001	14319	87	-13	100	73	14	73	14	86	100	50
15N03W08Q001	N/A	113	43	70	107	6	107	6	64	70	10
15N03W20Q001	38293	129	60	69	103	26	103	26	43	69	34
16N02W05B001	25511	65	-71	136	33	32	33	32	104	136	74
16N02W25B002	33868	55	-25	80	30	25	30	25	55	80	54
16N03W14H003	24683	66	-94	160	72	-6	72	-6	166	160	3
16N04W02P001	16308	163	63	100	139	24	139	24	76	100	42
17N02W09H002	25514	67	-52	119	49	18	49	18	101	119	56
17N02W30J002	16960	63	-119	182	44	19	44	19	163	182	51
17N03W08R001	39127	107	-13	120	88	19	88	19	101	120	28
17N03W32H001	35475	100	-38	138	92	8	92	8	130	138	35
18N02W18D001	24953	82	-83	165	69	13	69	13	152	165	24
18N02W36B001	16914	75	-3	78	53	22	53	22	56	78	59

Table 5-2. Groundwater Level Representative Monitoring Network and Sustainability Criteria

SWN	CASGEM ID	Ground Surface Elevation, ft	Minimum Threshold GWE, ft amsl	Minimum Threshold DTW, ft bgs	Measurable Objective GWE , ft amsl	Measurable Objective DTW, ft bgs	Interim Milestone GWE ft amsl	Interim Milestone DTW ft bgs	Margin of Operational Flexibility, ft	20th Percentile Domestic Wells, ft bgs	50% of Range Below Historical Low, ft bgs
19N02W08Q001	25762	108	12	96	79	29	79	29	67	96	72
19N02W33K001	19793	87	21	66	71	16	71	16	50	66	53
19N04W14M002	25787	186	46	140	151	35	151	35	105	140	50
20N02W11A001	17170	125	49	76	119	6	119	6	70	76	22
20N02W18R005	23986	131	29	103	70	61	70	61	42	84	103
20N02W25F001	23989	102	37	65	96	6	96	6	59	65	16
20N02W33B001	17174	105	31	74	100	5	100	5	69	74	17
20N03W07E001	37860	179	-50	229	33	146	33	146	83	148	229
21N02W01F001	38535	161	71	90	116	45	116	45	45	90	89
21N02W04G002	24993	178	41	138	103	75	103	75	63	92	138
21N02W05M001	39676	189	39	150	130	59	130	59	91	134	150
21N02W33M001	38536	149	52	97	94	55	94	55	42	82	97
21N02W36A002	21239	135	24	112	91	44	91	44	68	81	112
21N03W01R002	25232	203	48	155	151	52	151	52	103	108	155
21N03W23D001	23992	205	26	179	142	63	142	63	116	89	179
21N03W34Q002	25789	167	-54	221	36	131	36	131	90	125	221
21N04W12A004	24650	248	-108	356	11	237	11	237	119	98	356
22N02W30H002	25726	204	30	175	100	104	100	104	71	76	175
22N03W24E001	25236	231	-42	273	37	194	37	194	79	90	273

CASGEM ID = California Statewide Groundwater Elevation Monitoring Identification Code
GWE = groundwater elevation
DTW = depth to water
ft = feet
amsl = above mean sea level
bgs = below ground surface



Surface Water Monitoring Stream Gage

Representative Surface Water Depletion Monitoring Site

Colusa Subbasin

N

0 2.5 5

Scale in Miles

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

DRAFT **Figure 4-8**

Representative Surface Water Depletion Monitoring Network

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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Table 5-3. Depletions of Interconnected Surface Water Representative Monitoring Network and Sustainability Criteria

SWN	CASGEM ID	Ground Surface Elevation, ft	Minimum Threshold GWE, ft amsl	Minimum Threshold DTW, ft bgs	Measurable Objective GWE, ft amsl	Measurable Objective DTW, ft bgs	Interim Milestone GWE, ft amsl	Interim Milestone DTW, ft bgs	Margin of Operational Flexibility, ft	Fall 2015 DTW, ft bgs
13N01E11A001	18534	32	13	19	22	10	22	10	9	9
13N01W07G001	36246	90	-19	110	-10	100	-10	100	10	100
14N01W04K003	18554	37	3	34	12	25	12	25	9	24
15N01W05G001	14309	47	19	29	27	20	27	20	9	19
17N02W30J002	16960	63	26	37	44	19	44	19	18	27
20N02W11A001	17170	125	106	20	119	6	119	6	14	10
20N02W25F004	23991	102	87	15	97	5	97	5	10	5
21N02W01F004	40029	162	105	57	126	36	126	36	21	47
21N02W05M003	23996	189	125	64	148	41	148	41	23	54
21N02W36A002	21239	135	59	76	91	44	91	44	32	76
22N02W30H004	38609	204	161	43	179	25	179	25	18	33
22N03W24E003	25758	231	194	36	208	23	208	23	13	26

CASGEM ID = California Statewide Groundwater Elevation Monitoring Identification Code
GWE = groundwater elevation
DTW = depth to water
ft = feet
amsl = above mean sea level
bgs = below ground surface

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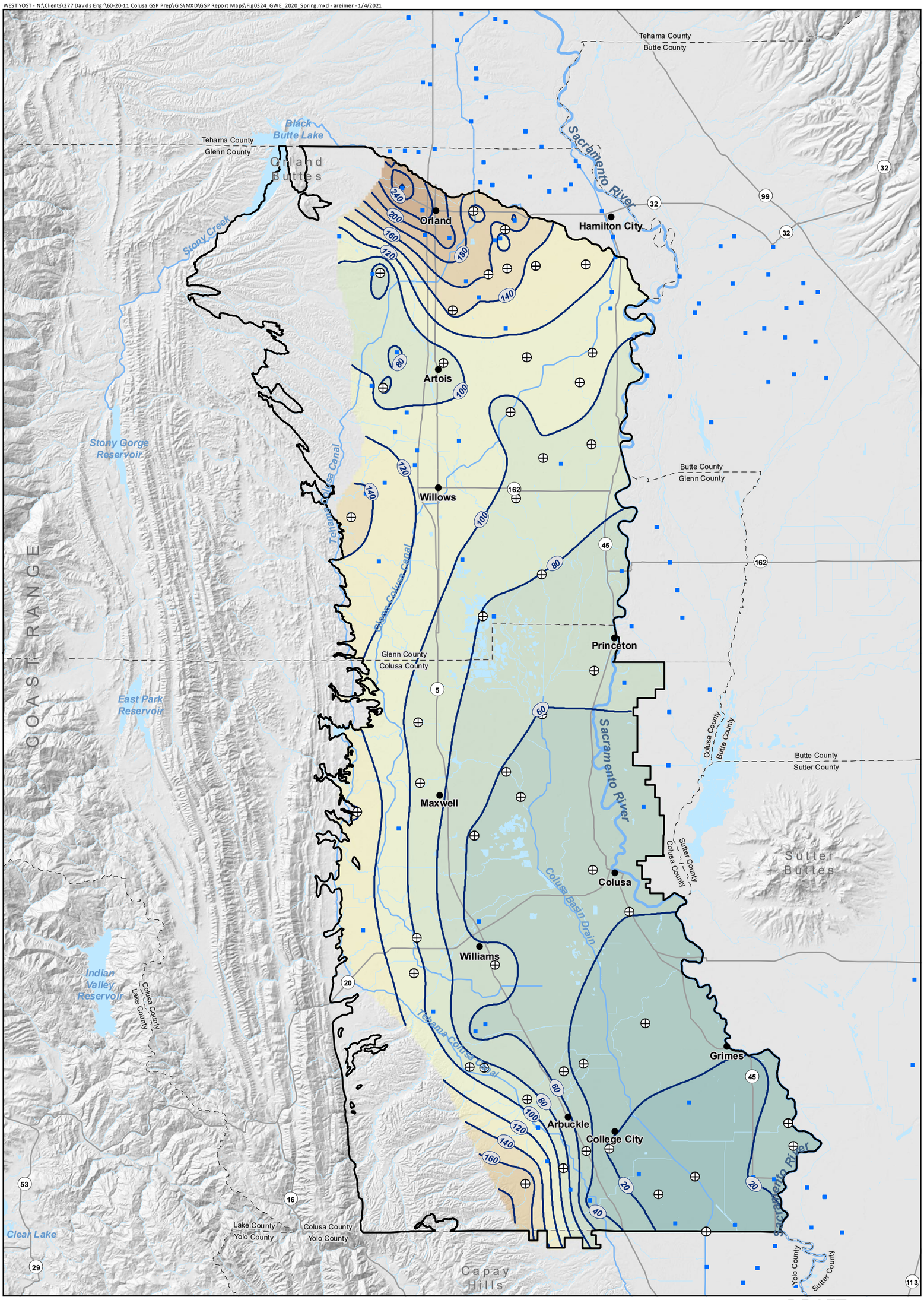

Groundwater Elevation (ft)

260 - 280	140 - 160	20 - 40
240 - 260	120 - 140	0 - 20
220 - 240	100 - 120	-20 - 0
200 - 220	80 - 100	-40 - -20
180 - 200	60 - 80	
160 - 180	40 - 60	

- Well Used for Contouring
- Monitoring Network Wells
- Groundwater Elevation Contour (20-Foot Interval)
- Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Vertical Datum: North American Vertical Datum of 1988, feet (NAVD 88).

N

0 2.5 5

Scale in Miles

DRAFT **Figure 3-24**

Groundwater Elevation Contours Spring 2020

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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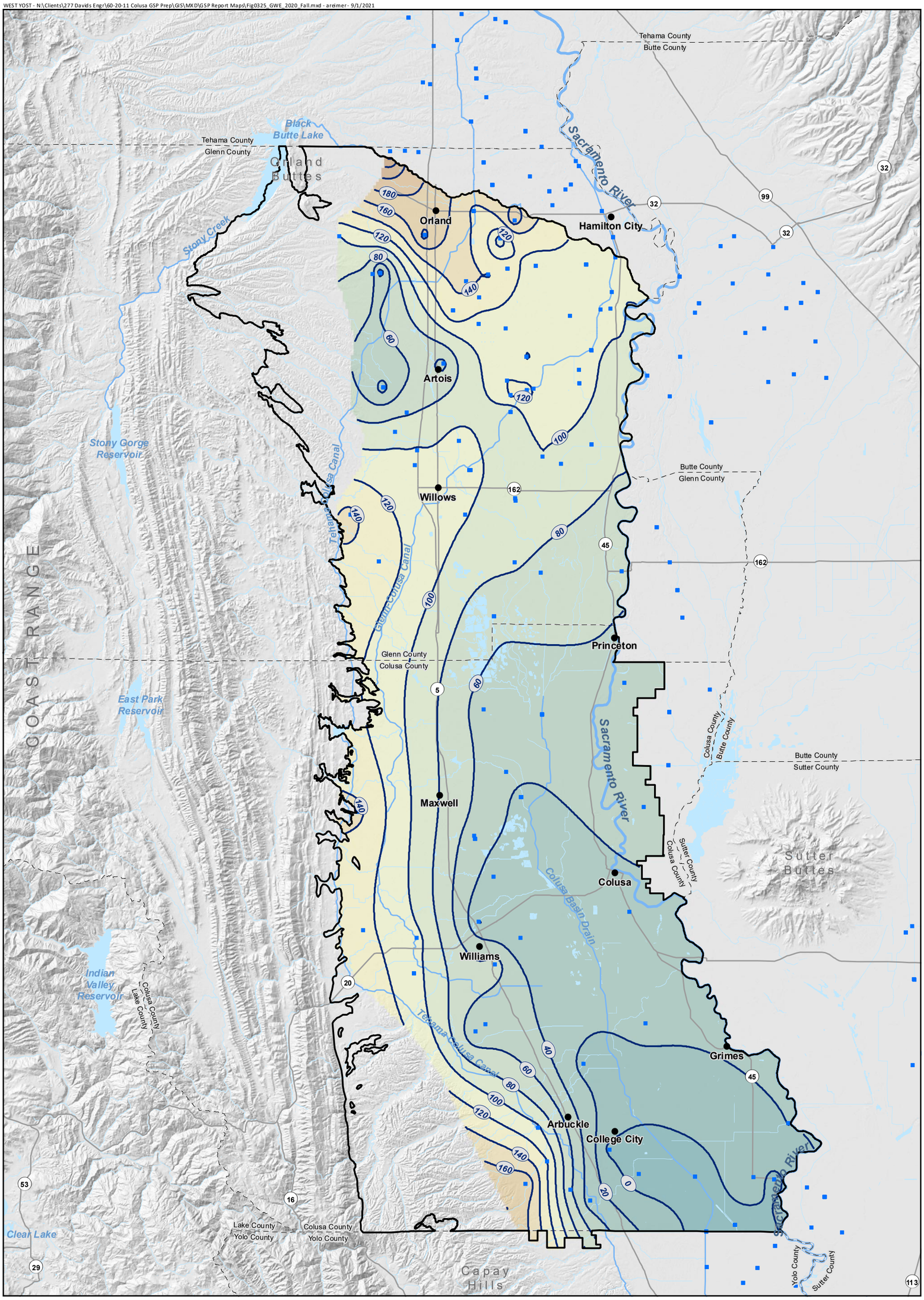

Groundwater Elevation (ft)

260 - 280	140 - 160	20 - 40
240 - 260	120 - 140	0 - 20
220 - 240	100 - 120	-20 - 0
200 - 220	80 - 100	-40 - -20
180 - 200	60 - 80	
160 - 180	40 - 60	

- Well Used for Contouring
- Groundwater Elevation Contour (20-Foot Interval)
- Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Vertical Datum: North American Vertical Datum of 1988, feet (NAVD 88).

N

0 2.5 5

Scale in Miles

DRAFT **Figure 3-25**

Groundwater Elevation Contours Fall 2020

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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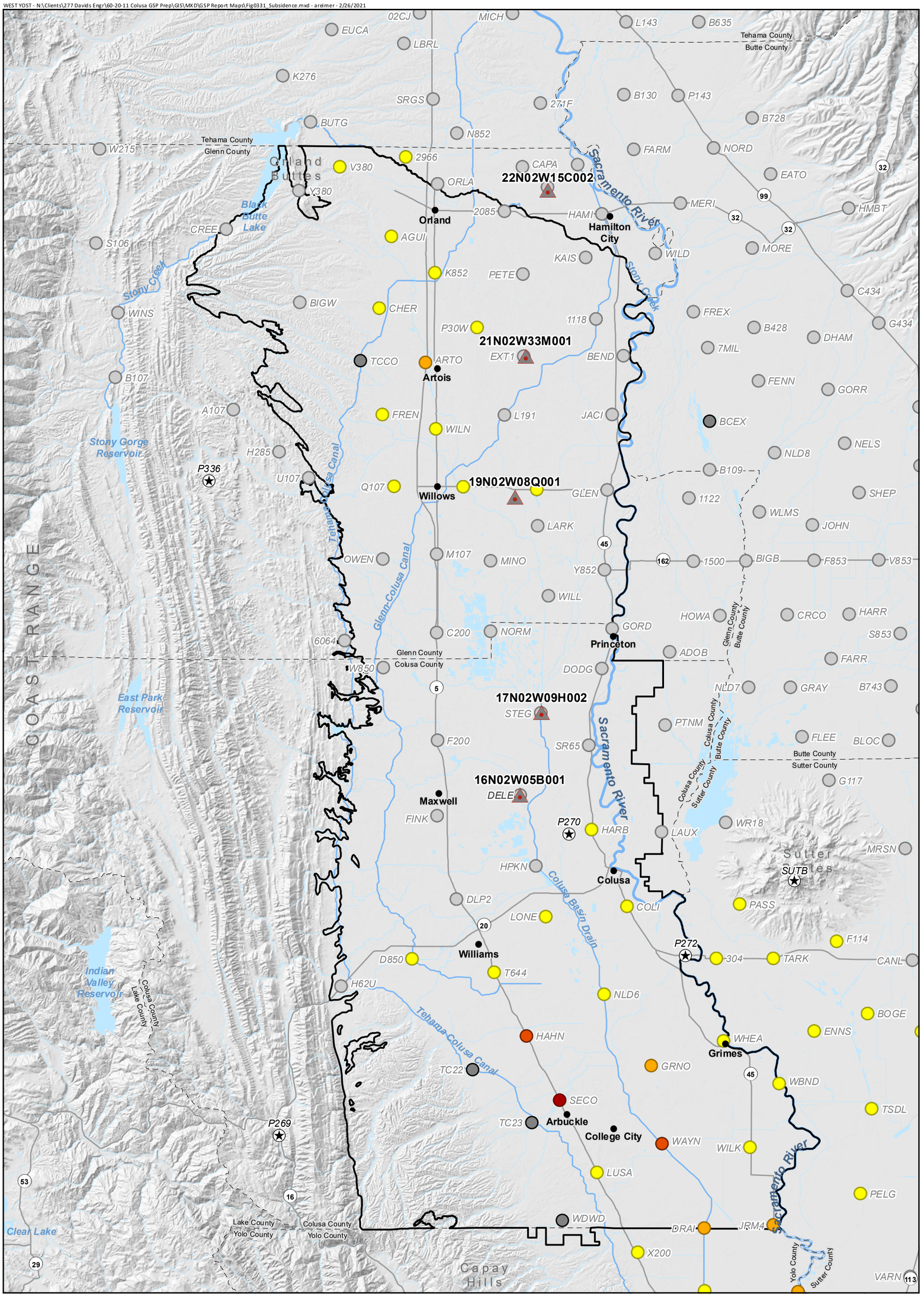

Source: Extensometers and continuous GPS stations were obtained from DWR and USGS. Benchmarks and displacement data were obtained from a resurvey report puublished by DWR (2020).

Datums: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Extensometer

Continuous GPS Station

Colusa Subbasin

Sacramento Valley Benchmark Subsidence Measured Between 2008 and 2017

- > 2 ft
- 1 - 2 ft
- 0.5 - 1 ft
- 2 inches - 0.5 ft
- < 2 inches
- New Benchmark or Not Surveyed

N

0 2.5 5

Scale in Miles

DRAFT **Figure 3-31**

Measured Subsidence 2008 to 2017

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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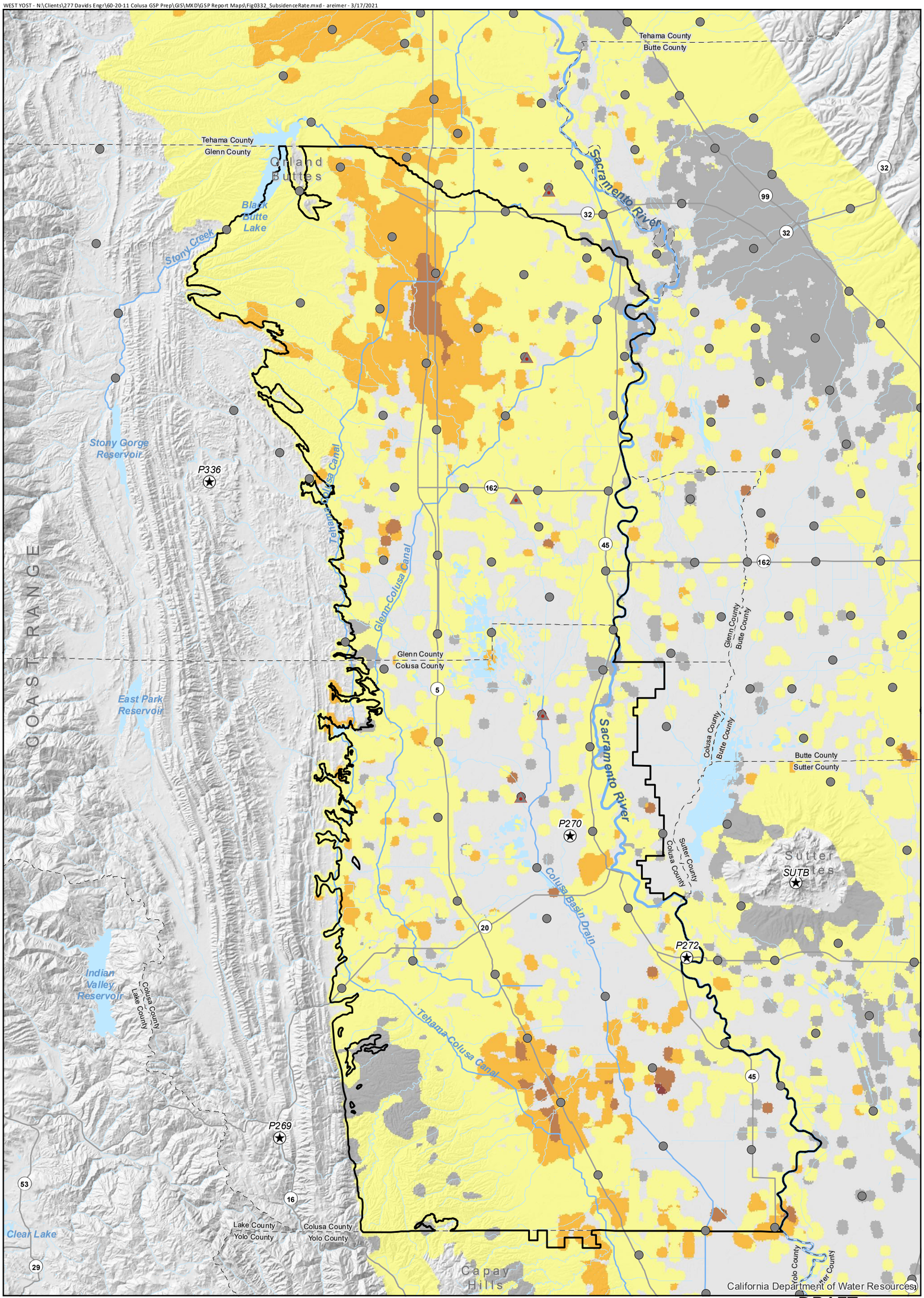

Source: TRE ALTAMiRA, 2020, InSAR Land Surveying and Mapping Services in Support of the DWR SGMA Program, Vertical Displacement v2019 Annual Rate 2018-09-01 to 2019-09-01, March 2020.

Datums: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

- Extensometer
- Continuous GPS Station
- Sacramento Valley Subsidence Benchmark
- Colusa Subbasin

Annual Subsidence Rate (inches per year) Between September 2018 and September 2019

- > 2
- 1 - 2
- 0.5 - 1
- 0 - 0.5
- Uplift or No Subsidence

N

0 2.5 5

Scale in Miles

DRAFT

Figure 3-32

Annual Subsidence Rate 2018 to 2019

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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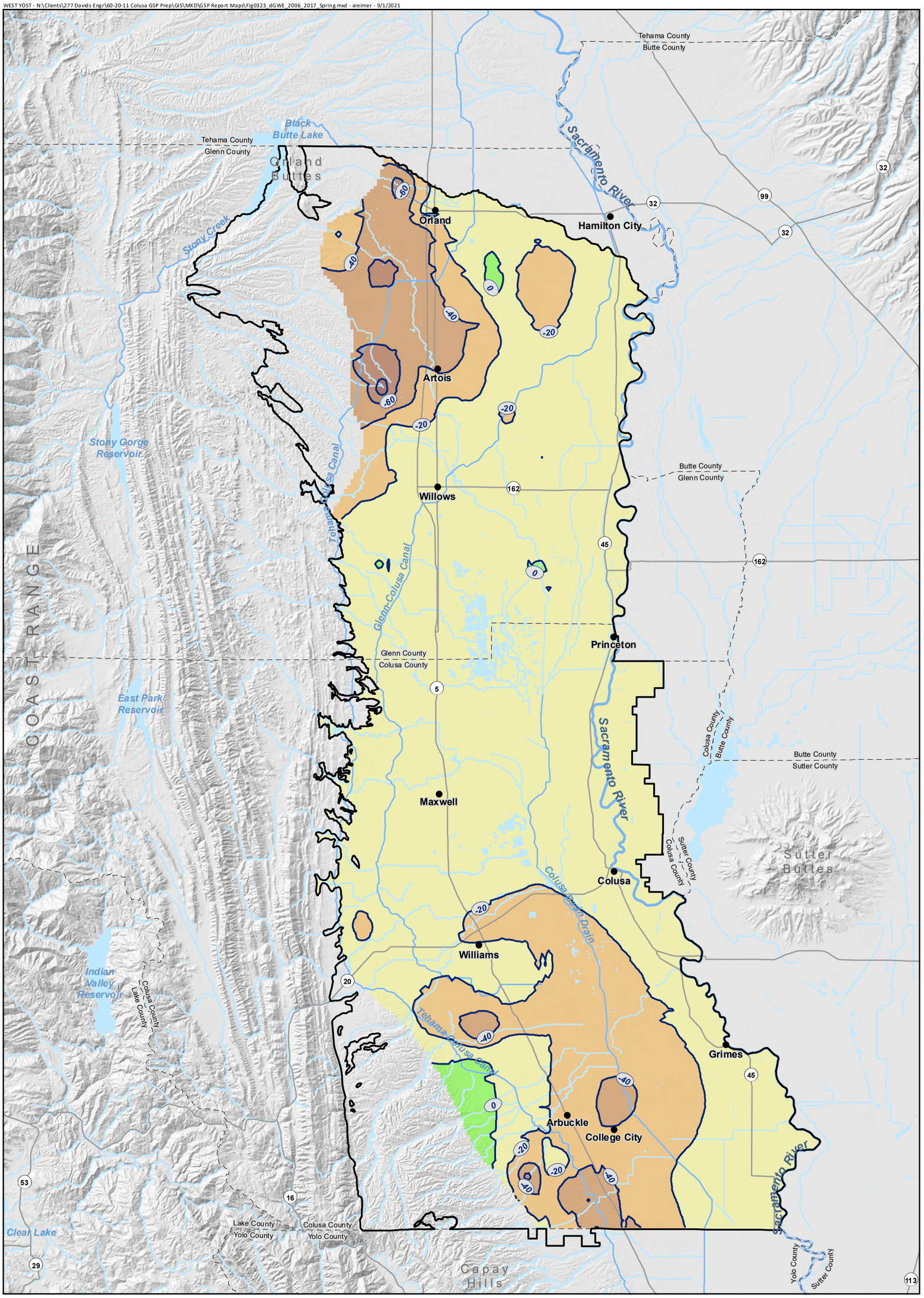

Change in Groundwater Elevation Contour (20-Foot Interval)

Colusa Subbasin

Change in Groundwater Elevation: Spring 2006 to Spring 2017

< -80 | -60 to -40 | -20 to 0

-80 to -60 | -40 to -20 | > 0

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Notes:

1. Negative change in groundwater elevation indicates a decrease in the spring groundwater elevation and an increase in the seasonal depth to water, from 2006 to 2017.

N

0 2.5 5

Scale in Miles

DRAFT **Figure 3-23**

Change in Groundwater Elevation Spring 2006 to Spring 2017

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

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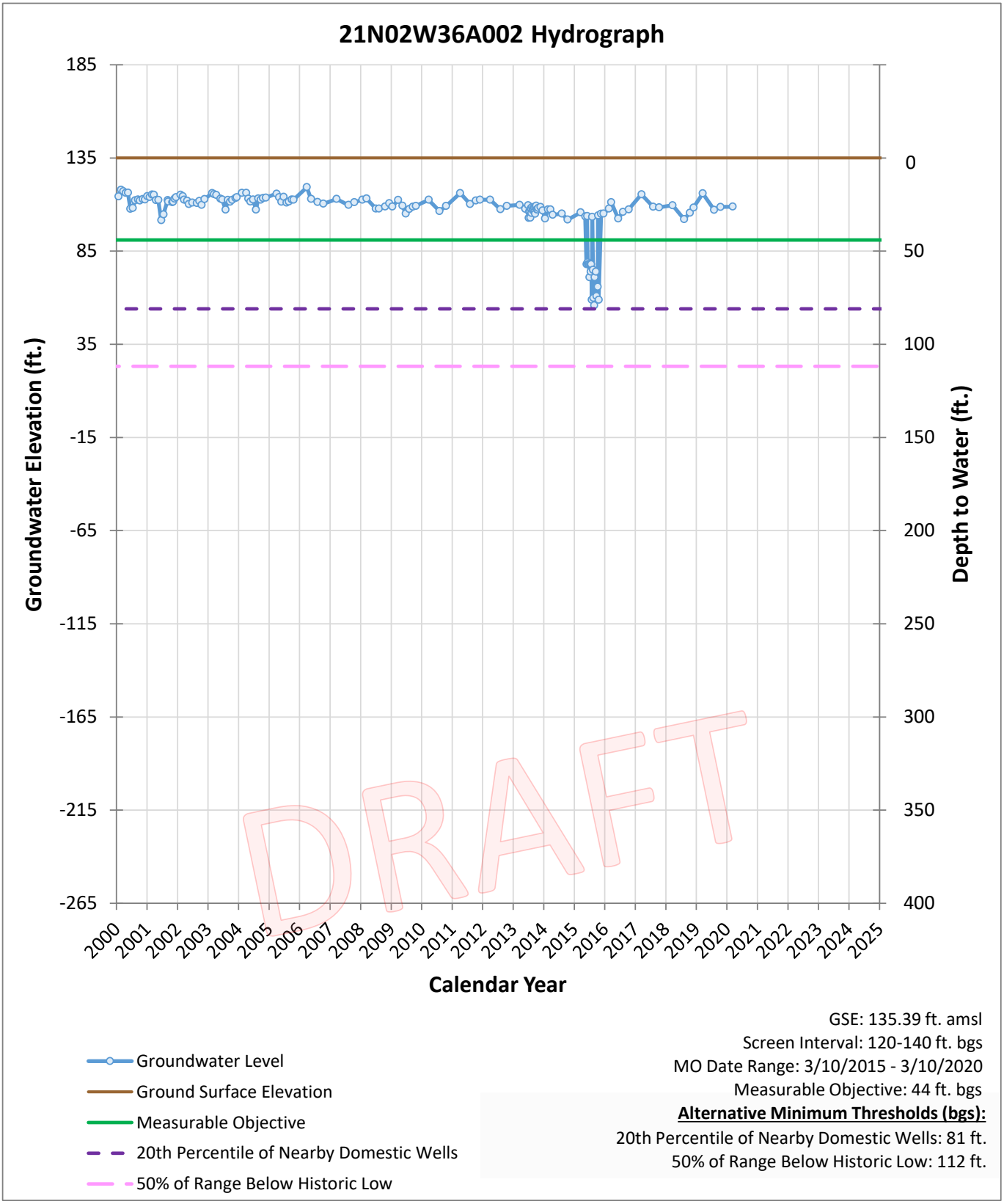
21N02W36A002 Hydrograph
Groundwater Elevation (ft.)
Depth to Water (ft.)
Calendar Year
185
135
85
35
-15
-65
-115
-165
-215
-265
0
50
100
150
200
250
300
350
400
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
DRAFT
Groundwater Level
Ground Surface Elevation
Measurable Objective
20th Percentile of Nearby Domestic Wells
50% of Range Below Historic Low
GSE: 135.39 ft. amsl
Screen Interval: 120-140 ft. bgs
MO Date Range: 3/10/2015 - 3/10/2020
Measurable Objective: 44 ft. bgs
Alternative Minimum Thresholds (bgs):
20th Percentile of Nearby Domestic Wells: 81 ft.
50% of Range Below Historic Low: 112 ft.

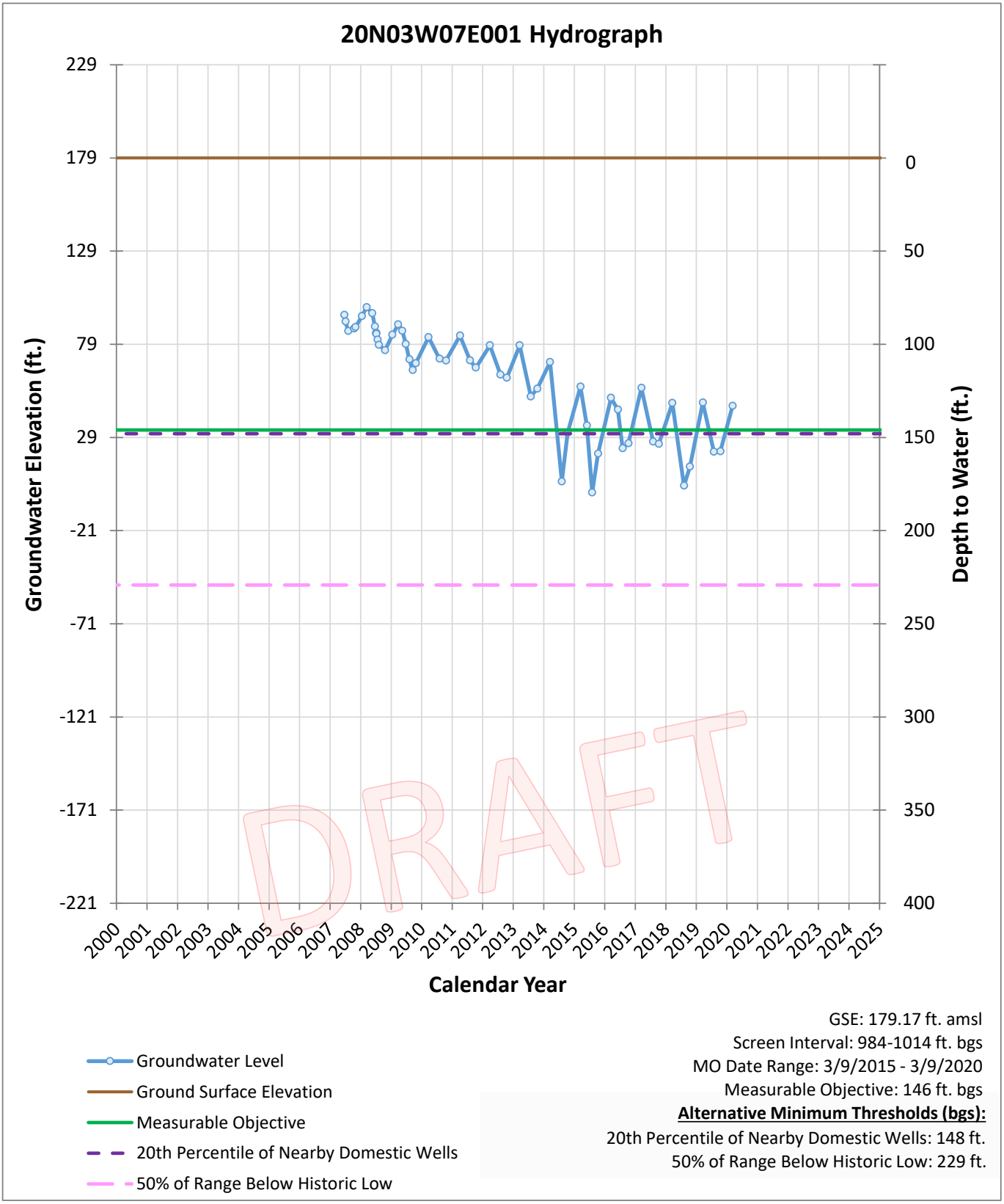
20N03W07E001 Hydrograph
Groundwater Elevation (ft.)
Depth to Water (ft.)
229
179
129
79
29
-21
-71
-121
-171
-221
0
50
100
150
200
250
300
350
400
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Calendar Year
DRAFT
Groundwater Level
Ground Surface Elevation
Measurable Objective
20th Percentile of Nearby Domestic Wells
50% of Range Below Historic Low
GSE: 179.17 ft. amsl
Screen Interval: 984-1014 ft. bgs
MO Date Range: 3/9/2015 - 3/9/2020
Measurable Objective: 146 ft. bgs
Alternative Minimum Thresholds (bgs):
20th Percentile of Nearby Domestic Wells: 148 ft.
50% of Range Below Historic Low: 229 ft.

Table 3-11. Average Annual Land and Surface Water System Inflows, Outflows, and Changes in Storage in taf/yr for the Water Budget Analysis Periods Listed in Table 3-9

Component	Historical Simulation	Current Conditions Baseline	Future Conditions, No Climate Change Baseline	Future Conditions, 2030 Climate Change Baseline[a]	Future Conditions, 2070 Climate Change Baseline[b]
Inflows					
Surface Water Inflows	11,747	12,556	12,556	12,597	12,715
Sacramento River Diversions	1,076	1,192	1,196	1,196	1,196
Stony Creek Diversions	92	95	91	91	91
Sacramento River Inflows[c]	10,500	11,188	11,188	11,228	11,335
Other Inflows from Boundary Streams	78	81	81	81	92
Precipitation	1,210	1,183	1,183	1,198	1,258
Groundwater Pumping	502	499	499	525	559
Agricultural	463	458	458	484	516
Urban and Industrial	11	11	10	10	10
Managed Wetlands	28	30	30	31	32
Stream Gains from Groundwater (Stream Accretions)	366	349	349	337	323
Total Inflow	**13,824**	**14,587**	**14,586**	**14,658**	**14,853**
Outflows					
Evapotranspiration	1,740	1,790	1,790	1,841	1,901
Agricultural	1,430	1,494	1,494	1,542	1,596
Urban and Industrial	22	28	28	28	28
Managed Wetlands	69	69	69	70	73
Native Vegetation	180	163	163	165	167
Canal Evaporation	40	36	36	36	36
Deep Percolation	441	416	415	415	411
Precipitation	174	162	162	160	156
Applied Surface Water	196	162	162	161	158
Applied Groundwater	72	92	91	94	97
Seepage	345	379	379	387	401
Streams	206	231	231	239	253
Canals and Drains	139	148	148	148	148
Surface Water Outflows	11,302	12,002	12,003	12,015	12,141
Precipitation Runoff	55	51	51	52	60
Applied Surface Water Return Flows	96	93	93	92	90
Applied Groundwater Return Flows	22	19	18	19	20
Sacramento River	9,371	11,049	11,050	11,086	11,187
Colusa Basin Drain	709	759	759	742	774

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Table 3-11. Average Annual Land and Surface Water System Inflows, Outflows, and Changes in Storage in taf/yr for the Water Budget Analysis Periods Listed in Table 3-9

Component	Historical Simulation	Current Conditions Baseline	Future Conditions, No Climate Change Baseline	Future Conditions, 2030 Climate Change Baseline[a]	Future Conditions, 2070 Climate Change Baseline[b]
Colusa Weir to Sutter Bypass	994	0	0	0	0
Other Outflows to Boundary Streams	56	32	32	23	10
Total Outflow	**13,828**	**14,587**	**14,587**	**14,658**	**14,853**
Change in Storage (Inflow - Outflow)	**-3**	**0**	**0**	**0**	**0**

(a) Central Tendency Climate Change Projections
(b) Sacramento River Diversions and Stony Creek Diversions are diversions from boundary streams outside the subbasin. About 20 percent of the total diversions come from streams within the subbasin and are included in the Sacramento River Inflow.
(c) Sacramento River Inflows include flows along the Sacramento River and the Colusa Basin Drain that enter the Colusa Subbasin.

1

Table 3-12. Average Annual Groundwater System Inflows, Outflows, and Changes in Storage in taf/yr for the Water Budget Analysis Periods Listed in Table 3-9

Component	Historical Simulation	Current Conditions Baseline	Future Conditions, No Climate Change Baseline	Future Conditions, 2030 Climate Change Baseline[a]	Future Conditions, 2070 Climate Change Baseline[b]
Inflows					
Subsurface Water Inflows	200	203	203	205	209
Deep Percolation	441	416	415	415	411
Precipitation	174	162	162	160	156
Applied Surface Water	196	162	162	161	158
Applied Groundwater	72	92	91	94	97
Seepage	345	379	379	387	401
Streams	206	231	231	239	253
Canals and Drains	139	148	148	148	148
Total Inflow	**986**	**997**	**997**	**1,008**	**1,021**
Outflows					
Subsurface Water Outflows	146	149	149	148	147
Groundwater Pumping	502	499	499	525	559
Agricultural	463	458	458	484	548
Urban and Industrial	11	11	10	10	10
Managed Wetlands	28	30	30	31	35
Stream Gains from Groundwater (Stream Accretions)	366	349	349	337	323
Total Outflow	**1,014**	**997**	**996**	**1,011**	**1,028**
Change in Storage (Inflow - Outflow)	**-28**	**1**	**1**	**-3**	**-7**

(a) Central Tendency Climate Change Projections
(b) Sacramento River Diversions and Stony Creek Diversions are diversions from boundary streams outside the subbasin. About 20 percent of the total diversions come from streams within the subbasin and are included in the Sacramento River Inflow.

Table 3-11. Average Annual Land and Surface Water System Inflows, Outflows, and Changes in Storage in taf/yr for the Water Budget Analysis Periods Listed in Table 3-9

Component	Historical Simulation	Current Conditions Baseline	Future Conditions, No Climate Change Baseline	Future Conditions, 2030 Climate Change Baseline[a]	Future Conditions, 2070 Climate Change Baseline[b]
Colusa Weir to Sutter Bypass	994	0	0	0	0
Other Outflows to Boundary Streams	56	32	32	23	10
Total Outflow	**13,828**	**14,587**	**14,587**	**14,658**	**14,853**
Change in Storage (Inflow - Outflow)	**-3**	**0**	**0**	**0**	**0**

(a) Central Tendency Climate Change Projections
(b) Sacramento River Diversions and Stony Creek Diversions are diversions from boundary streams outside the subbasin. About 20 percent of the total diversions come from streams within the subbasin and are included in the Sacramento River Inflow.
(c) Sacramento River Inflows include flows along the Sacramento River and the Colusa Basin Drain that enter the Colusa Subbasin.

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Table 3-12. Average Annual Groundwater System Inflows, Outflows, and Changes in Storage in taf/yr for the Water Budget Analysis Periods Listed in Table 3-9

Component	Historical Simulation	Current Conditions Baseline	Future Conditions, No Climate Change Baseline	Future Conditions, 2030 Climate Change Baseline[a]	Future Conditions, 2070 Climate Change Baseline[b]
Inflows					
Subsurface Water Inflows	200	203	203	205	209
Deep Percolation	441	416	415	415	411
Precipitation	174	162	162	160	156
Applied Surface Water	196	162	162	161	158
Applied Groundwater	72	92	91	94	97
Seepage	345	379	379	387	401
Streams	206	231	231	239	253
Canals and Drains	139	148	148	148	148
Total Inflow	**986**	**997**	**997**	**1,008**	**1,021**
Outflows					
Subsurface Water Outflows	146	149	149	148	147
Groundwater Pumping	502	499	499	525	593 ~~559~~
Agricultural	463	458	458	484	548
Urban and Industrial	11	11	10	10	10
Managed Wetlands	28	30	30	31	35
Stream Gains from Groundwater (Stream Accretions)	366	349	349	337	323
Total Outflow	**1,014**	**997**	**996**	**1,011**	1,063 ~~1,028~~
Change in Storage (Inflow - Outflow)	**-28**	**1**	**1**	**-3**	-42 ~~-7~~

(a) Central Tendency Climate Change Projections
(b) Sacramento River Diversions and Stony Creek Diversions are diversions from boundary streams outside the subbasin. About 20 percent of the total diversions come from streams within the subbasin and are included in the Sacramento River Inflow.

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Table 6-1. Summary of Key Colusa Subbasin Water Budget Parameters Influencing Formulation of Projects and Management Actions (average annual volumes, taf/yr)

Water Budget Parameter	Projected Future Conditions without Climate Change	Projected Future Conditions with 2070 Central Tendency Climate Change	Difference (Projected future with 2070 Central Tendency climate change minus without climate change)	Percent Difference[(a)]
Avg. Agricultural Evapotranspiration	1,494	1,596	102.0	6.8%
Precipitation	1,183	1,258	75.0	6.3%
Agricultural Pumping	458	516	58.0	12.7%
Avg. Rate of Change in Groundwater Storage, af/yr	0.6	-7.3	-7.9	-0.8%
Sacramento River and Stony Creek Diversions to Colusa Subbasin	1,287.0	1,287.0	0.0	0.0%
Net Steam Accretion	125	77	-48.0	-38.3%

(a) Calculated as the difference in the fourth column divided by the Projected Future Condition without Climate Change quantity in the second column, except for Avg. Rate of Change in Groundwater Storage, for which the percent difference is based on the approximately 1 million acre-feet that flow into and out of the Colusa Subbasin on an average annual basis. Water budget uncertainty is discussed in Chapter 3, Basin Setting, and model uncertainty is discussed in Appendix 3D. The average change in groundwater storage is considered to be within standard modeling error for this type of groundwater model analysis.

Under projected future conditions without climate change, groundwater storage is forecast to increase modestly, at an average rate of 0.6 taf/yr. With 2070 CT climate change and the associated increase in groundwater pumping to meet increased irrigation demands, groundwater storage is projected to decrease at a rate of 7.3 taf/yr. This net change of -7.9 taf/yr is 0.8 percent of the approximately one million acre-feet that flow into and out of the Colusa Subbasin groundwater system annually.

Under projected future conditions without climate change, net stream accretion (stream accretion minus stream depletion) is projected to be 125 taf/yr on average. This aggregate net stream accretion is for the Sacramento River, Stony Creek, and the Colusa Drain combined[2]. With 2070 CT climate change, net stream accretion is projected to remain positive but to decrease by about 48 taf/yr, or by 38 percent, with respect to the without climate change condition. However, viewed in relation to the average Sacramento River flow above the Feather River confluence of approximately 11.7 million acre-feet per year (af/yr) the projected change is roughly one half of one percent.

The aggregate changes in groundwater storage, 0.8 percent, and net stream accretion, 0.5 percent of the average Sacramento River Flow, are considered to be within standard modeling error for this type of analysis. The GSAs will continue to evaluate and review all Subbasin water budget parameters, including net

[2] A more detailed assessment of projected streamflow accretion-depletion is presented in Appendix 3G. The analysis considers the Sacramento River, Stony Creek, and the Colusa Drain individually and collectively, and evaluates temporal accretion-depletion patterns over the 50-year simulation period.

Modified Colusa Draft GSP Table 3-11.

Average Annual Land and Surface Water System Inflows, Outflows, and Changes in Storage in Acre-Feet/Year for the Water Budget Analysis Periods

A	B	C	D	E	F	G	H	I	J
Component	Historical Simulation, 1990 - 2015	Current Conditions Baseline, 2016 - 2065	Future Conditions, No Climate Change Baseline	Future Conditions, 2030 Climate Change Baseline[(a)]	Future Conditions, 2070 Climate Change Baseline[(b)]	2070 Future - Historical, AFY	2070 Future - Historical, Percent	2070 Future - Current, AFY	2070 Future - Current, Percent
Inflows									
Surface Water Inflows	11,747,000	12,556,000	12,556,000	12,597,000	12,715,000	**968,000**	**8.2%**	**159,000**	**1.3%**
Sacramento River Diversions	1,076,000	1,192,000	1,196,000	1,196,000	1,196,000	120,000	11.2%	4,000	0.3%
Stony Creek Diversions	92,000	95,000	91,000	91,000	91,000	-1,000	-1.1%	-4,000	-4.2%
Sacramento River Inflows	10,500,000	11,188,000	11,188,000	11,228,000	11,335,000	835,000	8.0%	147,000	1.3%
Other Inflows from Boundary Streams	78,000	81,000	81,000	81,000	92,000	14,000	17.9%	11,000	13.6%
Precipitation	1,210,000	1,183,000	1,183,000	1,198,000	1,258,000	**48,000**	**4.0%**	**75,000**	**6.3%**
Groundwater Pumping	502,000	499,000	499,000	525,000	559,000	**57,000**	**11.4%**	**60,000**	**12.0%**
Agricultural	463,000	458,000	458,000	484,000	516,000	53,000	11.4%	58,000	12.7%
Urban and Industrial	11,000	11,000	10,000	10,000	10,000	-1,000	-9.1%	-1,000	-9.1%
Managed Wetlands	28,000	30,000	30,000	31,000	32,000	4,000	14.3%	2,000	6.7%
Stream Gains from Groundwater (Stream Accretions)	366,000	349,000	349,000	337,000	323,000	**-43,000**	**-11.7%**	**-26,000**	**-7.4%**
Total Inflow	**13,824,000**	**14,587,000**	**14,586,000**	**14,658,000**	**14,853,000**	**1,029,000**	**7.4%**	**266,000**	**1.8%**
Outflows									
Evapotranspiration	1,740,000	1,790,000	1,790,000	1,841,000	1,901,000	**161,000**	**9.3%**	**111,000**	**6.2%**
Agricultural	1,430,000	1,494,000	1,494,000	1,542,000	1,596,000	166,000	11.6%	102,000	6.8%
Urban and Industrial	22,000	28,000	28,000	28,000	28,000	6,000	27.3%	0	0.0%
Managed Wetlands	69,000	69,000	69,000	70,000	73,000	4,000	5.8%	4,000	5.8%
Native Vegetation	180,000	163,000	163,000	165,000	167,000	-13,000	-7.2%	4,000	2.5%
Canal Evaporation	40,000	36,000	36,000	36,000	36,000	-4,000	-10.0%	0	0.0%
Deep Percolation	441,000	416,000	415,000	415,000	411,000	**-30,000**	**-6.8%**	**-5,000**	**-1.2%**
Precipitation	174,000	162,000	162,000	160,000	156,000	-18,000	-10.3%	-6,000	-3.7%
Applied Surface Water	196,000	162,000	162,000	161,000	158,000	-38,000	-19.4%	-4,000	-2.5%
Applied Groundwater	72,000	92,000	91,000	94,000	97,000	25,000	34.7%	5,000	5.4%
Seepage	345,000	379,000	379,000	387,000	401,000	**56,000**	**16.2%**	**22,000**	**5.8%**
Streams	206,000	231,000	231,000	239,000	253,000	47,000	22.8%	22,000	9.5%
Canals and Drains	139,000	148,000	148,000	148,000	148,000	9,000	6.5%	0	0.0%
Surface Water Outflows	11,302,000	12,002,000	12,003,000	12,015,000	12,141,000	**839,000**	**7.4%**	**139,000**	**1.2%**
Precipitation Runoff	55,000	51,000	51,000	52,000	60,000	5,000	9.1%	9,000	17.6%
Applied Surface Water Return Flows	96,000	93,000	93,000	92,000	90,000	-6,000	-6.3%	-3,000	-3.2%
Applied Groundwater Return Flows	22,000	19,000	18,000	19,000	20,000	-2,000	-9.1%	1,000	5.3%
Sacramento River	9,371,000	11,049,000	11,050,000	11,086,000	11,187,000	1,816,000	19.4%	138,000	1.2%
Colusa Basin Drain	709,000	759,000	759,000	742,000	774,000	65,000	9.2%	15,000	2.0%
Colusa Weir to Sutter Bypass	994,000	0	0	0	0	-994,000	-100.0%	0	
Other Outflows to Boundary Streams	56,000	32,000	32,000	23,000	10,000	-46,000	-82.1%	-22,000	-68.8%
Total Outflow	**13,828,000**	**14,587,000**	**14,587,000**	**14,658,000**	**14,853,000**	**1,025,000**	**7.4%**	**266,000**	**1.8%**
Change in Storage (Inflow - Outflow)	**-3,000**	**0**	**0**	**0**	**0**	**3,000**		**0**	
Net Stream Gains (Accretion)	**160,000**	**118,000**	**118,000**	**98,000**	**70,000**	**-90,000**	**-56.3%**	**-48,000**	**-40.7%**
Net Stream Accretion / GW Pumping	**31.9%**	**23.6%**	**23.6%**	**18.7%**	**12.5%**	**-157.9%**		**-80.0%**	
Sacramento River (Inflows - Outflows)	**1,129,000**	**139,000**	**138,000**	**142,000**	**148,000**	**-981,000**	**-86.9%**	**9,000**	**6.5%**

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Modified Colusa Draft GSP Table 3-12.

Average Annual Groundwater System Inflows, Outflows, and Changes in Storage in Acre-feet/Year for the Water Budget Analysis Periods

A	B	C	D	E	F	G	H	I	J
Component	Historical Simulation, 1990 - 2015	Current Conditions Baseline, 2016 - 2065	Future Conditions, No Climate Change Baseline	Future Conditions, 2030 Climate Change Baseline	Future Conditions, 2070 Climate Change Baseline	2070 Future - Historical, AFY	2070 Future - Historical, Percent	2070 Future - Current, AFY	2070 Future - Current, Percent
Inflows									
Subsurface Water Inflows	200,000	203,000	203,000	205,000	209,000	**9,000**	**4.5%**	**6,000**	**3.0%**
Deep Percolation	441,000	416,000	415,000	415,000	411,000	**-30,000**	**-6.8%**	**-5,000**	**-1.2%**
Precipitation	174,000	162,000	162,000	160,000	156,000	-18,000	-10.3%	-6,000	-3.7%
Applied Surface Water	196,000	162,000	162,000	161,000	158,000	-38,000	-19.4%	-4,000	-2.5%
Applied Groundwater	72,000	92,000	91,000	94,000	97,000	25,000	34.7%	5,000	5.4%
Seepage	345,000	379,000	379,000	387,000	401,000	**56,000**	**16.2%**	**22,000**	**5.8%**
Streams	206,000	231,000	231,000	239,000	253,000	47,000	22.8%	22,000	9.5%
Canals and Drains	139,000	148,000	148,000	148,000	148,000	9,000	6.5%	0	0.0%
Total Inflow	**986,000**	**998,000**	**997,000**	**1,007,000**	**1,021,000**	**35,000**	**3.5%**	**23,000**	**2.4%**
Outflows									
Subsurface Water Outflows	146,000	149,000	149,000	148,000	**147,000**	**1,000**	**0.7%**	**-2,000**	**-1.3%**
Groundwater Pumping	502,000	499,000	499,000	525,000	**593,000**	**91,000**	**18.1%**	**94,000**	**18.8%**
Agricultural	463,000	458,000	458,000	484,000	548,000	85,000	18.4%	90,000	19.7%
Urban and Industrial	11,000	11,000	10,000	10,000	10,000	-1,000	-9.1%	-1,000	-9.1%
Managed Wetlands	28,000	30,000	30,000	31,000	35,000	7,000	25.0%	5,000	16.7%
Stream Gains from Groundwater (Stream Accretions)	366,000	349,000	349,000	337,000	323,000	**-43,000**	**-11.7%**	**-26,000**	**-7.4%**
Total Outflow	**1,014,000**	**997,000**	**997,000**	**1,010,000**	**1,063,000**	**49,000**	**1.4%**	**66,000**	**3.1%**
Change in Storage (Inflow - Outflow)	**-28,000**	**1,000**	**0**	**-3,000**	**-42,000**	**-14,000**	**-75.0%**	**-43,000**	**-800.0%**
Net Stream Gains (Accretion)	**160,000**	**118,000**	**118,000**	**98,000**	**70,000**	**-90,000**	**-56.3%**	**-48,000**	**-40.7%**
Ratio Net Accretion / GW Pumping	**31.9%**	**23.6%**	**23.6%**	**18.7%**	**11.8%**	**-98.9%**		**-51.1%**	

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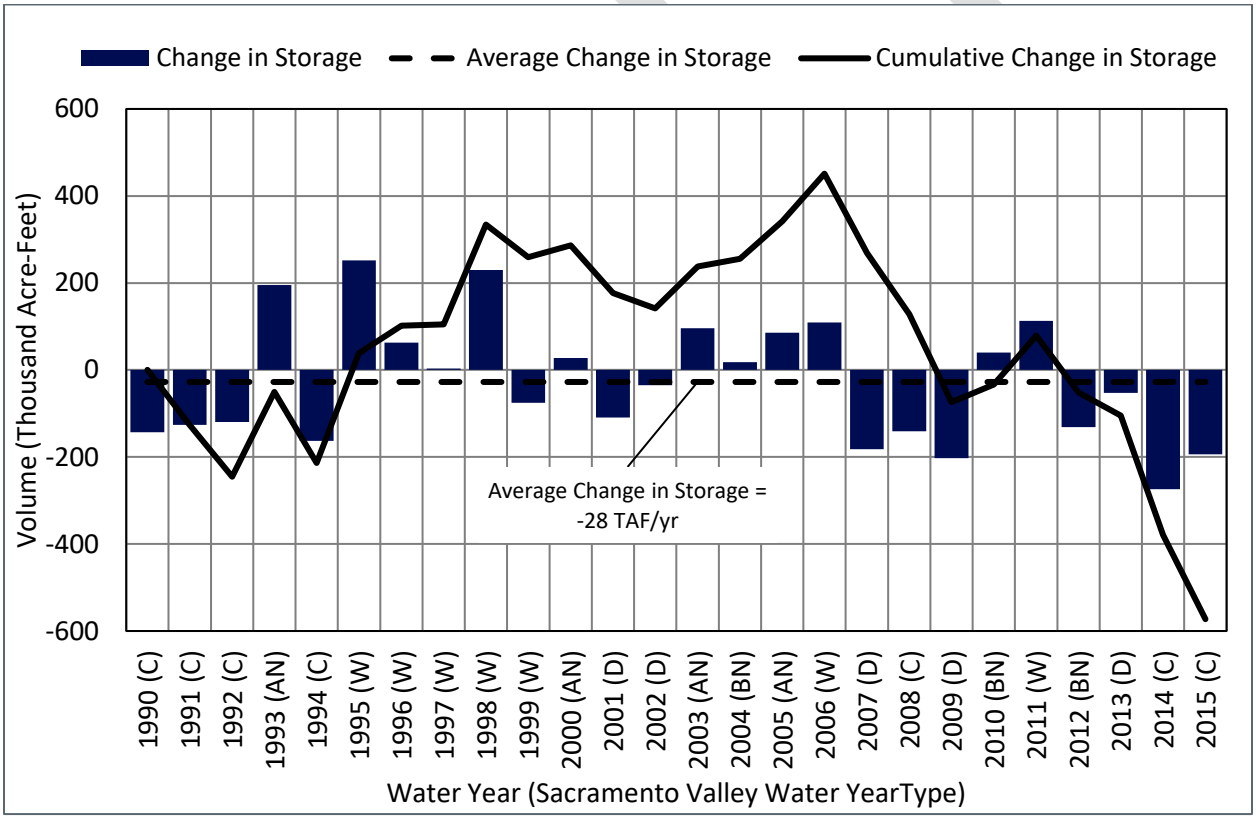
The average annual change in storage was -28 thousand acre-feet per year (taf/yr) over the historical water budget period of 1990 to 2015. This indicates that, on average, more groundwater has left the Colusa Subbasin than entered, resulting in an average net reduction in groundwater stored in the Colusa Subbasin. Figure 3-29 summarizes the annual change in storage and the cumulative change in storage in the Colusa Subbasin aquifer system over the historical water budget period. A decrease in groundwater storage occurred during critically dry (C), dry (D), and below normal (BN) water years. This is most evident between 2007 and 2015, when the region experienced a series of consecutive, multiple-year droughts. While critically dry, dry, and below normal water years almost always correspond with a decrease in storage, above normal (AN) and wet (W) water years do not always result in an increase in groundwater storage. On average, the Colusa Subbasin's storage volume is influenced more by dry years than wet years. This is likely due to both a greater reliance on groundwater supply during dry years when surface water is less readily available and the relatively slow nature of deep percolation to recharge the groundwater system during wet years. Most of the groundwater inflows and outflows within the Colusa Subbasin are exchanged directly with the land and surface water system overlying the Colusa Subbasin groundwater system. More information regarding the groundwater storage calculations can be found in the water budget section of this GSP (Section 3.3) and the model development and calibration Technical Memorandum prepared by Woodard and Curran and Davids Engineering (2021) (Appendix 3D).



Reference: Woodard and Curran and Davids Engineeirng. 2021. C2VSimFG-Colusa Model Development and Calibration Technical Memorandum: (Appendix 3D).

Figure 3-29. Change in Groundwater Storage

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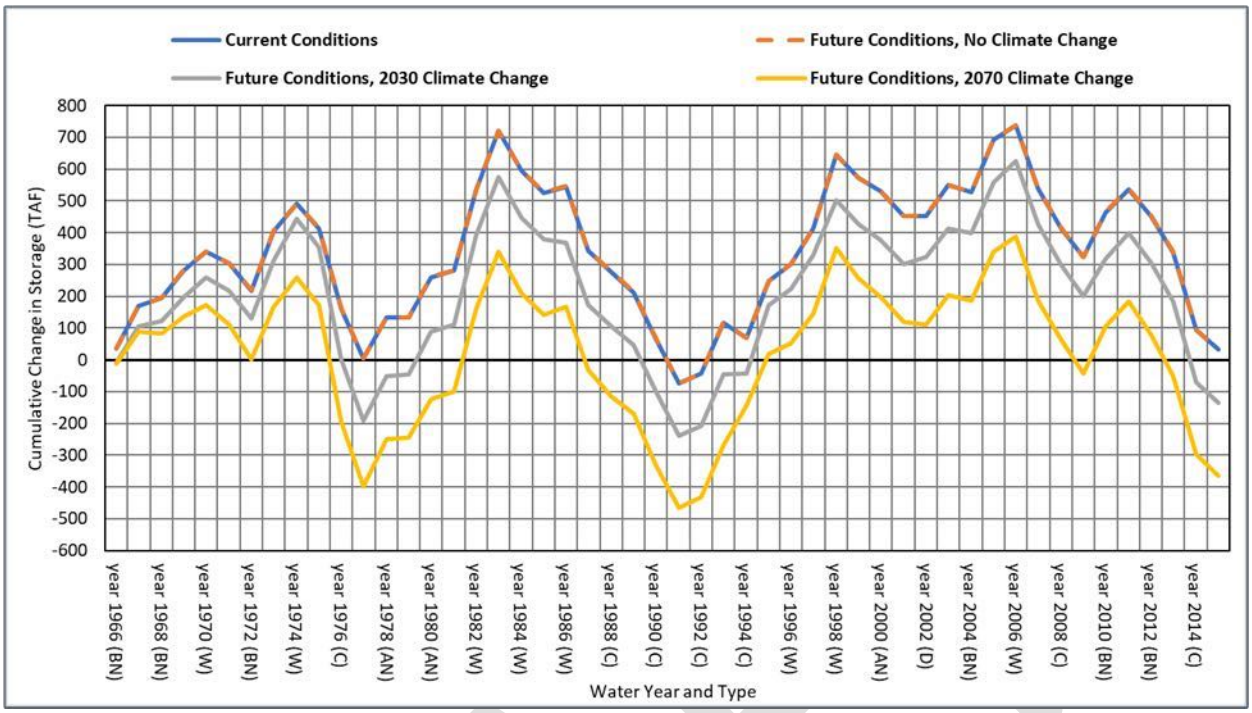


Figure 3-49. Cumulative Change in Groundwater Storage for Current and Future Conditions Baseline Scenarios

3.3.5 Water Budget Uncertainty

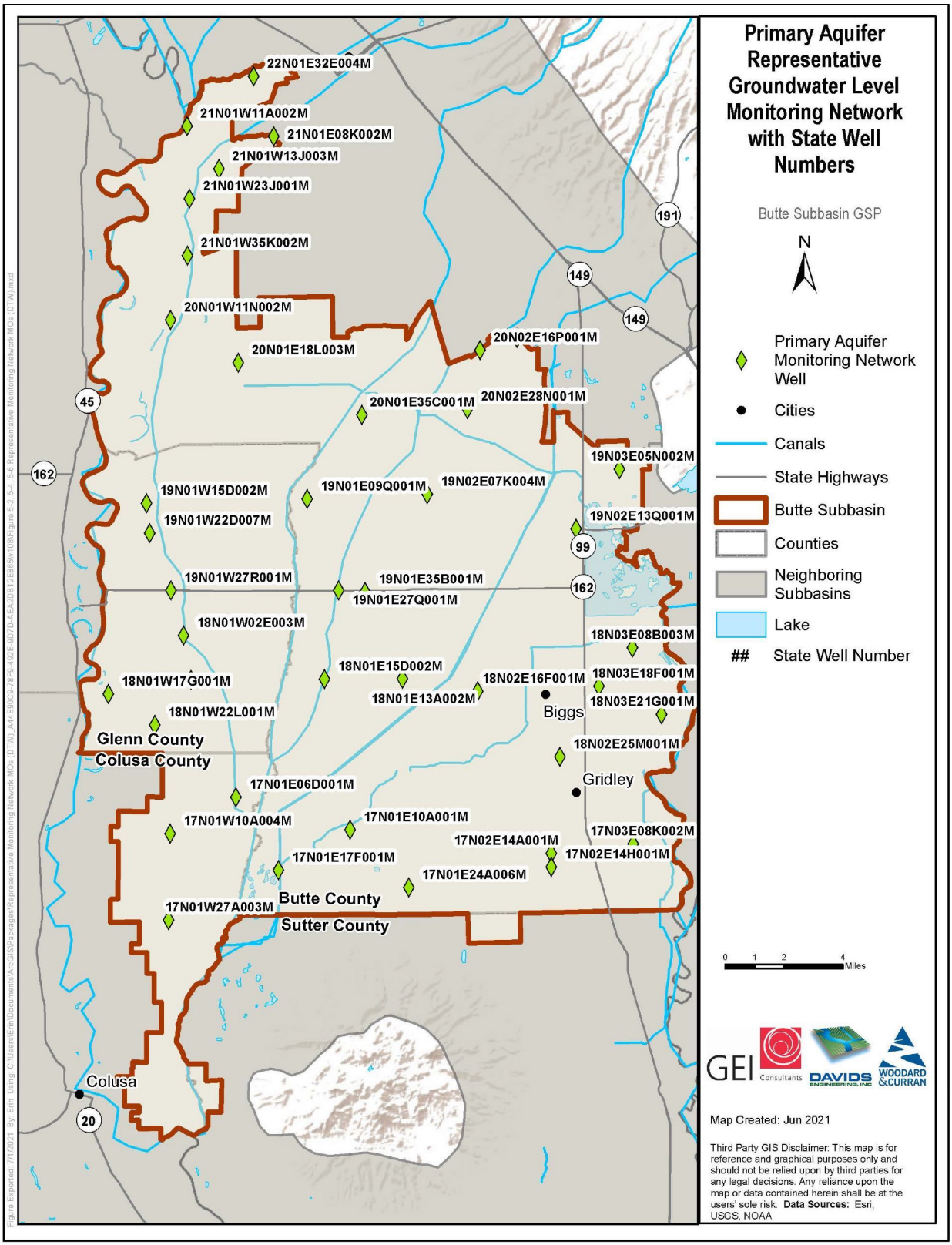
Water budget uncertainty refers to a lack of understanding of the subbasin setting that significantly affects an Agency's ability to develop sustainable management criteria and appropriate projects and management actions in a GSP, or to evaluate the efficacy of plan implementation, and therefore may limit the ability to assess whether a subbasin is being sustainably managed. Substantial uncertainty exists in all components of each water budget component. Substantial uncertainty also exits in the assumptions used to project potential future conditions related to planned development and associated urban demands, as well as, projections of climate change. Consequently, the estimated negligible or very small changes in groundwater storage for current and future water budgets, calculated as total subbasin inflows minus outflows, are highly uncertain. It is anticipated that confidence in model results will be increased over time through additional monitoring and data collection, refinements to C2VSimFG-Colusa input, and coordination with neighboring subbasins.

However, the uncertainties that currently exist do not substantially limit the ability to develop and implement a GSP for the subbasin including the ability to develop sustainable management criteria and appropriate projects and management actions, including improved monitoring, nor the ability to assess whether the subbasin is being sustainably managed over time. GSPs are by nature iterative, and each opportunity will allow for improvements that will (1) lower uncertainty and (2) facilitate more refined analyses of sustainable management criteria and projects and management actions, and (3) refine the GSP implementation.

Modified Butte Draft GSP Table 4-1 Primary Aquifer Monitoring Wells

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Well ID	State Well Number	CASGEM Number	Total Well Depth	Monitored Zone	Ground Surface Elevation (ft msl)	Table 4-1 Minimum Threshold Depth (bgs)	Appendix 4A Minimum Threshold Depth (bgs)*	Table 4-1 Minimum Threshold Elevation (ft msl)	Table 4-1 Measureable Objective Depth (bgs)	Appendix 4A Measurable Objective Depth (bgs)*	Table 4-1 Measureable Objective Elevation (ft msl)	Table 4-1 MT - MO Difference (feet)	Appendix 4A MT - MO Difference (feet)**	Well Type	Figure and Table 4-1 MT Calculation Method	Appendix4A MT Calculation Method**	Appendix4A Model Adjustment Applied (feet)
B-1	17N01E06D001M	25513	500	Intermediate	63.37	35	35	28	6	6	57	-29	-29	Irrigation	-20 feet	-20 feet	10
B-2	17N01E10A001M	16951	110	Very Shallow	65.34	42	42	23	17	17	48	-25	-25	Residential	-20 feet	-20 feet	-10
B-3	17N01E17F001M	33031	160	Shallow	58.97	34	34	25	7	7	52	-27	-27	Observation	-20 feet	-20 feet	3
B-4	17N01E24A006M	24328	75	Very Shallow	72.80	29	29	44	6	6	67	-23	-23	Observation	-20 feet	-20 feet	-2
B-5	17N01W10A004M	24660	117	Very Shallow	64.28	38	38	26	5	5	59	-33	-33	Observation	-20 feet	-20 feet	3
B-6	17N01W27A003M	24981	203	Shallow	66.61	43	43	24	14	14	53	-29	-29	Observation	-20 feet	-20 feet	0
B-7	17N02E14A001M	33033	102	Very Shallow	84.79	56	56	29	15	15	70	-41	-41	Irrigation	Shallowest 7%	Shallowest 7%	-10
B-8	17N02E14H001M	16956	102	Very Shallow	86.29	53	53	33	23	23	63	-30	-30	Other	-10 feet	-10 feet	-10
B-9	17N03E08K002M	33037	100	Very Shallow	91.27	38	38	53	13	13	78	-25	-25	Residential	-20 feet	-20 feet	-5
B-10	18N01E13A002M	34015	317	Intermediate	79.34	65	**54**	14	12	12	67	-53	**-42**	Irrigation	100% Historic	**-20 feet**	-3
B-11	18N01E15D002M	16376	112	Very Shallow	72.35	79	**59**	-7	7	7	65	-72	**-52**	Residential	100% Historic	**-20 feet**	3
B-12	18N01W02E003M	25507	200	Shallow	78.50	60	**50**	19	19	19	60	-41	**-31**	Observation	100% Historic	**-20 feet**	0
B-13	18N01W14B001M	16377	204	Shallow	72.38	73	**58**	-1	26	26	46	-47	**-32**	Irrigation	100% Historic	**-20 feet**	-9
B-14	18N01W17G001M	40068	108	Very Shallow	81.39	52	**47**	29	21	21	60	-31	**-26**	Irrigation	100% Historic	**-20 feet**	0
B-15	18N01W22L001M	16378	147	Shallow	72.39	57	**50**	15	17	17	55	-40	**-33**	Irrigation	100% Historic	**-20 feet**	0
B-16	18N02E16F001M	16382	80	Very Shallow	82.32	39	39	43	13	13	69	-26	-26	Irrigation	-10 feet	-10 feet	-12
B-17	18N02E25M001M	16383	220	Shallow	89.30	58	58	31	18	18	71	-40	-40	Irrigation	100% Historic	100% Historic	-12
B-18	18N03E08B003M	32764	463	Intermediate	112.30	59	59	53	29	29	83	-30	-30	Irrigation	-10 feet	-10 feet	-12
B-19	18N03E18F001M	16916	462	Shallow	99.80	44	44	56	14	14	86	-30	-30	Irrigation	100% Historic	100% Historic	-20
B-20	18N03E21G001M	16917	125	Very Shallow	106.28	50	50	56	31	31	75	-19	-19	Irrigation	-10 feet	-10 feet	-15
B-21	19N01E09Q001M	19780	200	Shallow	92.36	45	**42**	47	11	11	81	-34	**-31**	Irrigation	100% Historic	**-20 feet**	-5
B-22	19N01E27Q001M	19782	548	Intermediate	87.35	54	**47**	33	9	9	78	-45	**-38**	Observation	100% Historic	**-20 feet**	4
B-23	19N01E35B001M	23978	156.7	Shallow	86.50	35	35	52	4	4	83	-31	-31	Observation	-20 feet	-20 feet	0
B-24	19N01W15D002M	**50096**	300	Intermediate	91.00	54	**?**	37	25	25	66	-29	**?**	Residential	-20 feet	**?**	**?**
B-25	19N01W22D007M	24498	120	Very Shallow	87.38	54	**50**	33	20	20	67	-34	**-30**	Observation	100% Historic	**-20 feet**	-7
B-26	19N01W27R001M	19786	465	Very Shallow	83.38	86	**65**	-3	33	33	50	-53	**-32**	Irrigation	100% Historic	**-20 feet**	-10
B-27	19N02E07K004M	24324	192	Shallow	102.70	35	35	68	5	5	98	-30	-30	Observation	-20 feet	-20 feet	0
B-28	19N02E13Q001M	23979	221	Shallow	119.88	32	32	88	5	5	115	-27	-27	Observation	-20 feet	-20 feet	5
B-29	19N03E05N002M	34319	180	Very Shallow	142.31	98	**77**	44	37	37	105	-61	**-40**	Residential	100% Historic	**-20 feet**	-20
B-30	20N01E18L003M	23981	173	Very Shallow	107.35	28	28	79	5	5	102	-23	-23	Observation	-20 feet	-20 feet	5
B-31	20N01E35C001M	16135	92	Very Shallow	102.35	34	34	68	6	6	96	-28	-28	Residential	-20 feet	-20 feet	0
B-32	20N01W11N002M	24713	170	Shallow	107.37	54	**50**	53	22	22	85	-32	**-28**	Stockwatering	100% Historic	**-20 feet**	0
B-33	20N02E15H001M	16151	180	Shallow	144.01	103	**78**	41	44	44	100	-59	-34	Observation	100% Historic?	-20 feet	0
B-34	20N02E16P001M	16285	466	Intermediate	131.83	116	**80**	16	30	30	102	-86	**-50**	Irrigation	100% Historic	**-20 feet**	0
B-35	20N02E28N001M	35611	277	Intermediate	123.43	49	49	74	12	12	111	-37	-37	Other	100% Historic	100% Historic	5
B-36	21N01E08K002M	19253	181.2	Very Shallow	146.04	109	**79**	37	49	49	97	-60	**-30**	Irrigation	100% Historic	**-20 feet**	0
B-37	21N01W11A002M	24975	200	Shallow	129.30	38	38	91	15	15	114	-23	-23	Observation	-20 feet	-20 feet	3
B-38	21N01W13J003M	48992	400	Intermediate	127.68	70	**60**	58	25	25	103	-45	**-35**	Observation	100% Historic	**-20 feet**	0
B-39	21N01W23J001M	19739	54	Very Shallow	121.36	67	**54**	54	23	23	98	-44	**-31**	Irrigation	100% Historic	**-20 feet**	0
B-40	21N01W35K002M	21221	270	Shallow	114.36	41	41	73	18	18	96	-23	-23	Irrigation	-20 feet	-20 feet	0
B-41	22N01E32E004M	19363	160	Shallow	150.94	73	73	78	39	39	112	-34	-34	Residential	Shallowest 7%	Shallowest 7%	0
	* Value **Bolded** when the differ from Table 4-1 value.																
	** Value **Bolded** when the differ from Figure 4-1 value.																

Table modified after Draft Butte GSP Table 4-1 and other information in the GSP



2271 ***Figure 3-1. Primary Aquifer Representative Groundwater Level Monitoring Network***
2272

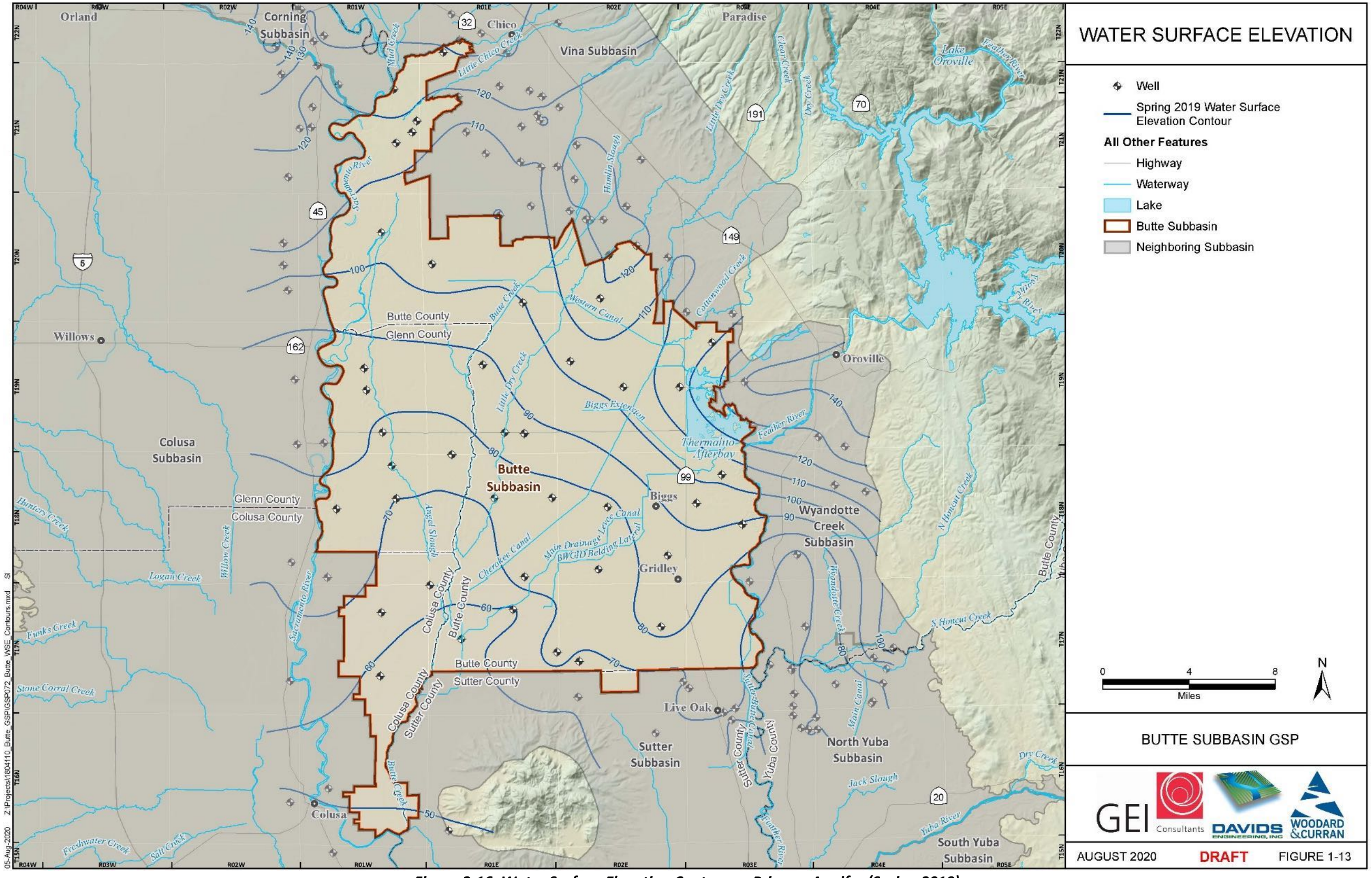


Figure 2-16. Water Surface Elevation Contours – Primary Aquifer (Spring 2019)

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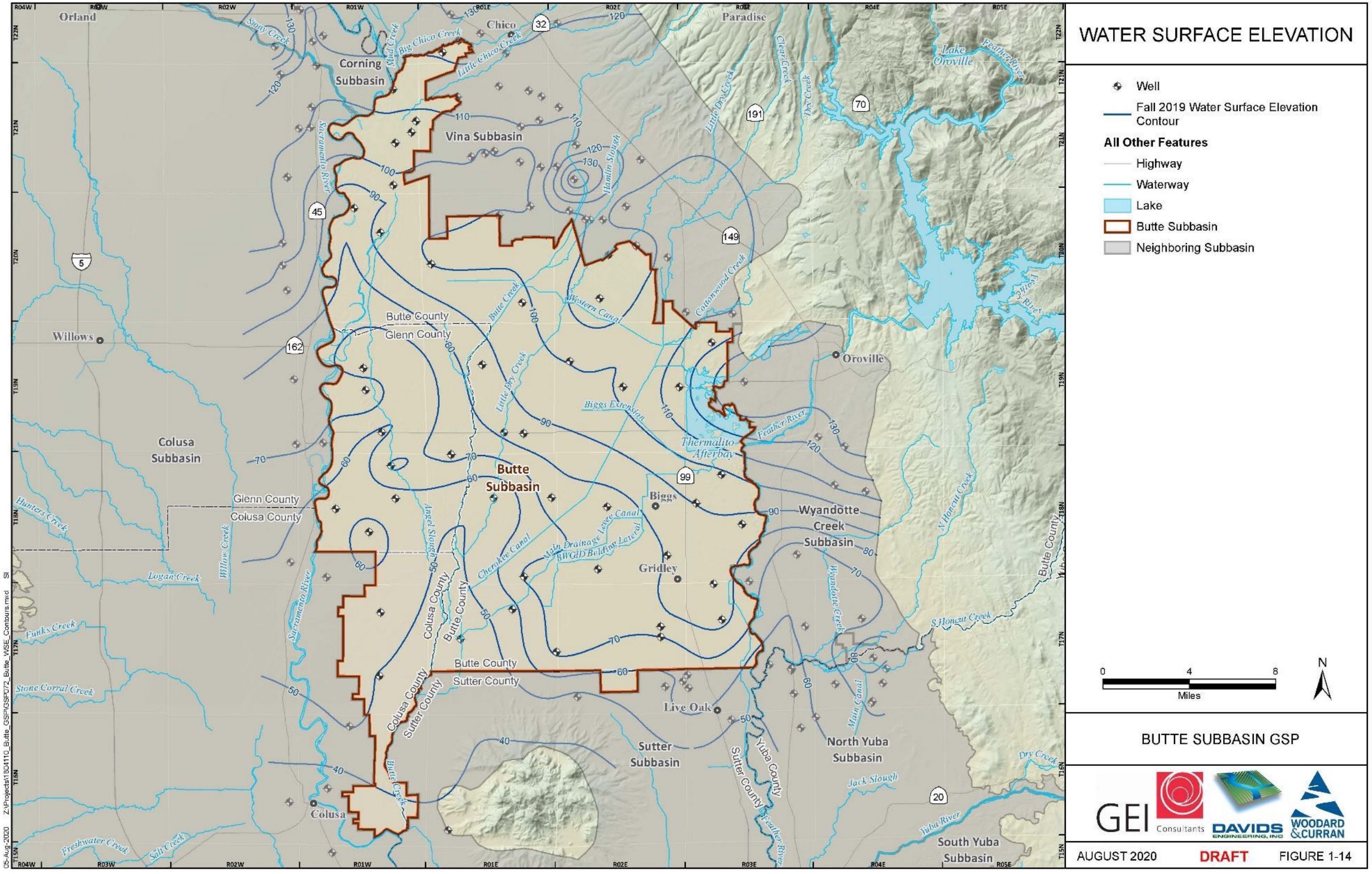

Figure 2-17. Water Surface Elevation Contours – Primary Aquifer (Fall 2019)

Groundwater Elevation Difference in Butte and Colusa GSP Monitoring Wells

West to East Across Sacramento River

Colusa GSP MW SWN	Colusa GSP MT GWE, ft amsl		Butte GSP MW SWN	Butte GSP MT GWE, ft amsl		GWE Difference, Butte GSP - Colusa GSP, ft
21N02W01F001	71		21N01W11A002M	91		20
21N02W36A002	24		21N01W23J001M	54		30
20N02W11A001	49		21N01W35K002M	73		24
20N02W18R005	29		20N01W11N002M	53		24
20N02W25F001	37					16
20N02W33B001	31					22
19N02W08Q001	12		19N01W15D002M	37		25
			19N01W22D007M	33		21
19N02W33K001	21		19N01W27R001M	-3		-24
			18N01W02E003M	19		-2
18N02W36B001	-3		18N01W17G001M	29		32
			18N01W22L001M	15		18
17N02W09H002	-52		17N01E06D001M	28		80
17N02W09H002	-52		17N01W10A004M	26		78
17N02W30J002	-119					145
16N02W05B001	-71		17N01W27A003M	24		95
17N02W30J002	-119					143

Audubon | CALIFORNIA

November 9, 2021

Colusa Groundwater Authority
Glenn Groundwater Authority
RE: Colusa Subbasin GSP
1213 Market Street
Colusa CA 95932

Sent via email to: mfahey@countyofcolusa.com

Re: Comments on the Draft Groundwater Sustainability Plan for the Colusa Subbasin

To Colusa Groundwater Authority and Glenn Groundwater Authority,

Audubon California appreciates the opportunity to provide public comment on the draft Colusa Subbasin Groundwater Sustainability Plan (GSP) prepared by the Colusa Groundwater Authority (CGA) and Glenn Groundwater Authority (GGA), collectively referred to hereafter as the "Colusa GSAs." Audubon California is a statewide nonprofit organization with a mission to protect birds and the places they need. Our organization has a long history of solutions-focused work in the Central Valley in collaboration with state and federal agencies, water districts, non-profits, and landowners. Audubon is reviewing draft GSPs as a stakeholder for the environment with a particular focus on managed wetlands. We are commenting on draft GSPs to provide technical assistance to Groundwater Sustainability Agencies (GSAs) to improve their GSPs prior to the deadline to submit final GSPs to the Department of Water Resources in January 2022. Audubon would also like to identify areas of opportunity to partner with landowners and GSAs to provide groundwater and wildlife habitat benefits in the implementation of the Sustainable Groundwater Management Act (SGMA).

Over 90 percent of historic wetlands in the Central Valley have been replaced with agriculture or urban development. Disconnected from natural water sources as a consequence of surface water diversions and groundwater over-pumping, wetland landowners must utilize surface water deliveries or pump groundwater to provide flooded habitat. But managed wetlands provide outsized public trust benefits for their minor water use.

The remaining wetlands in the Central Valley are a critical component of the Pacific Flyway, supporting millions of migratory waterfowl, hundreds of thousands of shorebirds, and state listed species like the Tricolored Blackbird. Central Valley managed wetlands are part of California's commitment to national and international Pacific Flyway agreements and provide significant public trust benefits, including habitat for migratory birds, recharge of overdrafted aquifers, carbon sequestration, and recreation opportunities for birders, hunters, and disadvantaged communities.

As recognized by the Colusa GSAs, managed wetlands require specific consideration in GSPs under SGMA statute and regulations, as detailed below. GSAs are required to identify managed wetlands as beneficial users of groundwater and as land uses and property interests and should recognize this land use consistent with other active users of surface and groundwater. The overall basin water budget must

include managed wetlands as a specific water use sector and the GSP is required to consider the effects of the GSP on managed wetlands as a beneficial user or land use.

When GSPs fail to adequately consider the water needs and recharge contributions of managed wetlands, projects and management actions may ignore managed wetlands, their need for protection as public trust resources, and their potential to be part of sustainability solutions. If future actions include groundwater allocations, managed wetlands face the potential of being excluded if not recognized in the GSP, risking further loss in critical wetland acreage.

SGMA Requirements Related to Managed Wetlands

A primary requirement for GSAs during GSP development is the consideration of the interests of "all beneficial uses and users of groundwater" [Water Code Section 10723.2], which includes "[e]nvironmental users of groundwater" [Water Code Section 10723.2(e)].

Articulated into the SGMA regulations, the concept of beneficial uses and users of groundwater is first represented in CCR, Title 23, Section 354.10. Notice and Communication, which directs the GSP to "…include a summary of information relating to notification and communication by the Agency with other agencies and interested parties including the following: (a) A description of the beneficial uses and users of groundwater in the basin, including the land uses and property interests potentially affected by the use of groundwater in the basin, the types of parties representing those interests, and the nature of consultation with those parties." [emphasis added].

Furthermore, the SGMA regulations provide a definition that explicitly includes managed wetlands as a beneficial user where:

> "'Water use sector' refers to categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation." CCR, Title 23, Section 351(al) [emphasis added].

GSAs are then directed to include all water user sectors in the description of the GSP area and to quantify groundwater use by these sectors in the historic, current and projected budgets [emphasis added]:

> CCR §354.8. Description of Plan Area: Each Plan shall include a description of the geographic areas covered, including the following information:
>
> (a) One or more maps of the basin that depict the following, as applicable:
>
> (4) Existing land use designations and the identification of water use sector and water source type.
>
> and,
>
> CCR §354.18. Water Budget:
>
> (b) The water budget shall quantify the following, either through direct measurements or estimates based on data:
>
> (3) Outflows from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow.

Given these explicit requirements, GSAs are required to identify and map managed wetlands and include their water needs in water budgets in the GSP.

Furthermore, each GSP is also required to describe "undesirable results" where such included:

> "Potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results." CCR, Title 23, Section 354.26(b)(3) [emphasis added]

Comment Overview

In reviewing this draft GSP, we applaud the Colusa GSAs for their proactive effort to include managed wetlands throughout the GSP. As a result, our comments are limited and summarized as follows:

1. Identification of managed wetlands: Audubon appreciates that the GSA has identified and specifically included managed wetlands in maps and water budgets, specifically the three primary refuges: Sacramento National Wildlife Refuge, Delevan National Wildlife Refuge, and Colusa National Wildlife Refuge.
2. Water budget: Audubon appreciates the specific inclusion of managed wetlands into the water budgets (e.g. Table 3-11). However, the future condition water budgets should reflect CVPIA Full Level 4 water supplies being available and delivered to each of the three national wildlife refuges. The use of 2013 to represent unconstrained delivery conditions (e.g. see GSP Table 3-9, page 3-88) reflects deliveries to these refuges that are less than the CVPIA Full Level 4 mandated quantities. Annual Full Level 4 water supplies during unconstrained conditions are as follows:
    a. Sacramento NWR = 50,000 acre-feet,
    b. Delevan NWR = 30,000 acre-feet, and
    c. Colusa NWR = 25,000 acre-feet.

    During constrained conditions, these same refuges generally are provided 75% of this quantity, as stipulated in their water delivery agreements with the U.S. Bureau of Reclamation.
3. Consideration of managed wetlands: Audubon appreciates that several of the listed projects included in Table 6-2 include identified opportunities for multi-benefit projects that provide water supply and wildlife habitat benefits.

Draft Groundwater Sustainability Plan Page-by-Page Comments

Additional page-by-page comments on the Colusa GSAs' draft GSP are detailed below. We welcome any follow up questions and look forward to seeing the issues raised below addressed in the final GSP submission in January 2022.

> Figure 2-8: Suggest modifying the color scheme or naming for the category "native" to distinguish the refuges from other "native" areas as the refuges are distinctly different land uses than the traditional native upland areas, for instance, in the southwestern portion of the subbasin. Private managed wetlands and managed wetlands in U.S. Fish and Wildlife Service Management Areas that have federal easements are currently not identified in land use or jurisdictional maps.
>
> Table 2-3, page 2-11: Since the three national wildlife refuges are mandated to receive stipulated quantities (though have yet to achieve them), this table should also list the CVPIA Full Level 4 quantities of: Sacramento NWR = 50,000 acre-feet, Delevan NWR = 30,000 acre-feet, and Colusa NWR = 25,000 acre-feet. While the historic average deliveries are useful for baseline understanding, modeling of future conditions should include the full water supplies for these three refuges.

Page 3-13, line 32/33: The term "land" should be added to the end of the sentence to result in "federal wildlife land."

Table 3-9, page 3-88: The future condition water supplies for the three national wildlife refuges should reflect the CVPIA Full Level 4 water supply. Deliveries in 2013, represented as a Shasta Non-critical year, did not result in Full Level 4 deliveries to these refuges. The CVPIA Full Level 4 quantities include a portion that is labeled "Level 2" that reflects delivery of CVP project water, and a portion labeled "Incremental Level 4" (the difference between Full Level 4 and Level 2) that can come from other sources. The GSP will need to make reasonable assumptions whether the Incremental Level 2 supply will be derived from other surface water sources or from groundwater, though either is possible.

Section 3.3.3.1 Historical (Water Budget), page 3-89: Under "Agricultural Water Demand" the following sentence is included: "*For ponded land uses (rice and managed wetlands), pond depths and pond drainage are also considered to simulate demands*." Under the "Current Conditions" (Section 3.3.3.2) and "Future Conditions Scenarios" (Section 3.3.3.3) water budget discussions, this same language is missing. Did these budgets recognize managed wetlands in a similar fashion as described for the historical budget? If so, we suggest adding the same sentence to each of the other water budget descriptions for clarity.

Table 3-11, page 3-96: As a result of including the CVPIA Full Level 4 water supplies for the national wildlife refuges, the values for the various future conditions for "Sacramento River Diversions" and "Groundwater Pumping – Managed Wetlands" as well as the "Evapotranspiration – Managed Wetlands" may all change. The table should be updated accordingly.

Table 3-12, page 3-97: Similar to the prior comment, values in this table for the future conditions would be expected to change when the CVPIA Full Level 4 water supply quantities are incorporated.

Section 6.5.2.3, page 6-84 to 6-86: Several demand reduction concepts are initially outlined in this section. Audubon suggests the following be considered associated with each suggested method:

1. Allocation: Use of groundwater by managed wetlands should not be restricted without adequate replacement with surface water sources, especially the national wildlife refuges. Managed wetlands in the Colusa subbasin provide invaluable benefits to the Pacific Flyway.
2. Allocation with a market: If a market is created and managed wetlands are assigned an allocation, such parcels should be able to participate in a market to optimize the use of their allocations for achieving habitat objectives, but managed wetlands should not be required to participate in a market to secure the water they need.
3. Land repurposing: Strategic siting of where irrigated lands are retired and others are kept in production should consider the potential benefits to wildlife. Areas surrounding protected areas, such as the Sacramento, Delevan and Colusa National Wildlife Refuges, should be prioritized habitat benefits.
4. Financial incentives: Public beneficial uses such as managed wetlands should not be subject to financial conditions that lesson the public benefit otherwise achieved on the lands.

Thank you for your consideration of Audubon California's comments. If you would like to discuss this matter further, please do not hesitate to contact me at (916) 737-5707 or via email at samantha.arthur@audubon.org.

Sincerely,



Samantha Arthur
Working Lands Program Director
Audubon California

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State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
North Central Region/Region 2
1701 Nimbus Road
Rancho Cordova, CA 95670
www.wildlife.ca.gov
(916) 358-2900

GAVIN NEWSOM, Governor
CHARLTON H. BONHAM, Director

October 26, 2021

Mary Fahey
Lisa Hunter
Colusa Subbasin
1213 Market Street
Colusa, CA 95932
mfahey@countyofcolusa.com
lhunter@countyofglenn.net

Subject: CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE COMMENTS ON THE COLUSA SUBBASIN DRAFT GROUNDWATER SUSTAINABILITY PLAN

Dear Ms. Fahey and Ms. Hunter:

The California Department of Fish and Wildlife (Department) appreciates the opportunity to provide comments on the Colusa Subbasin Draft Groundwater Sustainability Plan (GSP) prepared by the Colusa Groundwater Authority Groundwater Sustainability Agency (GSA) and Glenn Groundwater Authority GSA pursuant to the Sustainable Groundwater Management Act (SGMA). The Basin is designated as high priority under SGMA and must be managed under a GSP by January 31, 2022.

The Department is writing to support ecosystem preservation and enhancement in compliance with SGMA and its implementing regulations based on Department expertise and best available information and science. As trustee agency for the State's fish and wildlife resources, the Department has jurisdiction over the conservation, protection, and management of fish, wildlife, native plants, and the habitat necessary for biologically sustainable populations of such species (Fish & Game Code §§ 711.7 and 1802).

Development and implementation of GSPs under SGMA represents a new era of California groundwater management. The Department has an interest in the sustainable management of groundwater, as many sensitive ecosystems, species, and public trust resources depend on groundwater and interconnected surface waters (ISWs), including ecosystems on Department-owned and managed lands within SGMA-regulated basins.

SGMA and its implementing regulations afford ecosystems and species specific statutory and regulatory consideration, including the following as pertinent to GSPs:

- GSPs must **consider impacts to groundwater dependent ecosystems** (GDEs) (Water Code § 10727.4(l); see also 23 CCR § 354.16(g));
- GSPs must consider the interests of all beneficial uses and users of groundwater, including environmental users of groundwater (Water Code §

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10723.2) and GSPs must **identify and consider potential effects on all beneficial uses and users of groundwater** (23 CCR §§ 354.10(a), 354.26(b)(3), 354.28(b)(4), 354.34(b)(2), and 354.34(f)(3));

- GSPs must **establish sustainable management criteria that avoid undesirable results** within 20 years of the applicable statutory deadline, including **depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water** (23 CCR § 354.22 *et seq*. and Water Code §§ 10721(x)(6) and 10727.2(b)) and describe monitoring networks that can identify adverse impacts to beneficial uses of interconnected surface waters (23 CCR § 354.34(c)(6)(D)); and
- GSPs must **account for groundwater extraction for all water use sectors,** including managed wetlands, managed recharge, and native vegetation (23 CCR §§ 351(al) and 354.18(b)(3)).

Furthermore, the Public Trust Doctrine imposes a related but distinct obligation to consider how groundwater management affects public trust resources, including navigable surface waters and fisheries. Groundwater hydrologically connected to surface waters is also subject to the Public Trust Doctrine to the extent that groundwater extractions or diversions affect or may affect public trust uses. (*Environmental Law Foundation v. State Water Resources Control Board* (2018), 26 Cal. App. 5th 844; *National Audubon Society v. Superior Court* (1983), 33 Cal. 3d 419.) The GSA has "an affirmative duty to take the public trust into account in the planning and allocation of water resources, and to protect public trust uses whenever feasible." (*National Audubon Society*, *supra*, 33 Cal. 3d at 446.) Accordingly, groundwater plans should consider potential impacts to and appropriate protections for ISWs and their tributaries, and ISWs that support fisheries, including the level of groundwater contribution to those waters.

In the context of SGMA statutes and regulations, and Public Trust Doctrine considerations, groundwater planning should carefully consider and protect environmental beneficial uses and users of groundwater, including fish and wildlife and their habitats, GDEs, and ISWs.

The Department recognizes and appreciates the effort of the GSAs to characterize current and projected groundwater conditions through detailed modeling. However, the Department believes the GSP could improve its considerations of environmental users of groundwater and establish more protective management criteria. The Department is providing additional comments and recommendations in Attachment A.

If have any questions related to the Departments comments and/or recommendations on the Colusa Subbasin Draft GSP please contact Bridget Gibbons, Environmental Scientist, at bridget.gibbons@wildlife.ca.gov.

Sincerely,

DocuSigned by:
Kevin Thomas
A7A9A9C574C3415...

Kevin Thomas
Regional Manager, North Central Region

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Enclosures (Attachments A, B)

ec: California Department of Fish and Wildlife

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Groundwater Sustainability Agencies

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Attachment A

CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE COMMENTS ON THE COLUSA SUBBASIN DRAFT GROUNDWATER SUSTAINABILITY PLAN

COMMENTS AND RECOMMENDATIONS

The Department's comments are as follows:

1. **Comment #1** – **Interconnected Surface Water Systems** (3.2.7 Interconnected Surface Waters; starting page 3-77): The GSP does not include sufficient detail describing the timing of depletions of interconnected surface water (ISW).
    a. Issue: Though the GSP discusses annual gains and losses from interconnected surface waters in the subbasin and summarizes net gains by water year type (Table 3-6, page 3-79), the GSP does not include sufficient detail on the timing of depletions as required by 23 CCR § 354.16(f). In order to adequately assess ISW that may be gaining or losing at different times of the year, it is preferential to present net gain/loss values by month, rather than by year. Quantifying depletions by month for each reach will facilitate evaluation of impacts or benefits to environmental beneficial users that rely on surface waters during specific portions of the year.
    b. Recommendation: The Department recommends including net gains or losses to interconnected surface waters by month, rather than by year.

2. **Comment #2** – **Groundwater Dependent Ecosystems** (3.2.8 Groundwater Dependent Ecosystems; starting page 3-82): Groundwater dependent ecosystem (GDE) identification, required by 23 CCR § 354.16(g), is based on methods that risk exclusion of ecosystems that may depend on groundwater.
    a. Issues:
        i. <u>GDE Scoring Criteria:</u> The GSP assigns a rank of '1' (less likely to be a GDE) to '4' (more likely to be a GDE) to potential GDE areas within the Natural Communities Commonly Associated with Groundwater dataset. It is unclear how the rankings are utilized throughout the remainder of the GSP to assess monitoring networks, management criteria, or potential projects. Accordingly, the ranking system has no apparent actionable groundwater management relevance.
        ii. <u>Depth to Groundwater Threshold</u>: The GSP relies on a groundwater level threshold of 30-feet below the ground surface (bgs) to screen potential GDEs within the subbasin. However, mature Valley Oak

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(*Quercus lobata*) can access groundwater up to 80 feet bgs (Howard 1992, Lewis & Burgy 1964). The use of a 30-foot threshold may incorrectly result in Valley Oak communities receiving a GSP-imposed score of '1,' indicating that they are least likely to be a GDE.

iii. GDEs Near Surface Water: The GSP assesses whether potential GDE areas are located near surface waters or irrigated cropland, or both. The GSP considers potential GDE areas within 150 feet of surface waters, within 150 feet of irrigated rice paddies, and within 50 feet of other irrigated croplands to have access to surface water; and therefore, the GSP assigns these areas a score of '2' or '3,' indicating they are less likely to be groundwater dependent. The GSP states that "GDEs include vegetation and habitat that are wholly dependent on groundwater" (line 9, page 3-83); however, this narrow definition of a GDE disregards a GDE's adaptability and opportunistic approach to accessing water in which vegetation and ISW may rely on *both* surface water and groundwater across seasons and years. Furthermore, this GDE definition contradicts an earlier description of GDEs within the GSP, in which the plan states that "a GDE's dependence on groundwater refers to reliance of GDE species and/or communities on groundwater for all *or a portion of* their water needs" (line 3, page 3-82). Particularly as the GDE areas receiving scores of '2' or '3' have already been determined to be located in areas with depths to groundwater of less than 30 feet, proximity to potential surface waters is insufficient evidence to categorize them as 'less likely' to be GDEs.

iv. Data Gaps: The GSP states that there is potential for GDEs to be present in the uplands west of Orland and west of Arbuckle, but that groundwater level data is lacking in these areas and there is insufficient information "to determine their existence" (line 26, page 3-83). Rather than waiting an indeterminate amount of time to gather data to prove groundwater dependence of potential GDE areas and leaving the potential GDEs unclassified in the interim, the GSP should conservatively consider these areas to be GDEs until sufficient data is collected that proves otherwise.

v. Special Status Species: SGMA defines GDEs as ecological communities *or species* that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface [23 CCR § 351 (m)]. The GSP does not identify or discuss species that may be present within the subbasin that rely on groundwater,

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groundwater dependent ecosystems, or interconnected surface waters.

b. Recommendations:
    i. GDE Scoring Criteria: The GSP should clarify how the ranking system is meaningfully used in relationship to groundwater management criteria. Specifically, the GSP should clarify what GDE areas are retained for further analysis in the plan as environmental beneficial users of groundwater and how likely GDEs may be impacted by management criteria, including identification of potential undesirable results.
    ii. Depth to Groundwater Threshold: The Department recommends the GSP update the methodology for classifying GDEs to reflect accurate maximum potential rooting depth for Valley Oak communities. For areas of Valley Oak within the subbasin, the Department recommends the GSP apply a threshold of 80 feet bgs as the maximum depth at which the potential GDE could access groundwater. The Department accepts the use of a 30-foot threshold for other potential GDE areas within the subbasin that do not contain Valley Oak.
    iii. GDEs Near Surface Water: The Department recommends that the GSP err on the side of inclusivity of potential GDEs until there is site specific evidence that the overlying ecosystem has no significant dependence on groundwater across seasons and water year types.
    iv. Data Gaps: The GSP should conservatively assume that potential GDEs located in areas with poor groundwater level data availability are groundwater dependent, until such time that data is collected that demonstrates otherwise.
    v. Special Status Species: The Department recommends the GSP include a list of special status species that may be present within the Colusa Subbasin and an assessment of each species' likely groundwater dependence. The GSP should also include a spatial assessment of special status species within the subbasin to characterize which surface waters or GDE areas provide these species habitat or forage; this level of GDE-species-relationship assessment enables GSAs to prioritize GDE monitoring and management decisions.

3. **Comment #3 – Monitoring Networks** (4.2.5.4 Representative Surface Water Depletion Monitoring Network; starting page 4-33): The GSP should include

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additional details related to the plans to improve the monitoring network for GDEs and ISW within the subbasin.

a. Issue: The GSP states that the ISW representative monitoring network will also be used to monitor GDEs. The GSP does not present any information or figures to support its assertion that the ISW monitoring sites are located sufficiently near to GDEs to assess shallow groundwater levels in those areas. While the Department appreciates the GSP's acknowledgement of data gaps related to the characterization of GDEs and ISW within the subbasin and the GSP's proposed plan to install up to an additional 10 shallow monitoring wells, the GSP does not provide details on planned locations or timelines for installation of these additional monitoring locations.
b. Recommendation: The GSP should include additional detail related to the anticipated timeline for installation of additional wells to further refine ISW and GDE characterization and management. The Department recommends that the GSP assess the locations of special status species within the subbasin to determine which GDE areas likely provide priority habitat. GDE areas and ISW that support special status species or are most at risk of negative impacts due to groundwater pumping should be prioritized for monitoring to inform management actions (See Comment #2(v)).

4. **Comment #4 – Sustainable Management Criteria** (5.3.6 Depletion of Interconnected Surface Water, 5.4.6 Depletions of Interconnected Surface Water; starting pages 5-15 and 5-30): Interconnected surface water sustainable management criteria (SMC) may not protect against undesirable results for fish and wildlife beneficial uses and users.
    a. Issues:
        i. Minimum Thresholds: Minimum thresholds (MTs) for ISW are set at 10 feet below the measured historical low for each representative monitoring well. The GSP states that establishing MTs below the historic lows is necessary to provide a sufficient margin of operational flexibility during GSP implementation, and that no undesirable results were observed at the historic low; however, the GSP does not include sufficient analysis or discussion to support this claim. In 2015, the second of back-to-back critically dry water years in the Sacramento Valley which resulted in recent historical low groundwater levels, vegetated and aquatic GDEs experienced adverse impacts including stressed or dying riparian vegetation, poor instream habitat availability, and increased water temperatures (DFW 2019). It is unclear what, if any, studies or

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analyses were completed to assess whether environmental users within the subbasin experienced undesirable results at the historical low groundwater levels, or what metrics the GSP would evaluate to determine the presence of an undesirable result for GDEs or ISW in the event of additional groundwater decline beyond the historic low as the MTs allow. The ISW SMC are also referenced as protective of GDE beneficial users of groundwater according to the GSP, but the supporting discussion focuses on groundwater gradients and associated depletions. No analysis is presented that characterizes whether the established MTs are sufficient to maintain water levels that have historically been shallow enough to support GDEs, or if the MTs would permit groundwater levels to fall below root zones, removing groundwater as an available water source to some GDEs. If MTs are not protective of GDE access to groundwater supplies, significant impacts to environmental beneficial users of groundwater will likely be experienced before MTs are reached. Furthermore, the GSP reports annual net values for streamflow depletion from the modeled baseline conditions, baseline conditions with climate change, and baseline conditions with climate change and project scenarios. However, the annual analysis does not provide sufficient detail on the timing of depletions to adequately assess potential impacts to environmental users (See Comment #1). The GSP compares modeled annual depletions to *total* annual flow in these river systems, and uses this annual normalization to characterize groundwater contributions to ISW as nominal. This coarse annual comparison does not take into account how groundwater contributions to river base flows are often proportionately greater in dry years or during annual low-flow seasons, or how groundwater contributions play a key role in maintaining water quality and temperatures. Properly contextualizing groundwater contributions to surface water is especially important to understanding potential impacts of groundwater depletion on surface waters and their ecosystems, particularly when the GSP states that streamflow accretion is expected to decrease by 38.3% with climate change impacts (line 9, page 6-2).

ii. Undesirable Results: The GSP requires 25% of ISW representative monitoring wells in the subbasin to fall below their MTs for 24 consecutive months before identifying an undesirable result to GDEs or ISW. While environmental users are adapted to sustain short-term lowering of groundwater levels during dry periods,

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environmental users may not be able to sustain extended periods of reduced groundwater access that would result from allowing groundwater levels to fall to historic lows for 24 months. By the time an undesirable result is declared, and management actions are triggered in response to the undesirable result, environmental groundwater users will have already experienced significant stress and potentially irreversible mortality.

b. Recommendations:
    i. Minimum Thresholds: The Department recommends the GSP reselect minimum thresholds that would better protect environmental uses and users of groundwater, rather than enabling declines in groundwater levels over the implementation horizon beyond the historic low. Additional analyses of the specific impacts of the established thresholds on GDE and ISW beneficial users of groundwater should be included.
    ii. Undesirable Results: The Department recommends the GSP reconsider the 24-month duration of groundwater levels below MTs required to constitute an undesirable result, recognizing that extended durations of groundwater inaccessibility for environmental users will likely lead to adverse impacts that cannot be easily reversed when groundwater levels recover. At a minimum, the Department recommends identifying physical triggers (e.g., declining Normalized Difference Vegetation Index signals) and associated management actions (e.g., demand reduction) to enable the GSAs to identify and mitigate localized patterns of lowering groundwater or depleted ISW and associated negative impacts before the second year of MT exceedances yields more significant and undesirable impacts. These interim action triggers will help preempt irreversible losses and undesirable results for environmental users.

5. **Comment #5** – **Projects and Management Actions** (PMAs) (6.5.2.3 Long-term Demand Management Action, 6.5.2.4 Strategic Temporary Land Idling for Drought and Localized Short-Term Groundwater Management; starting page 6-84): The GSP should include additional metrics and timelines related to the implementation of demand management within the subbasin.
    a. Issue: The Department appreciates the GSP's identification of both short- and long-term demand management actions that will serve as a "backstop" to the other identified PMAs. As the other PMAs focus largely on implementing recharge projects that may be costly, rely on securing additional surface water supplies, and/or require potentially lengthy

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permitting processes, demand management may be necessary in instances where a quick response to undesirable results within the subbasin is needed. Though the GSP identifies various demand management strategies, the GSP states that these management actions are in the “early conceptual stage” and as such, no timelines have been determined.

b. Recommendation: The Department recommends detailing specific timelines and metrics that would trigger the implementation of the identified demand management scenarios should recharge projects encounter delays or fail to produce the anticipated groundwater benefits to the subbasin.

CONCLUSION

In conclusion, though the draft GSP provides detailed characterization of subbasin groundwater conditions, the GSP lacks a robust analysis of potential impacts to environmental beneficial users and should establish more protective management criteria. The Department recommends that the Colusa Subbasin GSAs address the above comments before GSP submission to DWR to best prepare for the following regulatory criteria for plan evaluation:

1. The assumptions, criteria, findings, and objectives, including the sustainability goal, undesirable results, minimum thresholds, measurable objectives, and interim milestones are not reasonable and/or not supported by the best available information and best available science (23 CCR § 355.4(b)(1)). (See Comment #1, 2, 4)
2. The GSP does not identify reasonable measures and schedules to eliminate data gaps. (23 CCR § 355.4(b)(2)) (See Comment #3)
3. The interests of the beneficial uses and users of groundwater in the basin, and the land uses and property interests potentially affected by the use of groundwater in the basin, have not been considered. (23 CCR § 355.4(b)(4)) (See Comment #1, 2, 4)
4. The projects and management actions are not feasible and/or not likely to prevent undesirable results and ensure that the basin is operated within its sustainable yield. (23 CCR § 355.4(b)(5)) (See Comment #4)

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Attachment B

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CITY MANAGER

Peter R. Carr

Date: October 20, 2021

To: Lisa Hunter, Program Manager, Glenn Groundwater Authority

From: Orland City Council

Subject: Comments on Draft Colusa Subbasin Groundwater Sustainability Plan

On behalf of the residents of the City of Orland, the Orland City Council recognizes the admirable cooperation of various water users in developing a plan, the scientific data that went into development of the plan, and the inherent assumptions necessarily undergirding the plan. In the spirit of public comment on the plan, we offer the following observations:

1. Chapter 5 states that the subbasin is currently being managed sustainably without undesirable results despite over 150 domestic wells going dry this summer alone as 2021 data is not yet included in plan development. It is notable that a key partner in the draft plan explained at the October 13th public meeting, "The current actual drought is more compelling than modeled future sustainability challenges."

2. The plan's allowance for up to 20% of domestic wells going dry may be understandable in light of the age and depths of most of the wells. However, depletion of up to 5% of groundwater storage (over 5 years) and inelastic subsidence of up to ½ foot per year were also considered acceptable in the July version of the draft plan, apparently due to an estimate that we still have 26-140 million AF (acre feet) of water in the aquifer. Consultants to the GGA suggest that 26M AF is reliably established, but the estimate of upwards of 140M AF is more of a projection. We are concerned about any reliance on the 140M AF estimate, and suggest that the subbasin should be more conservatively managed to an assumption of 26M AF.

3. We welcome the recent consultant proposal, adopted by the Board October 11th, to revise the plan with an amendment tightening the measurable objectives (MO) and minimum thresholds (MT) for inelastic subsidence, as the draft plan's original allowance for excessive subsidence would have exposed municipal services like water, wastewater and storm drainage to unacceptable risk of severe disruption.

4. City of Orland observes that the draft plan as written does not appear to adequately protect the integrity of domestic and municipal drinking water wells. With most said wells being less

than 200' deep, more than 20% would be dry by the time well depth MO were reached and almost all would be dry by the point MT were reached. It would seem that the MO and MT for well depths should be reconsidered and revised to a more conservative and protective standard.

5. Finally, we commend the GGA Board for its many projects in progress, planned and contemplated, as laid forth in Chapter 6. However, there do not yet appear to be real "triggers" that would commit the GGA to certain substantive actions when passing MO and approaching MT. We hope the GGA works with the State and consultants in coming years to develop and specify such triggers as a backstop to recharge projects in order to truly protect the precious drinking water resources on which the people of Orland and Glenn County rely.

Thank you for your consideration of our comments.

For the Orland City Council:

Bruce T. Roundy, Mayor

Janet Wackerman, City Clerk

Glenn-Colusa Irrigation District
Serving Our Lands and Environment Sustainably
Water Rights Established in 1883

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GENERAL MANAGER
Thaddeus L. Bettner, P.E.

DATE: October 25, 2021

TO: Colusa Groundwater Authority
Glenn Groundwater Authority
Corning Subbasin Groundwater Sustainability Agency
Tehama County Flood Control & Water Conservation District Groundwater Sustainability Agency
Butte Subbasin Groundwater Sustainability Agencies (all eleven)
Vina and Rock Creek Reclamation District Groundwater Sustainability Agencies

FROM: Holly Dawley, GCID Water Resources Manager

SUBJECT: Support for Groundwater Sustainability Plans and Concern about Groundwater Surface Water Interactions

---

Glenn-Colusa Irrigation District (GCID) is located in the heart of the Sacramento Valley; we are the largest and one of the oldest diverters of water from the Sacramento River. GCID diverts water from the Sacramento River through a 65-mile long irrigation canal into a complex system of nearly 500 miles of laterals. The water is delivered to more than 1,200 families who farm approximately 141,000 acres of valuable, productive agricultural land. More than $270 million of agricultural products are produced annually on Glenn-Colusa Irrigation District farms, helping to sustain an estimated 12,000 jobs in the region. GCID is also the sole source of surface water deliveries for three wildlife refuges – the Sacramento, Delevan and Colusa National Wildlife Refuges that comprise over 20,000 acres of critical wildlife habitat. Winter water supplied by GCID to thousands of acres of rice land also provides a rich oasis for migrating waterfowl.

GCID is an active member of the Colusa Groundwater Authority, the Glenn Groundwater Authority, and the Corning Subbasin Groundwater Sustainability Agency.

Support for Groundwater Sustainability Plans

GCID appreciates the opportunity to provide comment to your agency for Groundwater Sustainability Planning in the Sacramento Valley (Valley). As a member of three Groundwater Sustainability Agencies (GSAs) within the Valley, GCID staff have valued our participation in the development of two Draft Groundwater Sustainability Plans (GSPs) and support a collaborative approach to management across a shared resource. We support the adoption of the GSPs by each of the GSAs to meet the January 31, 2022, deadline and we look forward to continued participation during implementation.

Concern about Groundwater Surface Water Interactions

While we support the adoption of the GSPs, this communication serves as a formal written comment to highlight and express a particular area of concern that could lead

to the development of an incomplete decision framework and compromise the stability afforded to groundwater users in the various Sacramento Valley subbasins and more specifically to surface water users and senior water right holders which includes our District. We are writing to express deep concern regarding the lack of consideration in the GSPs about stream-aquifer interactions and impacts from unrestricted groundwater pumping.

This year in response to historically dry conditions, GCID and our fellow Sacramento River Settlement Contractors (SRSCs) took a multitude of voluntary actions significantly reducing the supply to our water users. These actions collaboratively supported watershed objectives in the face of declining storage and identified environmental concerns. While GCID and its partners were working daily for months with Central Valley Project (CVP) operators and State resource agencies to reduce surface water use and stabilize flows in the Sacramento River to help with Delta outflows and environmental needs, groundwater pumpers accessed the resource unabated impacting the stream flows we were actively working to stabilize.

As a significant contributor to groundwater recharge within the Valley, we only utilize that resource in years of shortage. We contribute every year to over 100,000 acre-feet (*Colusa GSP Draft, Appendix 3D, pg. 27*) of groundwater recharge even in Shasta critically dry years. However, we only utilize the resource when our surface water supplies are diminished by drought. Even with all of our voluntary surface water reductions in 2021, we only utilized 20,000 ac-ft of groundwater, while taking over 20,000 acres of land out of production to balance our supply and demand.

According to the Draft GSPs for Vina, Butte, Corning, and Colusa Subbasins, current year estimates of groundwater pumping, summarized in the table below, are over 1 million acre-feet per year (ac-ft/yr) in the region that surrounds our District.

Table 1, Groundwater Pumping in Subbasins in and around GCID (TAF)

	Historical	Current	Future, No Climate Change	Future, 2030 Climate Change	Future, 2070 Climate Change
Butte[a]	142.2	162.8	162.6	189.4	210.5
Vina[b]	243.5	209.2	215.8	225.9	238
Colusa[c]	502	499	499	525	559
Corning[d]	132.3	153		159.3	167.3
Totals (TAF)	***1020***	***1024***	***877.4***	***1099.6***	***1174.8***

Notes

[a]Butte Groundwater Sustainability Plan, Public Review Draft, Section 2, pg. 2-65

[b]Vina Groundwater Sustainability Plan, Public Final Draft, Section 2, pg. 82

[c]Colusa Groundwater Sustainability Plan, Final Draft Report, Section 3, pg. 3-96

[d]Corning Groundwater Sustainability Plan, Public Review Draft, Section 4, pg. 4-69

This groundwater pumping impacts groundwater storage as evidenced by declining groundwater levels and impacts surface-groundwater interactions as evidenced by decreased streamflow and more reaches becoming losing streams. These numbers

indicate a need to understand the origin of groundwater pumping and the potential impacts to the subbasins as water users pull from a shared resource. In looking at these pumping numbers, a particular concern that becomes palpable is that all the GSPs identify increased groundwater pumping which will result in groundwater storage impacts and will result in increased streamflow depletion.

After reviewing the documents, senior surface water rights holders and their operations seem to be a minor share of the use of the resource, but a significant contributor to the replenishment of the resource. We ask that as GSAs move from planning to implementation and continue to look for opportunities to leverage surface water over groundwater, you consider those members and partners with senior water rights and stable contracts that contribute to our shared aquifers and provide high quality environmental habitat. We look forward to better identifying and quantifying this benefit for the subbasins during implementation. Further, we ask that GSAs work with their County partners to consider land use planning and accountability.

Thank you for your consideration of these concerns. We urge you to consider language to address or at least acknowledge this issue in the GSPs. We look forward to working through this issue during implementation.

October 31, 2021

Colusa Groundwater Authority
1213 Market Street
Colusa, CA 95932

Submitted via email:lhunter@countyofglenn.net; mfahey@countyofcolusa.com

Re: Public Comment Letter for Colusa Subbasin Draft GSP

Dear Mary Fahey,

On behalf of the above-listed organizations, we appreciate the opportunity to comment on the Draft Groundwater Sustainability Plan (GSP) for the Colusa Subbasin being prepared under the Sustainable Groundwater Management Act (SGMA). Our organizations are deeply engaged in and committed to the successful implementation of SGMA because we understand that groundwater is critical for the resilience of California's water portfolio, particularly in light of changing climate. Under the requirements of SGMA, Groundwater Sustainability Agencies (GSAs) must consider the interests of all beneficial uses and users of groundwater, such as domestic well owners, environmental users, surface water users, federal government, California Native American tribes and disadvantaged communities (Water Code 10723.2).

As stakeholder representatives for beneficial users of groundwater, our GSP review focuses on how well disadvantaged communities, drinking water users, tribes, climate change, and the environment were addressed in the GSP. While we appreciate that some basins have consulted us directly via focus groups, workshops, and working groups, we are providing public comment letters to all GSAs as a means to engage in the development of 2022 GSPs across the state. Recognizing that GSPs are complicated and resource intensive to develop, the intention of this letter is to provide constructive stakeholder feedback that can improve the GSP prior to submission to the State.

Based on our review, we have significant concerns regarding the treatment of key beneficial users in the Draft GSP and consider the GSP to be **insufficient** under SGMA. We highlight the following findings:

1. Beneficial uses and users **are not sufficiently** considered in GSP development.
    a. Human Right to Water considerations **are not sufficiently** incorporated.
    b. Public trust resources **are not sufficiently** considered.
    c. Impacts of Minimum Thresholds, Measurable Objectives and Undesirable Results on beneficial uses and users **are not sufficiently** analyzed.
2. Climate change **is not sufficiently** considered.

3. Data gaps **are not sufficiently** identified and the GSP **does not have a plan** to eliminate them.
4. Projects and Management Actions **do not sufficiently consider** potential impacts or benefits to beneficial uses and users.

Our specific comments related to the deficiencies of the Colusa Subbasin Draft GSP along with recommendations on how to reconcile them, are provided in detail in **Attachment A.**

Please refer to the enclosed list of attachments for additional technical recommendations:

Attachment A	GSP Specific Comments
Attachment B	SGMA Tools to address DAC, drinking water, and environmental beneficial uses and users
Attachment C	Freshwater species located in the basin
Attachment D	The Nature Conservancy's "Identifying GDEs under SGMA: Best Practices for using the NC Dataset"
Attachment E	Maps of representative monitoring sites in relation to key beneficial users

Thank you for fully considering our comments as you finalize your GSP.

Best Regards,



Ngodoo Atume
Water Policy Analyst
Clean Water Action/Clean Water Fund



J. Pablo Ortiz-Partida, Ph.D.
Western States Climate and Water Scientist
Union of Concerned Scientists



Samantha Arthur
Working Lands Program Director
Audubon California



Danielle V. Dolan
Water Program Director
Local Government Commission



E.J. Remson
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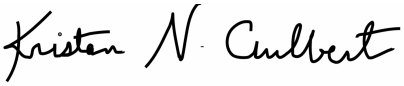
Amy Merrill, Ph.D.
Acting Director, California Program
American Rivers



Kristan Culbert
Associate Director, California Central Valley River Conservation
American Rivers

Attachment A

Specific Comments on the Colusa Subbasin Draft Groundwater Sustainability Plan

1. Consideration of Beneficial Uses and Users in GSP development

Consideration of beneficial uses and users in GSP development is contingent upon adequate identification and engagement of the appropriate stakeholders. The (A) identification, (B) engagement, and (C) consideration of disadvantaged communities, drinking water users, tribes,[1] groundwater dependent ecosystems, streams, wetlands, and freshwater species are essential for ensuring the GSP integrates existing state policies on the Human Right to Water and the Public Trust Doctrine.

A. Identification of Key Beneficial Uses and Users

Disadvantaged Communities, Drinking Water Users, and Tribes

The identification of Disadvantaged Communities (DACs), drinking water users, and tribes is **incomplete**. The GSP provides a map of tribal lands in the subbasin (Figure 2-5), and provides information on DACs, including identification by name and location on a map (Figure 2-6). However, the plan fails to clearly document the population of each DAC and the population dependent on groundwater as their source of drinking water in the subbasin.

While the plan provides a density map of domestic wells in the subbasin (Figure 2-7), the GSP fails to provide depth of these wells (such as minimum well depth, average well depth, or depth range) within the subbasin.

These missing elements are required for the GSAs to fully understand the specific interests and water demands of these beneficial users, and to support the consideration of beneficial users in the development of sustainable management criteria and selection of projects and management actions.

RECOMMENDATIONS

- Provide the population of each identified DAC. Identify the sources of drinking water for DAC members, including an estimate of how many people rely on groundwater (e.g., domestic wells, state small water systems, and public water systems).
- Include a map showing domestic well locations and average well depth across the subbasin (i.e., a map similar to Figure 2-7 showing average well depth per square mile).

[1] Our letter provides a review of the identification and consideration of federally recognized tribes (Data source: SGMA Data viewer) within the GSP from non-tribal members and NGOs. Based on the likely incomplete information available to our organizations for this review, we recommend that the GSA utilize the California Department of Water Resources' "Engagement with Tribal Governments" Guidance Document (https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents) to comprehensively address these important beneficial users in their GSP.

Interconnected Surface Waters

The identification of Interconnected Surface Waters (ISWs) is **insufficient**, due to lack of a comprehensive map of ISWs in the subbasin. Despite the lack of an ISW map, the GSP presents a thorough, comprehensive evaluation of ISWs in the subbasin as presented in Appendix 3G of the GSP (Evaluation of Depletions of Interconnected Surface Water in the Colusa Subbasin). Streamflow depletion in the Colusa Subbasin was evaluated using the C2VSimFG-Colusa model, an integrated hydrologic flow model for the subbasin. The model is described in Appendix 3D (Model Development and Calibration) and used groundwater and surface water data from 1990-2015. Appendix 3D describes the groundwater data used in the model, including spatial location of wells and screening depths. The ISW section of the GSP could be improved with the following recommendations.

RECOMMENDATIONS

- Provide a map showing all the stream reaches in the subbasin, with reaches clearly labeled as interconnected (gaining and losing) or disconnected. Consider any segments with data gaps as potential ISWs and clearly mark them as such on maps provided in the GSP.
- Discuss stream reaches in the interior of the subbasin. For example, discuss whether they were included in the groundwater model and discuss relevant depth to groundwater data. Clearly state that they are considered to be disconnected, if that is the case, and what data was utilized to support that conclusion.
- To confirm the results of the groundwater modeling analysis and support conclusions about the smaller interior stream reaches, overlay the stream reaches shown with depth-to-groundwater contour maps to illustrate groundwater depths and the groundwater gradient near the stream reaches. For the depth-to-groundwater contour maps, use the best practices presented in Attachment D. Specifically, ensure that the first step is contouring groundwater elevations, and then subtracting this layer from land surface elevations from a Digital Elevation Model (DEM) to estimate depth-to-groundwater contours across the landscape. This will provide accurate contours of depth to groundwater along streams and other land surface depressions where GDEs are commonly found.

Groundwater Dependent Ecosystems

The identification of Groundwater Dependent Ecosystems (GDEs) is **insufficient**. The GSP took initial steps to identify and map GDEs using the Natural Communities Commonly Associated with Groundwater dataset (NC dataset). However, we found that some mapped features in the NC dataset were improperly disregarded. NC dataset polygons were incorrectly removed in areas adjacent to irrigated fields or due to the presence of surface water supplies. However, this removal criteria is flawed since GDEs, in addition to groundwater, can rely on multiple water sources – including shallow groundwater receiving inputs from irrigation return flow from nearby irrigated fields – simultaneously and at different temporal/spatial scales. NC dataset polygons adjacent to irrigated land or surface water supplies can still potentially be reliant on shallow groundwater aquifers, and therefore should not be removed solely based on their proximity to irrigated fields or surface water supplies.

The GSP states (3-82): "*Average spring groundwater level data from 2014 to 2018 indicates that shallow groundwater levels (i.e., within 30 feet of ground surface) exists throughout most of the*

subbasin. A depth to water (DTW) of 30 feet based on the average DTW for 2014 to 2018 was used as one of the primary criteria in the initial screening of potential GDEs." While we recognize that the period 2014-2018 represents multiple water year types, we recommend that a longer baseline period (10 years from 2005 to 2015) be established to characterize groundwater conditions.

The GSP does not provide an inventory of the flora or fauna species present in the subbasin's GDEs, except to discuss the four most prevalent vegetation species. Furthermore, the GSP does not acknowledge endangered, threatened, or special status species in the subbasin.

RECOMMENDATIONS

- Provide a comprehensive set of maps for the subbasin's GDEs. For example, provide a map of the NC Dataset. On the map, label polygons retained, removed, or added to/from the NC dataset (include the removal reason if polygons are not considered potential GDEs, or include the data source if polygons are added). Discuss how local groundwater data was used to verify whether polygons in the NC Dataset are supported by groundwater in an aquifer. Refer to Attachment D of this letter for best practices for using local groundwater data to verify whether polygons in the NC Dataset are supported by groundwater in an aquifer.

- Use depth-to-groundwater data from multiple seasons and water year types (e.g., wet, dry, average, drought) to determine the range of depth to groundwater around NC dataset polygons. We recommend that a baseline period (10 years from 2005 to 2015) be established to characterize groundwater conditions over multiple water year types. Refer to Attachment D of this letter for best practices for using local groundwater data to verify whether polygons in the NC Dataset are supported by groundwater in an aquifer.

- Provide depth-to-groundwater contour maps, noting the best practices presented in Attachment D. Specifically, ensure that the first step is contouring groundwater elevations, and then subtracting this layer from land surface elevations from a DEM to estimate depth-to-groundwater contours across the landscape.

- If insufficient data are available to describe groundwater conditions within or near polygons from the NC dataset, include those polygons as "Potential GDEs" in the GSP until data gaps are reconciled in the monitoring network. It is not clear from the description in the GSP whether NC dataset polygons labeled with a 'GDE Likelihood Score' of 1 to 3 on Figure 3-36 are retained as potential GDEs.

- Include an inventory of the fauna and flora present within the subbasin's GDEs (see Attachment C of this letter for a list of freshwater species located in the Colusa Subbasin). Note any threatened or endangered species.

Native Vegetation and Managed Wetlands
Native vegetation and managed wetlands are water use sectors that are required to be included in the water budget.[2,3] The integration of these ecosystems into the water budget is **sufficient** because the GSP included the groundwater demands of native vegetation and managed wetlands in the historical, current, and projected water budgets.

B. Engaging Stakeholders

Stakeholder Engagement during GSP Development
Stakeholder engagement during GSP development is **insufficient**. SGMA's requirement for public notice and engagement of stakeholders is not fully met by the description in the Stakeholder Communication and Engagement Plan (Appendix 2E).[4]

We note the following deficiencies with the overall stakeholder engagement process:

- The opportunities for public involvement and engagement with DACs, drinking water users, tribes, and environmental stakeholders are described in very general terms. They include technical and informational workshops and meetings open to the public. No specific outreach targeted to DACs, drinking water users, tribes, or environmental stakeholders is described in the GSP.

- The plan does not include a plan for continual opportunities for engagement through the *implementation* phase of the GSP for DACs, domestic well owners, tribes, and environmental stakeholders.

RECOMMENDATIONS

- In the Stakeholder Communication and Engagement Plan, describe active and targeted outreach to engage DACs, drinking water users, tribes, and environmental stakeholders throughout the GSP development and implementation phases. Refer to Attachment B for specific recommendations on how to actively engage stakeholders during all phases of the GSP process.

- Describe efforts to consult and engage with DACs and domestic well owners within the subbasin.

[2] "'Water use sector' refers to categories of water demand based on the general land uses to which the water is applied, including urban, industrial, agricultural, managed wetlands, managed recharge, and native vegetation." [23 CCR §351(al)]
[3] "The water budget shall quantify the following, either through direct measurements or estimates based on data: (3) Outflows from the groundwater system by water use sector, including evapotranspiration, groundwater extraction, groundwater discharge to surface water sources, and subsurface groundwater outflow." [23 CCR §354.18]
[4] "A communication section of the Plan shall include a requirement that the GSP identify how it encourages the active involvement of diverse social, cultural, and economic elements of the population within the basin." [23 CCR §354.10(d)(3)]

- Utilize DWR's tribal engagement guidance to comprehensively address all tribes and tribal interests in the subbasin within the GSP.[5]
- Describe efforts to consult and engage with environmental stakeholders within the subbasin.

C. Considering Beneficial Uses and Users When Establishing Sustainable Management Criteria and Analyzing Impacts on Beneficial Uses and Users

The consideration of beneficial uses and users when establishing sustainable management criteria (SMC) is **insufficient**. The consideration of potential impacts on all beneficial users of groundwater in the basin are required when defining undesirable results and establishing minimum thresholds.[6,7,8]

Disadvantaged Communities and Drinking Water Users

For chronic lowering of groundwater levels, the minimum threshold at representative monitoring wells is calculated by finding the deeper value of: (1) 20th percentile of shallowest domestic well depths in the monitoring well's Thiessen polygon, and (2) 50% of range below the historical low groundwater elevation. The GSP states (p. 5-20): *"The GSAs chose this methodology for calculating the minimum threshold to balance the needs of multiple beneficial uses and users of the groundwater by allowing for adequate flexibility to compensate for drought periods while potentially protecting up to 80 percent of nearby domestic wells, therefore avoiding undesirable results. Additionally, anecdotal evidence provided by the GSA member stakeholders suggest that groundwater levels seen in 2015 did not result in significant and unreasonable impacts to beneficial uses and users. Although some wells in that period were dewatered, those wells were generally replaced with deeper wells. The GSAs therefore consider the historical low groundwater elevation to be protective of current and future beneficial uses and users."* Despite this analysis, the GSP does not sufficiently describe whether minimum thresholds will avoid significant and unreasonable loss of drinking water to domestic well users in those 20% not protected by the minimum threshold, and whether the undesirable results are consistent with the Human Right to Water policy.[9]

In addition, the GSP does not sufficiently describe or analyze direct or indirect impacts on DACs or tribes when defining undesirable results, nor does it describe how the groundwater levels minimum threshold will avoid significant and unreasonable impacts on beneficial users beyond 2015 and be consistent with Human Right to Water policy.

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[5] Engagement with Tribal Governments Guidance Document. Available at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Sustainable-Groundwater-Management/Best-Management-Practices-and-Guidance-Documents/Files/Guidance-Doc-for-SGM-Engagement-with-Tribal-Govt_ay_19.pdf

[6] "The description of undesirable results shall include [...] potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results." [23 CCR §354.26(b)(3)]

[7] "The description of minimum thresholds shall include [...] how minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests." [23 CCR §354.28(b)(4)]

[8] "The description of minimum thresholds shall include [...] how state, federal, or local standards relate to the relevant sustainability indicator. If the minimum threshold differs from other regulatory standards, the agency shall explain the nature of and the basis for the difference." [23 CCR §354.28(b)(5)]

[9] California Water Code §106.3. Available at: https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=WAT&sectionNum=106.3

The GSP states (3-67): *"Groundwater quality concerns within the Colusa Subbasin include locally elevated levels of salinity, TDS, adjusted sodium absorption ratio, arsenic, boron, hexavalent chromium, iron, manganese, and nitrate."* However, for degraded water quality, salinity is the only constituent of concern (COC) for which SMC are established in the subbasin. The minimum threshold for salinity has been established for electrical conductivity (EC) as the higher of either the recommended California Secondary Maximum Contaminant Level (SMCL), or the pre-2015 historical maximum recorded EC value. The use of the latter term, with no values associated with it, is inappropriate; the Plan must provide actual historical data identifying what this minimum threshold would be. Furthermore, this value should not in any case exceed the salinity objective in the Basin Plan.

The GSP states (5-11): *"Existing regulatory programs address most water quality concerns, and the CGA and GGA will coordinate with these programs, the lead regulatory agencies, and the regulated community within the Colusa Subbasin during implementation of this GSP, including during development and implementation of projects and management actions."* However, SMC should be established for all COCs in the subbasin impacted or exacerbated by groundwater use and/or management, in addition to coordinating with water quality regulatory programs.

RECOMMENDATIONS

Chronic Lowering of Groundwater Levels

- Describe direct and indirect impacts on drinking water users, DACs, and tribes when describing undesirable results and defining minimum thresholds for chronic lowering of groundwater levels.

Degraded Water Quality

- Describe direct and indirect impacts on drinking water users, DACs, and tribes when defining undesirable results for degraded water quality. For specific guidance on how to consider these users, refer to "Guide to Protecting Water Quality Under the Sustainable Groundwater Management Act."[10]
- Evaluate the cumulative or indirect impacts of proposed minimum thresholds for degraded water quality on drinking water users, DACs, and tribes.
- For EC, provide a summary table that presents the pre-2015 historical maximums, the salinity objective from the Basin Plan, the SMCL, and the resulting minimum thresholds. Ensure that the minimum thresholds do not exceed the salinity objective in the Basin Plan.
- Set minimum thresholds and measurable objectives for all water quality constituents within the subbasin that can be impacted and/or exacerbated as a result of groundwater use or groundwater management. Ensure they align with drinking water standards.[11]

[10] Guide to Protecting Water Quality under the Sustainable Groundwater Management Act https://d3n8a8pro7vhmx.cloudfront.net/communitywatercenter/pages/293/attachments/original/1559328858/Guide_to_Protecting_Drinking_Water_Quality_Under_the_Sustainable_Groundwater_Management_Act.pdf?1559328858.

[11] "Degraded Water Quality [...] collect sufficient spatial and temporal data from each applicable principal aquifer to determine groundwater quality trends for water quality indicators, as determined by the Agency, to address known water quality issues." [23 CCR §354.34(c)(4)]

Groundwater Dependent Ecosystems and Interconnected Surface Waters

Sustainable management criteria for chronic lowering of groundwater levels provided in the GSP do not consider potential impacts to environmental beneficial users. The GSP neither describes nor analyzes direct or indirect impacts on environmental users of groundwater when defining undesirable results. This is problematic because without identifying potential impacts to GDEs, minimum thresholds may compromise, or even destroy, these environmental beneficial users. Since GDEs are present in the subbasin, they must be considered when developing SMC for chronic lowering of groundwater levels.

Sustainable management criteria for depletion of interconnected surface water are established by proxy using groundwater levels at existing monitoring wells with locations and depths considered appropriate for monitoring groundwater with potential to influence interconnected streams. Minimum thresholds were established at groundwater levels that are 10 feet deeper than the observed Fall 2015 water level. However, if minimum thresholds are set to levels lower than historic low groundwater levels and the subbasin is allowed to operate at or close to those levels over many years, there is a risk of causing catastrophic damage to ecosystems that are more adverse than what was occurring at the height of the 2012-2016 drought. This is because California ecosystems, which are adapted to our Mediterranean climate, have some drought strategies that they can utilize to deal with short-term water stress. However, if the drought conditions are prolonged, the ecosystem can collapse.

No analysis or discussion is presented to describe how the SMC will affect GDEs, or the impact of these minimum thresholds on GDEs in the subbasin. Furthermore, the GSP makes no attempt to evaluate the impacts of the proposed minimum threshold on environmental beneficial users of surface water. The GSP does not explain how the chosen minimum thresholds and measurable objectives avoid significant and unreasonable effects on surface water beneficial users in the subbasin, such as increased mortality and inability to perform key life processes (e.g., reproduction, migration).

RECOMMENDATIONS

- When defining undesirable results for chronic lowering of groundwater levels, provide specifics on what biological responses (e.g., extent of habitat, growth, recruitment rates) would best characterize a significant and unreasonable impact to GDEs. Undesirable results to environmental users occur when ‘significant and unreasonable’ effects on beneficial users are caused by one of the sustainability indicators (i.e., chronic lowering of groundwater levels, degraded water quality, or depletion of interconnected surface water). Thus, potential impacts on environmental beneficial uses and users need to be considered when defining undesirable results in the subbasin.[12] Defining undesirable results is the crucial first step before the minimum thresholds can be determined.[13]

- When establishing SMC for the subbasin, consider that the SGMA statute [Water Code §10727.4(l)] specifically calls out that GSPs shall include “impacts on groundwater dependent ecosystems”.

[12] “The description of undesirable results shall include [...] potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results”. [23 CCR §354.26(b)(3)]

[13] The description of minimum thresholds shall include [...] how minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests.” [23 CCR §354.28(b)(4)]

- When defining undesirable results for depletion of interconnected surface water, include a description of potential impacts on instream habitats within ISWs when minimum thresholds in the subbasin are reached.[14] The GSP should confirm that minimum thresholds for ISWs avoid adverse impacts to environmental beneficial users of interconnected surface waters as these environmental users could be left unprotected by the GSP. These recommendations apply especially to environmental beneficial users that are already protected under pre-existing state or federal law.[6,15]

2. Climate Change

The SGMA statute identifies climate change as a significant threat to groundwater resources and one that must be examined and incorporated in the GSPs. The GSP Regulations require integration of climate change into the projected water budget to ensure that projects and management actions sufficiently account for the range of potential climate futures.[16] The effects of climate change will intensify the impacts of water stress on GDEs, making available shallow groundwater resources especially critical to their survival. Condon *et al.* (2020) shows that GDEs are more likely to succumb to water stress and rely more on groundwater during times of drought.[17] When shallow groundwater is unavailable, riparian forests can die off and key life processes (e.g., migration and spawning) for aquatic organisms, such as steelhead, can be impeded.

The integration of climate change into the projected water budget is **insufficient**. The GSP incorporates climate change into the projected water budget using DWR change factors for 2030 and 2070. However, the plan does not consider multiple climate scenarios (e.g., the 2070 extremely wet and extremely dry climate scenarios) in the projected water budget. The GSP should clearly and transparently incorporate the extremely wet and dry scenarios provided by DWR into projected water budgets or select more appropriate extreme scenarios for the subbasin. While these extreme scenarios may have a lower likelihood of occurring, their consequences could be significant and their inclusion can help identify important vulnerabilities in the subbasin's approach to groundwater management.

The GSP incorporates climate change into key inputs of (e.g., precipitation and evapotranspiration) of the projected water budget. However, imported water should also be adjusted for climate change and incorporated into the surface water flow inputs of the projected water budget. The sustainable yield is calculated based on the projected water budget with climate change incorporated. However, if the water budgets are incomplete, including the omission of extremely wet and dry scenarios and the omission of projected climate change effects on imported water inputs, then there is increased uncertainty in virtually every subsequent calculation used to plan for projects, derive measurable objectives, and set minimum thresholds. Plans that do not adequately include climate change projections may underestimate future

[14] "The minimum threshold for depletions of interconnected surface water shall be the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results." [23 CCR §354.28(c)(6)]

[15] Rohde MM, Seapy B, Rogers R, Castañeda X, editors. 2019. Critical Species LookBook: A compendium of California's threatened and endangered species for sustainable groundwater management. The Nature Conservancy, San Francisco, California. Available at: https://groundwaterresourcehub.org/public/uploads/pdfs/Critical_Species_LookBook_91819.pdf

[16] "Each Plan shall rely on the best available information and best available science to quantify the water budget for the basin in order to provide an understanding of historical and projected hydrology, water demand, water supply, land use, population, climate change, sea level rise, groundwater and surface water interaction, and subsurface groundwater flow." [23 CCR §354.18(e)]

[17] Condon et al. 2020. Evapotranspiration depletes groundwater under warming over the contiguous United States. Nature Communications. Available at: https://www.nature.com/articles/s41467-020-14688-0

impacts on vulnerable beneficial users of groundwater such as ecosystems, DACs, domestic well owners, and tribes.

RECOMMENDATIONS

- Integrate climate change, including extremely wet and dry scenarios, into all elements of the projected water budget to form the basis for development of sustainable management criteria and projects and management actions.
- Incorporate climate change into surface water flow inputs, including imported water, for the projected water budget.
- Incorporate climate change scenarios into projects and management actions.

3. Data Gaps

The consideration of beneficial users when establishing monitoring networks is **insufficient**, due to lack of specific plans to increase the Representative Monitoring Sites (RMSs) in the monitoring network that represent water quality conditions and shallow groundwater elevations around DACs, domestic wells, tribes, GDEs, and ISWs in the subbasin.

Figure 4-6 (Representative Groundwater Level Monitoring Network) shows insufficient representation of drinking water users and tribal users for groundwater elevation monitoring. Figure 4-7 (Representative Groundwater Quality Monitoring Network) shows insufficient representation of DACs and tribal users for water quality monitoring. Refer to Attachment E for maps of these monitoring sites in relation to key beneficial users of groundwater. These beneficial users may remain unprotected by the GSP without adequate monitoring and identification of data gaps in the shallow aquifer. The Plan therefore fails to meet SGMA's requirements for the monitoring network.[18]

The GSP provides some discussion of data gaps for GDEs and ISWs in Sections 4.2.4.5 (Proposed Actions to Address Data Gaps) and Section 7.1.2.1 (Expand Shallow Groundwater Level Monitoring Network), but does not provide specific plans, such as locations or a timeline, to fill the data gaps.

RECOMMENDATIONS

- Provide maps that overlay current and proposed monitoring well locations with the locations of DACs, domestic wells, tribes, GDEs, and ISWs to clearly identify potentially impacted areas.
- Increase the number of RMSs in the shallow aquifer across the subbasin as needed to adequately monitor all groundwater condition indicators across the subbasin and at appropriate depths for *all* beneficial users. Prioritize proximity to DACs, domestic wells, tribes, and GDEs when identifying new RMSs.

[18] "The monitoring network objectives shall be implemented to accomplish the following: [...] (2) Monitor impacts to the beneficial uses or users of groundwater." [23 CCR §354.34(b)(2)]

- Ensure groundwater elevation and water quality RMSs are monitoring groundwater conditions spatially and at the correct depth for *all* beneficial users - especially DACs, domestic wells, tribes, and GDEs.

- Describe biological monitoring that can be used to assess the potential for significant and unreasonable impacts to GDEs or ISWs due to groundwater conditions in the subbasin.

4. Addressing Beneficial Users in Projects and Management Actions

The consideration of beneficial users when developing projects and management actions is **insufficient** due to the failure to completely identify benefits or impacts of identified projects and management actions, including water quality impacts, to key beneficial users of groundwater such as GDEs, aquatic habitats, surface water users, DACs, drinking water users, and tribes. Therefore, potential project and management actions may not protect these beneficial users. Groundwater sustainability under SGMA is defined not just by sustainable yield, but by the avoidance of undesirable results for *all* beneficial users.

We commend the GSAs for including the Colusa Subbasin Multi-Benefit Groundwater Recharge project, developed in partnership with The Nature Conservancy. The GSP describes the multiple benefits of this project, including benefits to migratory shorebirds, DACs, private landowners, and groundwater conditions.

The GSP includes a domestic well mitigation program. However, the mitigation program is described as a potential project to be implemented on an as-needed basis instead of a proposed project that will be implemented within the GSP planning horizon.

RECOMMENDATIONS

- Clarify the planning horizon of the described domestic well mitigation program to ensure that it will proactively monitor and protect drinking water wells through GSP implementation. Refer to Attachment B for specific recommendations on how to implement a drinking water well mitigation program.

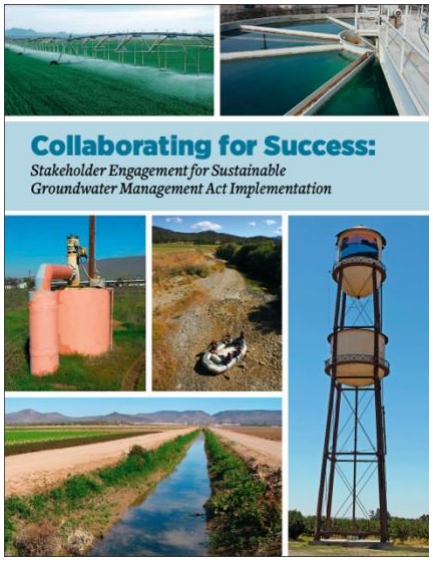
- For DACs and domestic well owners, include a discussion of whether potential impacts to water quality from projects and management actions could occur and how the GSAs plans to mitigate such impacts.

- Develop management actions that incorporate climate and water delivery uncertainties to address future water demand and prevent future undesirable results.

Attachment B

SGMA Tools to address DAC, drinking water, and environmental beneficial uses and users

Stakeholder Engagement and Outreach



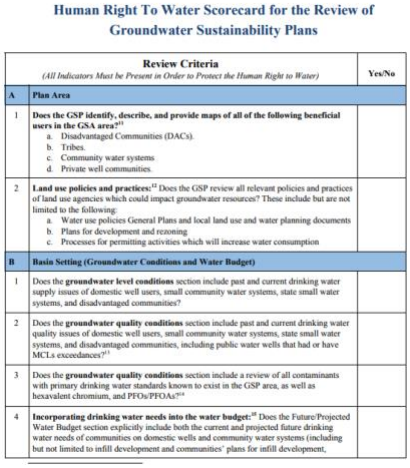
Clean Water Action, Community Water Center and Union of Concerned Scientists developed a guidance document called Collaborating for success: Stakeholder engagement for Sustainable Groundwater Management Act Implementation. It provides details on how to conduct targeted and broad outreach and engagement during Groundwater Sustainability Plan (GSP) development and implementation. Conducting a targeted outreach involves:

- Developing a robust Stakeholder Communication and Engagement plan that includes outreach at frequented locations (schools, farmers markets, religious settings, events) across the plan area to increase the involvement and participation of disadvantaged communities, drinking water users and the environmental stakeholders.

- Providing translation services during meetings and technical assistance to enable easy participation for non-English speaking stakeholders.

- GSP should adequately describe the process for requesting input from beneficial users and provide details on how input is incorporated into the GSP.

The Human Right to Water

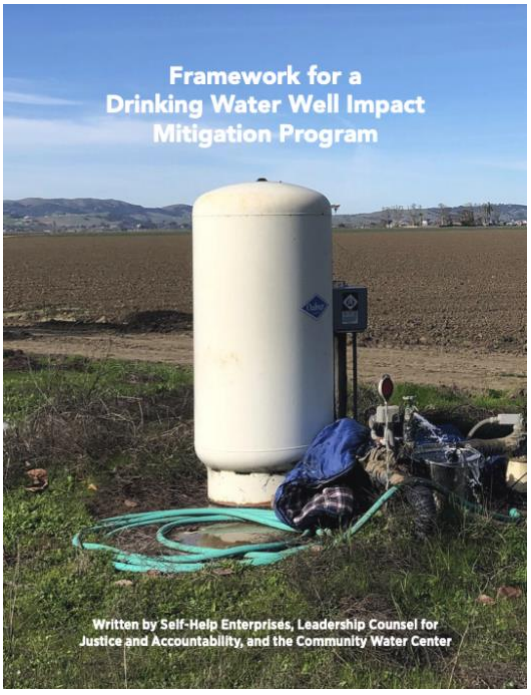


Human Right To Water Scorecard for the Review of Groundwater Sustainability Plans

	Review Criteria *(All Indicators Must be Present in Order to Protect the Human Right to Water)*	Yes/No
A	**Plan Area**	
1	**Does the GSP identify, describe, and provide maps of all of the following beneficial users in the GSA area?**[43] a. Disadvantaged Communities (DACs). b. Tribes. c. Community water systems. d. Private well communities.	
2	**Land use policies and practices:**[44] Does the GSP review all relevant policies and practices of land use agencies which could impact groundwater resources? These include but are not limited to the following: a. Water use policies General Plans and local land use and water planning documents b. Plans for development and rezoning c. Processes for permitting activities which will increase water consumption	
B	**Basin Setting (Groundwater Conditions and Water Budget)**	
1	Does the **groundwater level conditions** section include past and current drinking water supply issues of domestic well users, small community water systems, state small water systems, and disadvantaged communities?	
2	Does the **groundwater quality conditions** section include past and current drinking water quality issues of domestic well users, small community water systems, state small water systems, and disadvantaged communities, including public water wells that had or have MCLs exceedances?[45]	
3	Does the **groundwater quality conditions** section include a review of all contaminants with primary drinking water standards known to exist in the GSP area, as well as hexavalent chromium, and PFOs/PFOAs?[46]	
4	**Incorporating drinking water needs into the water budget:**[48] Does the Future/Projected Water Budget section explicitly include both the current and projected future drinking water needs of communities on domestic wells and community water systems (including but not limited to infill development and communities' plans for infill development,	

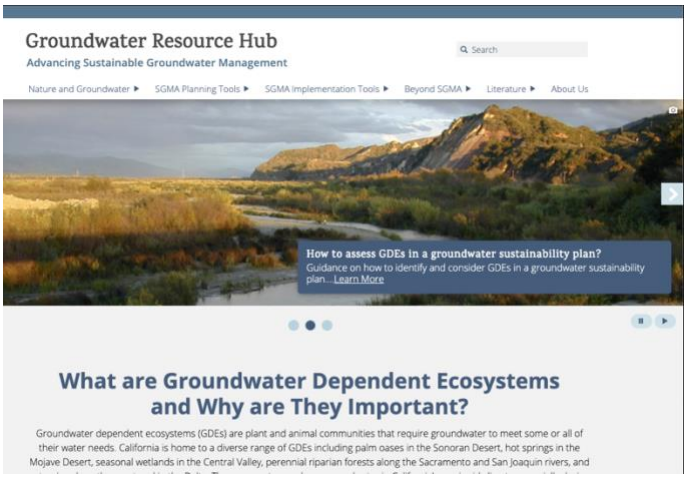
The Human Right to Water Scorecard was developed by Community Water Center, Leadership Counsel for Justice and Accountability and Self Help Enterprises to aid Groundwater Sustainability Agencies (GSAs) in prioritizing drinking water needs in SGMA. The scorecard identifies elements that must exist in GSPs to adequately protect the Human Right to Drinking water.

Drinking Water Well Impact Mitigation Framework



The Drinking Water Well Impact Mitigation Framework was developed by Community Water Center, Leadership Counsel for Justice and Accountability and Self Help Enterprises to aid GSAs in the development and implementation of their GSPs. The framework provides a clear roadmap for how a GSA can best structure its data gathering, monitoring network and management actions to proactively monitor and protect drinking water wells and mitigate impacts should they occur.

Groundwater Resource Hub



The Nature Conservancy has developed a suite of tools based on best available science to help GSAs, consultants, and stakeholders efficiently incorporate nature into GSPs. These tools and resources are available online at GroundwaterResourceHub.org. The Nature Conservancy's tools and resources are intended to reduce costs, shorten timelines, and increase benefits for both people and nature.

Rooting Depth Database



The Plant Rooting Depth Database provides information that can help assess whether groundwater-dependent vegetation are accessing groundwater. Actual rooting depths will depend on the plant species and site-specific conditions, such as soil type and

availability of other water sources. Site-specific knowledge of depth to groundwater combined with rooting depths will help provide an understanding of the potential groundwater levels are needed to sustain GDEs.

How to use the database

The maximum rooting depth information in the Plant Rooting Depth Database is useful when verifying whether vegetation in the Natural Communities Commonly Associated with Groundwater (NC Dataset) are connected to groundwater. A 30 ft depth-to-groundwater threshold, which is based on averaged global rooting depth data for phreatophytes[1], is relevant for most plants identified in the NC Dataset since most plants have a max rooting depth of less than 30 feet. However, it is important to note that deeper thresholds are necessary for other plants that have reported maximum root depths that exceed the averaged 30 feet threshold, such as valley oak (*Quercus lobata*), Euphrates poplar (*Populus euphratica*), salt cedar (*Tamarix spp.*), and shadescale (*Atriplex confertifolia*). The Nature Conservancy advises that the reported max rooting depth for these deeper-rooted plants be used. For example, a depth-to groundwater threshold of 80 feet should be used instead of the 30 ft threshold, when verifying whether valley oak polygons from the NC Dataset are connected to groundwater. It is important to re-emphasize that actual rooting depth data are limited and will depend on the plant species and site-specific conditions such as soil and aquifer types, and availability to other water sources.

The Plant Rooting Depth Database is an Excel workbook composed of four worksheets:

1. California phreatophyte rooting depth data (included in the NC Dataset)
2. Global phreatophyte rooting depth data
3. Metadata
4. References

How the database was compiled

The Plant Rooting Depth Database is a compilation of rooting depth information for the groundwater-dependent plant species identified in the NC Dataset. Rooting depth data were compiled from published scientific literature and expert opinion through a crowdsourcing campaign. As more information becomes available, the database of rooting depths will be updated. Please Contact Us if you have additional rooting depth data for California phreatophytes.

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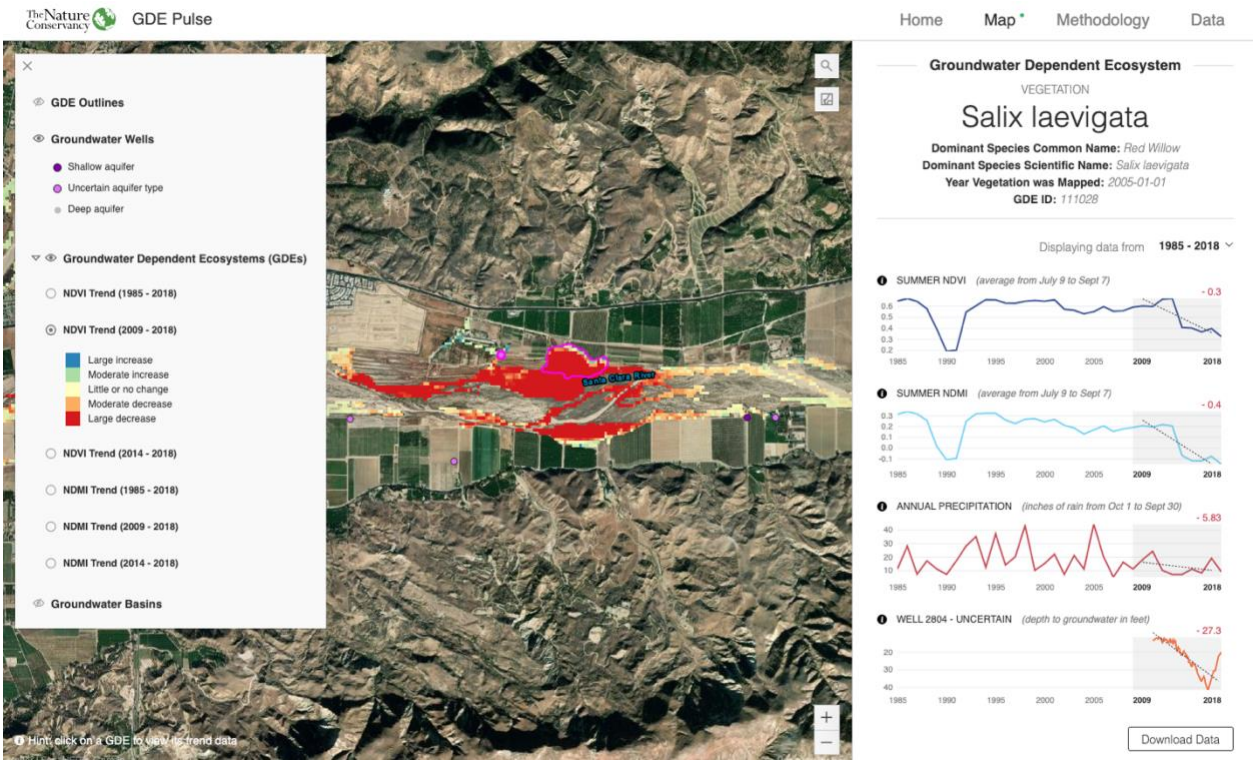
[1] Canadell, J., Jackson, R.B., Ehleringer, J.B. et al. 1996. Maximum rooting depth of vegetation types at the global scale. Oecologia 108, 583–595. https://doi.org/10.1007/BF00329030

GDE Pulse



GDE Pulse is a free online tool that allows Groundwater Sustainability Agencies to assess changes in groundwater dependent ecosystem (GDE) health using satellite, rainfall, and groundwater data. Remote sensing data from satellites has been used to monitor the health of vegetation all over the planet. GDE pulse has compiled 35 years of satellite imagery from NASA's Landsat mission for every polygon in the Natural Communities Commonly Associated with Groundwater Dataset. The following datasets are available for downloading:

Normalized Difference Vegetation Index (NDVI) is a satellite-derived index that represents the greenness of vegetation. Healthy green vegetation tends to have a higher NDVI, while dead leaves have a lower NDVI. We calculated the average NDVI during the driest part of the year (July - Sept) to estimate vegetation health when the plants are most likely dependent on groundwater.

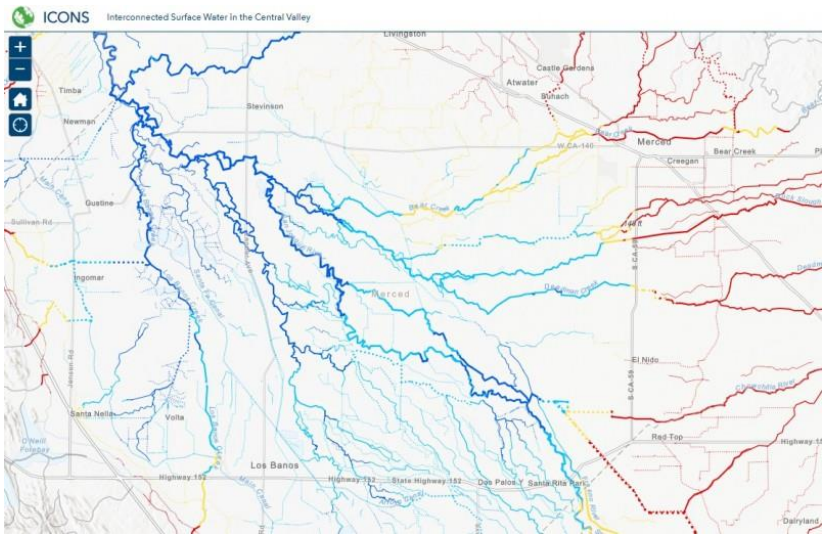
Normalized Difference Moisture Index (NDMI) is a satellite-derived index that represents water content in vegetation. NDMI is derived from the Near-Infrared (NIR) and Short-Wave Infrared (SWIR) channels. Vegetation with adequate access to water tends to have higher NDMI, while vegetation that is water stressed tends to have lower NDMI. We calculated the average NDVI during the driest part of the year (July–September) to estimate vegetation health when the plants are most likely dependent on groundwater.

Annual Precipitation is the total precipitation for the water year (October 1st – September 30th) from the PRISM dataset. The amount of local precipitation can affect vegetation with more precipitation generally leading to higher NDVI and NDMI.

Depth to Groundwater measurements provide an indication of the groundwater levels and changes over time for the surrounding area. We used groundwater well measurements from nearby (<1km) wells to estimate the depth to groundwater below the GDE based on the average elevation of the GDE (using a digital elevation model) minus the measured groundwater surface elevation.

ICONOS Mapper

Interconnected Surface Water in the Central Valley



ICONS maps the likely presence of interconnected surface water (ISW) in the Central Valley using depth to groundwater data. Using data from 2011-2018, the ISW dataset represents the likely connection between surface water and groundwater for rivers and streams in California's Central Valley. It includes information on the mean, maximum, and minimum depth to groundwater for each stream segment over the years with available data, as well as the likely presence of ISW based on the minimum depth to groundwater. The Nature Conservancy developed this database, with guidance and input from expert academics, consultants, and state agencies.

We developed this dataset using groundwater elevation data available online from the California Department of Water Resources (DWR). DWR only provides this data for the Central Valley. For GSAs outside of the valley, who have groundwater well measurements, we recommend following our methods to determine likely ISW in your region. The Nature Conservancy's ISW dataset should be used as a first step in reviewing ISW and should be supplemented with local or more recent groundwater depth data.

Attachment C

Freshwater Species Located in the Colusa Subbasin

To assist in identifying the beneficial users of surface water necessary to assess the undesirable result "depletion of interconnected surface waters", Attachment C provides a list of freshwater species located in the Colusa Subbasin. To produce the freshwater species list, we used ArcGIS to select features within the California Freshwater Species Database version 2.0.9 within the basin boundary. This database contains information on ~4,000 vertebrates, macroinvertebrates and vascular plants that depend on fresh water for at least one stage of their life cycle. The methods used to compile the California Freshwater Species Database can be found in Howard et al. 2015[1]. The spatial database contains locality observations and/or distribution information from ~400 data sources. The database is housed in the California Department of Fish and Wildlife's BIOS[2] as well as on The Nature Conservancy's science website[3].

Scientific Name	Common Name	Legal Protected Status		
		Federal	State	Other
BIRDS				
Agelaius tricolor	Tricolored Blackbird	Bird of Conservation Concern	Special Concern	BSSC - First priority
Coccyzus americanus occidentalis	Western Yellow-billed Cuckoo	Candidate - Threatened	Endangered	
Egretta thula	Snowy Egret			
Nycticorax nycticorax	Black-crowned Night-Heron			
Pandion haliaetus	Osprey		Watch list	
Riparia riparia	Bank Swallow		Threatened	
Actitis macularius	Spotted Sandpiper			
Aechmophorus clarkii	Clark's Grebe			
Aechmophorus occidentalis	Western Grebe			
Aix sponsa	Wood Duck			
Anas acuta	Northern Pintail			
Anas americana	American Wigeon			
Anas clypeata	Northern Shoveler			
Anas crecca	Green-winged Teal			
Anas cyanoptera	Cinnamon Teal			
Anas discors	Blue-winged Teal			
Anas platyrhynchos	Mallard			
Anas strepera	Gadwall			
Anser albifrons	Greater White-fronted Goose			
Ardea alba	Great Egret			
Ardea herodias	Great Blue Heron			

[1] Howard, J.K. et al. 2015. Patterns of Freshwater Species Richness, Endemism, and Vulnerability in California. PLoSONE, 11(7). Available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0130710

[2] California Department of Fish and Wildlife BIOS: https://www.wildlife.ca.gov/data/BIOS

[3] Science for Conservation: https://www.scienceforconservation.org/products/california-freshwater-species-database

Aythya affinis	Lesser Scaup			
Aythya americana	Redhead		Special Concern	BSSC - Third priority
Aythya collaris	Ring-necked Duck			
Aythya marila	Greater Scaup			
Aythya valisineria	Canvasback		Special	
Botaurus lentiginosus	American Bittern			
Bucephala albeola	Bufflehead			
Bucephala clangula	Common Goldeneye			
Butorides virescens	Green Heron			
Calidris alpina	Dunlin			
Calidris mauri	Western Sandpiper			
Calidris minutilla	Least Sandpiper			
Chen caerulescens	Snow Goose			
Chen rossii	Ross's Goose			
Chlidonias niger	Black Tern		Special Concern	BSSC - Second priority
Chroicocephalus philadelphia	Bonaparte's Gull			
Cinclus mexicanus	American Dipper			
Cistothorus palustris palustris	Marsh Wren			
Cygnus columbianus	Tundra Swan			
Empidonax traillii	Willow Flycatcher	Bird of Conservation Concern	Endangered	
Fulica americana	American Coot			
Gallinago delicata	Wilson's Snipe			
Gallinula chloropus	Common Moorhen			
Geothlypis trichas trichas	Common Yellowthroat			
Grus canadensis	Sandhill Crane			
Haliaeetus leucocephalus	Bald Eagle	Bird of Conservation Concern	Endangered	
Himantopus mexicanus	Black-necked Stilt			
Icteria virens	Yellow-breasted Chat		Special Concern	BSSC - Third priority
Ixobrychus exilis hesperis	Western Least Bittern		Special Concern	BSSC - Second priority
Limnodromus scolopaceus	Long-billed Dowitcher			
Lophodytes cucullatus	Hooded Merganser			
Megaceryle alcyon	Belted Kingfisher			
Mergus merganser	Common Merganser			
Numenius americanus	Long-billed Curlew			
Numenius phaeopus	Whimbrel			
Oxyura jamaicensis	Ruddy Duck			

Pelecanus erythrorhynchos	American White Pelican		Special Concern	BSSC - First priority
Phalacrocorax auritus	Double-crested Cormorant			
Phalaropus tricolor	Wilson's Phalarope			
Plegadis chihi	White-faced Ibis		Watch list	
Pluvialis squatarola	Black-bellied Plover			
Podiceps nigricollis	Eared Grebe			
Podilymbus podiceps	Pied-billed Grebe			
Porzana carolina	Sora			
Rallus limicola	Virginia Rail			
Recurvirostra americana	American Avocet			
Setophaga petechia	Yellow Warbler			BSSC - Second priority
Tachycineta bicolor	Tree Swallow			
Tringa melanoleuca	Greater Yellowlegs			
Tringa semipalmata	Willet			
Tringa solitaria	Solitary Sandpiper			
Vireo bellii	Bell's Vireo			
Xanthocephalus xanthocephalus	Yellow-headed Blackbird		Special Concern	BSSC - Third priority
CRUSTACEANS				
Branchinecta conservatio	Conservancy Fairy Shrimp	Endangered	Special	IUCN - Endangered
Branchinecta lynchi	Vernal Pool Fairy Shrimp	Threatened	Special	IUCN - Vulnerable
Lepidurus packardi	Vernal Pool Tadpole Shrimp	Endangered	Special	IUCN - Endangered
Linderiella occidentalis	California Fairy Shrimp		Special	IUCN - Near Threatened
Hyalella spp.	Hyalella spp.			
FISH				
Oncorhynchus mykiss irideus	Coastal rainbow trout			Least Concern - Moyle 2013
Spirinchus thaleichthys	Longfin smelt	Candidate	Threatened	Vulnerable - Moyle 2013
Acipenser medirostris ssp. 1	Southern green sturgeon	Threatened	Special Concern	Endangered - Moyle 2013
Oncorhynchus mykiss - CV	Central Valley steelhead	Threatened	Special	Vulnerable - Moyle 2013
Oncorhynchus tshawytscha - CV spring	Central Valley spring Chinook salmon	Threatened	Threatened	Vulnerable - Moyle 2013
Oncorhynchus tshawytscha - CV winter	Central Valley winter Chinook salmon	Endangered	Endangered	Vulnerable - Moyle 2013
HERPS				
Actinemys marmorata marmorata	Western Pond Turtle		Special Concern	ARSSC

Ambystoma californiense californiense	California Tiger Salamander	Threatened	Threatened	ARSSC
Anaxyrus boreas boreas	Boreal Toad			
Dicamptodon ensatus	California Giant Salamander			ARSSC
Rana boylii	Foothill Yellow-legged Frog	Under Review in the Candidate or Petition Process	Special Concern	ARSSC
Rana draytonii	California Red-legged Frog	Threatened	Special Concern	ARSSC
Spea hammondii	Western Spadefoot	Under Review in the Candidate or Petition Process	Special Concern	ARSSC
Thamnophis gigas	Giant Gartersnake	Threatened	Threatened	
Thamnophis sirtalis sirtalis	Common Gartersnake			
Pseudacris regilla	Northern Pacific Chorus Frog			
INSECTS & OTHER INVERTS				
Ablabesmyia spp.	Ablabesmyia spp.			
Acentrella insignificans	A Mayfly			
Ambrysus amargosus	Ash Meadows Naucorid			
Ambrysus mormon				Not on any status lists
Ambrysus spp.	Ambrysus spp.			
Anax junius	Common Green Darner			
Apedilum spp.	Apedilum spp.			
Argia lugens	Sooty Dancer			
Baetidae fam.	Baetidae fam.			
Baetis spp.	Baetis spp.			
Baetis tricaudatus	A Mayfly			
Belostomatidae fam.	Belostomatidae fam.			
Caenis latipennis	A Mayfly			
Centroptilum album	A Mayfly			
Centroptilum spp.	Centroptilum spp.			
Chironomidae fam.	Chironomidae fam.			
Chironomus anonymus				Not on any status lists
Chironomus spp.	Chironomus spp.			
Cladotanytarsus marki				Not on any status lists
Cladotanytarsus spp.	Cladotanytarsus spp.			
Coenagrionidae fam.	Coenagrionidae fam.			
Corisella decolor				Not on any status lists
Corixidae fam.	Corixidae fam.			

Cricotopus annulator				Not on any status lists
Cricotopus spp.	Cricotopus spp.			
Cryptochironomus curryi				Not on any status lists
Cryptochironomus spp.	Cryptochironomus spp.			
Dicrotendipes adnilus				Not on any status lists
Dicrotendipes spp.	Dicrotendipes spp.			
Ecdyonurus criddlei	A Mayfly			
Enallagma boreale	Boreal Bluet			
Enallagma carunculatum	Tule Bluet			
Enallagma civile	Familiar Bluet			
Enochrus spp.	Enochrus spp.			
Ephydridae fam.	Ephydridae fam.			
Fallceon quilleri	A Mayfly			
Fallceon spp.	Fallceon spp.			
Gomphidae fam.	Gomphidae fam.			
Harnischia spp.	Harnischia spp.			
Heptagenia adaequata				Not on any status lists
Heptagenia spp.	Heptagenia spp.			
Heptageniidae fam.	Heptageniidae fam.			
Hydrophilidae fam.	Hydrophilidae fam.			
Hydropsyche alternans				Not on any status lists
Hydropsyche californica	A Caddisfly			
Hydropsyche spp.	Hydropsyche spp.			
Hydroptila ajax	A Caddisfly			
Hydroptila spp.	Hydroptila spp.			
Ischnura cervula	Pacific Forktail			
Ischnura perparva	Western Forktail			
Laccobius spp.	Laccobius spp.			
Leptoceridae fam.	Leptoceridae fam.			
Libellula forensis	Eight-spotted Skimmer			
Libellula luctuosa	Widow Skimmer			
Libellula pulchella	Twelve-spotted Skimmer			
Libellulidae fam.	Libellulidae fam.			
Micrasema spp.	Micrasema spp.			
Microchironomus nigrovittatus				Not on any status lists
Microchironomus spp.	Microchironomus spp.			
Mideopsis pumila				Not on any status lists
Mideopsis spp.	Mideopsis spp.			

Nanocladius anderseni				Not on any status lists
Nanocladius spp.	Nanocladius spp.			
Nectopsyche spp.	Nectopsyche spp.			
Oecetis spp.	Oecetis spp.			
Oreodytes abbreviatus				Not on any status lists
Oreodytes spp.	Oreodytes spp.			
Pachydiplax longipennis	Blue Dasher			
Paltothemis lineatipes	Red Rock Skimmer			
Pantala flavescens	Wandering Glider			
Pantala hymenaea	Spot-winged Glider			
Paracladopelma alphaeus				Not on any status lists
Paracladopelma spp.	Paracladopelma spp.			
Parakiefferiella spp.	Parakiefferiella spp.			
Paratanytarsus spp.	Paratanytarsus spp.			
Pentaneura spp.	Pentaneura spp.			
Phaenopsectra dyari				Not on any status lists
Phaenopsectra spp.	Phaenopsectra spp.			
Polypedilum albicorne				Not on any status lists
Polypedilum spp.	Polypedilum spp.			
Procladius barbatulus				Not on any status lists
Procladius spp.	Procladius spp.			
Protochauliodes minimus				Not on any status lists
Protoptila erotica				Not on any status lists
Pseudochironomus spp.	Pseudochironomus spp.			
Rheotanytarsus spp.	Rheotanytarsus spp.			
Rhionaeschna multicolor	Blue-eyed Darner			
Serratella micheneri	A Mayfly			
Sigara alternata				Not on any status lists
Sigara mckinstryi	A Water Boatman			Not on any status lists
Sigara spp.	Sigara spp.			
Simulium anduzei				Not on any status lists
Simulium spp.	Simulium spp.			
Sperchon spp.	Sperchon spp.			
Sperchon stellata				Not on any status lists
Sympetrum corruptum	Variegated Meadowhawk			

Sympetrum madidum	Red-veined Meadowhawk			
Tanytarsus angulatus				Not on any status lists
Tanytarsus spp.	Tanytarsus spp.			
Tinodes belisus	A Caddisfly			
Tipulidae fam.	Tipulidae fam.			
Tramea lacerata	Black Saddlebags			
Tricorythodes explicatus	A Mayfly			
Tricorythodes spp.	Tricorythodes spp.			
Unionicolidae fam.	Unionicolidae fam.			
MAMMALS				
Castor canadensis	American Beaver			Not on any status lists
Lontra canadensis canadensis	North American River Otter			Not on any status lists
Neovison vison	American Mink			Not on any status lists
Ondatra zibethicus	Common Muskrat			Not on any status lists
MOLLUSKS				
Anodonta californiensis	California Floater		Special	
Ferrissia spp.	Ferrissia spp.			
Gonidea angulata	Western Ridged Mussel		Special	
Gyraulus spp.	Gyraulus spp.			
Helisoma spp.	Helisoma spp.			
Lymnaea spp.	Lymnaea spp.			
Lymnaeidae fam.	Lymnaeidae fam.			
Margaritifera falcata	Western Pearlshell		Special	
Menetus opercularis	Button Sprite			CS
Menetus spp.	Menetus spp.			
Physa spp.	Physa spp.			
Planorbidae fam.	Planorbidae fam.			
PLANTS				
Chloropyron palmatum	NA	Endangered	Special	CRPR - 1B.1
Orcuttia pilosa	Hairy Orcutt Grass	Endangered	Endangered	CRPR - 1B.1
Puccinellia simplex	Little Alkali Grass			
Tuctoria greenei	Green's Awnless Orcutt Grass	Endangered	Rare	CRPR - 1B.1
Alnus rhombifolia	White Alder			
Alopecurus carolinianus	Tufted Foxtail			
Alopecurus pratensis	NA			
Alopecurus saccatus	Pacific Foxtail			
Ammannia coccinea	Scarlet Ammannia			
Ammannia robusta	Grand Redstem			
Anemopsis californica	Yerba Mansa			
Arundo donax	NA			

Azolla filiculoides	NA			
Azolla microphylla	Mexican mosquito fern		Special	CRPR - 4.3
Baccharis salicina				Not on any status lists
Bacopa eisenii	Gila River Water-hyssop			
Bacopa rotundifolia	NA			
Bergia texana	Texas Bergia			
Boehmeria cylindrica	NA			Not on any status lists
Bolboschoenus fluviatilis				Not on any status lists
Bolboschoenus glaucus	NA			Not on any status lists
Bolboschoenus maritimus paludosus	NA			Not on any status lists
Brasenia schreberi	Watershield		Special	CRPR - 2B.3
Brodiaea nana				Not on any status lists
Calamagrostis nutkaensis	Pacific Small-reedgrass			
Callitriche heterophylla bolanderi	Large Water-starwort			
Callitriche heterophylla heterophylla	Northern Water-starwort			
Callitriche longipedunculata	Longstock Water-starwort			
Callitriche marginata	Winged Water-starwort			
Callitriche trochlearis	Waste-water Water-starwort			
Calochortus uniflorus	Shortstem Mariposa Lily		Special	CRPR - 4.2
Carex densa	Dense Sedge			
Carex feta	Green-sheath Sedge			
Carex nudata	Torrent Sedge			
Carex obnupta	Slough Sedge			
Carex vulpinoidea	NA			
Castilleja minor minor	Alkali Indian-paintbrush			
Cephalanthus occidentalis	Common Buttonbush			
Cicendia quadrangularis	Oregon Microcala			
Cirsium douglasii breweri				Not on any status lists
Cotula coronopifolia	NA			
Crassula aquatica	Water Pygmyweed			
Crypsis vaginiflora	NA			
Cyperus acuminatus	Short-point Flatsedge			
Cyperus erythrorhizos	Red-root Flatsedge			

Cyperus fuscus	NA			
Cyperus iria	NA			Not on any status lists
Cyperus squarrosus	Awned Cyperus			
Damasonium californicum				Not on any status lists
Datisca glomerata	Durango Root			
Delphinium uliginosum	Swamp Larkspur		Special	CRPR - 4.2
Downingia bella	Hoover's Downingia			
Downingia bicornuta	NA			
Downingia concolor	NA			
Downingia cuspidata	Toothed Calicoflower			
Downingia insignis	Parti-color Downingia			
Downingia ornatissima	NA			
Downingia pulchella	Flat-face Downingia			
Downingia yina	NA			
Echinochloa oryzoides	NA			
Echinodorus berteroi	Upright Burhead			
Elatine californica	California Waterwort			
Elatine heterandra	Mosquito Waterwort			
Elatine rubella	Southwestern Waterwort			
Eleocharis acicularis acicularis	Least Spikerush			
Eleocharis atropurpurea	Purple Spikerush			
Eleocharis bella	Delicate Spikerush			
Eleocharis coloradoensis				Not on any status lists
Eleocharis engelmannii engelmannii	Engelmann's Spikerush			Not on any status lists
Eleocharis macrostachya	Creeping Spikerush			
Eleocharis montevidensis	Sand Spikerush			
Eleocharis obtusa	Blunt Spikerush			
Eleocharis parishii	Parish's Spikerush			
Eleocharis quadrangulata	NA			
Eleocharis quinqueflora	Few-flower Spikerush			
Epilobium campestre	NA			Not on any status lists
Epilobium cleistogamum	Cleistogamous Spike-primrose			
Eragrostis hypnoides	Teal Lovegrass			
Eryngium aristulatum aristulatum	California Eryngo			
Eryngium articulatum	Jointed Coyote-thistle			
Eryngium castrense	Great Valley Eryngo			
Eryngium jepsonii	NA			Not on any status lists

Eryngium vaseyi vallicola				Not on any status lists
Eryngium vaseyi vaseyi	Vasey's Coyote-thistle			Not on any status lists
Euphorbia hooveri	NA			Not on any status lists
Euthamia occidentalis	Western Fragrant Goldenrod			
Fimbristylis autumnalis	NA			
Gratiola ebracteata	Bractless Hedge-hyssop			
Hastingsia alba	White Rushlily			
Helenium bigelovii	Bigelow's Sneezeweed			
Helenium puberulum	Rosilla			
Heteranthera limosa	NA			
Hydrocotyle ranunculoides	Floating Marsh-pennywort			
Hydrocotyle umbellata	Many-flower Marsh-pennywort			
Isoetes howellii	NA			
Isoetes nuttallii	NA			
Isolepis cernua	Low Bulrush			
Juncus acuminatus	Sharp-fruit Rush			
Juncus articulatus articulatus				Not on any status lists
Juncus diffusissimus	NA			
Juncus effusus effusus	NA			
Juncus effusus pacificus				
Juncus uncialis	Inch-high Rush			
Juncus usitatus	NA			Not on any status lists
Juncus xiphioides	Iris-leaf Rush			
Lasthenia ferrisiae	Ferris' Goldfields		Special	CRPR - 4.2
Lasthenia fremontii	Fremont's Goldfields			
Leersia oryzoides	Rice Cutgrass			
Lemna aequinoctialis	Lesser Duckweed			
Lemna gibba	Inflated Duckweed			
Lemna minor	Lesser Duckweed			
Lemna minuta	Least Duckweed			
Lemna turionifera	Turion Duckweed			
Lepidium oxycarpum	Sharp-pod Pepper-grass			
Limnanthes alba alba	White Meadowfoam			
Limnanthes douglasii douglasii	Douglas' Meadowfoam			
Limnanthes douglasii nivea	Douglas' Meadowfoam			
Limnanthes douglasii rosea	Douglas' Meadowfoam			

Limnanthes floccosa californica	Shippee Meadowfoam	Endangered	Endangered	CRPR - 1B.1
Limosella acaulis	Southern Mudwort			
Limosella aquatica	Northern Mudwort			
Lipocarpha micrantha	Dwarf Bulrush			
Ludwigia grandiflora	NA			
Ludwigia hexapetala	NA			Not on any status lists
Ludwigia palustris	Marsh Seedbox			
Ludwigia peploides montevidensis	NA			Not on any status lists
Ludwigia peploides peploides	NA			Not on any status lists
Lycopus americanus	American Bugleweed			
Lythrum californicum	California Loosestrife			
Lythrum portula	NA			
Marsilea vestita vestita	NA			Not on any status lists
Mimulus tricolor	Tricolor Monkeyflower			
Myosurus minimus	NA			
Myosurus sessilis	Sessile Mousetail			
Myriophyllum aquaticum	NA			
Myriophyllum hippuroides	Western Water-milfoil			
Najas gracillima	NA			
Najas guadalupensis guadalupensis	Southern Naiad			
Navarretia cotulifolia	Cotula Navarretia			
Navarretia heterandra	Tehama Navarretia			
Navarretia intertexta	Needleleaf Navarretia			
Navarretia leucocephala bakeri	Baker's Navarretia		Special	CRPR - 1B.1
Navarretia leucocephala leucocephala	White-flower Navarretia			
Navarretia leucocephala minima	Least Navarretia			
Orcuttia tenuis	Slender Orcutt Grass	Threatened	Endangered	CRPR - 1B.1
Oxypolis occidentalis	Western Cowbane			
Panicum dichotomiflorum	NA			
Paspalum distichum	Joint Paspalum			
Perideridia bolanderi involucrata	Bolander's Yampah			
Perideridia kelloggii	Kellogg's Yampah			
Perideridia oregana	Oregon Yampah			
Persicaria hydropiper	NA			Not on any status lists
Persicaria hydropiperoides				Not on any status lists

Persicaria lapathifolia				Not on any status lists
Persicaria maculosa	NA			Not on any status lists
Persicaria punctata	NA			Not on any status lists
Phacelia distans	NA			
Phragmites australis australis	Common Reed			
Phyla lanceolata	Fog-fruit			
Phyla nodiflora	Common Frog-fruit			
Pilularia americana	NA			
Plagiobothrys austiniae	Austin's Popcorn-flower			
Plagiobothrys greenei	Greene's Popcorn-flower			
Plagiobothrys humistratus	Dwarf Popcorn-flower			
Plagiobothrys leptocladus	Alkali Popcorn-flower			
Plantago elongata elongata	Slender Plantain			
Platanus racemosa	California Sycamore			
Pogogyne douglasii	NA			
Pogogyne zizyphoroides				Not on any status lists
Potamogeton diversifolius	Water-thread Pondweed			
Potamogeton foliosus foliosus	Leafy Pondweed			
Potamogeton gramineus	Grassy Pondweed			
Potamogeton nodosus	Longleaf Pondweed			
Potamogeton pusillus pusillus	Slender Pondweed			
Psilocarphus brevissimus brevissimus	Dwarf Woolly-heads			
Psilocarphus brevissimus multiflorus	Delta Woolly Marbles		Special	CRPR - 4.2
Psilocarphus oregonus	Oregon Woolly-heads			
Psilocarphus tenellus	NA			
Puccinellia nuttalliana	Nuttall's Alkali Grass			
Ranunculus bonariensis	NA			
Ranunculus pusillus pusillus	Pursh's Buttercup			
Ranunculus sceleratus	NA			
Rhododendron occidentale occidentale	Western Azalea			
Rorippa curvisiliqua curvisiliqua	Curve-pod Yellowcress			

Rorippa palustris palustris	Bog Yellowcress			
Rotala ramosior	Toothcup			
Rumex conglomeratus	NA			
Rumex salicifolius salicifolius	Willow Dock			
Rumex stenophyllus	NA			
Sagittaria latifolia latifolia	Broadleaf Arrowhead			
Sagittaria longiloba	Longbarb Arrowhead			
Sagittaria montevidensis calycina				Not on any status lists
Sagittaria sanfordii	Sanford's Arrowhead		Special	CRPR - 1B.2
Salix babylonica	NA			
Salix breweri	Brewer's Willow			
Salix exigua exigua	Narrowleaf Willow			
Salix gooddingii	Goodding's Willow			
Salix laevigata	Polished Willow			
Salix lasiandra lasiandra				Not on any status lists
Salix lasiolepis lasiolepis	Arroyo Willow			
Salix lutea	Yellow Willow			
Salix melanopsis	Dusky Willow			
Schoenoplectus acutus occidentalis	Hardstem Bulrush			
Schoenoplectus americanus	Three-square Bulrush			
Schoenoplectus pungens pungens	NA			
Schoenoplectus tabernaemontani	Softstem Bulrush			
Sequoia sempervirens				
Sidalcea hirsuta	Hairy Checker-mallow			
Sidalcea oregana hydrophila	Water-loving Checker-mallow		Special	CRPR - 1B.2
Sinapis alba	NA			
Sparganium eurycarpum eurycarpum				
Spirodela polyrhiza	NA			
Stachys ajugoides	Bugle Hedge-nettle			
Stachys albens	White-stem Hedge-nettle			
Stachys pycnantha	Short-spike Hedge-nettle			
Stachys stricta	Sonoma Hedge-nettle			
Stuckenia pectinata				Not on any status lists
Suaeda calceoliformis	American Sea-blite			
Symphyotrichum lentum	Suisun Marsh Aster		Special	CRPR - 1B.2

Toxicoscordion micranthum	NA			Not on any status lists
Typha domingensis	Southern Cattail			
Typha latifolia	Broadleaf Cattail			
Utricularia gibba	Humped Bladderwort			
Veronica anagallis-aquatica	NA			
Veronica catenata	NA			Not on any status lists
Wolffia borealis	Dotted Watermeal			
Wolffia brasiliensis	Pointed Watermeal		Special	CRPR - 2B.3
Wolffia globosa	Asian Watermeal			
Wolffiella oblonga	Saber-shape Bogmat			
Zannichellia palustris	Horned Pondweed			
Zizania palustris palustris	NA			

Attachment D

The Nature Conservancy

July 2019



IDENTIFYING GDEs UNDER SGMA

Best Practices for using the NC Dataset

The Sustainable Groundwater Management Act (SGMA) requires that groundwater dependent ecosystems (GDEs) be identified in Groundwater Sustainability Plans (GSPs). As a starting point, the Department of Water Resources (DWR) is providing the Natural Communities Commonly Associated with Groundwater Dataset (NC Dataset) online[1] to help Groundwater Sustainability Agencies (GSAs), consultants, and stakeholders identify GDEs within individual groundwater basins. To apply information from the NC Dataset to local areas, GSAs should combine it with the best available science on local hydrology, geology, and groundwater levels to verify whether polygons in the NC dataset are likely supported by groundwater in an aquifer (Figure 1)[2]. This document highlights six best practices for using local groundwater data to confirm whether mapped features in the NC dataset are supported by groundwater.

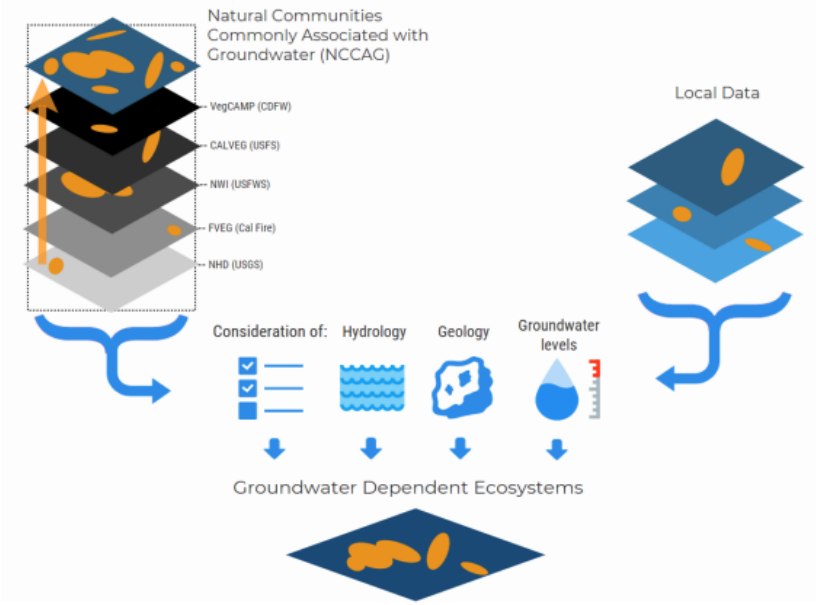


Figure 1. Considerations for GDE identification.
Source: DWR[2]

[1] NC Dataset Online Viewer: https://gis.water.ca.gov/app/NCDatasetViewer/
[2] California Department of Water Resources (DWR). 2018. Summary of the "Natural Communities Commonly Associated with Groundwater" Dataset and Online Web Viewer. Available at: https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Groundwater-Management/Data-and-Tools/Files/Statewide-Reports/Natural-Communities-Dataset-Summary-Document.pdf

The NC Dataset identifies vegetation and wetland features that are good indicators of a GDE. The dataset is comprised of 48 publicly available state and federal datasets that map vegetation, wetlands, springs, and seeps commonly associated with groundwater in California[3]. It was developed through a collaboration between DWR, the Department of Fish and Wildlife, and The Nature Conservancy (TNC). TNC has also provided detailed guidance on identifying GDEs from the NC dataset[4] on the Groundwater Resource Hub[5], a website dedicated to GDEs.

BEST PRACTICE #1. Establishing a Connection to Groundwater

Groundwater basins can be comprised of one continuous aquifer (Figure 2a) or multiple aquifers stacked on top of each other (Figure 2b). In unconfined aquifers (Figure 2a), using the depth-to-groundwater and the rooting depth of the vegetation is a reasonable method to infer groundwater dependence for GDEs. If groundwater is well below the rooting (and capillary) zone of the plants and any wetland features, the ecosystem is considered disconnected and groundwater management is not likely to affect the ecosystem (Figure 2d). However, it is important to consider local conditions (e.g., soil type, groundwater flow gradients, and aquifer parameters) and to review groundwater depth data from multiple seasons and water year types (wet and dry) because intermittent periods of high groundwater levels can replenish perched clay lenses that serve as the water source for GDEs (Figure 2c). Maintaining these natural groundwater fluctuations are important to sustaining GDE health.

Basins with a stacked series of aquifers (Figure 2b) may have varying levels of pumping across aquifers in the basin, depending on the production capacity or water quality associated with each aquifer. If pumping is concentrated in deeper aquifers, SGMA still requires GSAs to sustainably manage groundwater resources in shallow aquifers, such as perched aquifers, that support springs, surface water, domestic wells, and GDEs (Figure 2). This is because vertical groundwater gradients across aquifers may result in pumping from deeper aquifers to cause adverse impacts onto beneficial users reliant on shallow aquifers or interconnected surface water. The goal of SGMA is to sustainably manage groundwater resources for current and future social, economic, and environmental benefits. While groundwater pumping may not be currently occurring in a shallower aquifer, use of this water may become more appealing and economically viable in future years as pumping restrictions are placed on the deeper production aquifers in the basin to meet the sustainable yield and criteria. Thus, identifying GDEs in the basin should done irrespective to the amount of current pumping occurring in a particular aquifer, so that future impacts on GDEs due to new production can be avoided. A good rule of thumb to follow is: *if groundwater can be pumped from a well - it's an aquifer*.

[3] For more details on the mapping methods, refer to: Klausmeyer, K., J. Howard, T. Keeler-Wolf, K. Davis-Fadtke, R. Hull, A. Lyons. 2018. Mapping Indicators of Groundwater Dependent Ecosystems in California: Methods Report. San Francisco, California. Available at: https://groundwaterresourcehub.org/public/uploads/pdfs/iGDE_data_paper_20180423.pdf
[4] "Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans" is available at: https://groundwaterresourcehub.org/gde-tools/gsp-guidance-document/
[5] The Groundwater Resource Hub: www.GroundwaterResourceHub.org

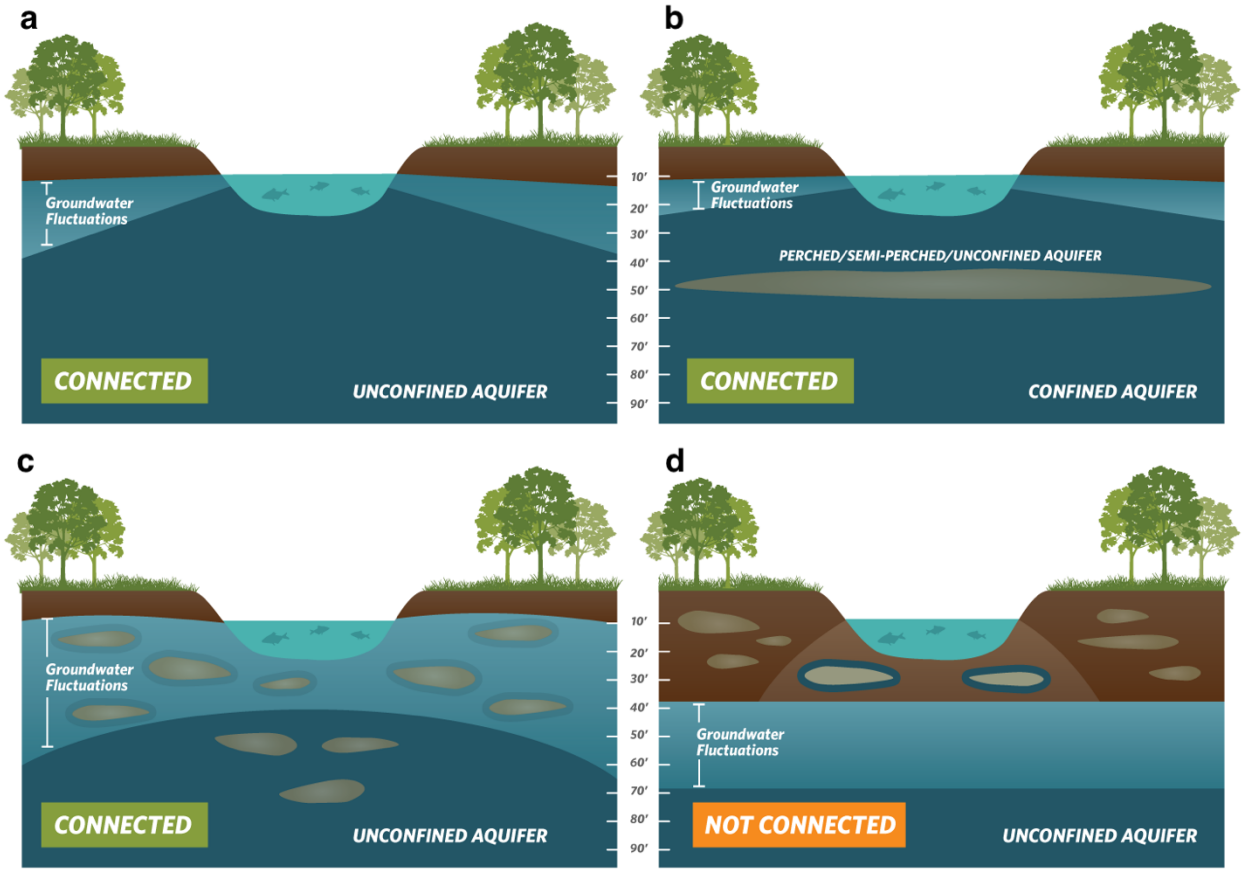


Figure 2. Confirming whether an ecosystem is connected to groundwater. Top: (a) Under the ecosystem is an unconfined aquifer with depth-to-groundwater fluctuating seasonally and interannually within 30 feet from land surface. **(b)** Depth-to-groundwater in the shallow aquifer is connected to overlying ecosystem. Pumping predominately occurs in the confined aquifer, but pumping is possible in the shallow aquifer. **Bottom: (c)** Depth-to-groundwater fluctuations are seasonally and interannually large, however, clay layers in the near surface prolong the ecosystem's connection to groundwater. **(d)** Groundwater is disconnected from surface water, and any water in the vadose (unsaturated) zone is due to direct recharge from precipitation and indirect recharge under the surface water feature. These areas are not connected to groundwater and typically support species that do not require access to groundwater to survive.

BEST PRACTICE #2. Characterize Seasonal and Interannual Groundwater Conditions

SGMA requires GSAs to describe current and historical groundwater conditions when identifying GDEs [23 CCR §354.16(g)]. Relying solely on the SGMA benchmark date (January 1, 2015) or any other single point in time to characterize groundwater conditions (e.g., depth-to-groundwater) is inadequate because managing groundwater conditions with data from one time point fails to capture the seasonal and interannual variability typical of California's climate. DWR's Best Management Practices document on water budgets[6] recommends using 10 years of water supply and water budget information to describe how historical conditions have impacted the operation of the basin within sustainable yield, implying that a baseline[7] could be determined based on data between 2005 and 2015. Using this or a similar time period, depending on data availability, is recommended for determining the depth-to-groundwater.

GDEs depend on groundwater levels being close enough to the land surface to interconnect with surface water systems or plant rooting networks. The most practical approach[8] for a GSA to assess whether polygons in the NC dataset are connected to groundwater is to rely on groundwater elevation data. As detailed in TNC's GDE guidance document[4], one of the key factors to consider when mapping GDEs is to contour depth-to-groundwater in the aquifer that is supporting the ecosystem (see Best Practice #5).

Groundwater levels fluctuate over time and space due to California's Mediterranean climate (dry summers and wet winters), climate change (flood and drought years), and subsurface heterogeneity in the subsurface (Figure 3). Many of California's GDEs have adapted to dealing with intermittent periods of water stress, however if these groundwater conditions are prolonged, adverse impacts to GDEs can result. While depth-to-groundwater levels within 30 feet[4] of the land surface are generally accepted as being a proxy for confirming that polygons in the NC dataset are supported by groundwater, it is highly advised that fluctuations in the groundwater regime be characterized to understand the seasonal and interannual groundwater variability in GDEs. Utilizing groundwater data from one point in time can misrepresent groundwater levels required by GDEs, and inadvertently result in adverse impacts to the GDEs. Time series data on groundwater elevations and depths are available on the SGMA Data Viewer[9]. However, if insufficient data are available to describe groundwater conditions within or near polygons from the NC dataset, include those polygons in the GSP until data gaps are reconciled in the monitoring network (see Best Practice #6).

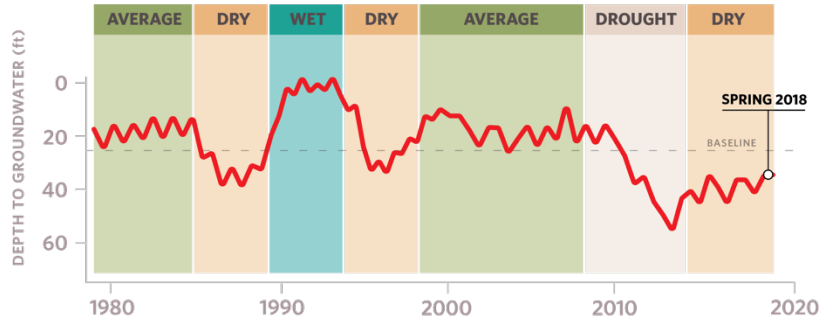


Figure 3. Example seasonality and interannual variability in depth-to-groundwater over time. Selecting one point in time, such as Spring 2018, to characterize groundwater conditions in GDEs fails to capture what groundwater conditions are necessary to maintain the ecosystem status into the future so adverse impacts are avoided.

[6] DWR. 2016. Water Budget Best Management Practice. Available at: https://water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/BMP_Water_Budget_Final_2016-12-23.pdf

[7] Baseline is defined under the GSP regulations as "historic information used to project future conditions for hydrology, water demand, and availability of surface water and to evaluate potential sustainable management practices of a basin." [23 CCR §351(e)]

[8] Groundwater reliance can also be confirmed via stable isotope analysis and geophysical surveys. For more information see The GDE Assessment Toolbox (Appendix IV, GDE Guidance Document for GSPs[4]).

[9] SGMA Data Viewer: https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer

BEST PRACTICE #3. Ecosystems Often Rely on Both Groundwater and Surface Water

GDEs are plants and animals that rely on groundwater for all or some of its water needs, and thus can be supported by multiple water sources. The presence of non-groundwater sources (e.g., surface water, soil moisture in the vadose zone, applied water, treated wastewater effluent, urban stormwater, irrigated return flow) within and around a GDE does not preclude the possibility that it is supported by groundwater, too. SGMA defines GDEs as "ecological communities and species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" [23 CCR §351(m)]. Hence, depth-to-groundwater data should be used to identify whether NC polygons are supported by groundwater and should be considered GDEs. In addition, SGMA requires that significant and undesirable adverse impacts to beneficial users of surface water be avoided. Beneficial users of surface water include environmental users such as plants or animals[10], which therefore must be considered when developing minimum thresholds for depletions of interconnected surface water.

GSAs are only responsible for impacts to GDEs resulting from groundwater conditions in the basin, so if adverse impacts to GDEs result from the diversion of applied water, treated wastewater, or irrigation return flow away from the GDE, then those impacts will be evaluated by other permitting requirements (e.g., CEQA) and may not be the responsibility of the GSA. However, if adverse impacts occur to the GDE due to changing groundwater conditions resulting from pumping or groundwater management activities, then the GSA would be responsible (Figure 4).

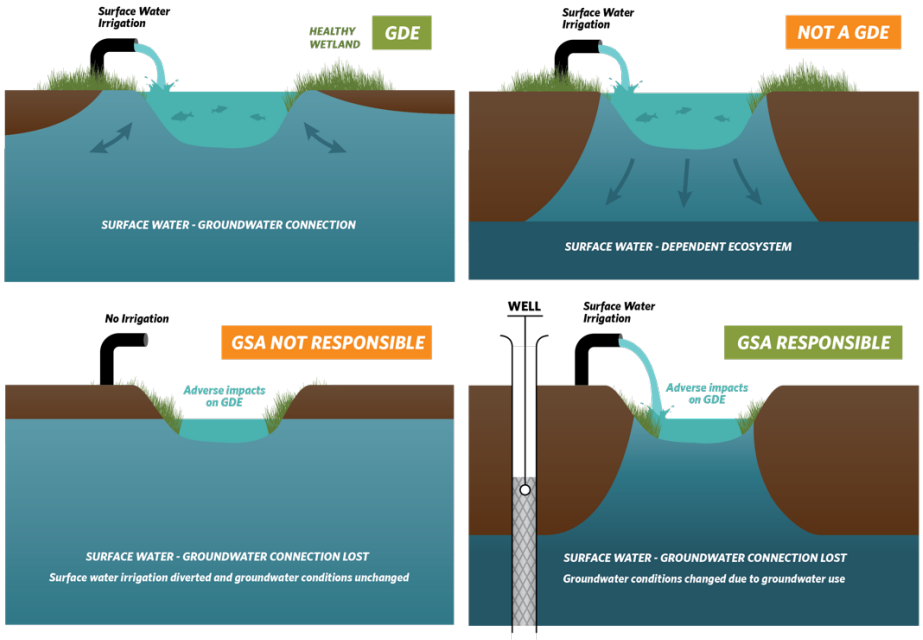


Figure 4. Ecosystems often depend on multiple sources of water. Top: (Left) Surface water and groundwater are interconnected, meaning that the GDE is supported by both groundwater and surface water. **(Right)** Ecosystems that are only reliant on non-groundwater sources are not groundwater-dependent. **Bottom: (Left)** An ecosystem that was once dependent on an interconnected surface water, but loses access to groundwater solely due to surface water diversions may not be the GSA's responsibility. **(Right)** Groundwater dependent ecosystems once dependent on an interconnected surface water system, but loses that access due to groundwater pumping is the GSA's responsibility.

[10] For a list of environmental beneficial users of surface water by basin, visit: https://groundwaterresourcehub.org/gde-tools/environmental-surface-water-beneficiaries/

BEST PRACTICE #4. Select Representative Groundwater Wells

Identifying GDEs in a basin requires that groundwater conditions are characterized to confirm whether polygons in the NC dataset are supported by the underlying aquifer. To do this, proximate groundwater wells should be identified to characterize groundwater conditions (Figure 5). When selecting representative wells, it is particularly important to consider the subsurface heterogeneity around NC polygons, especially near surface water features where groundwater and surface water interactions occur around heterogeneous stratigraphic units or aquitards formed by fluvial deposits. The following selection criteria can help ensure groundwater levels are representative of conditions within the GDE area:

- Choose wells that are within 5 kilometers (3.1 miles) of each NC Dataset polygons because they are more likely to reflect the local conditions relevant to the ecosystem. If there are no wells within 5km of the center of a NC dataset polygon, then there is insufficient information to remove the polygon based on groundwater depth. Instead, it should be retained as a potential GDE until there are sufficient data to determine whether or not the NC Dataset polygon is supported by groundwater.

- Choose wells that are screened within the surficial unconfined aquifer and capable of measuring the true water table.

- Avoid relying on wells that have insufficient information on the screened well depth interval for excluding GDEs because they could be providing data on the wrong aquifer. This type of well data should not be used to remove any NC polygons.

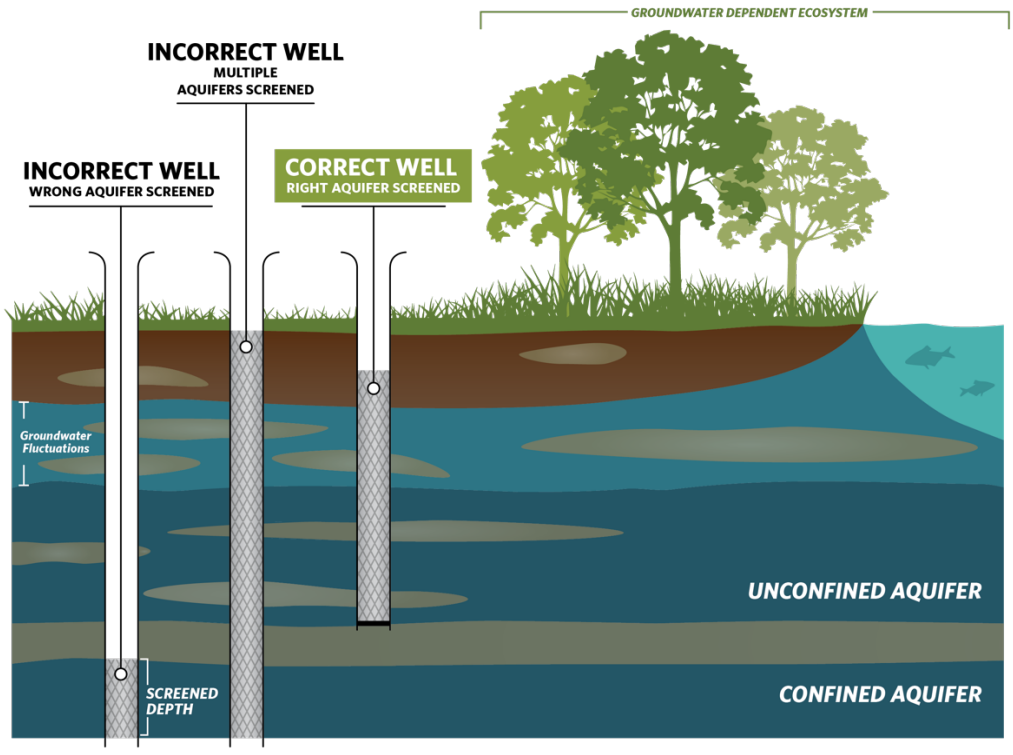


Figure 5. Selecting representative wells to characterize groundwater conditions near GDEs.

BEST PRACTICE #5. Contouring Groundwater Elevations

The common practice to contour depth-to-groundwater over a large area by interpolating measurements at monitoring wells is unsuitable for assessing whether an ecosystem is supported by groundwater. This practice causes errors when the land surface contains features like stream and wetland depressions because it assumes the land surface is constant across the landscape and depth-to-groundwater is constant below these low-lying areas (Figure 6a). A more accurate approach is to interpolate **groundwater elevations** at monitoring wells to get groundwater elevation contours across the landscape. This layer can then be subtracted from land surface elevations from a Digital Elevation Model (DEM)[11] to estimate depth-to-groundwater contours across the landscape (Figure b; Figure 7). This will provide a much more accurate contours of depth-to-groundwater along streams and other land surface depressions where GDEs are commonly found.

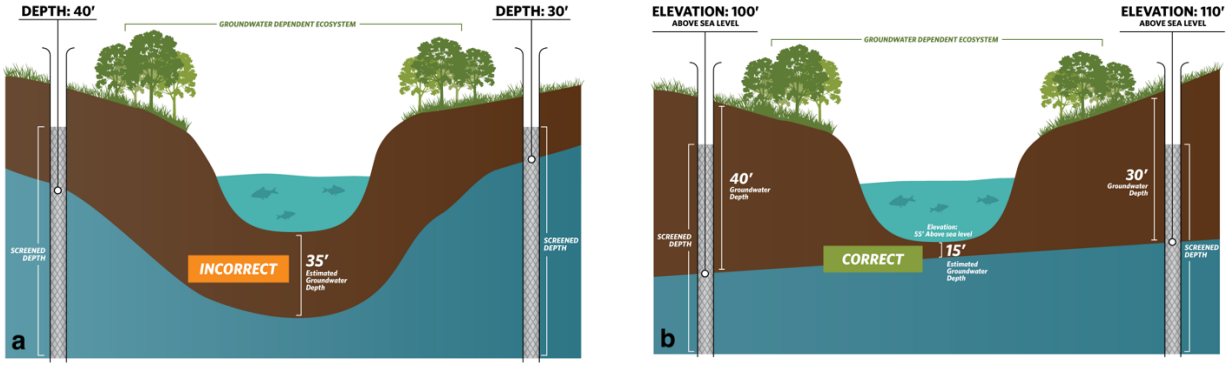


Figure 6. Contouring depth-to-groundwater around surface water features and GDEs. (a) Groundwater level interpolation using depth-to-groundwater data from monitoring wells. **(b)** Groundwater level interpolation using groundwater elevation data from monitoring wells and DEM data.

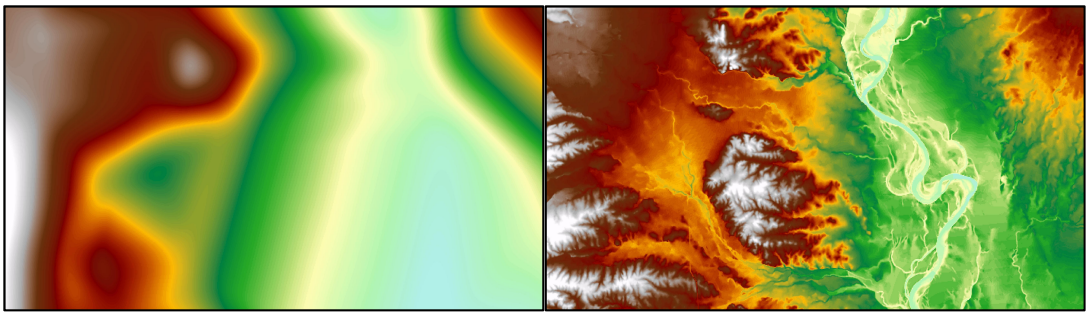


Figure 7. Depth-to-groundwater contours in Northern California. (Left) Contours were interpolated using depth-to-groundwater measurements determined at each well. **(Right)** Contours were determined by interpolating groundwater elevation measurements at each well and superimposing ground surface elevation from DEM spatial data to generate depth-to-groundwater contours. The image on the right shows a more accurate depth-to-groundwater estimate because it takes the local topography and elevation changes into account.

[11] USGS Digital Elevation Model data products are described at: https://www.usgs.gov/core-science-systems/ngp/3dep/about-3dep-products-services and can be downloaded at: https://iewer.nationalmap.gov/basic/

BEST PRACTICE #6. Best Available Science

Adaptive management is embedded within SGMA and provides a process to work toward sustainability over time by beginning with the best available information to make initial decisions, monitoring the results of those decisions, and using the data collected through monitoring programs to revise decisions in the future. In many situations, the hydrologic connection of NC dataset polygons will not initially be clearly understood if site-specific groundwater monitoring data are not available. If sufficient data are not available in time for the 2020/2022 plan, **The Nature Conservancy strongly advises that questionable polygons from the NC dataset be included in the GSP until data gaps are reconciled in the monitoring network.** Erring on the side of caution will help minimize inadvertent impacts to GDEs as a result of groundwater use and management actions during SGMA implementation.

KEY DEFINITIONS

Groundwater basin is an aquifer or stacked series of aquifers with reasonably well-defined boundaries in a lateral direction, based on features that significantly impede groundwater flow, and a definable bottom. *23 CCR §341(g)(1)*

Groundwater dependent ecosystem (GDE) are ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface. *23 CCR §351(m)*

Interconnected surface water (ISW) surface water that is hydraulically connected at any point by a continuous saturated zone to the underlying aquifer and the overlying surface water is not completely depleted. *23 CCR §351(o)*

Principal aquifers are aquifers or aquifer systems that store, transmit, and yield significant or economic quantities of groundwater to wells, springs, or surface water systems. *23 CCR §351(aa)*

ABOUT US

The Nature Conservancy is a science-based nonprofit organization whose mission is *to conserve the lands and waters on which all life depends*. To support successful SGMA implementation that meets the future needs of people, the economy, and the environment, TNC has developed tools and resources (www.groundwaterresourcehub.org) intended to reduce costs, shorten timelines, and increase benefits for both people and nature.

Attachment E

Maps of representative monitoring sites in relation to key beneficial users

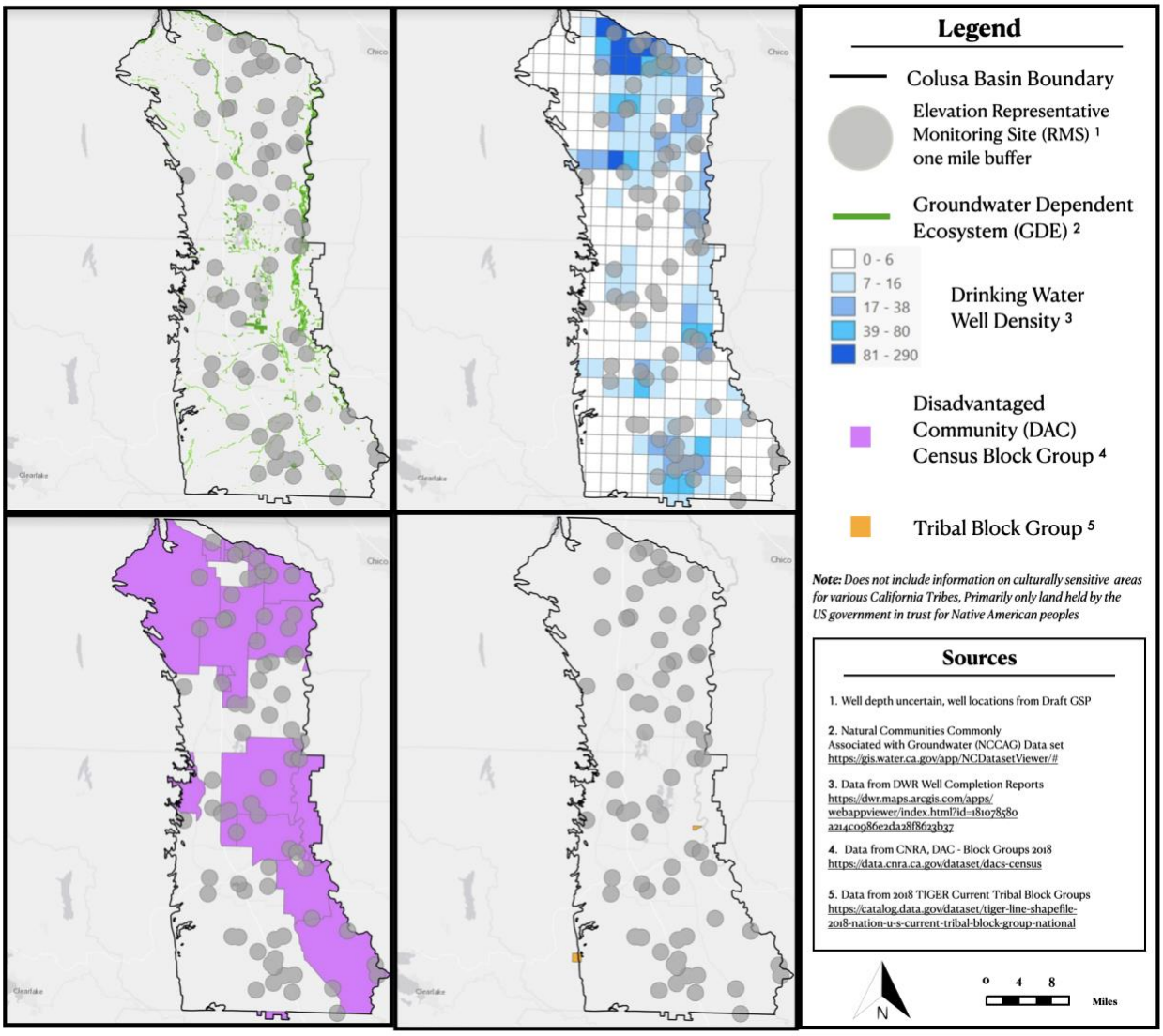


Figure 1. Groundwater elevation representative monitoring sites in relation to key beneficial users: a) Groundwater Dependent Ecosystems (GDEs), b) Drinking Water users, c) Disadvantaged Communities (DACs), and d) Tribes.

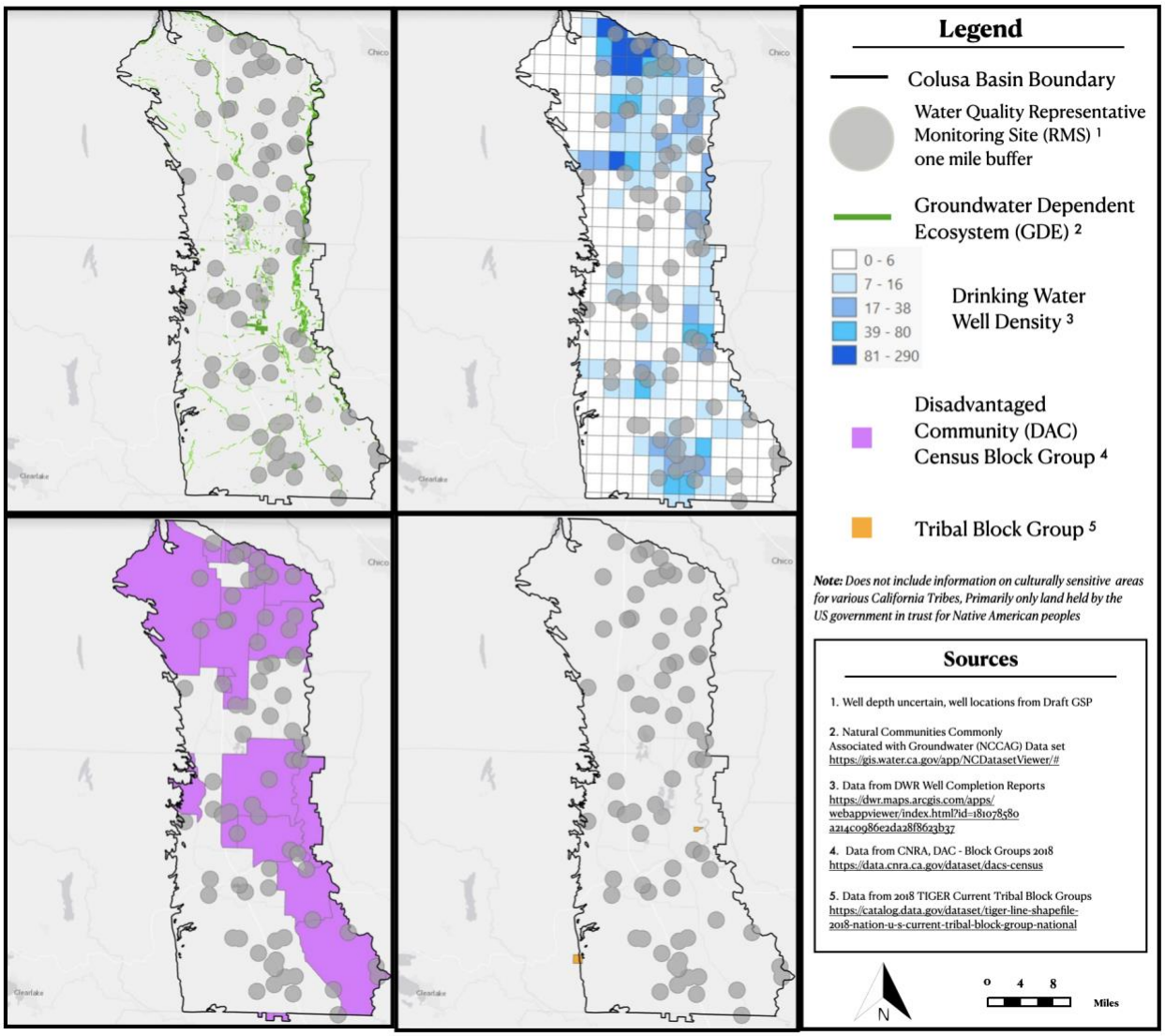


Figure 2. Groundwater quality representative monitoring sites in relation to key beneficial users: a) Groundwater Dependent Ecosystems (GDEs), b) Drinking Water users, c) Disadvantaged Communities (DACs), and d) Tribes.

2B-3. Emails

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From:	Ben King
To:	Mary Fahey
Cc:	Gosselin, Paul; Buck, Christina; Ben King
Subject:	FW: Hydrogeology of the Sutter Basin, California 1971
Date:	Monday, November 18, 2019 2:44:12 PM
Attachments:	George Curtin Sutter Basin.pdf USGS Sacramento Valley Tectonism.pdf

---

Hi Mary,

Here is the cite of the first paragraph of the Abstract for Hydrogeology of the Sutter Basin by George Curtin:

"***A mound of saline water exists in continental sediments between two fresh water rivers in the Sutter Basin of the Sacramento Valley, California. This saline water has moved from the marine sediments, at depth, upward along the Sutter Basin Fault and then through 2,000 feet of alluvium."***

I have also attached the USGS Sacramento Valley Tectonism Study published in 1987. This USGS report explains the faults surrounding the ancient Sutter Buttes volcano and the fact that the faults are still active.

As I mentioned, I am concerned about the potential for further later movement of the salt water northward towards the Butte Sink that may be cause by future groundwater substitution on east side of the Sacramento River near Colusa. As you know Colusa, Grimes, Sutter and Meridian use groundwater. The other issue that came to my mind was the potential for further deterioration due to future earthquake activity.

Perhaps – this area might be a good candidate for an Aerial mapping if the mapping could detect higher chloride levels in the groundwater?

Thanks again

Ben King

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Late Cenozoic Tectonism of the Sacramento Valley, California

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1359

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SUP. DOCS: This page is to be distributed according to the standard IGS mailing list for U.S. Geological Survey Professional Papers.

USER: This reprint of figure 5 should replace the present figure 5 of U.S. Geological Survey Professional Paper 1359. It was reprinted to correct the seismic reflection profile which was inadvertently printed backwards.

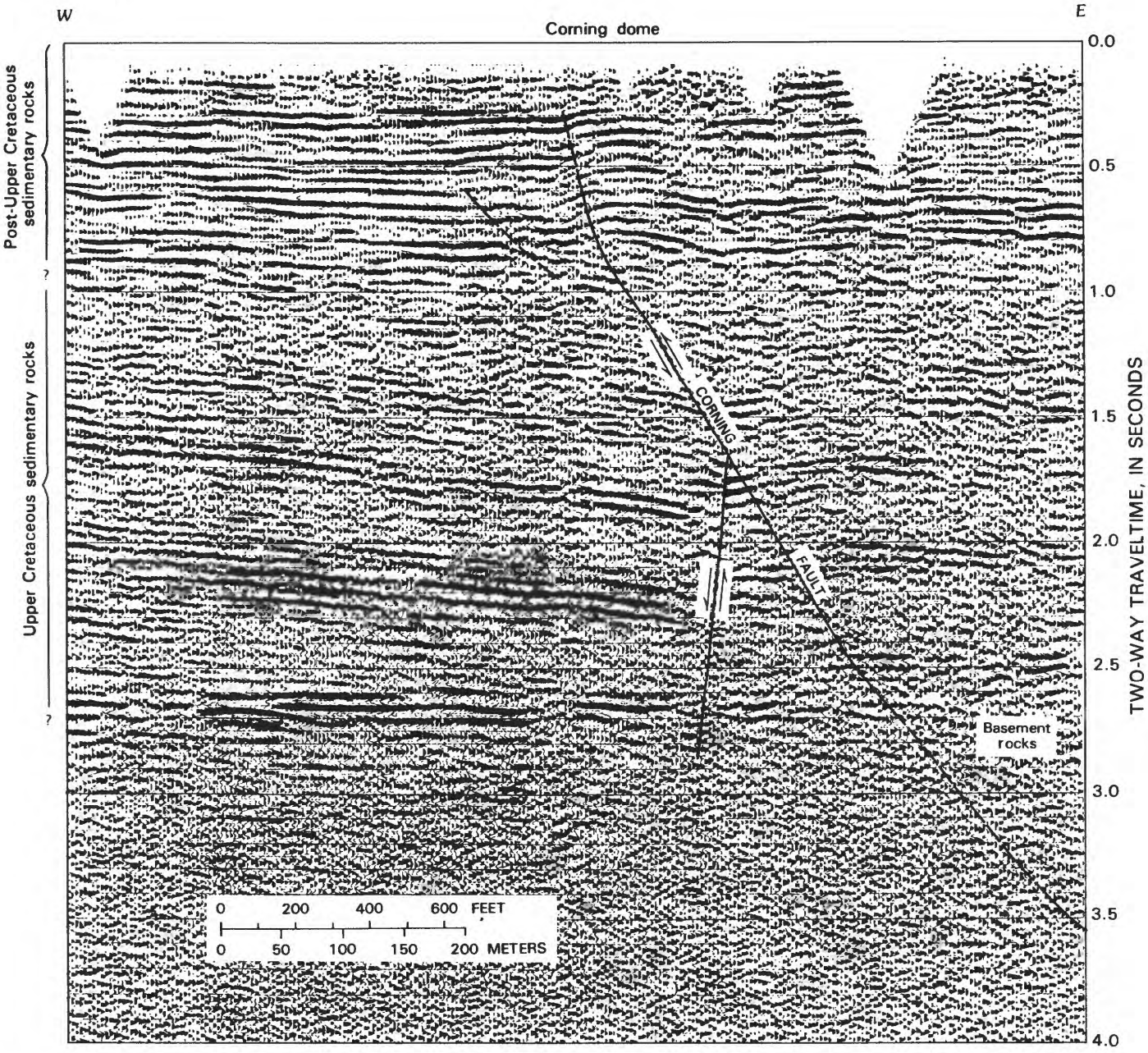

FIGURE 5.—Seismic reflection profile, from Seisdata Services Inc., showing structural and generalized stratigraphic relations across Corning fault between Corning and Red Bluff, Calif.

Late Cenozoic Tectonism of the Sacramento Valley, California

By DAVID S. HARWOOD *and* EDWARD J. HELLEY

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LATE CENOZOIC TECTONISM OF THE SACRAMENTO VALLEY, CALIFORNIA

By DAVID S. HARWOOD and EDWARD J. HELLEY

ABSTRACT

Structure contours drawn on top of the Cretaceous rocks in the Sacramento Valley define a large number of diversely oriented folds and faults that are expressed in topographic, hydrologic, and geologic features at the land surface. Although many of the structures in the valley have a protracted history of movement, some dating back to the late Mesozoic, a remarkable number of these structures show late Cenozoic deformation that can be accurately determined from folding and faulting of widespread, dated Pliocene and Pleistocene volcanic units. These time-stratigraphic units are used to define structural domains of essentially contemporaneous late Cenozoic deformation that was characterized by east-west compressive stress. The oldest structural domain is located in the southeastern part of the valley, where east-side-up reverse movement on the Willows fault ceased prior to deposition of continentally derived sediments of late Miocene and early Pliocene age. In the middle Pliocene to early Pleistocene, east-west compressive deformation progressed northward through the valley so that the youngest late Cenozoic deformation is recorded in east-northeast-trending folds and faults in the Battle Creek domain, at the northernmost part of the valley. The northward progression of east-west compressive deformation appears to be related to the northward eclipse of eastward subduction of the Juan de Fuca plate before the northwestward migration of the Mendocino triple junction along the continental margin west of the valley.

Much of the east-west compressive stress that affected the valley in the late Cenozoic was accommodated by east-side-up reverse movement on the steeply east-dipping, northwest-trending Willows fault and the north-trending Corning fault that splays off from the main stem of the Willows fault north of Sutter Buttes. Significant strain release also occurred on the northwest-trending fault beneath the Chico monocline and on the east-northeast-trending Red Bluff, Battle Creek, and Bear Creek faults in the past 2.0 m.y. Southeast of Sutter Buttes, the Willows fault follows the boundary between dense, magnetic, presumably ophiolitic basement to the west and Sierran basement to the east. The Chico monocline follows the same basement boundary north of Sutter Buttes, but that structure is stepped eastward from the trace of the Willows fault. It seems reasonably certain that the southeastern extension of the Willows fault and the Chico monocline fault are middle and late Cenozoic structures, respectively, that owe their existence and orientation, in part, to earlier, Mesozoic tectonic juxtapositioning of significantly different basement terranes.

INTRODUCTION

The Oroville earthquake ($M = 5.6$, August 1, 1975) added a new dimension to geologic studies of the Sacramento Valley. That event, more than any of the infrequent earthquakes that previously occurred in the area, awakened the geologic and engineering communities to the potential of active faulting in the valley and in the adjacent Sierran foothills. Because the Oroville earthquake occurred near the Lake Oroville dam (fig. 1) at a time when other large dams were being constructed along the Sierran foothills, several geologic studies, including this one, were conducted to specifically evaluate the late Cenozoic structural history of the region (Woodward-Clyde Consultants, 1977; Harwood and others, 1981; Helley and others, 1981; Helley and Harwood, 1985).

For about a half century prior to the Oroville earthquake, most geologic investigations of the Sacramento Valley (fig. 1) focused on locating natural gas in the deeper parts of the valley fill and water resources in the near-surface deposits. These investigations produced a wealth of stratigraphic and structural data that was gathered primarily from numerous gas fields scattered throughout the valley (map A, pl. 1). Several geologic syntheses resulted from these studies, but they were designed primarily to facilitate further exploration for these valuable resources and did not emphasize late Cenozoic tectonism (Bryan, 1923; Repenning, 1960; Olmsted and Davis, 1961; Safonov, 1968; Hackel, 1966; Redwine, 1972; California Department of Water Resources, 1978).

Recent developments in the concept of plate tectonics have given new emphasis and scope to regional geologic analyses by enabling integration of studies in the valley with those in the Coast Ranges to the west and the Sierra Nevada to the east (fig. 2). Within this concept, the Sacramento Valley was interpreted to be a late Mesozoic forearc basin (Dickinson, 1970; Ingersoll, 1976, 1978a, 1978b; Dickinson and Seely, 1979) that formed contemporaneously with and between the accretionary trench deposits of the Franciscan Complex to the west (Ernst, 1965, 1970; Blake and Jones, 1974; Blake and others, 1974) and an eastern magmatic arc complex, the roots of which are exposed in the Sierra Nevada (Hamilton, 1969). Although debate about the extent, geographic origin, and nature of the material accreted to the Mesozoic continental margin continues (Coney and others, 1980), the basic three-component model of an arc-trench system remains fundamental (Dickinson and Seely, 1979). Although the Sacramento Valley may be the most completely studied ancient forearc basin in the world (Ingersoll and others, 1977), the emphasis and scope of published paleogeo-

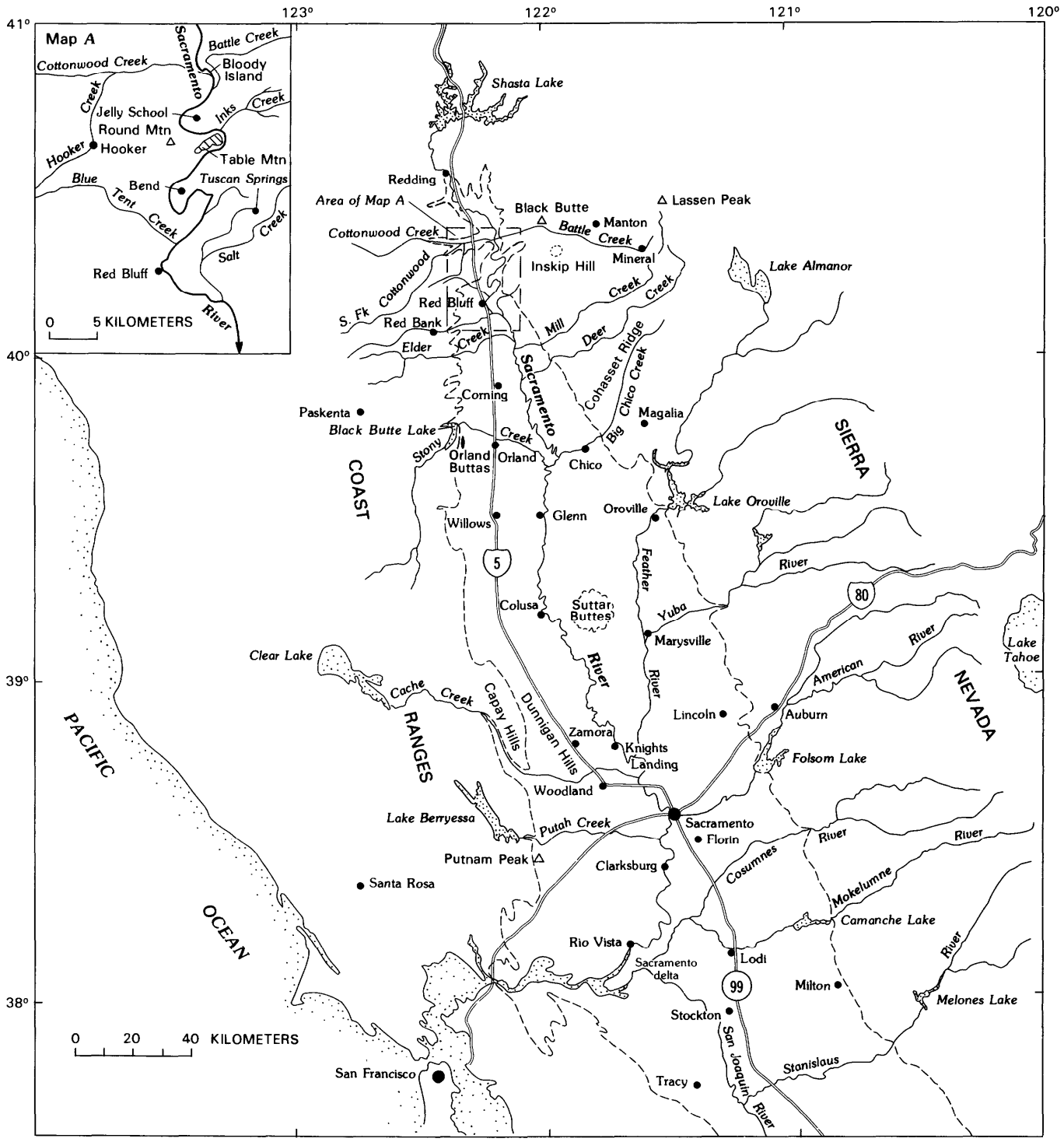


FIGURE 1.—Index map of northern California showing 500-foot topographic contour (dashed), which coincides approximately with boundary of Sacramento Valley.

graphic and paleotectonic studies generally precluded detailed analysis of late Cenozoic tectonism.

Structures discussed in this report are generally too young to provide new data for the late Mesozoic arc-trench model. In fact, a major objective of this report is to document that most of the folds and faults in the valley either formed in the late Cenozoic or are older structures that have undergone renewed deformation in the past few million years. In this respect, structures in the valley are more closely related to tectonic models of Cenozoic subduction, including subsequent lateral convergence along the San Andreas fault system and extension in the Basin and Range province to the east, than they are to the late Mesozoic tectonic models (Hamilton and Myers, 1966; Atwater, 1970; Christiansen and Lipman, 1972; Atwater and Molnar, 1973; Dickinson, 1979).

ACKNOWLEDGMENTS

The structure contour map presented in this report (pl. 1) integrates subsurface data from many summary reports of oil and gas operations published by the California Division of Oil and Gas. Credit is given to specific authors of gas field reports in the "Sources of Data" shown on plate 1, and we would like to express our appreciation to those authors, whose work contributed much of the basic data for our compilation. In addition to published reports, we analyzed well logs from a number of areas in the valley, and we acknowledge the courteous service provided by the staff of the Woodland office of the California Division of Oil and Gas.

Interpretation of the subsurface data was influenced to a great degree by exceptionally high-quality seismic-reflection profiles purchased from Seisdata Services Inc. We thank Seisdata Services Inc. for allowing us to reproduce a small segment of one of those profiles in this report.

We thank David Wagner of the California Division of Mines and Geology for sending us a preprint of his detailed map and discussion of the Capay Valley-Capay Hills area. Special thanks are given to the California Academy of Sciences for making available their collection of thin sections of basement rocks that were penetrated in wells in the Sacramento Valley.

We also acknowledge stimulating discussions with our colleagues J.A. Bartow, M.C. Blake, Jr., K.F. Fox, Jr., D.L. Jones, R.J. McLaughlin, T.H. Nilsen, A.M. Sarna-Wojcicki, and C.M. Wentworth. These discussions sharpened the focus of many points in this report, but responsibility for the analysis of subsurface structures and regional tectonism rests with Harwood, and the mapping of surficial deposits, which document the youthfulness of many structures, rests with Helley.

REGIONAL SETTING

The Sacramento Valley comprises the northern third of the Great Valley of California (fig. 2)—a broad, fertile lowland situated between mountainous terrains of the Coast Ranges to the west and the Sierra Nevada to the east. Marine sedimentary rocks, ranging in age from Late Jurassic to early Miocene, underlie the deeper parts of the Sacramento Valley. They are unconformably capped by a relatively thin cover of alluvial deposits and locally prominent volcanic rocks of early Miocene to Holocene age.

Marine sedimentary rocks exposed on the west flank of the Sacramento Valley record a nearly unbroken depositional sequence from Upper Jurassic through Upper Cretaceous (Lachenbruch, 1962; Ingersoll and others, 1977). On the east side of the valley, Upper Cretaceous sandstone and shale, described by Taft and others (1940) and Haggart and Ward (1984), rest unconformably on metamorphic and plutonic rocks of the Sierra Nevada basement and indicate a progressive eastward onlap of marine sedimentation during the late Mesozoic (Ingersoll and others, 1977). In a broad area south of Sutter Buttes, younger Upper Cretaceous sandstone and shale record a westward-prograding deltaic sequence and marine regression (Drummond and others, 1976; Garcia, 1981) during the Late Cretaceous, as the depositional basin was broadly uplifted and tilted to the south and west. Intermittent periods of uplift and subsidence, apparently caused by Paleogene subduction and possibly by lateral faulting to the west (Nilsen and Clarke, 1975; Nilsen and McKee, 1979), affected the depositional basin through the early Tertiary.

Four distinct submarine canyons developed during the uplift cycles, and they were subsequently filled with transgressive marine sequences during times of subsidence (fig. 2). Almgren (1978) has documented three ancient oscillatory tectonic-depositional cycles in the southern part of the Sacramento Valley. He concludes that the Martinez canyon was cut in the late early to middle Paleocene, the Meganos canyon was cut in early Oligocene and filled in late Oligocene and early Miocene, and the Markley canyon was cut in early Oligocene and filled in early Miocene time. Although the timing of the fourth submarine canyon is not as closely constrained by the sedimentary record as the other three, Redwine (1972) concluded that the Princeton canyon, located in the north-central part of the valley (fig. 2), was cut and filled between the late Paleocene and early Eocene, probably coincident with the formation of the Martinez canyon to the south (Almgren, 1978). Eocene marine deposits in the Princeton canyon apparently grade northward and eastward into alluvial deposits derived from the northern Sierra Nevada.

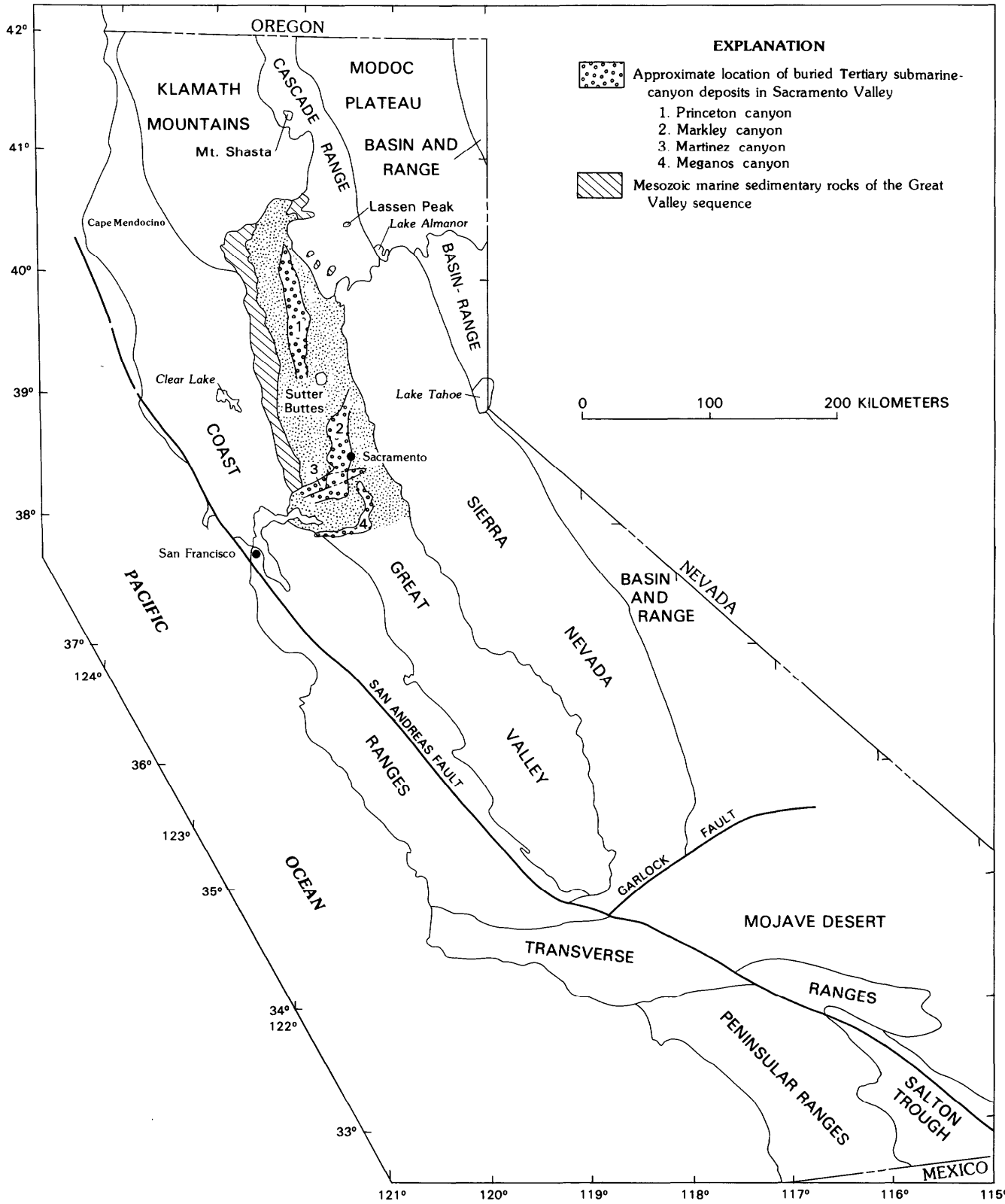


FIGURE 2.—Outline of geomorphic provinces in California and general location of buried Tertiary submarine canyon deposits in Sacramento Valley (stippled).

By the early Miocene, the northern part of the Sacramento Valley clearly was an emergent area, subjected to fluvial erosion and deposition. During this time, between 23.8 and 22.3 m.y. ago according to Dalrymple (1964), the Lovejoy Basalt was erupted from a vent or vents in the northern Sierra Nevada (Durrell, 1959) and flowed westward in a confined channel until it reached the Sacramento Valley near Oroville. Upon reaching the valley, the Lovejoy Basalt spread laterally, filling distributary alluvial channels (van den Berge, 1968) and flowed both westward, across the present axis of the valley now occupied by the Sacramento River at least to Orland Buttes, and southward at least to the vicinity of Putnam Peak (Weaver, 1949) (fig. 1), 260 km from the presumed source. Because of its distinctive characteristics, widespread distribution in both the surface and subsurface parts of the Sacramento Valley, and radiometrically determined age, the Lovejoy Basalt is an important marker unit (pl. 1) that places an age constraint on Cenozoic deformation in the valley.

After eruption of the Lovejoy Basalt, alluvial sediments of late middle Miocene to early Pliocene age accumulated in the central and southern part of the valley, capping marine sedimentary rocks deposited in the Princeton and Markley canyons (Redwine, 1972; Almgren, 1978). These alluvial deposits, however, are not present in surface exposures in the northern part of the valley, where Pliocene alluvium of the Tehama Formation in the northwest and coeval volcanic rocks of the Tuscan Formation in the northeast rest directly on the Lovejoy Basalt or on older rocks where the Lovejoy is missing.

A widespread felsic pumiceous tuff, the Nomlaki Tuff Member of the Tuscan and Tehama Formations, occurs at or near the base of the Pliocene rocks and serves as a second important time-stratigraphic marker in the valley, dated at 3.4 m.y. (Evernden and others, 1964). The Nomlaki, which was erupted from the vicinity of Lassen Peak, generally marks the beginning of volcanic activity that has occurred intermittently into historic time at the southern end of the Cascade Range (fig. 2). Pliocene and Pleistocene volcanic rocks, erupted from the Lassen area, flowed westward and interfingered with alluvial deposits of the ancestral Sacramento River system in the northern part of the valley (Anderson, 1933; Lydon, 1968; Harwood and others, 1981; Helley and others, 1981). Several of the volcanic units have been dated (Harwood and others, 1981), and they are important time indicators for the late Cenozoic depositional and tectonic evolution of the Sacramento Valley. Two informally designated volcanic units, the Rockland ash bed (referred to as the ash of Mount Maidu by Harwood and others, 1981) and the basalt of Deer Creek, dated at 0.45 and 1.09 m.y., respectively (Meyer and others, 1980; Harwood and others, 1981), are particularly significant because they bracket the age of the Red Bluff Formation. The Red Bluff forms a thin, widespread gravel pediment that unconformably caps the Pliocene rocks in the northern part of the valley. The fact that the Red Bluff Formation is faulted and folded clearly establishes the presence of late Cenozoic deformation, within the past million years, on most of the major features shown on the structure contour map (pl. 1).

A volcanic center, composed of andesitic fragmental deposits intruded by late-stage rhyolite domes, formed at Sutter Buttes in the central part of the valley between 2.4 and 1.4 m.y. ago (Williams, 1929; Williams and Curtis, 1977). This late Cenozoic volcanic center is located over a northwest-trending tectonic boundary that juxtaposes a basement of dense, magnetic, presumed oceanic crust (Cady, 1975; Griscom, 1973) on the west against metamorphic and plutonic rocks of the Sierran basement on the east. The boundary between the basement terranes is a Mesozoic tectonic feature that apparently has been reactivated by Cenozoic deformation (Harwood, 1984). Southeast of Sutter Buttes, the Willows fault approximately follows the contact between oceanic and Sierran basement terranes, and northeast of Sutter Buttes that basement boundary lies beneath the Chico monocline.

In the southeastern part of the valley, structure contours are drawn on the basement surface (pl. 1). In the rest of the valley, the datum is the top of the Cretaceous rocks. Contouring procedures are described on plate 1.

INTERPRETATION OF BASEMENT CONTOURS

The most pronounced deflection in basement contours is located beneath Sutter Buttes (pl. 1). This anomaly in basement topography was shown first by Smith (1964) and mentioned briefly by Williams and Curtis (1977, p. 6), who noted more than 395 m of local relief on the basement surface but offered no interpretation of the anomaly. Although some of the upwelling of the basement surface may be related to volcanic intrusion at Sutter Buttes, Harwood (1984) suggests that much of the basement uplift was related to east-side-up movement on the Willows fault, which passes just west and south of the Sutter Buttes.

Data from deep wells a few kilometers north of Sutter Buttes (pl. 1) indicate that the basement surface has a major deflection related to a northeast-trending fold or fault, or both. All of these possible structural configurations were investigated, and we conclude that the structure in the area is a northeast-trending fold, faulted along its southeast limb. The fault is interpreted to be a steeply dipping to vertical normal fault with southeast-side-down displacement. Both the fold and fault, however, appear to die out to the northeast.

In a zone southeast of Sutter Buttes that extends to the Stockton fault (pl. 1), variations in the slope of the base-

ment surface are shown by northwest-trending zones of broadly spaced and relatively close-spaced contours. The basement surface may dip eastward locally in those areas marked by broadly spaced contours (see Jacobsen, 1981), but well data are too sparse to locate closed contours in this area, even if they would show at the chosen contour interval of 150 m.

From Sacramento south to the Stockton fault, the slope of the basement steepens significantly west of the −1,500-m contour. This change in basement slope lies near the eastern edge of the positive gravity and magnetic anomalies in the Great Valley that Cady (1975) interpreted to represent ophiolitic oceanic crust tectonically juxtaposed against Sierran basement rocks to the east. Reports of two wells south of Sacramento, however, show "granite" and "gneiss" at −1,954 m and −2,861 m, respectively, suggesting that the interpreted suture between oceanic and Sierran basements is not marked by the topographic break in the basement surface at the −1,500-m contour. It must be emphasized, however, that these identifications of basement rocks were made some time ago by the operators who drilled the wells, and it is possible that the "granite" may be a leucocratic rock associated with ophiolitic basement, such as plagiogranite, and the "gneiss" may be any dark-colored rock, even part of the ophiolitic basement. It seems reasonably certain, in any case, that the topographic break at the −1,500-m contour is controlled in some measure by a fault, possibly the extension of the Willows fault southeast of Sutter Buttes. It is interesting, and not altogether fruitless, to speculate that the Willows fault southeast of Sutter Buttes coincides with and represents the up-section propogation of the major fault between oceanic crust and the arc-massif basement of the Sierra Nevada. If such is the case, the Willows fault southeast of the Sutter Buttes may represent a structure inherited from the upper-slope discontinuity, a region of structural weakness over the boundary between forearc-basin and arc-massif basements, identified by Karig and Sharman (1975) in modern forearc basins.

From Sutter Buttes north to Chico, a number of wells penetrate basement rocks reported as diorite, gabbro, noritic gabbro, and serpentine. Not surprisingly, this part of the Sacramento Valley is characterized by large, positive gravity and magnetic anomalies that mark the northern part of the inferred Great Valley ophiolitic basement (Cady, 1975). Some thin sections of gabbro and diorite from wells in this area, contained in a collection of thin sections of basement rocks held by the California Academy of Sciences, reveal remarkably fresh coarse- and medium-grained clinopyroxene-plagioclase rocks that show pronounced cumulate textures. These textures, previously unrecognized, provide supporting evidence for the interpretation that the source rocks of the Great Valley anomaly are oceanic crust.

South and east of Sutter Buttes, several wells penetrate rocks reported as granite, granodiorite, metavolcanic rocks, and "gneiss" typical of rocks exposed in the Sierran foothills. The outline of granitic plutonic rocks, shown on plate 1, was determined from reported basement rocks, augmented by our interpretation of residual isostatic gravity data (Roberts and others, 1981). The boundary between the Sierran basement and mafic and ultramafic rocks of probable ophiolitic basement trends about N. 45° E. from Sutter Buttes to Oroville. It is clearly marked by significant changes in the gravity and magnetic patterns of the respective areas. The basement contours do not reflect this inferred lithologic change, and the northeast-trending fault north of Sutter Buttes is contained within the mafic-ultramafic basement terrane.

Sierran crystalline rocks are exposed in several deep canyons that cut through the Pliocene volcanic rocks of the Tuscan Formation east of Chico (Harwood and others, 1981). The mafic-ultramafic basement appears to abut against Sierran basement rocks along a major basement fault beneath the Chico monocline. This tectonic juxtaposition of basement terranes was proposed first by Griscom (1973), and the basement fault he proposed from geophysical data is confirmed by stratigraphic data. The basement fault beneath the Chico monocline shows east-side-up displacement with a minimum stratigraphic throw of 367 m on the basement surface. This fault represents late Cenozoic deformation superposed on a segment of the late Mesozoic boundary between the forearc-basin and arc-massif basements, and it is thus part of the upper-slope discontinuity (Karig and Sharman, 1975).

STRUCTURAL FEATURES IN THE VALLEY FILL

Structure contours drawn on top of the Cretaceous rocks outline a large number of diversely oriented folds and faults distributed throughout the valley. Some of these structures, such as the Corning domes, the Chico monocline, and the Dunnigan Hills anticline, have topographic expression and were recognized in the early ground-water studies of the valley by Kirk Bryan (1923). Most of the other structures do not have obvious surface expression, and they were discovered during exploration and development of the numerous small gas fields in the valley (pl. 1, map A). Although detailed reports have been published for many of the gas fields, few reports have synthesized the data from these studies into detailed structural analyses of the valley as a whole. Noteworthy exceptions to this generalization exist, however, and include the early stratigraphic and structural synthesis by Safonov (1968), the detailed study of the Princeton submarine channel system by Redwine (1972), and the continuing efforts of the California Division of Mines and

Geology to compile available data from the valley into small-scale maps of the entire state (Jennings, 1977).

The extent of many of the faults, particularly the complex pattern of the Willows fault and the relations between that fault system and many folds in the northern valley, has not been reported previously. Analyses of well logs, which are the basis for most reports of individual gas fields, do not provide sufficient data to interpret unequivocally the structure of each field. If recognizable stratigraphic units in the well logs are at different elevations in adjacent wells, it is generally impossible to determine if the units are offset by folding or faulting, or both, without additional data from surface exposures or seismic-reflection profiles. Our interpretation of the structural relations in the valley is based on data from well logs, augmented by detailed mapping of the surficial deposits by Helley, and exceedingly valuable seismic-reflection data obtained from Seisdata Services Inc.

WILLOWS FAULT SYSTEM

The main stem of the Willows fault was discovered in the subsurface rocks of the northern valley when it was penetrated by the Marathon Oil Company (formerly Ohio Oil Company) "Capital Company No. 1" well during development of the Willows-Beehive Bend gas field in the late 1950's (California Division of Oil and Gas, 1960; Alkire, 1962; 1968). From the discovery well, Redwine (1972) traced the Willows fault in the subsurface southeast to Sutter Buttes and suggested that it extended northwest of the discovery well, possibly connecting with the surface fault mapped west of the Orland Buttes (Anderson and Russell, 1939; Jennings and Strand, 1960). On the basis of the distribution of Quaternary units immediately south of Orland Buttes and of two seismic profiles north of the buttes, we have extended the Willows fault into northwestern Tehama County. At Orland Buttes, Upper Cretaceous rocks, the Lovejoy Basalt, and the Tehama Formation, on the up-thrown side of the Willows fault, are juxtaposed against the Tehama Formation on the down-thrown fault block to the west.

Redwine (1972) documented displacement on a 40-km segment of the main stem of the fault from east of Willows to Sutter Buttes and concluded that it dipped 74° or steeper to the east and showed reverse, east-side-up movement that decreased upward toward the surface. He found that the Princeton submarine channel was localized by movement on the fault and that vertical separation in the discovery well varied from about 488 m on top of the Cretaceous rocks to about 477 m on the top of the Eocene Capay Formation.

The pattern of deformation on the Willows fault and its effect on the thickness and facies patterns in the Capay Formation are clearly shown in figure 3. In this approximately east-trending cross section through the Marathon "Capital Company No. 1" well (No. 3, fig. 3), the thalweg of the Princeton channel, which is occupied by marine shale of the Capay, coincides with a syncline in the underlying Upper Cretaceous rocks. The west limb of the complementary anticline in the Upper Cretaceous rocks is broken by east-side-up movement on the Willows fault. The electric logs show that west of the fault the Capay is composed of shale, and east of the fault it is dominantly sandstone that interfingers with shale eastward toward the thalweg of the channel. Folding and faulting clearly postdated the deposition of Upper Cretaceous strata and preceded the deposition of the Capay and occurred between about 60 and 53 m.y. ago. During that time there was some erosion of the Upper Cretaceous rocks, particularly along the channel thalweg. The westward increase in sandstone and a complementary decrease in thickness of the Capay toward the fault suggest that the anticlinal welt of Upper Cretaceous rocks was a shoal area during Capay deposition. Because the shale-rich Capay west of the fault is about the same thickness as the sandstone-rich Capay east of the fault, there appears to have been little, if any, deformation on the Willows fault in this area during deposition of the Capay. The section shows about 475 m of post-Capay offset and possibly small offset on the base of the Tehama, but the amount of post-Pliocene offset is difficult to determine because there is no record for the upper part of well 2 (fig. 3).

CORNING FAULT

Data from a number of sources indicate that the Willows fault is far more extensive and complex than previously thought. The first clue that the Willows fault branched into a multistrand fault system was provided by an analysis of seismicity of the northern valley and Sierran foothills after the Oroville earthquake. Marks and Lindh (1978) located a number of small-magnitude earthquakes along a zone that originated near the Marathon "Capital Company No. 1" well in the Willows-Beehive Bend gas field and extended north about 30 km, rather than following the northwest trend of the Willows fault. These epicenters are shown relative to the trace of the Willows fault in figure 4. The trend of seismic events suggests that a north-trending fault splayed off from the main stem of the Willows fault and passed west of the Corning domes (pl. 1). In the Corning gas fields, analysis of well records by the Sacramento Petroleum Association (1962) showed an anticlinal fold in the area of the Corning domes, with about 121 m of maximum closure on the base of the Tehama Formation in the north dome and a steeply dipping southeast-trending fault located at the north end of south Corning dome, but it did not identify a fault west of them.

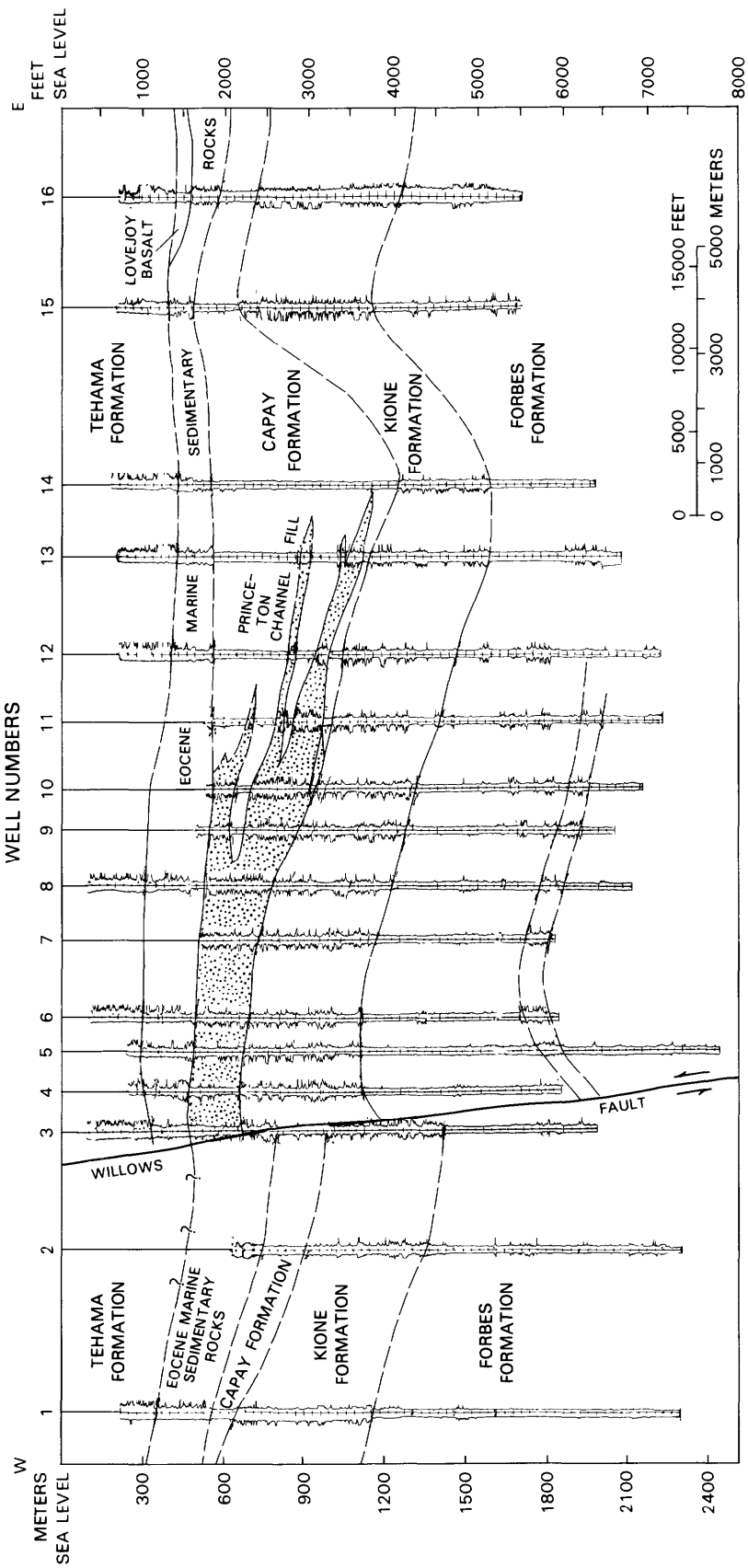


FIGURE 3.—Cross section showing electric logs and stratigraphic and structural relations across Willows-Beehive Bend gas field, Calif. Sandstone in Capay Formation indicated by stipple. Willows fault penetrated in well No. 3. Names of wells shown in appendix. Stratigraphic nomenclature used may not necessarily conform to that adopted by U.S. Geological Survey.

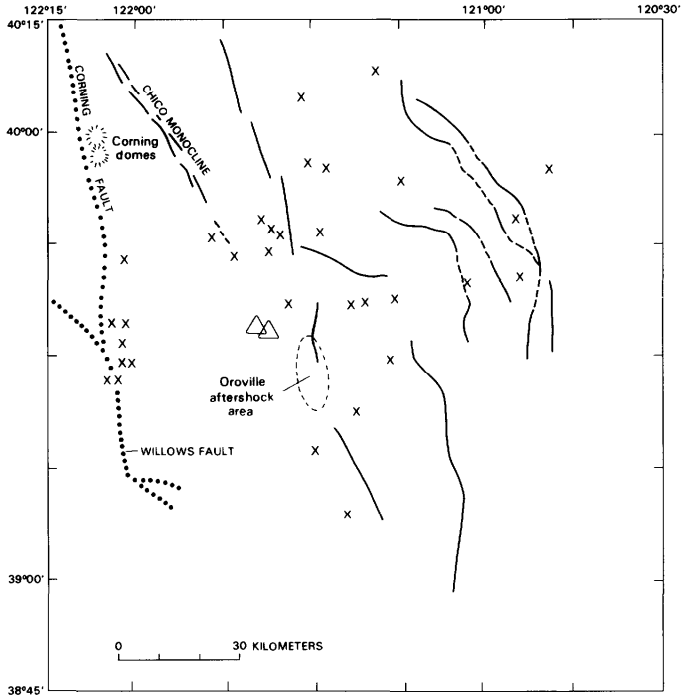


FIGURE 4.—Epicenters (X) of seismic events in area of Oroville, Calif., from June 1975 to August 1976 (modified from Marks and Lindh, 1978). Note north trend of epicenters extending from Willows fault approximately along trace of Corning fault. Unlabeled heavy lines indicate other faults. Triangles show epicenters of two unusually deep (40 km) earthquakes.

Seismic-reflection profiles in the area by Seisdata Services Inc. have identified a major north-trending, steeply east-dipping reverse fault that passes west of the Corning domes and the Greenwood anticline. We call this structure the Corning fault (pl. 1), and part of one of the profiles across it is shown in figure 5. The profile clearly shows that the shallow reflecting horizons in the eastern block are arched beneath the Corning dome by east-side-up drag on the Corning fault. It is also apparent in the profile that the vertical displacement increases with depth, indicating progressive deformation through time, similar to the deformation pattern on the main stem of the Willows fault in the Willows-Beehive Bend gas field (fig. 3). Curiously, however, the amount of vertical displacement of the Upper Cretaceous and younger strata shown on the profile is relatively small compared to the offset of the basement surface suggested by the few deep wells in the area shown on figure 6.

The deepest well east of the Corning fault is the Shell Oil Company "Victor Ranch No. 4" (sec. 7, T. 23 N., R. 2 W.), which bottomed in the Venado Sandstone of Late Cretaceous (Turonian) age at an elevation of −3,713 m (fig. 6). Lithologic information from this well helps interpret the seismic-reflection profile, and its total depth provides a minimum value for the basement elevation 8 km east of the Corning fault. Although local variations in the slope of the basement surface exist, the basement generally dips about 5° SW. between the Chico monocline and the Corning fault. The intersection of the basement surface and the Corning fault ranges in elevation from about −3,900 m in the north to about −4,600 m in the south. This south-southeast plunging line of intersection appears to lie significantly above the basement surface west of the Corning fault.

West of the Corning fault, only one well, the Shell Oil Company "Vilche No. 2" (sec. 5, T. 27 N., R. 4 W.), reached basement, which was serpentinite penetrated at an elevation of −5,978 m (fig. 6). Data from this well are not sufficient to determine the dip of the basement surface west of the Corning fault, but the dip immediately west of the fault may be the same as that just east of the fault, assuming that the basement surface was not chaotically tilted prior to deposition of the Great Valley sequence. If such is the case, the −6,000-m contour can be extrapolated south of the Shell Oil Company "Vilche No. 2" well parallel to the contours east of the Corning fault, as shown on figure 6. This extrapolation gives a vertical separation of about 1,500 m on the basement surface if one assumes no offset on the Red Bluff fault (fig. 6). Because the Red Bluff fault (discussed in a following section of this report) shows down-to-the-south displacement of the valley fill, similar basement offset on the Red Bluff fault would increase the basement separation on the Corning fault. Therefore, 1,500 m of vertical offset on the basement surface across the Corning fault is considered to be a minimum value.

The reason why the basement offset does not appear on the seismic reflection profile is not known. Perhaps the energy input was not sufficient to generate reflections from the deeper basement. Alternatively, the Venado Sandstone, which thickens westward, may have masked reflections from older rocks of the Great Valley sequence and the basement surface west of the Corning fault. Whatever the reason, geologic data strongly suggest that the basement was offset at least 1,500 m on the Corning fault prior to Turonian time and that pre-Turonian rocks of the Great Valley sequence, deposited on the down-dropped block of the fault were unconformably overlapped by the Venado Sandstone. Post-Turonian displacement on the Corning fault is a few hundred meters.

The youngest deposits deformed by the Corning fault are gravels of the Pleistocene Red Bluff Formation, the age of which is between 0.45 and 1.09 m.y. (Harwood and others, 1981).

NORTHWEST EXTENSION OF WILLOWS FAULT

The location of the Willows fault system north and northwest of Orland Buttes is not clearly indicated by direct evidence in either the surface or subsurface rocks.

Wells are sparse in this area of the valley, particularly west of the probable trace of the main stem of the Willows fault. For that reason, the structure contours are very generalized and of little value in locating even major structures.

Our projection of the Willows fault into the Cold Fork, Elder Creek, and Paskenta faults (pl. 1) mapped by Jones and others (1969) is based primarily on the outcrop pattern of the Tehama Formation. North of Elder Creek, the Tehama Formation dips gently east, and the Nomlaki Tuff Member is at the base of the Tehama or is, at most, a few tens of meters above its base. South of Elder Creek, however, the Tehama dips more steeply eastward into the valley, and the Nomlaki is a few hundred meters above the base of the Tehama. This outcrop pattern of the Tehama Formation suggests that the underlying Great Valley sequence was topographically higher and projected farther east into the valley north of the Willows fault prior to deposition of the Pliocene strata. The position of the Nomlaki Tuff Member, relative to the base of the Tehama on opposite sides of the Willows fault, indicates that the Tehama filled a topographic low southwest of the fault

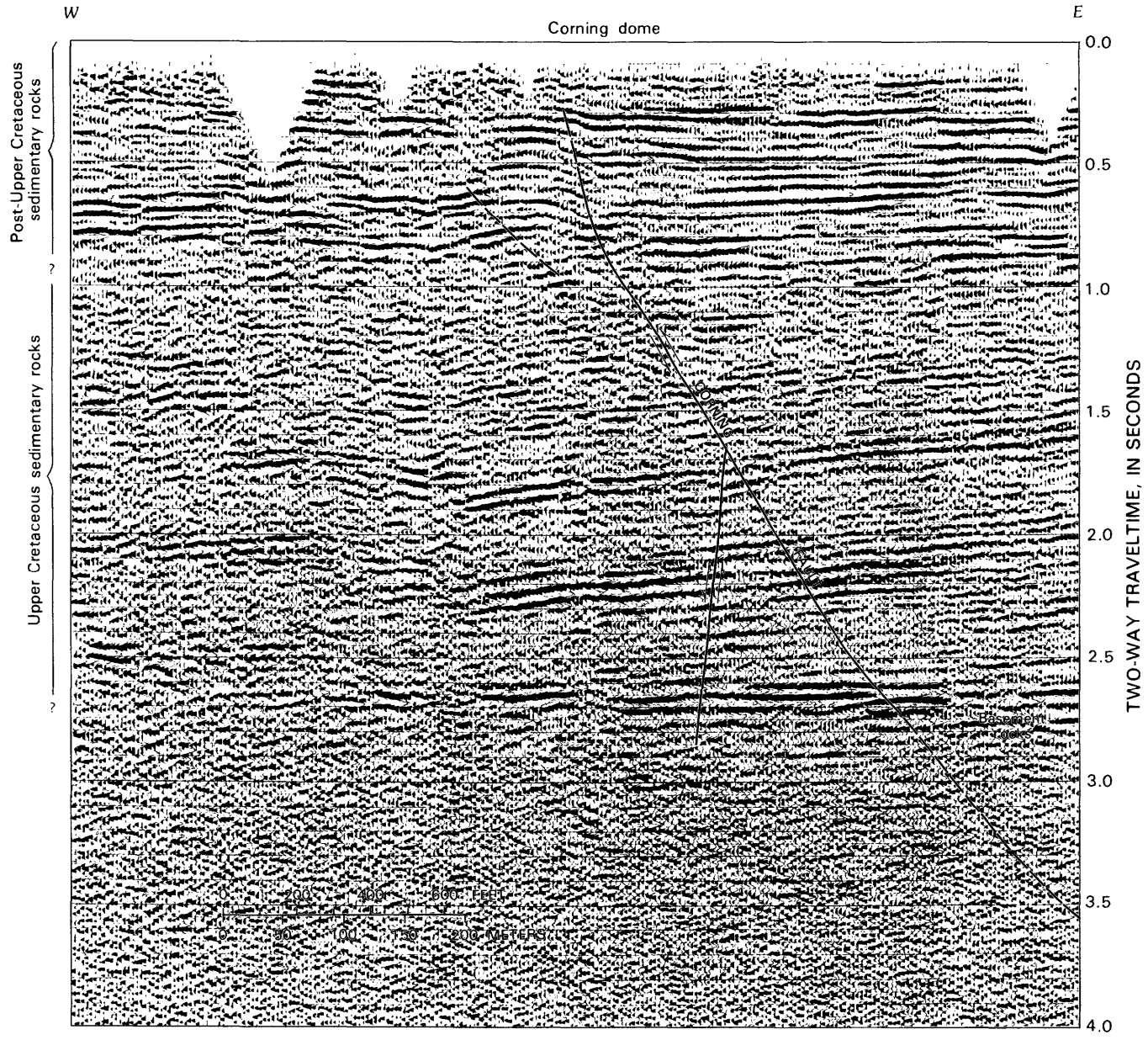


FIGURE 5.—Seismic-reflection profile, from Seisdata Services Inc., showing structural and generalized stratigraphic relations across Corning fault between Corning and Red Bluff, Calif.

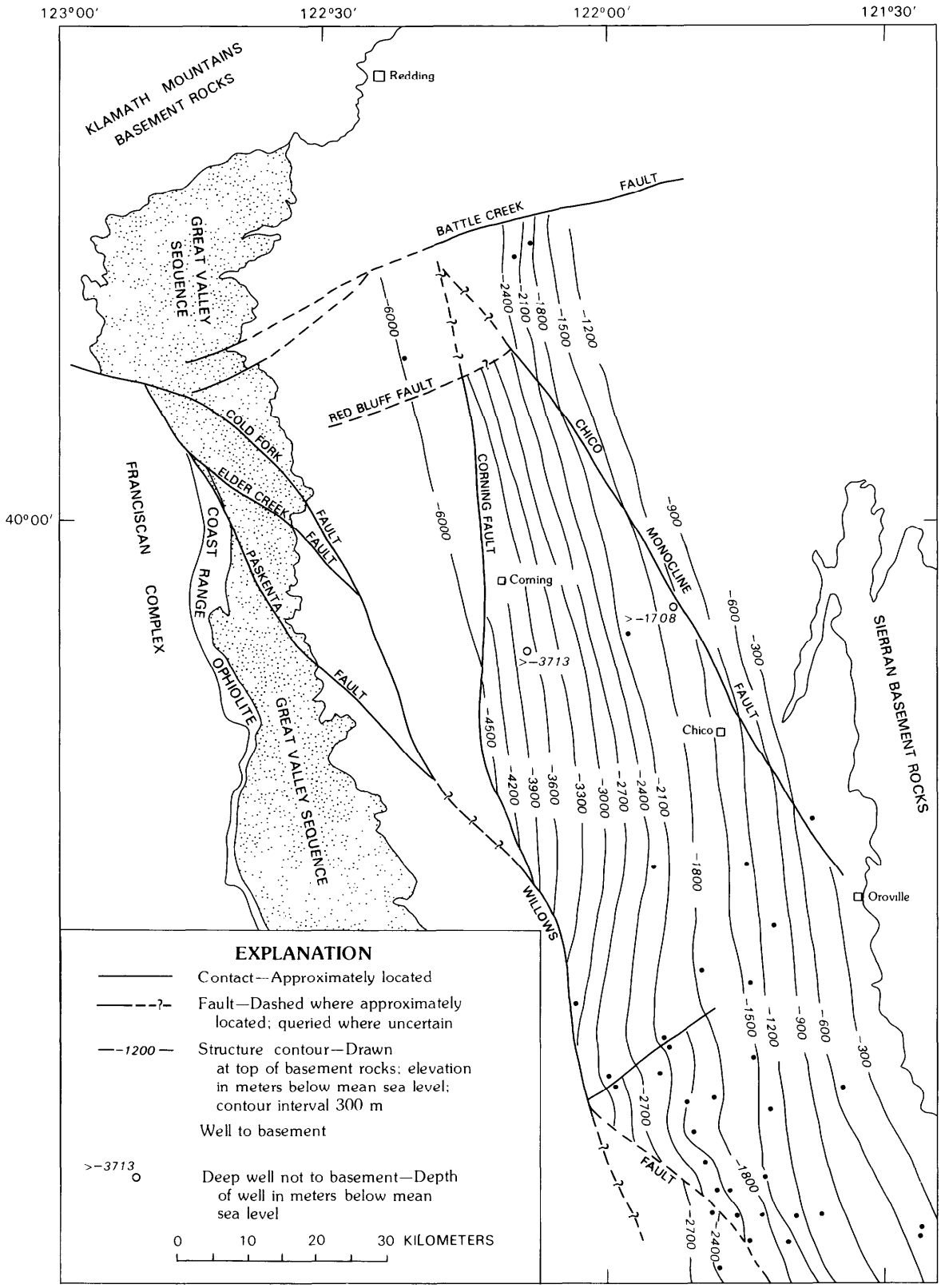


FIGURE 6.—Map of northern Sacramento Valley showing structure contours, drawn on top of basement rocks, used to estimate amount of vertical displacement of basement across Corning fault.

prior to eruption of the Nomlaki about 3.4 m.y. ago. We interpret the topographic low, reflected by the thicker basal part of the Tehama, to be the result of east-side-up movement on the Willows fault, prior to and possibly during, deposition of the lower part of the Tehama Formation. If this interpretation is correct, late Cenozoic movement on the Willows-Elder Creek fault system differs significantly, in style and amount of displacement, from the Cretaceous movement on the Elder Creek-Cold Fork-Paskenta fault system oulined by Jones and Irwin (1971).

Jones and Irwin (1971) inferred at least 96 km of left-lateral displacement of the Lower Cretaceous (Valanginian) strata along the combined Cold Fork-Elder Creek-Paskenta faults. They concluded that this deformation commenced shortly after deposition of the Valanginian strata and continued concurrently with deposition until at least the middle Late Cretaceous. Well-documented vertical displacement of Upper Cretaceous and overlying rocks on the Willows fault in the Willows-Beehive Bend gas field is not incompatible with left-lateral displacement on the Elder Creek fault system to the northwest, but it does indicate that the inferred lateral displacement was accompanied, or postdated by, a major component of east-side-up vertical movement. This vertical movement is consistent with the interpretation that the Elder Creek fault system represents tear faults in the upper plate of the Coast Range thrust (Jones and Irwin, 1971), along which the Klamath Mountains terrane moved upward and westward over the Coast Ranges province (fig. 2).

SOUTHEAST EXTENSION OF WILLOWS FAULT

Location of the Willows fault southeast of Sutter Buttes is not closely constrained by sparse well data along the eastern margin of the valley. No seismic-reflection profiles, that we are aware of, extend far enough east to cross the fault. However, wells in three widely spaced areas do extend far enough east from the deeper parts of the valley to cross the fault, and they provide the most direct evidence for the southeastern extension of the Willows fault. The first area we investigated extends southwest from near Marysville and passes through the Tisdale gas field (pl. 1, map A) just southeast of Sutter Buttes. A cross section (fig. 7) through wells in this area shows that the slope of the basement is significantly steeper east of the Willows fault (between wells 4 and 5, fig. 7), and we infer about 165 m of east-side-up displacement on the basement surface. Shale of the Eocene Capay Formation is recognizable in all of the electric logs in figure 7, and that unit shows about 100 m of displacement between wells 4 and 5. The base of continental deposits (nonmarine sedimentary rocks), which coincides generally with the base of fresh water in the valley, is difficult to identify in all the well logs of this section, but it does not appear to be offset between wells 3 and 5. The dip of the fault is not constrained in this section, and we have shown a steeply east-dipping reverse fault between wells 4 and 5, primarily because the pattern of offset in that area is so similar to that on the Willows fault to the northwest.

About 23 km southeast of the Tisdale gas field, a second line of wells extends from the Sacramento River near Knight's Landing northeastward toward Lincoln. Interest was directed initially to this line of wells because the outline of the Markley canyon, shown by Almgren (1978), is sharply deflected to the south in this area. A section through this line of wells is shown in figure 8. All of the sedimentary rocks in this part of the valley, except those in the Markley canyon, are offset up to the east between wells 3 and 4 (fig. 8). The amount of displacement appears to increase downward in the section from about 30 m at the base of the continental deposits to about 45 m in sandstone and shale sequences in the Upper Cretaceous rocks. Displacement of the basement is inferred to be about 150 m, but the depth to basement west of the Willows fault is not closely constrained by available well data. The most interesting aspect of the section is the marked asymmetry of the Markley canyon fill. Canyon development may have shifted progressively westward, to be localized immediately east of this part of the Willows fault, where the deepest part of the asymmetric canyon fill is located. This pattern of erosion and sedimentation suggests that late Oligocene and early Miocene movement on the Willows fault directly influenced the location and form of the Markley canyon.

The third line of wells we investigated extends from the Sacramento River near Clarksburg to the area east of Florin, where a series of low hills underlain by Pliocene continental deposits of the Laguna Formation rise above the surrounding Pleistocene alluvial deposits. A section through these wells is shown in figure 9. The electric log of the D. D. Feldman "Unit Plan No.1" well (sec. 8, T. 7 N., R. 6 E.); (No. 9, fig. 9) shows an obvious repeat in the Cretaceous rocks just above the basement. We interpret this repeat to represent east-side-up displacement on the Willows fault, which was intersected by the well at an elevation of −1,277 m. If this interpretation is correct, the basement surface is offset about 120 m. A similar offset is shown by Upper Cretaceous rocks.

West of the Willows fault (fig. 9), a steeply east-dipping normal fault, previously unreported, offsets the Capay Formation and older rocks down to the east about 153 m. This normal fault does not appear to offset the base of post-Eocene and younger nonmarine rocks, nor are these rocks offset by the Willows fault to the east. Offset of the basement between wells 5 and 6 (fig. 9) appears to be east side up and suggests early reverse movement on the east-dipping fault.

The location of the Willows fault southeast of Florin is

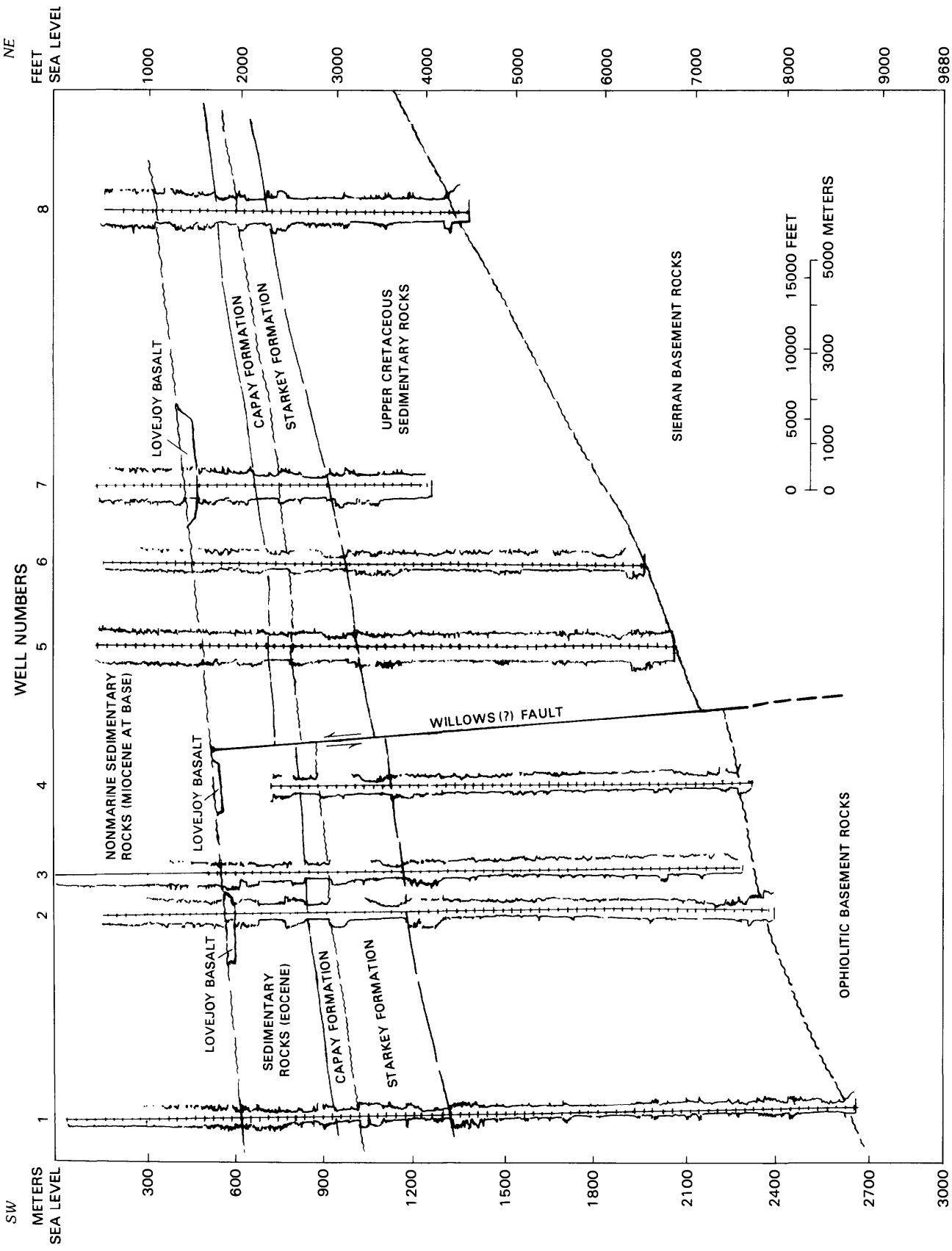


FIGURE 7.—Cross section showing electric logs and stratigraphic and structural relations across possible southeast extension of Willows fault near Tisdale gas field southeast of Sutter Buttes, Calif. Names of wells listed in appendix. Stratigraphic nomenclature used may not necessarily conform to that adopted by U.S. Geological Survey.

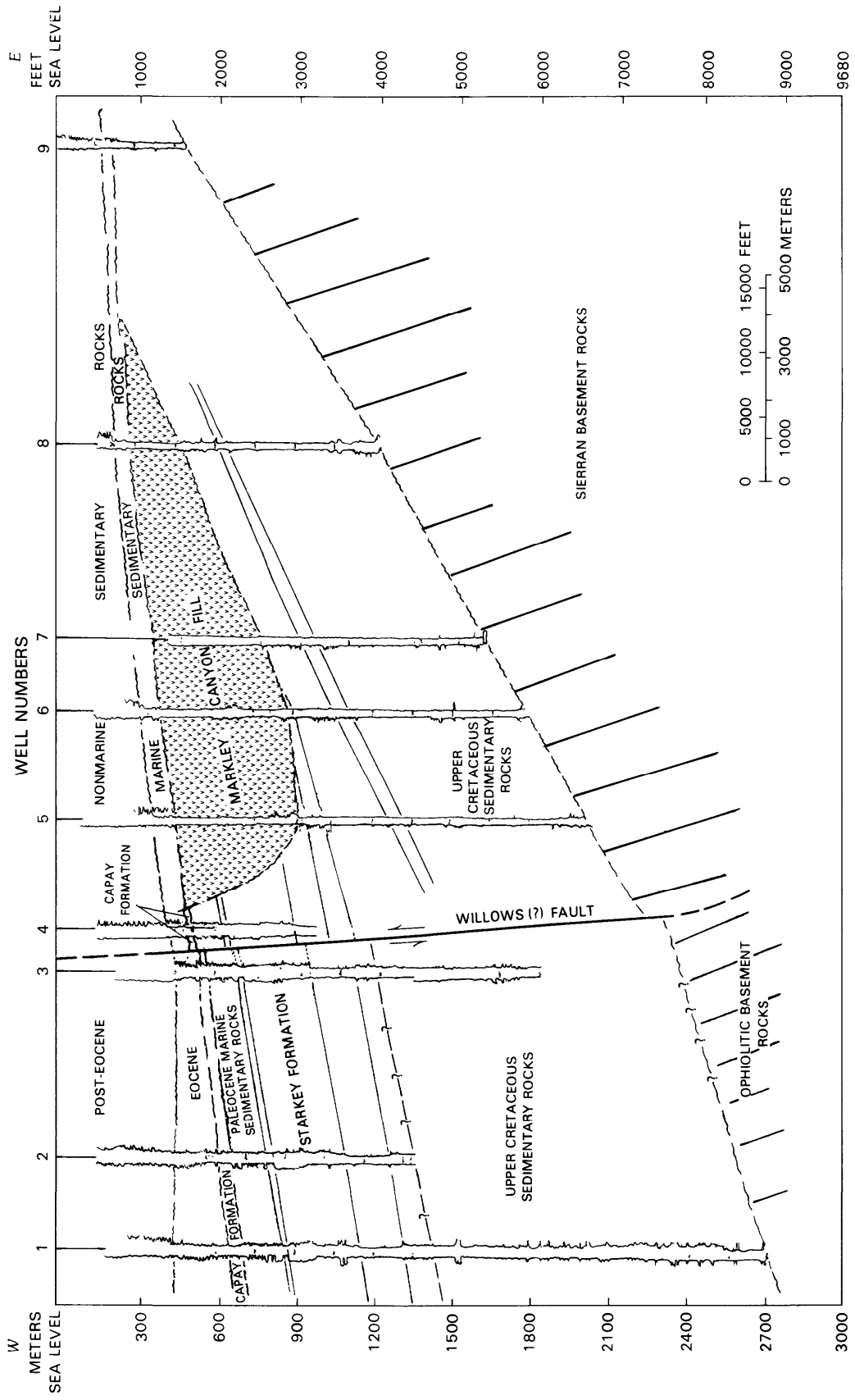


FIGURE 8.—Cross section showing electric logs and stratigraphic and structural relations across possible southeast extension of Willows fault near Catlett-Nicolaus gas fields, Calif. Names of wells listed in appendix. Note asymmetry of Markley canyon fill (patterned) and absence of offset in post-Eocene continental deposits. Stratigraphic nomenclature used may not necessarily conform to that adopted by U.S. Geological Survey.

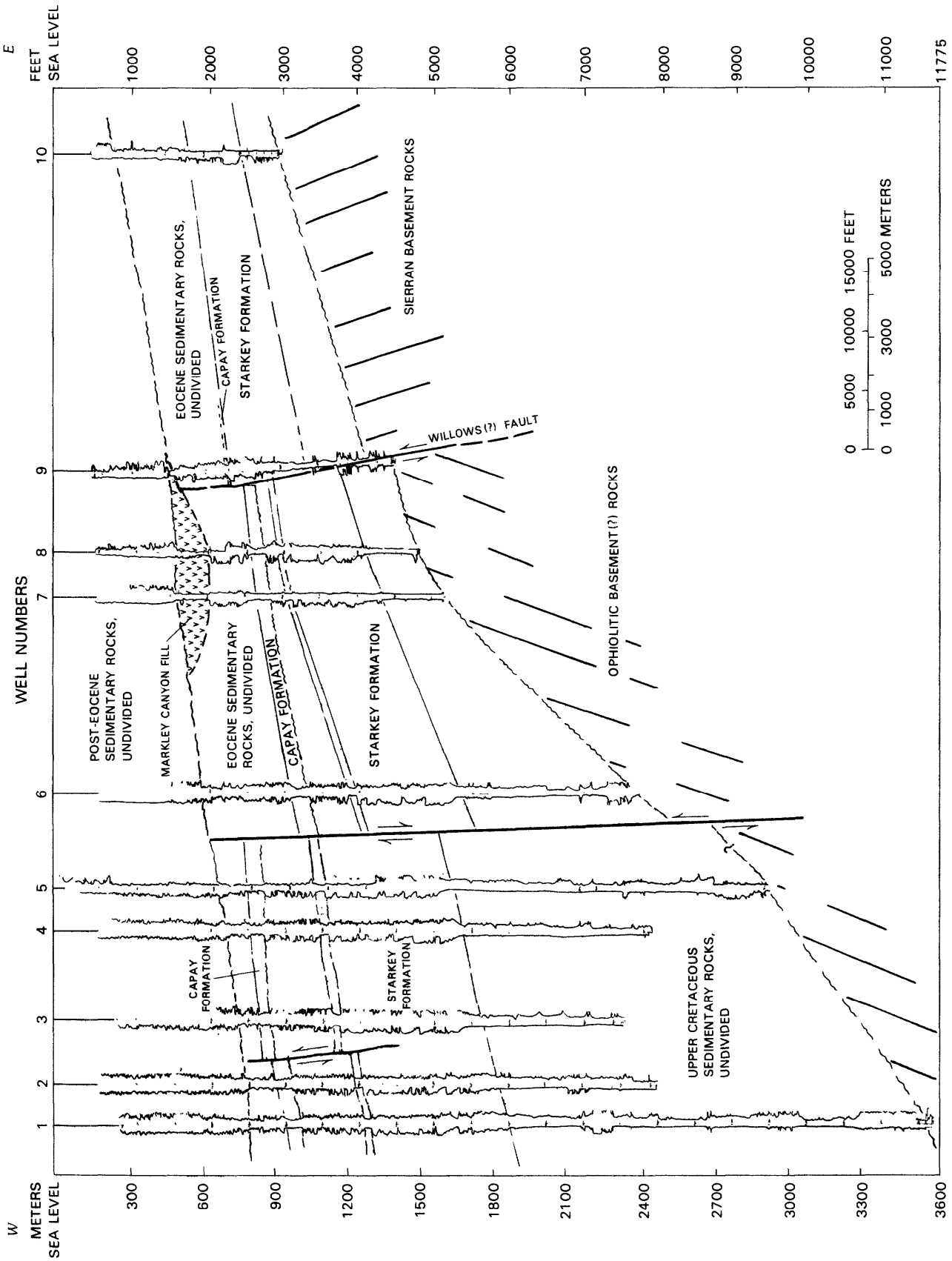


FIGURE 9.—Cross section showing electric logs and stratigraphic and structural relations across possible southeast extension of Willows fault southeast of Florin, Calif. Names of wells listed in appendix. Note repeated electric-log pattern near bottom of well 9 and apparent early east-side-up displacement of basement by unnamed fault between wells 5 and 6, followed by east-side-down offset of Cretaceous and early Tertiary rocks. Stratigraphic nomenclature used may not necessarily conform to that adopted by U.S. Geological

uncertain. A section through several wells east and west of the Lodi gas field, shown in figure 10, indicates a minor deflection in the Capay Formation between wells 6 and 7, but the underlying Cretaceous rocks and the basement surface are not significantly offset in that area. The general east-side-up flexure of the Capay between wells 6 and 7 is the type of deformation that would be expected adjacent to the Willows fault, but the absence of offset in underlying units argues against the existence of the fault. Deformation expressed as fault movement north of Lodi may be expressed as gentle warping to the south.

STRUCTURES NORTHEAST OF THE WILLOWS FAULT

The Willows fault diagonally transects the Sacramento Valley from northwest to southeast and divides the region into two late Cenozoic structural provinces. To the northeast, on the upthrown block of the Willows fault, the present axis of the Sacramento Valley is underlain by the Los Molinos and Glenn synclines (pl. 1). These narrow synclines, coupled with the Corning domes to the west and the Chico monocline to the east, have tightly controlled the course of the Sacramento River and influenced alluvial deposition during the late Quaternary. This tectonic control of alluvial deposition has profoundly influenced land use, particularly in the northeastern part of the valley, where a narrow strip of cultivated land, shown near the top of figure 11, flanks the river and lies directly over the trace of the Los Molinos syncline. South of the constricting influence of the Corning domes and the Chico monocline, late Quaternary alluvial deposits spread laterally across much of the valley over the Glenn syncline, the axial trace of which controls the present course of the Sacramento River as far south as Glenn, Calif. (pl. 1). From Glenn to Colusa, the course of the river lies along the trace of the Willows fault.

From the vicinity of Willows southeast to the Sacramento Delta, the downthrown southwest block of the Willows fault is capped by Holocene basin deposits that flooded over the broad Zamora syncline (pl. 1), burying older deposits, to rest unconformably on Upper Cretaceous rocks north of the Dunnigan Hills. The following part of the report discusses specific structural features on the northeast block of the Willows fault.

SUTTER BUTTES

Sutter Buttes (fig. 11) is a prominent set of hills composed of late Cenozoic volcanic rocks that rise about 635 m above the floor of the Sacramento Valley 15 km northwest of Marysville. According to Williams and Curtis (1977), volcanism and accompanying deformation of the surrounding sedimentary rocks occurred between 2.4 and 1.4 m.y. ago and consisted of two phases. During the early phase of magma injection, Upper Cretaceous and Tertiary rocks were arched into a dome 13 km across, broken by normal and high-angle reverse faults, and rapidly eroded so that the Tertiary rocks were stripped from the core of the dome before the explosive phase of volcanism. Explosive volcanism produced the rampart beds of tuff and tuff breccia that form the peripheral deposits of the buttes (fig. 11).

Extensive drilling for natural gas located an elongate dome in the subsurface about 10 km west of Sutter Buttes. Williams and Curtis (1977) referred to this structure as the buried Colusa buttes, but because it lacks surface expression, we refer to it as the buried Colusa dome (fig. 12). In the buried Colusa dome, several wells (fig. 12) penetrated volcanic rocks similar in composition and age to those in the Sutter Buttes. These data led Williams and Curtis (1977) to conclude that the buried Colusa dome formed solely by forceful magma injection contemporaneous with magmatism at Sutter Buttes. We suggest, however, that magmatism may have been localized by movement on the Willows fault and possibly by movement on the Mesozoic tectonic boundary between ophiolitic and Sierran basement terranes which passes beneath the eastern margin of Sutter Buttes (fig. 12).

The orientation and movement patterns of structures at Sutter Buttes and the buried Colusa dome suggest that deformation occurred in a regional east-west compressive stress field. The distribution of structural features at Sutter Buttes is distinctively asymmetrical. Beds in the Upper Cretaceous rocks on the south and southeast sides of the buttes dip steeply away from the core. Locally, they are overturned. Beds on the north and northwest sides of the buttes generally dip gently away from the core. As shown in figure 12, folds and faults are more abundant on the eastern half of the buttes and the wavelength of folds is tighter there than on the west. In addition to the small normal faults that surround the core of the dome, the eastern half of the dome is cut by a prominent set of steeply inward-dipping, arcuate high-angle reverse faults. This pattern of structural features indicates that the core of Sutter Buttes was thrust eastward as it moved upward.

The northward elongation of the buried Colusa dome strongly suggests that it too was formed in an east-west compressive stress regime. In fact, the amplitude, wavelength, and axial extent of the buried Colusa dome are remarkably similar to folds that occur just east of the Willows fault farther north (pl. 1; fig. 3). Although Redwine (1972) projected the Willows fault southeastward across the buried Colusa dome, our analysis of subsurface data suggests that a fault, possibly the Willows fault or a splay fault related to it, may lie just west of the buried Colusa dome. We conclude that the buried Colusa dome formed partly by east-side-up drag on a high-angle reverse fault along its western margin and partly by magma in-

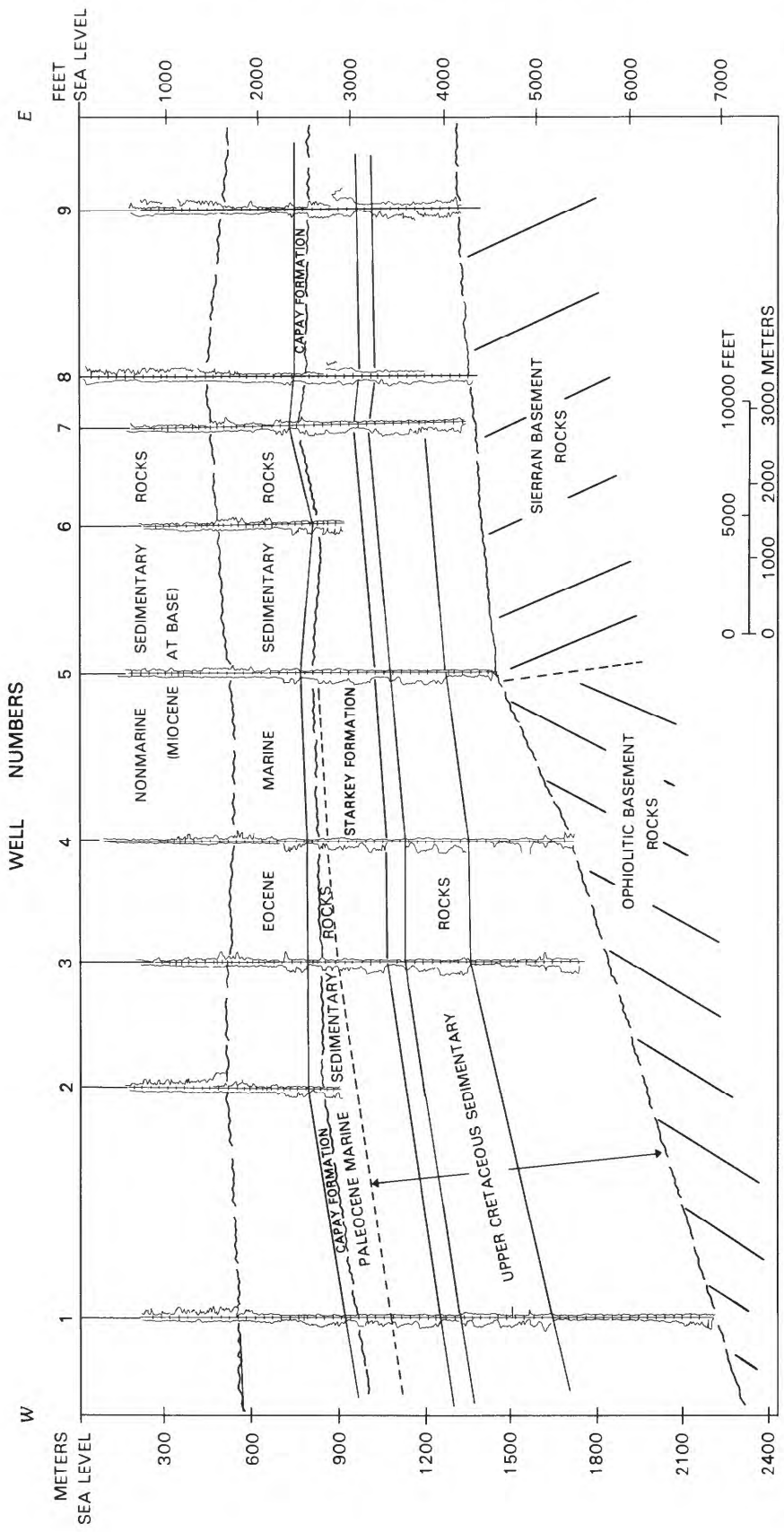


FIGURE 10.—Cross section showing electric logs and stratigraphic and structural relations across possible southeast extension of Willows fault (approximately follows trace of well 5) in area of the Lodi and Galt gas fields, Calif. Names of wells listed in appendix. Stratigraphic nomenclature used may not necessarily conform to that adopted by U.S. Geological Survey.

jection that was localized by movement on that fault.

The pattern of radial normal faults around the core of Sutter Buttes, flanked by reverse faulting to the east and west, assuming that the Willows fault was involved in the tectonism, is the type of deformation found by Withjack and Scheiner (1982) in their modelling experiments of doming in a compressive stress field. Although it is difficult to unequivocally separate magmatic doming from regional compressive deformation in the Sutter Buttes area, supporting evidence for the regional east-west compressive stress field is found in the Chico monocline about 40 km to the north.



FIGURE 11.—U.S. Air Force high-altitude oblique aerial photograph showing northern Sacramento Valley viewed to the north from vicinity of Sutter Buttes (center foreground), a late Pliocene and early Pleistocene volcanic center, approximately 16 km in diameter. Dark core of buttes composed primarily of andesite surrounded by lighter colored volcaniclastic deposits that form peripheral rampart beds of Williams and Curtis (1977). Narrow strip of cultivated land (dark) along Sacramento River (SR) between Corning domes (CD) and Chico monocline (CM) is surface expression of Los Molinos syncline (pl. 1). Oroville dam (OD) located near north end of Cleveland Hills faults where ground rupture occurred during August 1, 1975, Oroville earthquake.

CHICO MONOCLINE

The Chico monocline (fig. 13) is a northwest-trending, southwest-facing flexure that bounds the northeast side of the Sacramento Valley between Chico and Red Bluff. East of the monocline, Pliocene volcanic rocks of the Tuscan Formation dip less than 5° SW., but bedding steepens to 20° or more along the monoclinal flexure where the Tuscan dips beneath Quaternary deposits of the valley. The trace of the monocline is characterized by a complex surface pattern of anastomosing fault strands

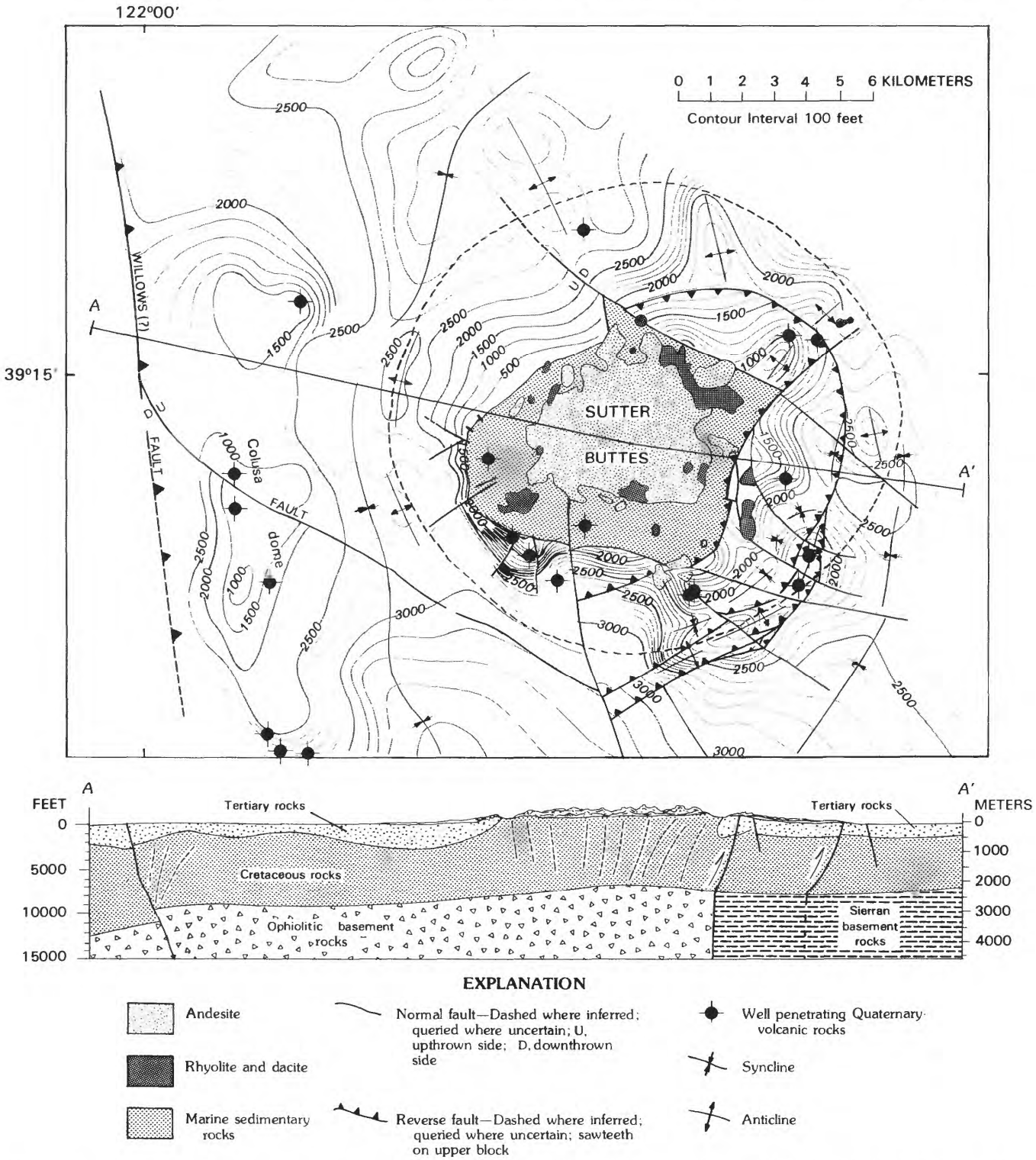


FIGURE 12.—Structure contour map of area around Sutter Buttes, modified from Williams and Curtis (1977, fig. 11) with data from Redwine (1972) and from our examination of electric logs in area of buried Colusa dome. Structure contours in feet; datum is top of the Kione sand of local usage (Williams and Curtis, 1977). Dashed circle on map marks approximate outer limit of rampart beds on valley floor; thin dashed lines on section represent schematic paths of magma injection.



FIGURE 13.—Composite of two U.S. Air Force high-altitude oblique aerial photographs showing pronounced linear trace of Chico monocline (CM, upper right to lower left), broad alluvial fan west of Chico monocline capped by Red Bluff Formation (RB, gray, uncultivated grazing land), and dissected topography of Tuscan Formation (TF) to east. DC, Deer Creek; CD, north Corning dome. Sacramento River (SR) follows trace of Los Molinos syncline (LMS) between north Corning dome and alluvial fan to east.

that show both west- and east-side-down displacements of small magnitude (Harwood and others, 1981).

Structure contours drawn on top of the Cretaceous rocks in the vicinity of the monocline indicate clearly that the Cretaceous strata are flexed and faulted by a major northwest-trending fault at depth beneath the surface trace of the monocline (pl. 1). The best control on the amount of displacement on the master fault beneath the Chico monocline comes from a line of wells that extends generally westward from the Exxon "C. C. Baccala No. 1" well (No. 4, fig. 14), which was drilled just west of the monocline about 18 km northwest of Chico. Although the Baccala well did not reach basement, it bottomed in Upper Cretaceous conglomerate at a depth of −1,700 m and provides a minimum elevation on the basement immediately west of the monocline when used in conjunction with the Pacific Western "Cana No. 1" well (No. 2, fig. 14) that reached serpentine at a depth of −2,100 m about 9 km to the west. Although no wells have been drilled east of the monocline, some control on the elevation and dip of the unconformities at the top and base of the Upper Cretaceous rocks is provided by exposures of these surfaces in several deep canyons to the east. When the trend of the basement surface at these exposures is projected westward, to pass beneath the bottom of the Baccala well, a minimum east-side-up offset of 365 m in the basement rocks is indicated on the fault beneath the monocline (fig. 14). The dip of this major fault cannot be determined directly from surface exposures or subsurface well data, but we show it as a steeply east-dipping reverse fault, because gravity and magnetic data (Griscom, 1973; Cady, 1975; Roberts and others, 1981) indicate that the relatively dense and magnetic basement beneath the northern part of valley extends eastward beneath the Sierran basement exposed east of the monocline. In the Sierran foothills southeast of Oroville, steep east dips are also commonly found in surface exposures of faults that may be the southeastward continuation of the fault beneath the monocline.

From available geophysical evidence, it appears that the fault beneath the monocline is a major tectonic boundary, with a long and complex tectonic history, along which the Sierran basement to the east was juxtaposed against highly magnetic, dense ophiolitic basement to the west (Cady, 1975; Griscom, 1973). These basement terranes were tectonically juxtaposed prior to deposition of the Upper Cretaceous strata. If this interpretation is correct, the fault beneath the Chico monocline may represent a part of the upper-slope discontinuity of Karig and Sharman (1975) that marks the boundary between basement of the late Mesozoic forearc basin to the west and that of the magmatic arc complex to the east. The Chico monocline, in that case, would be a structure inherited from the upper-slope discontinuity, possibly when that major tectonic break was reactivated by late Cenozoic subduction north of the migrating Mendocino triple junction.

The Chico monocline is clearly a late Cenozoic tectonic feature. It formed after deposition of the Ishi Tuff Member of the Tuscan Formation, about 2.6 m.y. ago and prior to the eruption of the olivine basalt of Deer Creek 1.09 m.y. ago (Harwood and others, 1981). Late Cenozoic displacement on the Chico monocline fault has been predominantly east side up, with an apparent component of left-lateral movement that may have contributed to the formation of the Salt Creek, Tuscan Springs and Sevenmile domes at the north end of the monocline and possibly influenced the northeast-trending Inks Creek fold system and Battle Creek fault zone farther northwest.

There is some indication that the Chico monocline fault may be active. The olivine basalt of Deer Creek is offset, but the amount of offset is small. Similarly, a few faults along the monocline show scarps about 1 m in height in the surface of the Tuscan Formation (Harwood and others, 1981). These observations indicate that movement has taken place on the monocline fault system within the past million years. In their study of regional seismicity after the Oroville earthquake, Marks and Lindh (1978)

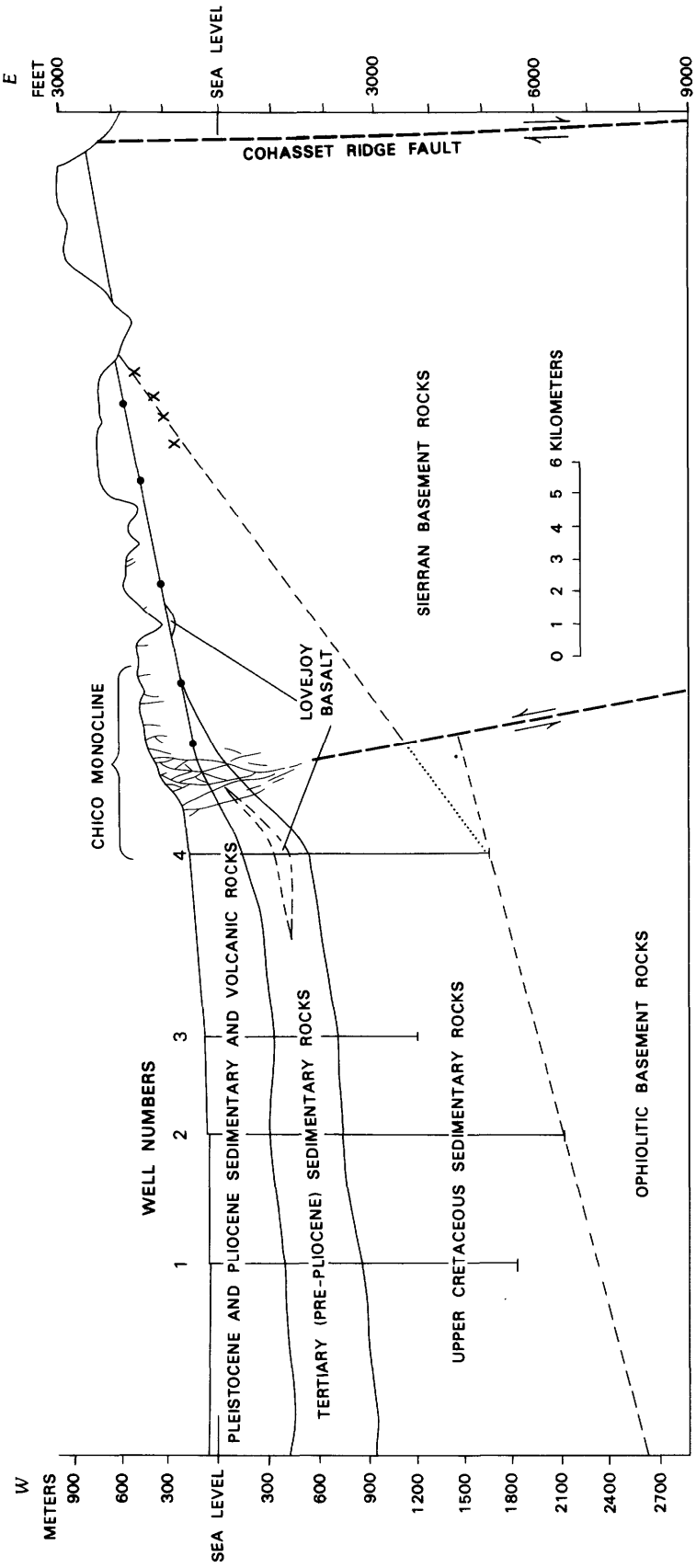


FIGURE 14.—Cross section across Chico monocline about half way between Chico and Red Bluff, Calif., showing offset of basement terranes. Dots indicate unconformity at base of Tuscan Formation, as projected into line of section; x's indicate unconformity at base of Upper Cretaceous rocks, as projected into line of section. Names of wells listed in appendix.

identified two events west of the Oroville aftershock zone at a depth of 40 km, significantly below the main cluster of aftershocks associated with the Oroville earthquake. We interpret those deep events to have occurred on the

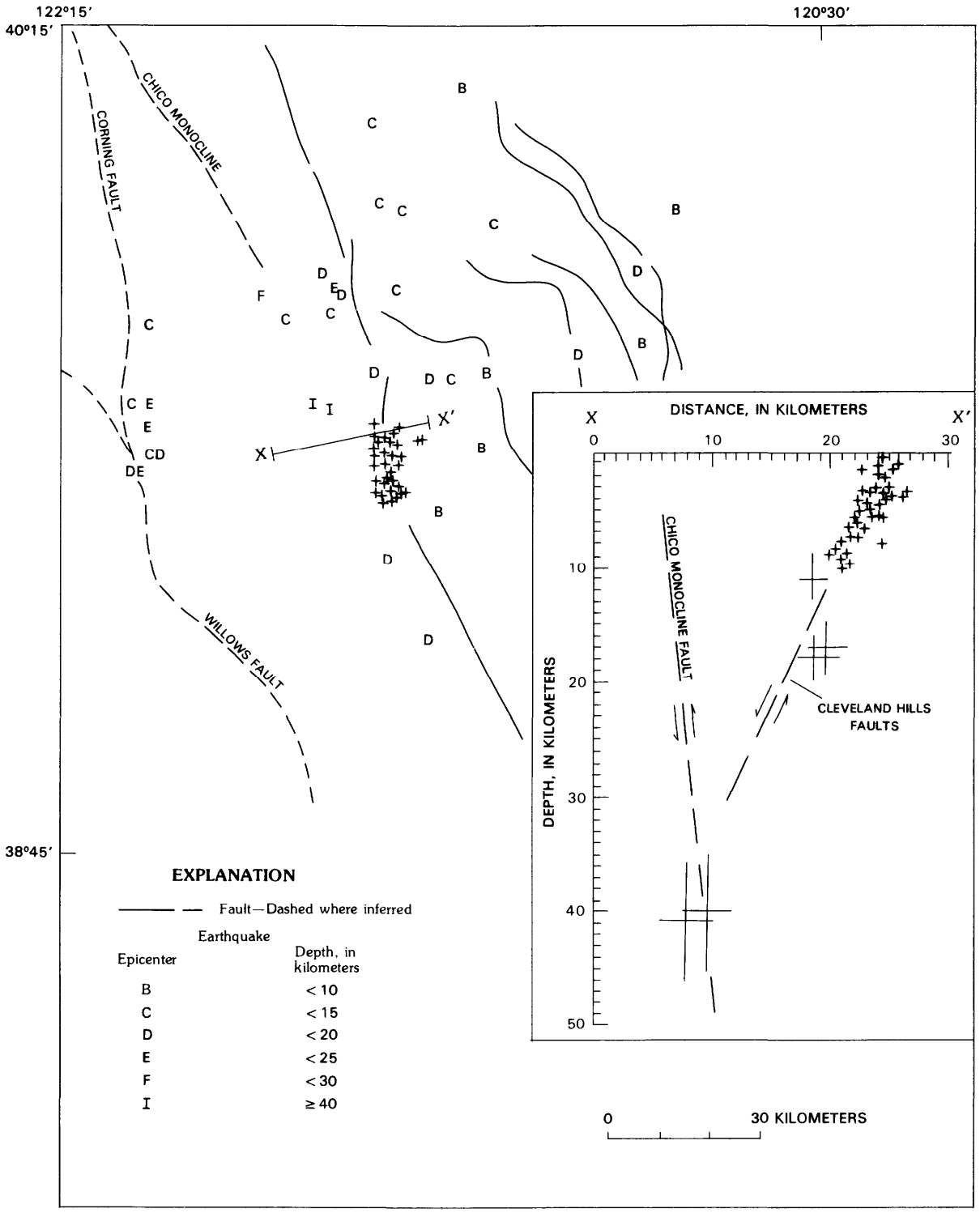


FIGURE 15.—Map and section showing locations of Oroville earthquake aftershocks (crosses on section) in relation to Cleveland Hills faults and Chico monocline (modified from Marks and Lindh, 1978). Earthquakes labeled I on map (largest crosses on section) at a depth of about 40 km are interpreted to have occurred on Chico monocline fault.

basement fault beneath the Chico monocline and not on the Cleveland Hills faults, where most of the aftershock events were located (fig.15). The steeply east-dipping normal fault, shown east of the Chico monocline on figure 15, is one of several short, north- and north-northwest-trending normal faults that extend along the northern foothills of the Sierra Nevada (pl. 1). This normal fault is probably part of the fault system on which the August 1, 1975, Oroville earthquake occurred.

BATTLE CREEK FAULT ZONE

The Battle Creek fault zone strikes east-northeast across the Sacramento Valley between Red Bluff and Redding, nearly at right angles to the trend of the Chico monocline. East of the Sacramento River, the Battle Creek fault zone is marked by a pronounced south-facing escarpment, shown in figure 16, that extends from the river northeastward toward Lassen Peak for a distance of 32 km. Fault strands within this part of the fault zone dip steeply southeast and show predominantly south-side-down, normal fault movement (Harwood and others, 1980; Helley and others, 1981). Vertical displacement on the fault zone increases from about 45 m just east of the Sacramento River to 330 m at Black Butte (fig. 1) and to about 440 m north of Manton. A small component of right-lateral strike-slip movement is suggested by fractures on some of the fault strands, but the exact amount of lateral displacement is not known.

West of the Sacramento River, the valleys of Cottonwood Creek and its south fork are probably controlled in part by the Battle Creek fault system, but modern stream activity and agricultural practices obscure any young traces of the faults east of the South Fork of Cottonwood Creek (pl. 1). At the South Fork of Cottonwood Creek and along Red Bank Creek, late Quaternary terraces show evidence of young faulting (Helley and others, 1981). To the west-southwest, the faults in the terrace deposits merge into previously mapped faults in the Red Bluff and Tehama Formations, and, on strike, they appear to merge with tear faults in the upper plate of the Coast Range thrust mapped by Bailey and Jones (1973).



FIGURE 16.—Photograph of Battle Creek fault scarp (BC) capped by basaltic cinder cone of Black Butte. View to northeast along Highway 36 and across rolling grassy plains underlain by volcanic fanglomerate correlated with the Red Bluff Formation.

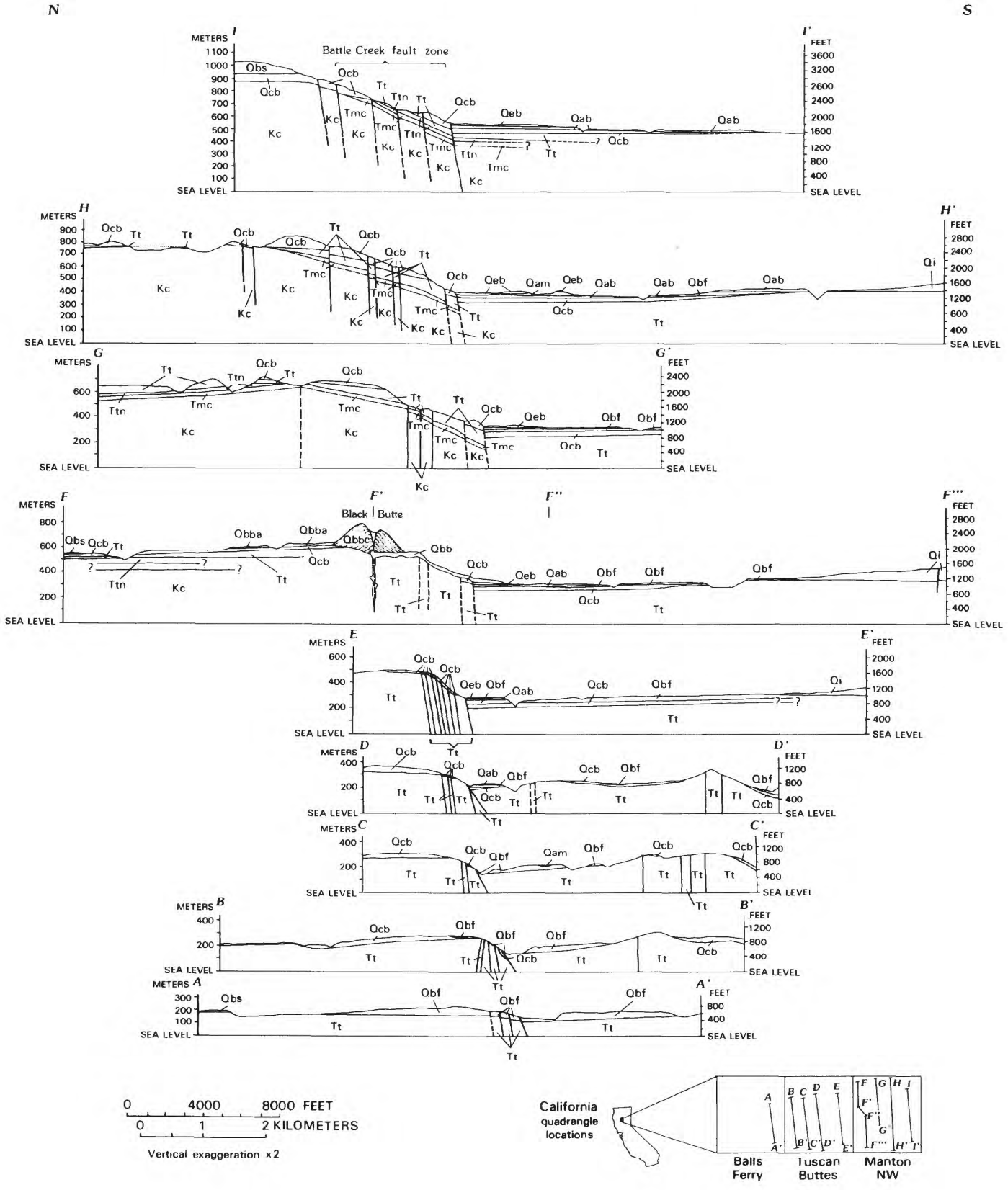
The orientation and distribution of faults in the Battle Creek fault zone east of the Sacramento River are shown in figure 17. Section *A-A′* is located 2.4 km east of the Sacramento River and shows relatively little offset of the fanglomerate that caps the Tuscan Formation. As the fault zone extends eastward, offset on the various Pliocene and Pleistocene units and the height of the fault scarp increases. From near the Sacramento River east to Black Butte (sections *A-A′* through *F-F′*, fig. 17), the fault strands are closely grouped along the fault scarp, but east of Black Butte (sections *G-G′* through *I-I′*, fig. 17) the fault strands are more widely spaced. In map view, the eastern fault strands veer northwestward and appear to die out a short distance north of the escarpment (Harwood and others, 1980).

Several clusters of small-magnitude earthquakes were reported along the eastern third of the Battle Creek fault zone, generally east of Black Butte (Bolt, 1979). Since 1980 the California seismic net of the U.S. Geological Survey has recorded several small-magnitude earthquakes (J. Eaton, oral commun., 1982) that lie approximately along the Battle Creek fault zone and extend west nearly to the Sacramento River.

Coarse volcanic fanglomerate, correlated here with the Red Bluff Formation by soil stratigraphy and geomorphic surface, is offset by the Battle Creek fault zone east of the Sacramento River and dates the major movement as younger than 1.09 m.y. The Rockland ash bed (referred to as the ash of Mount Maidu by Helley and others, 1981) appears to have been partly channeled by the Battle Creek fault scarp, suggesting that the faulting occurred prior to about 0.45 m.y. ago, the age of the Rockland ash bed (Meyer and others, 1980).

INKS CREEK FOLD SYSTEM

A set of northeast-trending folds, referred to as the Inks Creek fold system by Helley and others (1981), deforms the rocks south of the Battle Creek fault zone and structurally controls the major loops in the Sacramento River at Jelly School and the nearby Table Mountain (pl. 1; figs. 1, 18). The axial trace of the major syncline in the fold set passes through Table Mountain and extends northeastward, nearly coincident with Inks Creek. The complementary anticline to the north arches the volcanic fanglomerate, which is correlated with the Red Bluff Formation, and the underlying basalt of Coleman Forebay (Helley and others, 1981), exposing strata of the uppermost part of the Tuscan Formation northeast of Jelly


N
S
I
I'
METERS
FEET
Battle Creek fault zone
Qbs
Qcb
Tt
Ttn
Tmc
Kc
Qeb
Qab
SEA LEVEL
H
H'
Qam
Qbf
Qi
G
G'
F
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Black Butte
Qbba
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E
E'
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0 4000 8000 FEET
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Vertical exaggeration x2
California quadrangle locations
Balls Ferry
Tuscan Buttes
Manton NW

School. Axial surfaces of the folds are vertical, and fold axes plunge 20°–35° SW. Axial traces of the folds change strike to the northeast so that the anticlinal trace merges with the trend of the Battle Creek fault zone and apparently dies out along the fault to the east-northeast.

West of the Sacramento River, the Inks Creek fold system is expressed as a broad area of uplift known as the Hooker dome (fig. 18). This structure, which has profoundly influenced drainage patterns in the area, particularly along Hooker Creek and Blue Tent Creek (fig. 18), is underlain by the Tehama Formation capped by a few scattered erosional remnants of the Red Bluff Formation.

The Inks Creek fold system is clearly reflected in the structure contours drawn on top of the Cretaceous rocks, which show a closure of about 485 m over the anticline (pl. 1). Although only a few wells in this area reach basement, the elevation of the basement in two wells drilled on the anticline of the Inks Creek fold system is higher than the total depth of some wells to the west that bottomed in Upper Cretaceous rocks. These data indicate that the basement was deformed, along with the cover rocks, during formation of the Inks Creek fold system. They also strongly suggest that the folds shown by the structure contours on plate 1 involve the basement of the valley rather than deformation on a decollement or a series of detachment thrusts in the cover rocks.

The fact that the anticlinal trace of the Inks Creek fold system merges with the Battle Creek fault zone suggests a genetic relation between these major structures. If this interpretation is correct, evidence for the age of the Inks Creek fold system provides data for the age of movement on the Battle Creek fault zone. At Round Mountain, about 3 km southwest of Jelly School, the Rockland ash bed rests unconformably on the eroded western contact of the Red Bluff Formation at an elevation of 160 m. We assume that the ash was deposited in an ancestral channel of the Sacramento River, which apparently formed a large westward bend at that time extending from Bloody Island on the north to the vicinity of Bend on the south (fig. 18). Uplift and erosion of the Red Bluff Formation, which was deposited between 0.45 and 1.09 m.y. ago, had begun

EXPLANATION

Qi	BASALTIC ROCKS OF INSKIP HILL VOLCANIC CENTER (QUATERNARY)--Undifferentiated basalt of Inskip Hill
	BASALTIC ROCKS OF BLACK BUTTE VOLCANIC CENTER (QUATERNARY)--Consist of:
Qbbc	Cinder-cone deposits
Qbba	Cinder-blanket deposits
Qbb	Basalt flow of Black Butte
Qbs	BASALT OF SHINGLETOWN RIDGE (QUATERNARY)
Qeb	BASALT OF EAGLE CANYON (QUATERNARY)
Qab	HYPERSTHENE ANDESITE OF BROKEOFF MOUNTAIN (QUATERNARY)
Qam	ASH OF MOUNT MAIDU (QUATERNARY)--Equivalent to the Rockland ash bed of Sarna-Wojcicki and others (1985)
Qbf	ALLUVIAL FAN DEPOSITS OF BATTLE CREEK (QUATERNARY)
Qcb	BASALT OF COLEMAN FOREBAY (QUATERNARY)
Tt	TUSCAN FORMATION, UNDIVIDED (PLIOCENE)--Locally divided into:
Ttn	Nomlaki Tuff Member
Tmc	MONTGOMERY CREEK FORMATION (EOCENE)
Kc	CHICO FORMATION (UPPER CRETACEOUS)

FIGURE 17.—Geologic cross sections showing statigraphic and structural relations along Battle Creek fault zone. Note eastward increase in height of fault scarp and amount of offset of geologic units from section A-A′ to section I-I′. Geologic units from Helley and others (1981).

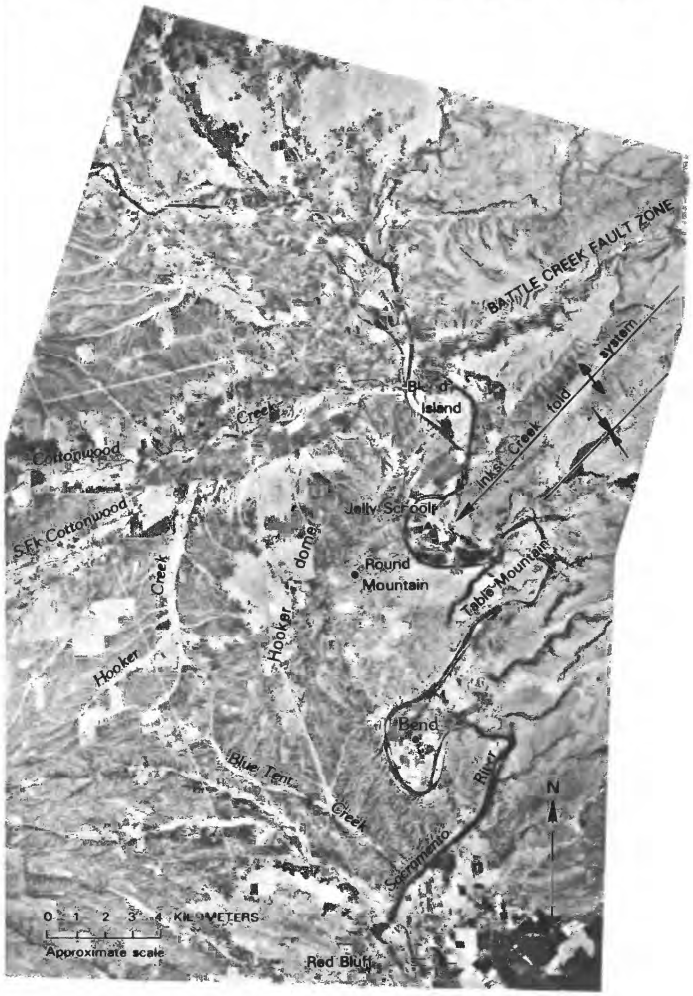


FIGURE 18.—Composite of two U.S. Air Force high-altitude vertical aerial photographs showing topographic expression of Inks Creek fold system (axial traces), Hooker dome, and Battle Creek fault zone.

prior to deposition of the ash. In contrast to the occurrence of the ash at Round Mountain, alluvial deposits of the lower part of the Riverbank Formation are found at an elevation of 120 m in this region, and they flank the present sinuous course of the Sacramento River through the structurally controlled loops of the river at Jelly School and Table Mountain. Clearly, the Sacramento River was forced into its tortuous course around the Inks Creek fold system by early Riverbank time. We conclude, therefore, that the Inks Creek fold system and at least some of the displacement on the Battle Creek fault zone developed in the timespan between 0.45 m.y., the age of the ash, and about 0.4 m.y. ago, the age of the lower part of the Riverbank Formation (Marchand and Allwardt, 1981).

SALT CREEK, TUSCAN SPRINGS, AND SEVENMILE DOMES

Small areas of Upper Cretaceous marine rocks are exposed beneath the Pliocene Tuscan Formation in Salt Creek, at Tuscan Springs, and in Sevenmile Creek between the north end of the Chico monocline and the Inks Creek fold system (pl. 1). In each area, beds in the Tuscan dip outward, away from the Upper Cretaceous rocks, and define three small domes, shown on plate 1 as the Salt Creek, Tuscan Springs, and Sevenmile domes.

The long axes of the domes trend north-northeast and plunge 15°–25° NE. and SW. Cold sulfurous springs are present in the Salt Creek and Tuscan Springs domes, and olivine basalt rests unconformably on steeply northwest-dipping Upper Cretaceous rocks in the core of Sevenmile dome. The olivine basalt was extruded from a north-trending fissure after the Tuscan Formation was domed and erosion had exposed the Upper Cretaceous rocks.

The age of the olivine basalt is unknown, but it probably is a few tens of thousands of years old, at most, and is roughly coeval with similar basalt flows and cinder cones found at Inskip Hill (pl. 1) and Black Butte along the Battle Creek fault zone. The domes probably formed during the same phase of late Quaternary deformation about 0.4–0.45 m.y. ago that produced the Inks Creek fold system and the Battle Creek fault zone, and they are thus younger than the Chico monocline.

RED BLUFF FAULT

The Red Bluff fault is a subsurface structure that extends southwest of Red Bluff for at least 25 km. West of Red Bluff, there is no surface feature associated unequivocally with the fault, and its location on plate 1 is taken from Jennings' (1977) geologic map of California. Apparently Jennings included the fault on that map on the basis of seismic-reflection data obtained from private industry (Oliver and Griscom, 1980). We have not seen that data or any other seismic profiles that might cross the fault. Griscom (1973) inferred the existence of a major northeast-trending fault in the area from magnetic data.

East of Red Bluff, structure contours on top of the Cretaceous rocks outline a major anticline, the broad crest of which lies beneath the Salt Creek, Tuscan Springs, and Sevenmile domes. The axial trace of this anticline roughly coincides with the east-northeast projection of the Red Bluff fault, but there is no indication that the Tuscan Formation is faulted at the surface along the N. 70° E. trend. The southeast limb of the anticline may be faulted at depth, but surface and subsurface data are too sparse to either prove or refute that structural possibility. Between Tuscan Springs and the Humble "Cone Ranch No. 1" well (sec. 20, T. 27 N., R. 2 W.) to the south, the top of the Cretaceous sequence drops about 1,433 m over a distance of less than 8 km. The lower elevation is due to warping and faulting on the Chico monocline fault, as well as to folding and possible faulting along the northeast projection of the Red Bluff fault.

From our reinterpretation of a north-south section along the Sacramento River near Red Bluff given by Redwine (1972, section *F-F'*), the base of the Tehama Formation could be offset, down to the south, by as much as 141 m across the Red Bluff fault just east of Red Bluff. Because of the lack of northeast-trending surface faulting in the Tuscan to the east, however, it seems unlikely that all of that differential elevation is due to fault displacement; much of it may be related to folding over a fault at depth.

FAULTS SOUTH OF INSKIP HILL

The northwest-trending arcuate faults that are shown south of Inskip Hill (pl. 1) are a gross simplification of the faults and fractures found in that area. In detail, the Tuscan Formation is laced with a dense network of short anastomosing faults along which thin lines of shrubs and trees grow (fig. 19). The amount of offset on a single fault is small, generally a few meters or less, and there appears to be no significant cumulative offset in the Tuscan Formation across the fractured area.

The arcuate pattern of faults is concave toward the area of Mineral, to the east, where Wilson (1961) identified a major volcanic center that he called Mount Maidu. It seems reasonably certain that the fracture pattern is related to volcanic-tectonic activity in the Lassen area, but whether it is associated with Mount Maidu or some other volcanic center is uncertain.

STRUCTURES SOUTHWEST OF THE WILLOWS FAULT

With the exception of the buried Colusa dome, the subsurface structure of the valley southeast of the Willows fault to the Sacramento Delta is dominated by the Zamora

syncline. South of buried Colusa dome, the Zamora syncline is asymmetrical and has a broad, gently west-dipping east limb that extends to the Sierran foothills and a steeply dipping west limb that is warped by southeast-plunging folds. North of the buried Colusa dome, the axial trace of the Zamora syncline intersects the Willows fault, and the top of the Upper Cretaceous rocks defines a generally east-dipping homocline.The following sections discuss structural features west of the axial trace of the Zamora syncline.

CAPAY VALLEY-CAPAY HILLS AREA

Cache Creek drains east from Clear Lake and enters the Sacramento Valley west of Woodland, through the tectonically controlled depression of Capay Valley. On the west, Capay Valley is flanked by the eastern slope of the Coast Ranges that contain a remnant of Eocene marine sandstone and shale of the Capay Formation (Redwine, 1972) resting unconformably on Upper Cretaceous marine rocks (Kirby, 1943a). Beds in the Capay and underlying rocks dip 25°-55° E. The Capay Hills, previously known as the Rumsey Hills (Kirby, 1943b), lie immediately east of Capay Valley and are underlain by the same Upper Cretaceous rocks exposed to the west. Here, however, the Cretaceous rocks lie in the core of a faulted southeast-plunging anticline, shown by structure contours on plate 1. They are unconformably overlain by nonmarine sandstone and shale of the Pliocene Tehama Formation. The Eocene Capay Formation is not present in the Capay Hills or in the Capay Valley, where scattered subsurface and surface data indicate that the Tehama rests unconformably on Upper Cretaceous rocks.

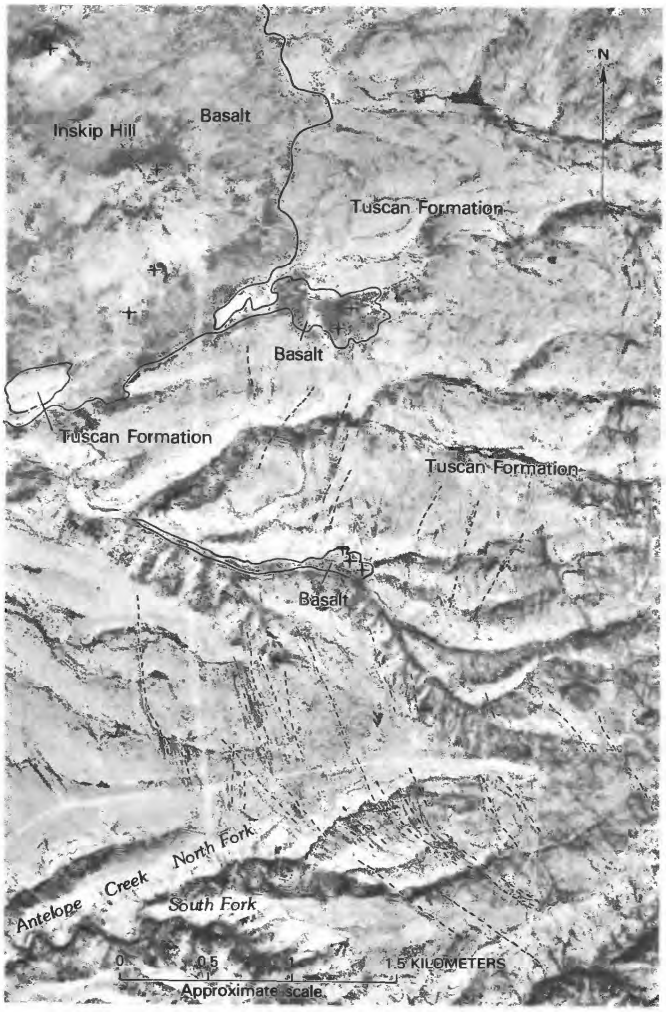


FIGURE 19.—Low-altitude vertical aerial photograph (U.S. Geological Survey) showing arcuate fault pattern (dashes) and cinder cones (crosses) south of Inskip Hill. Gray incised plains are underlain by the Tuscan Formation; thin dark lines are concentrations of brush and trees growing along fault traces.

On the floor of Capay Valley, the Tehama and older rocks have been eroded, and old stream channels have been filled with a variety of Quaternary alluvial deposits. Alluvial deposits of the upper part of the Modesto Formation indicate that Cache Creek entered the Sacramento Valley through a channel cut in the Tehama Formation near the west boundary of Capay Valley in late Wisconsin time. During the past 12,000 years the course of Cache Creek has shifted eastward so that the creek now exits Capay Valley through a sharp gorge cut into the relatively resistant Upper Cretaceous rocks at the southern end of Capay Hills. The shift in the course of Cache Creek and the surface and subsurface data that show faulting in the Tehama Formation provide strong evidence for late Cenozoic tectonism in Capay Valley.

Along the west flank of the Capay Hills, Kirby (1943b) mapped a northwest-trending, east-dipping thrust, the Sweitzer fault, and a lower ancilliary thrust, the Eisner fault; both faults place Upper Cretaceous rocks in contact with the Tehama. Wagner and Saucedo (1984) have reinterpreted the Sweitzer and Eisner faults as west-dipping normal faults. Their interpretation of the Sweitzer fault is supported by subsurface data at the south end of Capay Hills, where the contact between the Forbes and Guinda Formations of Kirby (1943a) is downfaulted about 50 m on the west (fig. 20, wells 3 and 4). Compared to other faults in the area, the Sweitzer fault appears to have played a relatively minor part in the structural evolution of the Capay Valley and Capay Hills.

West of the Sweitzer fault, the contact between the Forbes and Guinda Formations was reported at an elevation of about 219 m beneath the Capay Valley (fig. 20, well 2). That contact is displaced about 610 m up to the west along the northwest-trending, steeply east-dipping East Valley fault (fig. 20). Along the west margin of Capay Valley, the contact between Upper Cretaceous rocks and the Tehama Formation is down faulted about

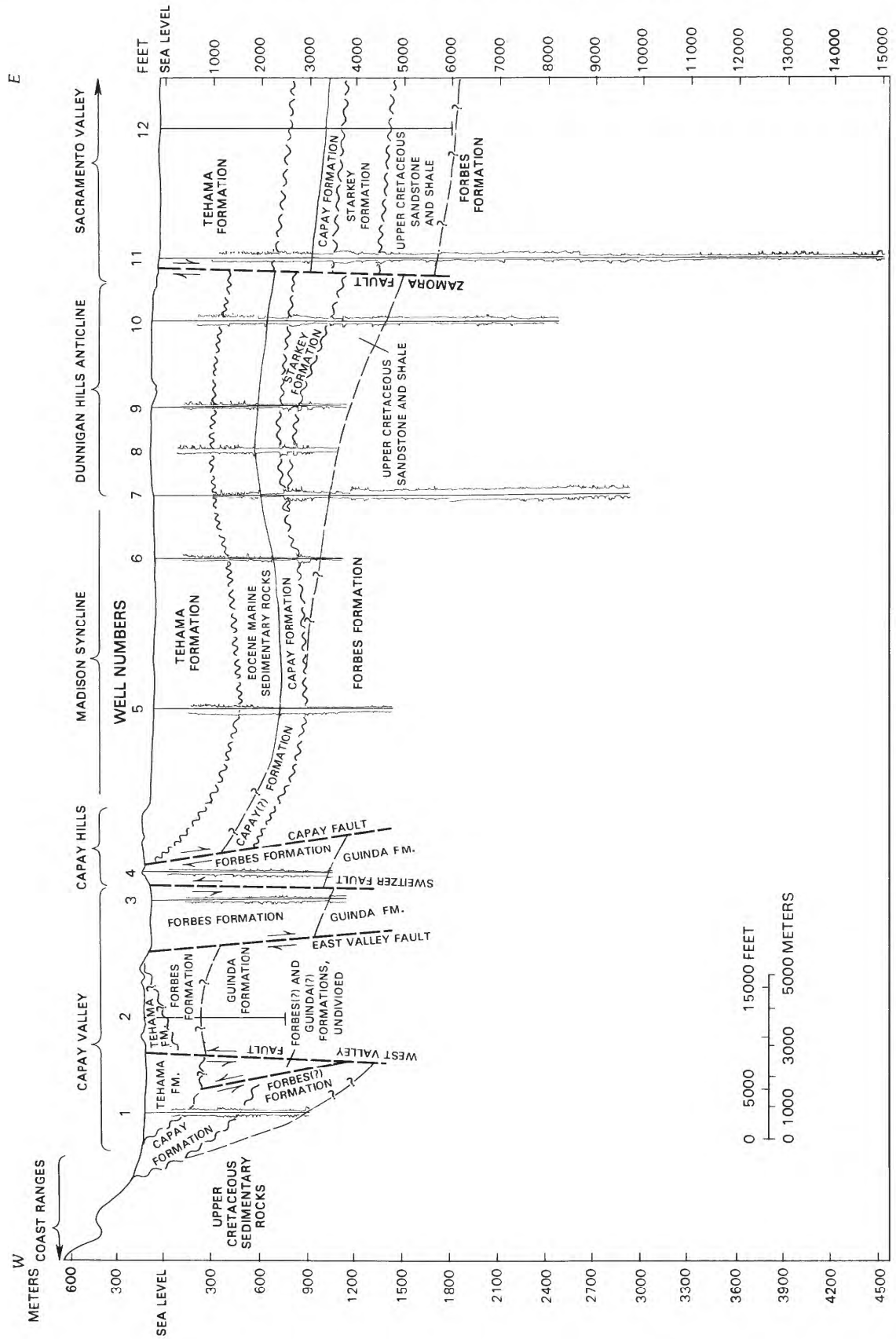


FIGURE 20.—Cross section showing electric logs and stratigraphic and structural relations in Capay Valley, Capay Hills, and Dunnigan Hills. Names of wells listed in appendix. Stratigraphic nomenclature used may not necessarily conform to that adopted by U.S. Geological Survey.

150 m to the west by the near-vertical West Valley fault (fig. 20). At the south end of Capay Valley, Upper Cretaceous rocks are thrust over the Eocene Capay Formation along a thrust or high-angle reverse fault that is exposed to the south along the east flank of the Coast Ranges (pl. 1). The location of this thrust or high-angle reverse fault is unknown east of the West Valley fault.

East of Capay Hills, the Capay Formation unconformably overlies east-dipping Upper Cretaceous rocks beneath the Madison syncline and the Dunnigan Hills anticline (pl. 1; fig. 20). The Capay Formation and overlying Eocene marine rocks are not exposed in the Capay Hills where the Pliocene Tehama Formation rests unconformably on Upper Cretaceous rocks. Because the Capay Formation is present west of Capay Valley, however, we assume that the Capay Formation once extended over the area of the Capay Hills but that it was eroded from the area after west-side-up movement on the Capay fault (fig. 20) and the other high-angle reverse faults to the west under Capay Valley. In this interpretation, the minimum displacement on the Capay fault would be about 700 m. Major west-side-up reverse movement occurred on the Capay fault, the East Valley fault, and the unnamed thrust or high-angle reverse fault to the west in post-Eocene time and before deposition of the Tehama Formation, which contains the 3.4-m.y. old Putah Tuff Member near its base (Sarna-Wojcicki, 1976). West-side-down movement occurred on the West Valley fault subsequent to deposition of the Tehama Formation, and east-side-down, post-Tehama displacement also may have occurred on the East Valley fault and the Capay fault.

DUNNIGAN HILLS ANTICLINE AND THE ZAMORA FAULT

Near Woodland, Bryan (1923) recognized accordant summit elevations capped by Red Bluff gravel on a series of northwest-trending dissected uplands that he called the Hungry Hollow Hills, but which are now known as the Dunnigan Hills. The northeast flank of the upland is bounded by a linear escarpment that Bryan called the Hungry Hollow fault, but which is referred to here as the Zamora fault (pl. 1; fig. 20). He recognized down-to-the-east displacement of at least 121 m at the north end of the fault scarp and offset of about 60 m near Cache Creek to the south (Bryan, 1923, p. 79).

Bryan's early work, combined with the topographic relief in the area, made the Dunnigan Hills a prime target for early seismic-reflection studies that resulted in the discovery of the Dunnigan Hills gas field in 1946 (Rofe, 1962). The gas-producing structure is a doubly plunging, northwest-trending anticline along which various Upper Cretaceous sandstone beds are unconformably capped by the Eocene Capay Formation (fig. 20). This major structure has topographic relief. Red Bluff gravel wraps around the northwest-plunging nose of the fold and occurs in scattered patches along the east flank, on the crest line, and at the southeast-plunging nose of the fold. Oat Creek (pl. 1) and Bird Creek to the southeast (not shown on pl. 1) are antecedent to the fold and change from southeast to northeast courses approximately at its axial trace.

Data from a recent well drilled near Zamora by the U.S. Geological Survey provide new information on the amount of late Cenozoic deformation in the area. A conspicuous volcanic ash bed, penetrated at a depth of −137 m (Page and Bertoldi, 1983), has been correlated tentatively by mineralogy and chemical composition of the glass with the Rockland ash bed by C. E. Meyer and A. M. Sarna-Wojcicki (oral commun., 1982). Because the ash occurs directly above Red Bluff gravels elsewhere in the valley (Harwood and others, 1981; Helley and others, 1981), it is assumed that the ash overlies the Red Bluff in the Zamora well and that there is a minimum of 220 m of vertical displacement of the Red Bluff Formation. This vertical separation is the result of folding on the Dunnigan Hills anticline and displacement on the Zamora fault (fig. 20).

MIDLAND FAULT

The Midland fault is a major subsurface structure that was discovered in the Sacramento Delta during development of the Rio Vista gas field between 1936 and 1943 (Frame, 1944). Through data from extensive drilling, the fault was extended about 25 km north of the Rio Vista field to the Maine Prairie gas field (Arleth, 1968). North of that field, the location of the Midland fault is uncertain. Redwine (1972) proposed that the Sweitzer fault, mapped by Kirby (1943b) in the Capay Hills, was the northwest continuation of the Midland fault. Although Jennings (1977) showed the Midland-Sweitzer fault connection, suitably queried, on his geologic map of California, that interpretation is no longer considered correct (C. Jennings, oral commun., 1981). The location of the Midland fault south of the Rio Vista gas field is uncertain.

In the Rio Vista gas field, the Midland fault is actually a north-trending, steeply west-dipping to vertical fault zone that offsets Paleocene and Eocene rocks down to the west in a series of fault blocks as shown in figure 21. Early in the development of the Rio Vista gas field, it became apparent that movement on the Midland fault had controlled local patterns of Tertiary sedimentation. Frame (1944) noted that the Capay Formation was significantly thicker west of the Midland fault, and he suggested that maximum movement occurred on the fault during or at the close of Capay deposition. Although the Capay Formation shows the greatest amount of syntectonic thickening across the fault, all of the Paleocene and Eocene units show some differential thickening west of the fault (Bur-

roughs and others, 1968). In his detailed analysis of depositional and tectonic cycles in the southern Sacramento Valley, Almgren (1978) demonstrated approximately 610 m of episodic movement on the fault between the early Paleocene and early Oligocene. There is no indication that early Oligocene or younger deposits are offset by the Midland fault; therefore, it appears that the Midland fault was an active structural feature on the early Tertiary continental margin but that it has not been active in the late Cenozoic.

By combining data presented by Burroughs and others (1968) and Almgren (1978), it is possible to calculate approximate displacement rates on the Midland fault during the early Tertiary. Calculation of the displacement rates, shown in figure 22, assumes that displacement occurred on a single fault strand during the time deduced for various units by Almgren (1978) and that initial offset began in the Paleocene. Between 60 and 53 m.y. ago the slip rate was 3.8 cm/1,000 yr. The rate increased to a maximum of 7.2 cm/1,000 yr between 53 and 50 m.y., and it decreased significantly to 0.75 cm/1,000 yr between 49 and 42 m.y.

THORNTON ANTICLINE

The Thornton anticline, or the Thornton arch of Silcox (1968), is an east- to southeast-trending, west-plunging fold that is transected in part by closely spaced northwest-trending faults that generally show west-side-down displacements of less than 20 m. The fold extends from the east-central part of the Sacramento Delta to the vicinity of Lodi and provides structural control for several gas fields along its trace. Silcox (1968) provides the most detailed information on the structural development of the

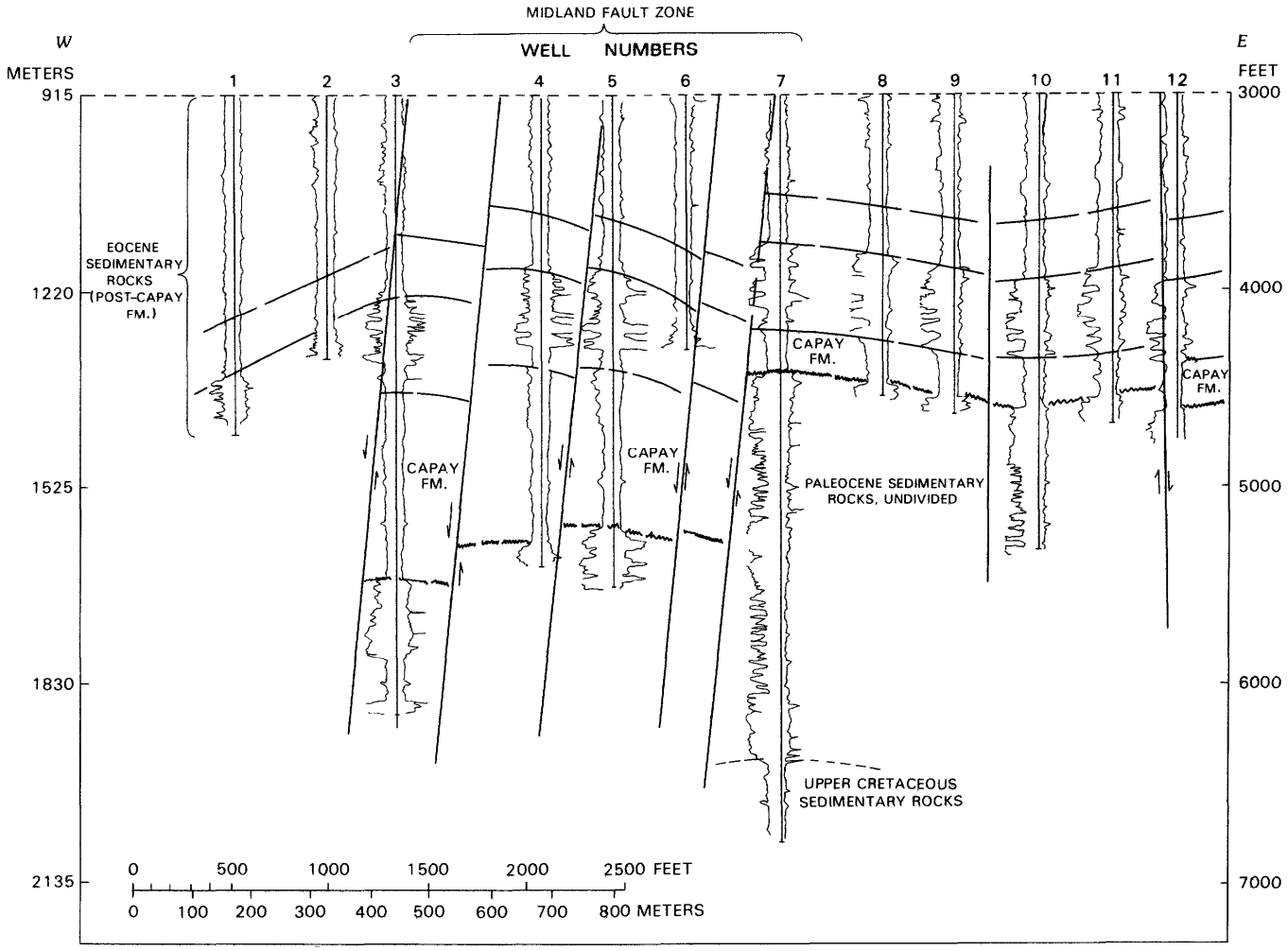


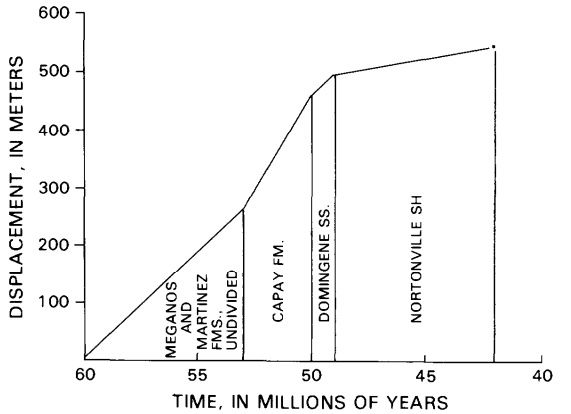
FIGURE 21.—Cross section showing electric logs and stratigraphic and structural relations across Midland fault zone in Rio Vista gas field (modified from Burroughs and others, 1968). Note significant thickening of the Eocene Capay Formation west of easternmost strand of Midland fault zone. Names of wells given by Burroughs and others (1968).

Thornton anticline in his description of the Thornton and Walnut Grove gas fields.

According to Silcox (1968) initial development of the Thornton anticline occurred prior to deposition of the basal Eocene rocks and may have been contemporaneous with Paleocene displacement on the Midland fault to the west. Maximum flexure of the structure apparently occurred in the late Eocene when lower and middle Eocene rocks were eroded and subsequently buried unconformably beneath deposits of the Markley submarine canyon. Miocene continental rocks, which were deposited unconformably on Markley canyon fill, do not show any significant folding over the Thornton anticline, nor are they offset by the northwest-trending faults that cut earlier deposits along the fold. Therefore, the structures are pre-Miocene.

STOCKTON FAULT

The Stockton fault is a northeast-trending, southeast-dipping subsurface fault that extends across the southern part of the Sacramento Valley between Tracy (south of pl. 1) on the west and the vicinity of Milton on the east. The fault lies north of a cross-valley, northeast-trending structural high in the basement, known as the Stockton arch, that apparently was discovered during some of the earliest seismic-reflection profiling done in the valley in the mid-1930's. Wells drilled near the Stockton fault during that time found only minor amounts of gas, and the relations between displacement on the Stockton fault and folding in the Upper Cretaceous marine rocks were not determined until development of the Lathrop gas field during the late 1940's. Teitsworth (1968), in his analysis of the Lathrop gas field, presents the most detailed study of the complex tectonic history of the Stockton fault. His work coupled with our analysis of wells to basement north of the Stockton fault, and Bartow's (1983) analysis of wells south of the fault provide the data for this discussion.



UNIT	DIFFERENTIAL THICKNESS (m)	POSTFORMATION OFFSET (m)	TOTAL OFFSET (m)	TIME (m.y. ago)	RATE (cm/10³ yr)
Nortonville Sh	15	38	53	(49-42)	0.75
Domingene Ss.	26	23	49	(50-49)	4.9
Capay Fm.	215	0	215	(53-50)	7.2
Meganos and Martinez Fms., undivided	260	5	265	(60-53)	3.8

FIGURE 22.—Graph showing amounts and rates of offset on Midland fault zone, assuming all displacement occurred on a single fault strand and that displacement began in the Paleocene. Amount of offset and syntectonic thickening of units taken from figure 21 (modified from Burroughs and others, 1968).

Near the city of Stockton, the −3,000-m basement contour is offset about 5 km in a left-lateral sense and depressed about 300 m down to the south, but the vertical component of movement is not closely controlled in that area. Eastward, near the −2,500-m contour, the basement surface is offset left-laterally about 6 km and depressed nearly 500 m south of the fault. The vertical component of displacement there is reasonably well controlled by wells north and south of the fault. Both the left-lateral and vertical components of displacement decrease eastward along the Stockton fault and appear to die out completely between the −500-m and 0 basement contours. No trace of the Stockton fault has been mapped in the exposed metamorphic rocks of the Sierran foothills between the north end of Gopher Ridge and the Mokelumne River (pl. 1) (Wagner and others, 1981).

Teitsworth's (1968) study of the Lathrop gas field (pl. 1, map A), which is located about 9 km southeast of Stockton, corroborates our analysis of the basement offset on the Stockton fault and adds valuable data about the amount and timing of deformation recorded in the Upper Cretaceous rocks. Teitsworth concluded that the Upper Cretaceous rocks were thicker south of the Stockton fault, indicating south-side-down vertical movement during early phases of deposition, and that they were subsequently offset about 3 km left-laterally during Late Cretaceous time. Deposition of Upper Cretaceous marine shale followed earlier strike-slip displacement on the Stockton fault, and these marine shale units also show left-lateral displacement. Following deposition and strike-slip displacement of the uppermost Upper Cretaceous unit in the area, but prior to deposition of Miocene continental strata that unconformably cap the Upper Cretaceous section, the Stockton fault experienced about 1,000 m of reverse, south-side-up movement (Teitsworth, 1968). During this period of reverse movement, west- and west-northwest-trending anticlines formed in the Upper Cretaceous rocks south of the fault, providing closure that trapped the gas in the Lathrop and East Stockton gas fields (pl. 1, map A). The trend of these folds and the northwest-trending anticlines in the Roberts Island and McDonald Island gas fields (pl. 1, map A) north of the Stockton fault indicate northeast-southwest compression in the area during the period of reverse movement on the Stockton fault. Teitsworth (1968) concluded that reverse

movement probably occurred after the middle Eocene but before deposition of Miocene continental deposits. However, he shows a west-northwest-trending fold in contours drawn on the base of the Miocene rocks south of the Stockton fault, from which we conclude that the northeast-southwest compressive stress operated in the area into the middle Tertiary.

FAULTS IN THE SIERRAN FOOTHILLS

Clark (1960) combined data from a number of sources with his own field observations to produce the first regional structural synthesis of the Sierran foothills. He defined the Foothill fault system as a group of northwest-trending, steeply east-dipping to vertical faults that tectonically separate distinctive belts of Paleozoic and Mesozoic rocks for more than 320 km along strike in the western foothills of the Sierra Nevada. He recognized that the component faults in the system were actually complex fault zones marked by multiple fault strands and intensely sheared, cataclastic, and crumpled rocks, which were associated geographically, in many areas, with major bodies of sheared serpentinite. On the basis of limited paleontologic and radiometric data, he concluded that the major tectonic activity of the Foothill fault system occurred in the Late Jurassic.

Although displacement of Tertiary volcanic units was recognized locally along segments of the Foothill fault system after Clark's study (Bateman and Warhaftig, 1966), few investigations were made into the late Cenozoic deformational history of the fault system before the Oroville earthquake. That seismic event produced ground rupture on the Cleveland Hills faults (Clark and others, 1976) and opened the question of potential late Cenozoic deformation within the whole Foothill fault system.

In their earthquake evaluation studies of the Auburn Dam area, Woodward-Clyde Consultants (1977) made a regional analysis of potential late Cenozoic deformation along many linear features related to the Foothill fault system, and they trenched those linear features that had direct bearing on their Auburn Dam study. That study provided most of the data for our analysis of those strands of the fault system in the border zone between the Sierran foothills and the Sacramento Valley.

COHASSET RIDGE FAULT

Cohasset Ridge is a prominent south- to southwest-trending interfluve located northeast of Chico, between the major drainages of Big Chico Creek and Deer Creek. The ridge is capped by at least two essentially contemporaneous olivine basalt flows that appear to have originated in the Butte Mountain area (about 12 km east of pl. 1), on the southwest slope of a Pliocene volcano named Mount Yana by Lydon (1968). The olivine basalts flowed southwestward in channels eroded in the underlying Tuscan Formation, but subsequent erosion has inverted the topography so that the basalt now stands as the highest unit on the ridge. The olivine basalt of Cohasset Ridge represents the final phase of volcanism that reached the Sacramento Valley from Mount Yana. The upper basalt flow has been dated at 2.41 m.y. (Harwood and others, 1981).

East of Brushy Mountain (pl. 1), the olivine basalt of Cohasset Ridge is abruptly truncated on the east by a steeply east-dipping fault that strikes about N. 40° W., roughly parallel to the Chico monocline fault. Aune (cited in Woodward-Clyde Consultants, 1977) first recognized this fault, which he called the Cohasset Ridge fault, and concluded that the eastern equivalents of the olivine basalt of Cohasset Ridge were downfaulted to the east about 30 m along the normal fault. The Cohasset Ridge fault can be traced north of Deer Creek through an intensely fractured zone in the Tuscan Formation to the vicinity of Mill Creek, where it becomes obscured by a complex pattern of west- and northwest-trending arcuate faults (pl. 1; fig. 19). Although the area south of Deer Creek is heavily forested and the slopes are covered by a veneer of colluvium, the trace of the Cohasset Ridge fault is defined by a prominent topographic linear feature, observed by Rich and Steele (1974), that extends nearly to Magalia, where it apparently is intersected by the Magalia fault.

The Cohasset Ridge fault is a northwest-trending, steeply east-dipping fault that has experienced at least 30 m of east-side-down normal movement in the past 2.41 m.y.

MAGALIA FAULT

About 9 km north of Magalia, (pl. 1), the Cohasset Ridge fault is intersected by the N. 20° W.-trending Magalia fault. Extensive mine workings, which followed Tertiary auriferous gravel deposits at the base of the Tertiary volcanic sequence in the area, provide detailed data on the nature and local extent of the Magalia fault (Gassaway, 1899; Logan, 1930; Woodward-Clyde Consultants, 1977).

Although the Magalia fault is shown as a single fault on the map, detailed mine maps indicate that the fault is actually a complex fault zone consisting of numerous fault strands that have different orientations and amounts of displacement. In the Dix mine at the north end of the mining district, the gold-bearing gravels are offset 28 m down to the east. Southeastward along the trace of the Magalia fault at the Black Diamond mine, the gravel deposits are offset 68 m down to the east. Farther southeast at the Magalia mine, the channel deposits are offset down to the west from 2 to 11 m along three reverse

faults that trend N. 60° W. and dip 58° NE.

From the mining records it appears that the various fault strands in the Magalia fault zone have experienced episodic and different movement through the Tertiary, with both normal east-side-down and reverse east-side-up displacement recorded. The relative ages of this disparate movement pattern along the Magalia fault are unknown, but the youngest movement appears to post-date movement on the Cohasset Ridge fault.

CLEVELAND HILLS FAULTS

The Cleveland Hills faults coincide with surface ruptures that occurred during the Oroville earthquake. During that seismic event, the ground surface failed in a 3.8-km long en echelon pattern of north- and north-northwest-trending normal faults that showed at least 55 mm of horizontal separation across the surface ruptures and as much as 180 mm of west-side-down vertical separation (Clark and others, 1976). Aftershocks of the Oroville earthquake defined a zone of seismic activity, assumed to coincide with the controlling fault, that dipped about 60° W. and trended nearly due north (fig. 15; also Bufe and others, 1976).

Trenches, dug across the zone of surface rupture by the California Department of Water Resources and logged by Akers and McQuilkin (1975), showed a gouge zone about 2 m wide in the bedrock below the surface ruptures that was flanked by 2-4 m of intensely fractured rock transitional into the country rock of foliated greenstone. The gouge zone contains anastomosing shear zones of deformed gouge that provide evidence of repeated earlier faulting along the zone of the ground failure. Earlier deformation in the area is also indicated by 30-60 m of apparent west-side-down offset of an erosion surface of probable Pleistocene age across the Cleveland Hills faults (Aune, 1975).

About 5.7 km northwest of the Cleveland Hills faults (pl. 1), Creely (1965) mapped a north-trending, steeply east-dipping fault that offset the base of Pleistocene or older gravel deposits about 2 m down to the west. Clark and others (1976) reported a second fault in the area that showed minor east-side-down offset of the gravel deposit.

FAULTS SOUTHEAST OF OROVILLE

In their earthquake evaluation of the Auburn Dam area, Woodward-Clyde Consultants (1977) identified a number of prominent linear features in the Sierran foothills southeast of the Cleveland Hills faults. With the exception of the northeast- and north-trending Highway 49 and Hancock Creek lineament zones (pl. 1), the linear features they investigated have northwest trends that coincide closely with the projected trace of the Chico monocline fault. The linear features were trenched extensively and logged in detail (Woodward-Clyde Consultants, 1977), and trench data were integrated with surficial geologic investigations in each area. Evidence of movement in the past 10 m.y. (Woodward-Clyde Consultants' definition of the "late Cenozoic") was detected in the trenches across the northwest-trending linear features, which are shown on plate 1 as the Swains Ravine, Spenceville, and Maidu fault zones and the Dewitt fault.

Deformation in the bedrock exposed in the trenches is remarkably similar to that shown in trenches across the Cleveland Hills faults. In most areas, bedrock beneath the surface lineaments contained one or more zones of slickensided clay-rich gouge a few meters wide or less. The gouge commonly contained anastomosing shear zones composed of polydeformed gouge and thin clay seams that indicated multiple phases of deformation. Rock adjacent to the gouge zones commonly was highly fractured, bleached, or manganese-stained and injected by thin quartz veins. In some trenches, a paleosol rested unconformably on bedrock and was offset locally along the faults marked by the gouge zones. That evidence led Woodward-Clyde Consultants (1977) to conclude that at least some of the faulting had occurred in the past 100,000 years. Based on the evidence presented by Woodward-Clyde Consultants (1977) and our observations in many of the trenches that they excavated during that study, we agree with their conclusions.

REGIONAL STRUCTURAL ANALYSIS

STRUCTURAL DOMAINS IN THE SACRAMENTO VALLEY

As we have shown in preceding sections of this report, late Cenozoic structural features in the valley have diverse orientations and displacement histories. In spite of this diversity, large areas of the valley are characterized by coeval structures that appear to have formed in a similar stress regime. To analyze the late Cenozoic structural evolution of the Sacramento Valley, we have grouped coeval structures that have similar displacement patterns into structural domains (fig. 23).

Delineating the various structural domains obviously depends on correctly identifying and correlating late Cenozoic deposits throughout the valley. Many of the late Cenozoic alluvial deposits are similar in outcrop characteristics, but fortunately they contain or are bracketed by distinctive tephra beds or volcanic flows that allow widespread correlation of alluvial units and provide absolute age control for the alluvial and tectonic histories of the region. In this regard, we have used the following time-stratigraphic units to define the late Cenozoic structural domains of the valley:

Unit	*Age/Age range (m.y.)*	*Reference*
Rockland ash bed	0.4-0.45	Sarna-Wojcicki and others (1985); Meyer and others (1980)
Red Bluff Formation	0.5-1.0	Harwood and others (1981)
Olivine basalt of Deer Creek	1.09	Harwood and others (1981)
Ishi Tuff Member of the Tuscan Formation	2.6	Harwood and others (1981; unpublished data, 1985)
Volcanic rocks of Sutter Buttes	1.4-2.4	Williams and Curtis (1977)
Nomlaki Tuff Member of the Tuscan and Tehama Formations	3.4	Evernden and others (1964)
Putah Tuff Member of the Tehama Formation	3.4	Sarna-Wojcicki (1976)

With the exception of the Dunnigan Hills, the structural domains shown in figure 23 become progressively younger northward through the valley. Late Cenozoic deformation in the Dunnigan Hills domain apparently overlapped that in the Corning domain, but the respective styles of deformation and the inferred stress regimes discussed in a later section differ significantly. This point emphasizes the fact that the structural domains include tectonic features that are homogeneous in time and style of deformation as far as we can determine. To a certain extent, the ages of the structural domains reflect the distribution of the time-stratigraphic units used to identify the major late Cenozoic deformation in a domain. It may be possible to subdivide some domains as more information on the distribution of the younger time-stratigraphic units becomes available. Furthermore, it is important to note that ascribing an age to the late Cenozoic deformation in a domain does not imply that all deformation necessarily began or ended within that time. Many late Cenozoic structural features in the valley formed over earlier structures in the upper Mesozoic or Tertiary rocks, and thus they owe their existence, in part, to tectonic heredity. In some areas, historic low-magnitude earthquakes can be identified with specific structural features such as the Battle Creek fault zone (Bolt, 1979) and Corning fault (Marks and Lindh, 1978), indicating that strain is currently being released on these structures.

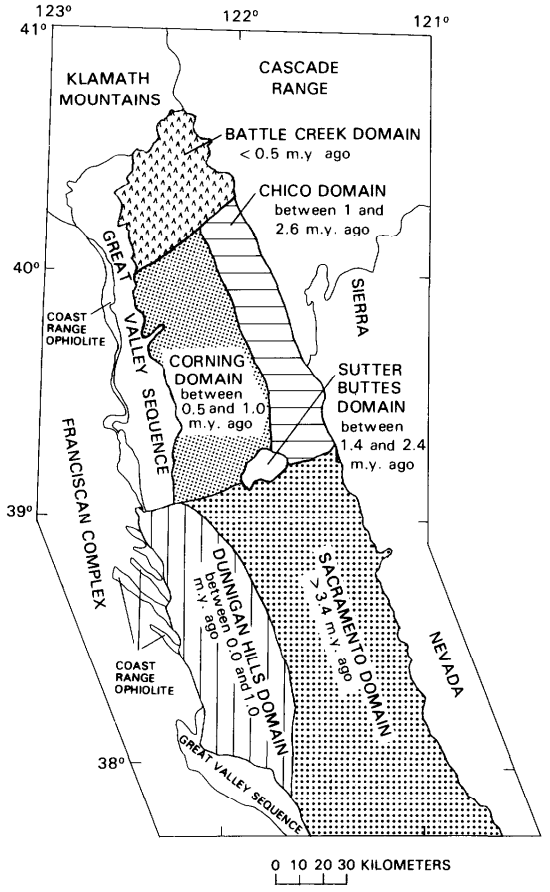


FIGURE 23.—Structural domains in Sacramento Valley. Numbers under domain names give duration or age of deformation that produced late Cenozoic structures in that domain.

SACRAMENTO DOMAIN

The Sacramento domain includes the Stockton fault, the Midland fault, the Thornton anticline, and the possible southeast extension of the Willows fault and other unnamed northwest-trending faults southeast of Sutter Buttes. None of these structures appear to offset or deform late Cenozoic alluvial deposits that are younger than the Nomlaki Tuff Member (figs. 7-10; Silcox, 1968; Teitsworth, 1968).

The minimum age of deformation is difficult to determine. If the Markley submarine canyon was localized, in part, by movement on the southeast extension of the Willows fault, as suggested by figures 8 and 9, then major deformation occurred in the domain in the middle Tertiary and could be as young as early Miocene, which is the upper age of the Markley canyon fill (Almgren, 1978). However, the Pliocene Laguna Formation, which contains the Nomlaki Tuff Member near its base just east of Marysville (Bussaca, 1982), does not appear to be offset in this domain; therefore, we conclude that deformation is older than 3.4 m.y. Upper Cretaceous rocks indicate syndepositional offset on the Stockton fault (Teitsworth, 1968) so the maximum age of deformation is Late Cretaceous.

The Willows fault north of Sutter Buttes (fig. 3) and the faults in Capay Valley (fig. 20) also show protracted deformation, ranging in age from Late Cretaceous to the middle Tertiary, that undoubtedly was contemporaneous with deformation in the Sacramento domain.

SUTTER BUTTES DOMAIN

The complex pattern of folds and faults at Sutter Buttes and the buried Colusa dome was interpreted by Williams

(1929) and Williams and Curtis (1977) to have formed by forceful intrusion of magma between 2.4 and 1.4 m.y. ago. Harwood (1984; this report) suggested that magmatism was localized at Sutter Buttes and the buried Colusa dome by movement on the Willows fault and possibly on the Mesozoic tectonic boundary between oceanic and Sierran basement terranes beneath Sutter Buttes. In this interpretation, deformation in the Sutter Buttes domain occurred through the combined effects of forceful intrusion of magma and east-west compression in a regional stress field.

Deformation in the Sutter Buttes domain may have overlapped in time with deformation in the Chico domain. However, the style of tectonism at Sutter Buttes is unique, and the area must be considered as a separate domain in a regional analysis.

Although Williams and Curtis (1977) suggested that Sutter Buttes formed in roughly half a million years, based on volume and morphology of volcanic deposits, their K/Ar ages for the volcanic complex range from about 1.4 to 2.4 m.y., and we have used that age range as the age of the structural domain.

CHICO DOMAIN

The Chico monocline is the dominant structure in the Chico domain (fig. 23). The monoclinal flexure and the controlling fault at depth (fig. 14) formed after the eruption of the Ishi Tuff Member of the Tuscan Formation, about 2.6 m.y. ago (Harwood, unpub. data, 1984), but before the eruption of the olivine basalt of Deer Creek, about 1.0 m.y. ago (Harwood and others, 1981). Formation of the monocline resulted directly from uplift of the northern Sierra Nevada and rupture along the controlling fault beneath the monocline. On the basis of geophysical evidence (Griscom, 1973; Cady, 1975), it seems reasonably certain that the controlling fault was a major late Mesozoic structure, separating oceanic from magmatic-arc crustal blocks, that was reactivated in the late Cenozoic.

Late Cenozoic tectonic uplift markedly increased erosion in streams antecedent to the monocline from Deer Creek northwest to Salt Creek just east of Red Bluff. Due to their tectonically steepened gradients, these streams deposited coarse, bouldery alluvial fanglomerate composed of volcanic material derived from the Tuscan Formation, extending from the monoclinal arch westward into the valley. The olivine basalt of Deer Creek filled the ancestral channel of Deer Creek east of the monocline and cascaded over the coarse fanglomerate, forming westward-overturned folds at the base of the flow west of the monoclinal flexure.

In Salt Creek and along nearby Hogback Road just east of Red Bluff, the fanglomerate (unit QTog of Harwood and others, 1981) rests unconformably on a partially stripped soil that developed on the Tuscan Formation. The soil indicates a significant period of nondeposition and weathering prior to flexing of the monocline and prior to rapid deposition of the alluvial fanglomerate. A period of erosion also followed deposition of the fanglomerate. The Red Bluff Formation was deposited unconformably on both the Tuscan and fanglomerate in Salt Creek. These stratigraphic relations, coupled with the fact that the Ishi Tuff Member is flexed, eroded, and unconformably overlain by the olivine basalt of Deer Creek along the monocline, establish deformation in the Chico domain between 1.0 and 2.6 m.y. This is clearly before deformation in the Corning domain to the west, where the Red Bluff is significantly folded and faulted.

The orientation of the horizontal compressive stress vector is not closely constrained in the Chico domain. Slickensides on some faults along the monocline flexure have a rake of 35° NW., suggesting some left-lateral oblique slip on the northwest-trending fault system. Whether the slickensides developed at the time the monocline formed or subsequently is unknown, but if they do record strain released during flexing of the monocline, the principal horizontal stress may have been oriented approximately east-west.

CORNING DOMAIN

West of the Chico monocline in an area extending to the Willows fault, late Cenozoic structures range in orientation from northwest to approximately north. The main stem of the Willows fault and the fault along the flank of South Corning dome nearly parallel the trend of the Chico monocline. On the other hand, the Corning fault, the Corning domes, and the Los Molinos and Glenn synclines trend more northerly than the monocline and converge on that structure near Red Bluff. All of these structures, within the Corning domain (fig. 23), deform the Red Bluff Formation and thus postdate the flexing of the Chico monocline. However, the subparallel orientation of structures in the Corning domain northeast of the Willows fault and of those in the Chico domain suggests that all may have formed in a common stress field.

The maximum horizontal compressive stress probably was oriented approximately east-west, normal to the trace of the Corning domes. The Corning fault might represent one shear diagonal of the strain ellipse, and the northwest-trending faults would indicate the other shear diagonal. In this model, strain release would have migrated westward with time, beginning along the Chico monocline and later moving to the Corning domes and Corning fault. Clearly, some offset may have occurred on the Corning fault and the northwest part of the Willows fault during formation of the monocline, and the small amount of offset in the olivine basalt of Deer Creek over the monocline may have occurred during the upwarping of the Red Bluff

Formation over the Corning domes.

The area of the Corning domain southwest of Sutter Buttes and the Willows fault is largely capped by Holocene basin deposits that lap westward onto Upper Cretaceous rocks along the western margin of the valley. These deposits could obscure many structures that might be recorded in the Red Bluff Formation in that area, indicating that the downthrown side of the Willows fault has been a structural basin throughout most of the late Quaternary.

DUNNIGAN HILLS DOMAIN

The Dunnigan Hills domain (fig. 23) includes the Zamora fault, the Dunnigan Hills anticline, the Madison syncline, and the tectonically complex area of Capay Valley and the Capay Hills. The Red Bluff Formation is folded by the Dunnigan Hills anticline and offset by the Zamora fault along the east margin of the Dunnigan Hills (fig. 20). Therefore, the late Cenozoic structures in that area are at least as young as the folds and faults in the vicinity of Corning domes, and they could be younger. Because there is no clear evidence for the minimum age of structures in the domain, we assume that late Cenozoic deformation ranges from 1.0 m.y. to the present.

Although the late Cenozoic deformation may overlap in time with that in the Corning and Battle Creek domains, the orientation and movement pattern of structures are significantly different. The northwest-trending axial surface of the Dunnigan Hills anticline and normal displacement on the northwest-trending Zamora fault suggest that these structures may have formed in a stress field in which the maximum horizontal compressive stress was oriented approximately north-south and the least horizontal compressive stress (maximum extension) was oriented approximately east-west. Because this is the present orientation of the stress field associated with the San Andreas fault in this area (Zoback and Zoback, 1980), late Cenozoic structures in the Dunnigan Hills domain may be related to right-slip wrench tectonism associated with movement on the San Andreas fault system (Allen, 1981).

BATTLE CREEK DOMAIN

The Battle Creek domain (fig. 23) is the youngest structural domain and occurs at the northern end of the valley. It is characterized by northeast-trending folds and faults oriented nearly perpendicular to the north- and northwest-trending structures of other domains to the south.

Late Cenozoic displacement on the northeast-trending, steeply south-dipping faults is invariably down to the south, with a suggestion of minor right-lateral slip on the Battle Creek fault system (Helley and others, 1981). The amount of horizontal separation on the Battle Creek fault is unknown, but it probably is on the order of a few tens of meters to a few hundred meters at the most. The Bear Creek and Red Bluff faults are not exposed well enough to establish or refute the occurrence of late Cenozoic horizontal slip on those structures. The amount of vertical displacement increases eastward along the Battle Creek fault zone, with about half of the vertical separation of units caused by broad anticlinal folding and half by fault displacement (fig. 17). Vertical separation of late Cenozoic units on the Bear Creek and Red Bluff faults is also accomplished partly by folding.

These observations, plus the fact that the Inks Creek fold system appears to be genetically related to folding and faulting on the Battle Creek fault zone, indicate that the structures in the Battle Creek domain formed either by northwest-southeast horizontal compressive stress or by right-lateral shear stress. Strain was released initially by folding, followed by rupture and predominantly normal fault displacement. Initial movement on the Battle Creek fault zone postdated deposition of fanglomerate, which is correlated with the Red Bluff Formation, and the fault scarp restricted movement of the proximal ash-flow part of the Rockland ash bed. Deformation younger than 0.45 m.y. is indicated by distribution of the early Riverbank-age alluvial deposits north of the Battle Creek fault zone and in the tectonically controlled loops of the Sacramento River around the Inks Creek fold system. The late Cenozoic structures in the Battle Creek domain formed in the past half million years.

Little surface evidence is available to document deformation before the late Cenozoic in the Battle Creek domain. A detailed analysis of paleomagnetic directions and lithofacies in the Upper Cretaceous marine rocks and Eocene continental rocks, which locally overlie the Cretaceous rocks, might provide data to resolve this question, but we did not pursue these studies. In the light of recent paleomagnetic studies (Simpson and Cox, 1980; Beck and Plumley, 1980; Magill and Cox, 1981), which suggest a two-phase, clockwise rotation of the Oregon Coast Ranges and possibly of the Klamath Mountains in Eocene and post-Oligocene times, we believe the Battle Creek domain may be a zone of decoupling between the Klamath Mountains and Oregon Coast Ranges provinces to the north and the Sacramento Valley-Sierra Nevada provinces to the south.

VALLEY STRUCTURES RELATED TO REGIONAL STRESS PATTERNS

With the exception of structures in the Dunnigan Hills domain and recent movement on the Cleveland Hills faults, late Cenozoic folds and faults in the Sacramento Valley appear to have formed in an east-west compressive stress regime. The north- and northwest-trending

Willows, Corning, and Chico monocline faults dip steeply east and show reverse displacements. The east-northeast-trending Red Bluff, Battle Creek, and Bear Creek faults dip steeply south and have normal offsets. The axial traces of many folds are parallel to the trends of adjacent faults, and the folding appears to be related to drag on those faults. The amount of lateral displacement on faults in the valley is difficult to determine, but the rake of slickensides and the orientation of ancilliary fractures suggest minor left-lateral movement on the northwest-trending Chico monocline fault and minor right-lateral slip on the east-northeast-trending Battle Creek fault zone. These kinematic patterns are consistent with a regional stress field in which the maximum horizontal component of compressive stress is oriented about N. 75° E. (Harwood, 1984).

The late Cenozoic kinematic pattern and inferred east-west compressive stress regime in the Sacramento Valley appear to be anomalous with respect to contemporary tectonism in adjacent regions. In the California Coast Ranges to the west and in the northern Basin and Range province to the east, north-trending faults generally show normal and right-lateral displacements, east-trending faults show reverse and left-lateral movement, and northwest- and northeast-trending faults show dominantly right-lateral and left-lateral displacement, respectively (Zoback and Zoback, 1980; Hill, 1982). From these kinematic patterns, as well as earthquake focal-plane solutions, and in-situ stress measurements, Zoback and Zoback (1980) and Hill (1982) inferred that the maximum horizontal compressive stress was oriented approximately north-south and the least horizontal compressive stress (maximum extension) was oriented approximately east-west. Hill (1982) related the contemporary stress patterns to movement between the North American and Pacific plates and visualized the western part of the North American plate as a continuous broad zone of deformation following the model first proposed by Atwater (1970).

East-west compressive deformation in the Sacramento Valley suggests that the late Cenozoic stress field was not homogeneous between the continental margin and the northern Basin and Range province. Instead, the Sacramento Valley apparently acted as an independent block where relatively small-scale compressive strain was periodically released in response to large-scale right-lateral transform tectonism in the San Andreas fault zone to the west and major east-west crustal extension in the northern Basin and Range province to the east.

Furthermore, the well-dated deformation patterns in the Sacramento Valley indicate that the compressive strain was not released randomly but, rather, that the late Cenozoic structural features formed in a sequential pattern that is progressively younger to the north. Northward progression of the compressive deformation implies a northward-migrating stress regime or a migrating energy source sufficient to initiate deformation in a regional compressive stress field. The interaction of lithospheric plates along the continental margin appears to provide a reasonable mechanism for generating the sequential compressive strain release observed in the valley.

Successive positions of the Mendocino transform, extrapolated backward in time to 4.0 m.y. at a rate of 5.5 cm/yr (Atwater and Molnar, 1973), are shown relative to the late Cenozoic structural domains in the Sacramento Valley in figure 24. Each domain is characterized by a particular set of late Cenozoic structural features that formed during a definite period of time. The time of deformation in the structural domains is linked to respective positions of the Mendocino transform by corresponding patterns on figure 24. Compressive deformation in the Sacramento domain occurred prior to eruption of the Nomlaki and Putah Tuff Members of the Tehama Formation about 3.4 m.y. ago, but we are unable to correlate movement on specific structures in that domain with relative plate motions shown by successive positions of the Mendocino transform. Beginning with magmatism and deformation in the Sutter Buttes domain about 2.4 m.y. ago, however, reasonable correlation exists between the position of the Mendocino transform and progressive east-west compressive deformation in the Sacramento Valley. This correlation clearly reflects the availability of geologic information that dates deformation in the northern part of the valley, but it may also reflect a greater degree of tectonism in the valley over the past 2.4 m.y. that was related to increased tectonism ahead of the advancing Mendocino triple junction (fig. 24).

According to Silver (1971), an episode of major bending and fracturing occurred in the Juan de Fuca plate (fig. 24) between 2.5 and 0.5 m.y. ago. This deformation apparently increased the north-south compressive stress ahead of the advancing Mendocino triple junction and caused underthrusting of oceanic crust in the Juan de Fuca plate beneath the Mendocino transform. Dickinson and Snyder (1979a) suggested that this type of instability at the Mendocino triple junction would increase the east-west extensional stress in the vicinity of the triple junction and possibly cause eastward migration of right-slip strain release along the San Andreas fault zone. Internal deformation of the Juan de Fuca plate also may have changed the rate and relative motion of the subducted part of that plate relative to the North American plate sufficiently to initiate magmatism at Sutter Buttes and at the Pliocene volcanic centers of Mount Yana and Mount Maidu (fig. 24) (Lydon, 1968) about 2.4 m.y. ago. Subsequent relative movement of the North American plate southwestward from its position above the subducted Juan de Fuca slab, over the eastern projection of the Mendocino transform and onto the area of the slab

window of Dickinson and Snyder (1979b), may have initiated progressive deformation in the Sacramento Valley north of the Sutter Buttes domain.

According to Dickinson and Snyder (1979b), an expanding, triangular-shaped region, which they called the slab window, has developed east of the lengthening San Andreas transform since the rise-trench encounter about 20 m.y. ago. As the slab window expanded, upwelling asthenosphere came into contact with the base of the North American crust producing an expanding region of Neogene extensional tectonism. The northern boundary of the slab window, which is the eastern projection of the Mendocino transform, migrated northward as a consequence of the northward migration of the Mendocino triple junction and relative motion between the North American and Juan de Fuca plates. Successive positions of the northern boundary of the slab window beneath the Sacramento Valley for the past 2.5 m.y. are shown in figure 25.

About 2.5 m.y. ago, the northern boundary of the slab window was located approximately at the latitude of Sutter Buttes (fig. 25*A*). As the North American plate moved southwestward relative to the Juan de Fuca plate, the base of the valley crust near Sutter Buttes moved off the subducted ocean crust of the Juan de Fuca plate and encountered asthenophere in the slab window. This change in thermal regimes at the base of the valley crust possibly reactivated the Willows fault and the ancient tectonic boundary between ophiolitic basement rocks and the Sierran basement rocks, allowing magma to rise and differentiate below Sutter Buttes and the buried Colusa dome. Subsequent southwestward relative movement of the North American plate exposed an increasing area of the Sacramento Valley and northern Sierra Nevada crustal blocks to the higher thermal regime of the slab window. Basaltic volcanism erupted in the Tahoe-Almanor graben (fig. 25*A*) north of Lake Tahoe soon after magmatism began at Sutter Buttes (Dalrymple, 1964). Ac-

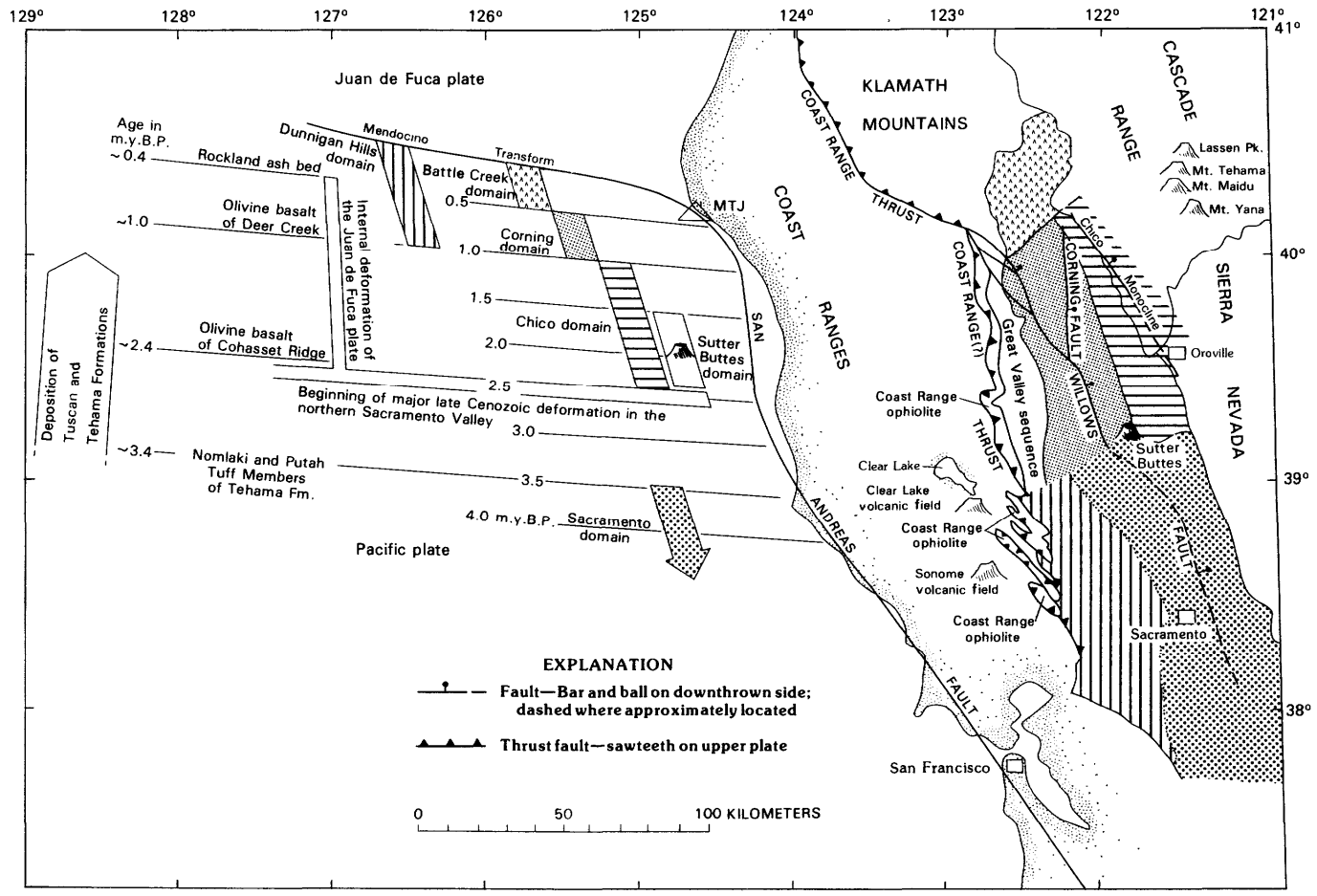
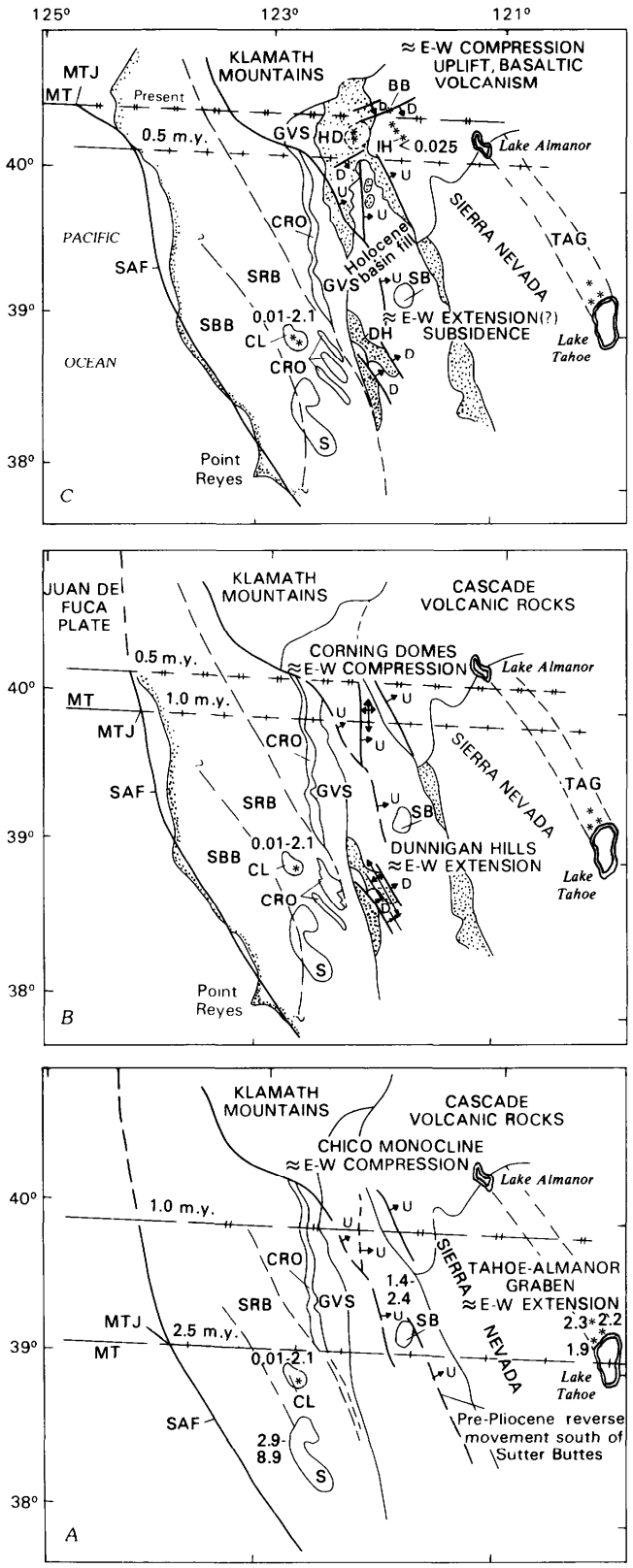


FIGURE 24.—Map of northwestern California relating late Cenozoic structural features and structural domains (patterned) to inferred position of the Mendocino triple junction (MTJ) during time structures formed. Position of Mendocino transform shown in 0.5-m.y. increments during past 4.0 m.y. Dated volcanic units used to bracket age of deformation in Sacramento Valley shown at left.



celerated uplift of the Sierra Nevada, which began about 3.0 m.y. ago in the central part of the range (Huber, 1981; Slemmons and others, 1979), eventually caused rupture between 2.5 and 1.0 m.y. ago along the Mesozoic fault that separates valley and Sierran blocks beneath the Chico monocline. Volcanism at Clear Lake (fig. 25), which began about 2.1 m.y. ago (Donnelly-Nolan and others, 1981), lagged behind passage of the northern boundary of the slab window and has continued nearly to the present.

Between 1.0 and 0.5 m.y. ago (fig. 25*B*), exposure of the base of the valley crust to the slab window may have reactivated the basement fault in the vicinity of the Corning domes, resulting in east-west compressional tectonism. Wrench tectonism and related east-west extension apparently started to affect the southwestern part of the valley after creating a zone of high shear strain in the Santa Rosa block (Fox, 1983), located in the eastern part of the Coast Ranges province. This is the earliest evidence of east-west extensional tectonism found in the valley and suggests a delay time of about 2.5 m.y. between passage of the slab-window boundary and production of recognizable extensional structures.

In the past 0.5 m.y., the northern boundary of the slab window has passed beneath about half of the Battle Creek domain (figs. 24, 25*C*). The morphology of the valley in the Battle Creek domain, therefore, may reflect recent,

EXPLANATION

- Pliocene and Pleistocene alluvium
- * Volcanic center at—
  - BB Black Butte
  - IH Inskip Hill
  - HD Hooker dome
  - CL Clear Lake
  - SB Sutter Buttes
  - S Sonoma volcanic field
- TAG Tahoe-Almanor graben
- MT Mendocino transform
- MTJ Mendocino triple junction
- SAF San Andreas fault
- SBB Sebastopol block
- SRB Santa Rosa block
- CRO Coast Range ophiolite
- GVS Great Valley sequence
- DH Dunnigan Hills
- 1.4-2.4 Numbers indicate age or time of formation of feature, in millions of years. ≈ means approximate
- Contact—Dashed where inferred
- Fault—Dashed where inferred; arrow indicates dip
- D Normal—D, hanging wall
- U Reverse—U, hanging wall
- Doubly plunging anticline
- Syncline

FIGURE 25.—Sketch maps of northwestern California showing inferred positions of northern boundary (barbed dashed lines) of slab window of Dickinson and Snyder (1979b) at about 2.5 and 1.0 m.y. (*A*), 1.0 and 0.5 m.y. (*B*) and 0.5 m.y. and present (*C*).

and possibly on-going, structural changes in the deeper parts of the valley fill and basement caused in part by changes in the thermal regime beneath the thick valley crust. This hypothesis was investigated by Helley and Jaworowski (1983), who used the distribution of the Red Bluff pediment as a surface indicator of deeper valley structures. The elevation of the floor rises abruptly north of Red Bluff, and the dissected uplands expose the Pliocene Tehama Formation that is unconformably capped by remnants of the Red Bluff Formation. Drainage patterns reflect local structures, such as Hooker dome (fig. 18), and major creeks locally follow the dominant northeast structural trends. The gradient of the Sacramento River steepens significantly across the Battle Creek domain, and its incised meanders are structurally controlled. Many of these geomorphic features are preserved, in somewhat more subdued form, around Corning domes and elsewhere in the valley south of Red Bluff (Helley and Jaworowski, 1985).

The northeast-trending Inks Creek fold system and the folding associated with the Battle Creek and Red Bluff faults suggest a northwest-southeast compressive stress system. If such is the case, however, normal displacement on the Bear Creek, Battle Creek, and Red Bluff faults are anomalous. The structural features in the Battle Creek domain may reflect a stress regime in which the maximum horizontal compressive stress (east-west) and the least horizontal compressive stress (north-south) vectors are more nearly equal. This inferred change in the stress pattern may be caused by oblique subduction of the Juan de Fuca plate and the possible buttressing effect of the Klamath Mountains on deformation in the northernmost part of the Sacramento Valley.

CONCLUSIONS

Kinematic patterns of late Cenozoic structural features in the Sacramento Valley differ significantly from those in the Coast Ranges province to the west and the northern Basin and Range province to the east. Certainly for the past 2.5 m.y., and probably much longer, deformation in the valley has occurred in a regional stress field in which the maximum horizontal component of compressive stress was oriented approximately east-west and the minimum component of compressive stress (maximum extension) was oriented approximately north-south. Within this stress regime, strain has been released primarily by reverse movement on north- and northwest-trending high-angle faults and associated folding in the sedimentary rocks of the valley fill. This style of deformation contrasts sharply with the pattern of northwest-trending en echelon folds and pull-apart basins, and east-west oriented thrust faults associated with large-scale right-lateral displacements on the San Andreas fault system (Blake and others, 1978; Graham, 1978; Harding, 1976; McLaughlin, 1981; Page, 1981) and the pattern of pervasive normal faulting, widespread volcanism, and large-scale east-west extension in the Basin and Range province (Christiansen and Lipman, 1972; Lipman and others, 1972; Zoback and others, 1981). During the late Cenozoic, the Sacramento Valley appears to have acted as an independent block on which relatively small-scale compressive deformation was imposed by eastward-directed subduction that was followed by large-scale transform tectonism along the continental margin and major east-west crustal extension in the Basin and Range. Early Tertiary deformation on the Willows fault and in the area of Capay Valley may be related to eastward tectonic wedging of the Franciscan Complex described by Wentworth and others (1984).

Tectonic heredity appears to have played a significant role in late Cenozoic deformation in the Sacramento Valley. Many of the faults that break or drape the upper Cenozoic deposits are located over pre-existing structures within and at the boundaries of basement blocks that were tectonically juxtaposed and broken during the Mesozoic and early Tertiary. The tectonic boundary between ophiolitic and Sierran basement rocks apparently has been reactivated beneath the Chico monocline and the possible southeast extension of the Willows fault. The Corning fault occurs over a Mesozoic fault within the ophiolitic basement terrane.

Within the past 2.5 m.y., at least, late Cenozoic east-west compressive deformation has progressed northward so that structures observed in the Battle Creek domain are a million years younger than those around Sutter Buttes. The northward progress of late Cenozoic deformation correlates with extrapolated positions of the Mendocino transform. Deformation may have been initiated by thermal changes in the valley basement as the North American plate moved relatively southwestward off the subducted oceanic crust of the Juan de Fuca plate and over asthenosphere in the slab window proposed by Dickinson and Snyder (1979b). During this sequential deformation, the relative magnitude of the horizontal compressive stress vectors appears to have changed. The kinematic pattern of structures south of Red Bluff suggests that east-west compression was dominant ($S_{maxEW} >> S_{minNS}$) and resulted in high-angle reverse faulting. However, the horizontal compressive stresses appear to have been more nearly equal ($S_{maxEW} \cong S_{minNS}$) in the Battle Creek domain causing northeast-trending folds and normal displacements on east-northeast-trending faults.

Northwest-trending folds and normal displacement on the Zamora fault suggest that east-west extension may have affected the southwestern part of the valley during the past million years, when east-west compressive deformation was occurring in the Corning domain. Focal-plane solutions constrained by geologic data in the Clear

Lake area indicate that the maximum compressive stress in the Coast Ranges is presently oriented approximately north-south (Bufe and others, 1981). These data, coupled with the observation that right-lateral tectonism is more intense in the Coast Ranges adjacent to the Dunnigan Hills domain than it is to the west or north (Fox, 1983), suggest that late Cenozoic deformation in the Dunnigan Hills domain was related to wrench tectonism on the San Andreas fault system. If such is the case, the beginning of right-lateral wrench tectonism in the valley appears to have lagged behind the northward migration of the Mendocino triple junction by about 2.5 m.y. A similar delay was noted between the migration of the triple junction and the build-up of maximum heat flow in the Coast Ranges by Lachenbruch and Sass (1980).

The well-dated and diverse deformation patterns in the Sacramento Valley indicate that late Cenozoic tectonism evolved through the region in response to major crustal movements outside the valley's physiographic boundaries. East-west compressive tectonism may have been imposed on the valley by eastward subduction of the Juan de Fuca plate, and consequent tectonic wedging of the Franciscan Complex coupled with a major component of westward stress due to east-west extension in the Basin and Range province.

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APPENDIX—*Wells with electric well-log data shown in cross sections*

Well no.	Operator	Well name	Sec.-T.-R.
	Wells on figure 3		
1.	Texaco	Cross No. 1	27-20N.-3W.
2.	Franco Western Oil Co.	Dunlap 36-1	36-20N.-3W.
3.	Marathon Oil Co.	Capital Co. No. 1	30-20N.-2W.
4.	R. W. McBurney	Westpet Sunray McBurney Capitol No. 1	30-20N.-2W.
5.	Mobil Oil Corp.	Capital Co. No. 30-1	30-20N.-2W.
6.	Mobil Oil Corp.	Section 29 Unit No. 4	29-20N.-2W.
7.	R. W. McBurney	Section 29 Unit No. 2	29-20N.-2W.
8.	Mobil Oil Corp.	Section 48 Unit No. 4	21-20N.-2W.
9.	Mobil Oil Corp.	Section 48 Unit No. 1	21-20N.-2W.
10.	Standard Oil Co.	Doheny N. G. Unit No. 1	22-20N.-2W.
11.	Mobil Oil Corp.	Section 46 Unit No. 2	27-20N.-2W.
12.	Bettie A. McBurney	Reserve McBurney Unit S1 No. 1	26-20N.-2W.
13.	Bettie A. McBurney	Section 52 Unit No. 3	25-20N.-2W.
14.	Neaves Pet. Devel. Co.	Neaves Capital 53-1	32-20N.-1W.
15.	Mobil Oil Corp.	Dano Seco No. 1	33-20N.-1W.
16.	Calif. Time Pet. Inc.	Butte Dano Seco No. 4	34-20N.-1W.
	Wells on figure 7		
1.	Occidental	Zumwalt K-2	12-13N.-1E.
2.	Shell	Strat. test well	31-14N.-2E.
3.	G. E. Kadane & Sons	Lamb No. 1	30-14N.-2E.
4.	Atlantic	AMKH et al	28-14N.-2E.
5.	Atlantic	Continental Stent No. 1	15-14N.-2E.
6.	Kenneth L. Sperry	Shannon No. 1	10-14N.-2E.
7.	Exxon	Shannon No. 1	14-14N.-2E.
8.	Pearson Sibert	Tom No. 1	5-14N.-3E.
	Wells on figure 8		
1.	Sun Oil Co.	SMC Cameron Dougherty No. 1	31-12N.-3E.
2.	McCulloch Oil & Gas Corp.	McCulloch-Magoon et al. No. 1	32-12N.-3E.
3.	Davis Oil Co.	Aileen Marty No. 1	35-12N.-3E.
4.	Davis Oil Co.	Van Dyke No. 1	35-12N.-3E.
5.	Decalta Int. Corp.	Osterli No. 3	31-12N.-4E.
6.	Sun Oil Co.	Lenert No. 55-29	29-12N.-4E.
7.	Kenneth L. Sperry	Davis No. 1	21-12N.-4E.
8.	Plateau Oil & Gas Co.	Van Dyke No. 1	24-12N.-4E.
9.	Exxon	Bonnefeld No. 1	10-12N.-5E.

Well no.	Operator	Well name	Sec.-T.-R.
	Wells on figure 9		
1.	Rocky Mtn. Drilling Co.	Murdoch No. 1	27-7N.-4E.
2.	McCulloch Oil & Gas Corp.	Scribner No. 1	27-7N.-4E.
3.	Chevron	Correa No. 1	24-7N.-4E
4.	Neaves Pet. Devel. Co.	Neaves-Standard Oil Sims No. 3	18-7N.-5E.
5.	Chevron	Sims Comm. No. 2	18-7N.-5E.
6.	Calif. Expln. Co.	Sacramento Unit A	16-7N.-5E.
7.	Union Oil Co. of Calif.	Union Dow Attorney General No. 1	13-7N.-5E.
8.	Intex Oil Co.	Unit plan No. 1	19-7N.-6E.
9.	D. D. Feldman	Unit plan No. 1	8-7N.-6E.
10.	Norris Oil Co.	Waegell No. 1	6-7N.-7E.
	Wells on figure 10		
1.	Shell Oil Co.	Shell-Brevelli No. 1	4-4N.-6E.
2.	Amerada Hess Corp.	Comm. 1-2	2-4N.-6E.
3.	Amerada Hess Corp.	Comm. 1-1	1-4N.-6E.
4.	Aminoil USA, Inc.	Comm. 2-1	12-4N.-6E.
5.	Union Oil Co. of Calif.	V-B-G No. 1	7-4N.-7E.
6.	Amerada Hess Corp.	Lodi Comm. 8-1	8-4N.-7E.
7.	Amerada Hess Corp.	Lodi Comm. 9-1	9-4N.-7E.
8.	Shell Oil Co.	Ferrera No. 1-10	10-4N.-7E.
9.	Ben Owens Drilling Co.	Thompson No. 1	11-4N.-7E.
	Wells on figure 14		
1.	Solar Drilling Co.	Solar-McElroy-Crawford No. 1	5-23N.-1W.
2.	Pacific Western	Cana No. 1	11-23N.-1W.
3.	Exxon	G. U. Roney No. 1	1-23N.-1W.
4.	Exxon	C. C. Baccala No. 1	28-24N.-1E.
	Wells on figure 20		
1.	Neaves Pet. Devel. Co.	Neaves-Cobb No. 1	11-10N.-3W.
2.	Empire Oil and Gas Co.	Porterfield No. 1	18-10N.-2W.
3.	Texaco, Inc.	Esparto c.h. No. 2	17-10N.-2W.
4.	Dow Chemical Co.	Duncan No. 1	9-10N.-2W.
5.	Gulf Oil Corp.	A. B. Stevens No. 1	7-10N.-1W.
6.	Atlantic Oil Co.	Irrigated Valley Land No. 1	4-10N.-1W.
7.	A. A. Hopkins, Jr.	Manler No. 62-3	3-10N.-1W.
8.	C. K. M. Oil Co.	Mast No. 1	35-11N.-1W.
9.	Gulf Oil Corp.	L. M. Bemmerley No. 1	36-11N.-1W.
10.	E. B. Towne	Slaven No. 1	30-11N.-1W.
11.	Arco	Reiff No. 1	29-11N.-1W.
12.	Arco	Hermle No. 1	15-11N.-1E.

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GEOCHEMISTRY OF GROUND WATER IN THE SACRAMENTO VALLEY, CALIFORNIA

REGIONAL AQUIFER-SYSTEM ANALYSIS



U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1401–B

Geochemistry of Ground Water in the Sacramento Valley, California

By LAURENCE C. HULL

CENTRAL VALLEY OF CALIFORNIA RASA PROJECT

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1401–B



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CONVERSION FACTORS

Factors for converting inch-pound units to the International System (SI) of units are given below:

Multiply	*By*	*To obtain*
acres	0.004047	km^2 (square kilometers)
acre-ft (acre-feet)	0.001233	hm^3 (cubic hectometers)
ft (feet)	0.3048	m (meters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)

Degrees Fahrenheit are converted to degrees Celsius by using the formula: °C=(°F-32)/1.8

Additional abbreviations:

µg/L	(micrograms per liter)
mm	(millimeters)
mg/L	(milligrams per liter)
(mg/L)/yr	(milligrams per liter per year)

National Geodetic Vertical Datum of 1929 (NGVD of 1929). A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is sometimes referred to as sea level in this report.

CENTRAL VALLEY OF CALIFORNIA RASA PROJECT

GEOCHEMISTRY OF GROUND WATER IN THE SACRAMENTO VALLEY, CALIFORNIA

By LAURENCE C. HULL

ABSTRACT

A geochemical investigation was done to evaluate temporal changes in water quality and to determine the processes that control water chemistry in shallow ground water of the Sacramento Valley, California. A total of 671 chemical analyses from 651 wells were used to study the processes controlling water chemistry. Temporal variations in dissolved-solids and nitrate concentrations were studied in 140 and 62 wells, respectively, having multiple observations with time.

The Sacramento Valley can be divided into six hydrochemical facies having distinctive chemical compositions. Waters from the Tuscan volcanic rocks and Victor Plain facies, along the eastern margin, have lower concentrations of dissolved solids and higher concentrations of silica than the waters from other areas of the Sacramento Valley. Ground waters in the basin hydrochemical facies (Butte Basin and Sutter Basin) along the valley axis are higher in iron, manganese, arsenic, and potassium. West side facies, the north alluvial fans and south alluvial fans, are low in silica. The south alluvial fans facies is higher in dissolved solids and has very high boron concentrations.

Significant increases have occurred in dissolved-solids and nitrate concentrations since the mid-1950's. Dissolved solids increased in five of the six hydrochemical facies, with rates ranging from 0.95 milligrams per liter per year in the Tuscan volcanic rocks facies to 4.75 milligrams per liter per year in the south alluvial fans facies. Nitrate-nitrogen did not significantly increase in the Tuscan volcanic rocks, Butte Basin, or Sutter Basin hydrochemical facies. Rates of increase of 0.036, 0.036, and 0.099 milligrams per liter per year occurred in the Victor Plain, south alluvial fans, and north alluvial fans, respectively.

Two processes control over 50 percent of the spatial variation in ground-water chemistry. Thirty-six percent of the variation in the data is explained by the effects of recharge water chemistry on the chemistry of ground water. Low dissolved solids and high silica from east-side recharge produces fairly uniform conditions in east-side ground waters. Recharge from the northwest is intermediate in dissolved solids and silica. Southwest recharge is high in dissolved solids, boron, and fluoride. High boron concentrations in the ground water originate in thermal springs in the Coast Ranges. A second important process consists of reactions occurring in the fine-grained sediments of the flood basin in the central part of the Sacramento Valley. Reducing conditions here produce higher concentrations of manganese, iron, and arsenic. Nitrate concentrations are low, probably reflecting denitrification reactions.

Precipitation and dissolution of aluminosilicates appear to control the relation between silica and aluminum in parts of the valley. Silica and aluminum in ground waters of the Sutter Basin hydrochemical facies show parallel behavior and have a ratio of 3 to 1. In the Tuscan volcanic rocks facies silica and aluminum are inversely related and are controlled by the solubility of halloysite. The clay minerals halloysite and illite were identified in the sediments. The clay mineral predicted to be the most stable in equilibrium with valley ground water is montmorillonite. Halloysite represents an intermediate step in the weathering of primary minerals to more stable secondary phases.

INTRODUCTION

GEOGRAPHY

The Sacramento Valley comprises the northern third of the Central Valley of California in the north-central part of the State (fig. 1). It is a sedimentary basin bounded by mountains to the east (Sierra Nevada), northeast (Cascade Range), and west (Coast Ranges). To the south, the valley merges with the delta of the Sacramento and San Joaquin Rivers. The area lies between 38°30′ and 40°15′ N. latitude, and 121°15′ and 122°30′ W. longitude. The valley covers about 4,400 square miles, is 150 miles in length from Red Bluff to the delta, and ranges in width from about 8 miles at Red Bluff to about 50 miles near the southern end. The topography consists of generally flat plains, with low dissected hills near the margins. The elevation of the valley at the southern end is near sea level, increasing northward and reaching 300 feet above sea level near Red Bluff. The relatively flat topography of the valley is interrupted near the center, where a volcanic neck of late Tertiary age, Sutter Buttes, rises 2,100 feet above the valley floor.

The Sacramento River enters the valley from the north and flows along the entire length of the valley before entering the delta region to the south. The Feather River is the only other principal stream that flows through the valley. The Sacramento and Feather Rivers are fed by tributaries draining the surrounding mountain areas. From the Sierra Nevada come the American, Bear, Yuba, and Feather Rivers. The Cascade Range is drained primarily by Big Chico, Butte, Mill, and Deer Creeks in the area adjacent to the Sacramento Valley. The streams entering the valley from the west rise in the Coast Ranges and are much smaller than the streams from the east. Thomes, Stony, Cache, and Putah Creeks are the only sizable streams entering

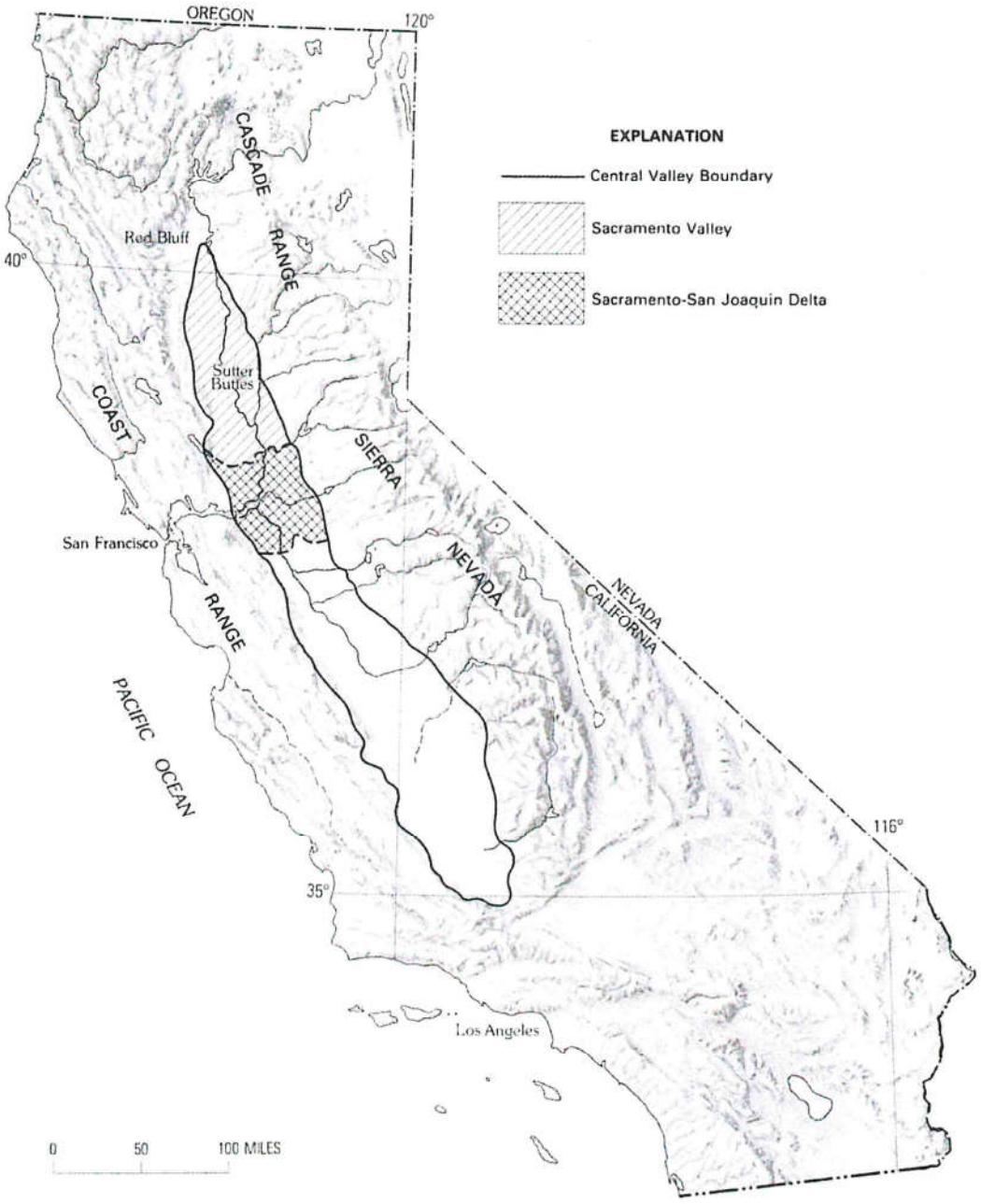

FIGURE 1.—Location map showing Sacramento Valley of California.

the west side of the valley. (See pl. 1*B* for stream locations.)

Little precipitation falls in the valley during the summer growing season, and irrigation is necessary to support extensive agricultural development. Early irrigated farming began in the mid-1800's as the gold miners moving to California created a demand for foodstuffs. Development of irrigation was slow, however, until the drought of 1864 stimulated the construction of new irrigation projects. During both world wars, heavy demand for agricultural products spurred periods of rapid development. Ground water has always lagged behind surface water as a source of irrigation water, amounting to only about 10 percent of the total use in the late 1910's. Since the late 1950's, however, the use of ground water has been increasing, and in 1970,

it accounted for about 40 percent of all irrigation water used in the Sacramento Valley.

PURPOSE AND SCOPE

The U.S. Geological Survey began a series of hydrologic investigations—the regional aquifer systems analysis (RASA) program—to aid effective management of the Nation's ground-water resources by providing information on the hydrology and geochemistry of regional aquifer systems (Bennett, 1979). The Central Valley aquifer project, covering the Central Valley of California, is one of 29 such projects throughout the country and was started because of the long history of ground-water development and the importance of the area's agricultural production to the national economy (Bertoldi, 1979). Specific water-quality information needed for effective management in the future includes (1) the general inorganic chemical character of water from aquifers currently in use, (2) delineation of areas where degradation is occurring and where degradation may occur in the future, (3) the changes that have occurred in ground-water quality with time, and (4) the processes that control ground-water chemistry. This report evaluates temporal changes and geochemical processes as they influence the chemical quality of shallow ground water in the Sacramento Valley, the northern third of California's Central Valley. A companion report (Fogelman, 1983) deals with spatial variations in the chemical character of ground water and the delineation of areas of potential water-quality problems for this same study region.

DATA COMPILATION

Collection of additional water-quality samples was unnecessary because of the extensive data base of the U.S. Geological Survey and California Department of Water Resources. Chemical analyses from 653 wells throughout the Sacramento Valley sampled by the Geological Survey between 1974 and 1976 were already in the Survey's water-quality file (Fogelman, 1975, 1976; Fogelman and Rockwell, 1977). From the unpublished files of the California Department of Water Resources, an additional 2,136 analyses from 281 wells were added to the water-quality file. During the summer of 1979, 63 additional samples were collected by the Geological Survey in Yolo County to extend coverage into an area where high boron concentrations suggested a need for water-quality evaluation. All wells from which chemical analyses were used in this study have driller's logs on file with the California Department of Water Resources. Thus, reasonably reliable information is available about depths and perforated intervals for these wells. Some of the samples represented multiple observations over time from single wells, and these were used for the temporal studies. Samples for the period 1974–79 were examined, and complete analyses with less than 5 percent error in the electrical balance between cations and anions were used to study the spatial variation in the valley. These latter data consisted of 671 analyses from 651 wells.

Manipulation of data files and the statistical analyses used in this report were accomplished using the Statistical Analysis System (SAS)[1] programs on the U.S. Geological Survey's Reston computer system.

WELL-NUMBERING SYSTEM

Wells are identified according to their location in the rectangular system used for the subdivision of public lands. The identification consists of the township number, north or south; the range number, east or west; and the section number. A section is further divided into sixteen 40-acre tracts lettered consecutively (except I and O), beginning with A in the northeast corner of the section and progressing in a sinusoidal manner to R in the southeast corner. Within the 40-acre tract, wells are sequentially numbered in the order they are inventoried. The final letter refers to the base line and meridian relative to which the townships and ranges are numbered. For the Sacramento Valley, this is the Mount Diablo base line and meridian (M). Figure 2 shows how the well number 11N/02E–23N01M is derived.

ACKNOWLEDGMENTS

The California Department of Water Resources has cooperated with the U.S. Geological Survey in past studies during which much of the data analyzed in this report were collected. The Department also provided additional unpublished chemical-quality data from their files. The author would like to thank J. R. Slack of the Geological Survey for his helpful suggestions on trend analysis. The cooperation of the residents of the Central Valley who have permitted the Geological Survey to collect water samples from their wells is also appreciated.

DESCRIPTION OF THE STUDY AREA

GEOLOGY AND GEOMORPHOLOGY

The Geology and geomorphology of the Sacramento Valley have been covered in detail by Olmsted and Davis (1961), the California Division of Mines and Geol-

[1]Use of trade names does not imply endorsement and is used for information only.

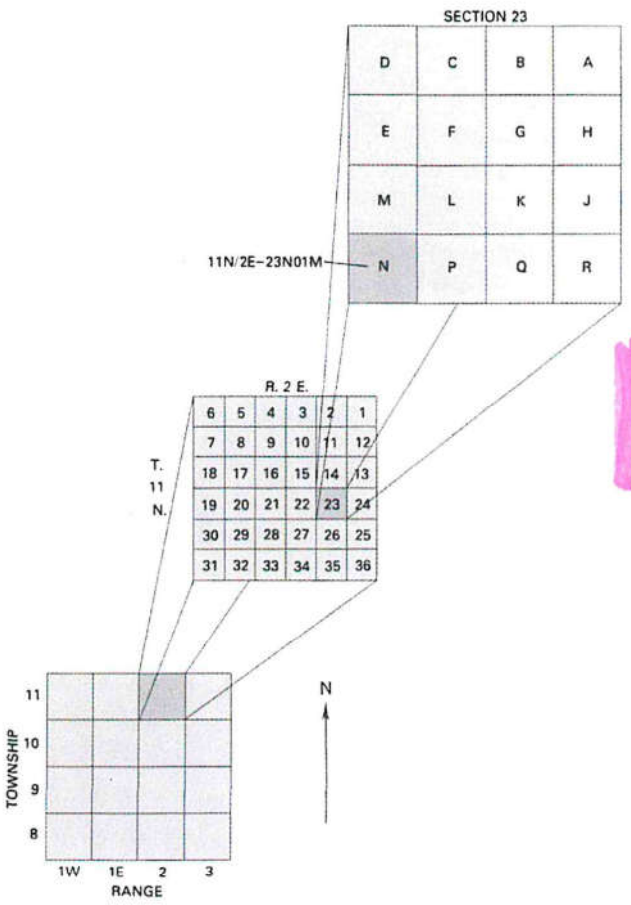

FIGURE 2.—Well-numbering system.

ogy (1966), and the California Department of Water Resources (1978a). Detailed maps and complete descriptions of the geology can be found in these publications. In this section, the geology and geomorphology are only briefly reviewed, with particular attention given to water-bearing characteristics and importance for water quality.

GEOLOGIC SYNOPSIS

The Sacramento Valley is an elongated structural trough trending to the northwest through central California. The trough is filled with a thick accumulation of sediments, perhaps as much as 50,000 feet in the deepest parts. Deposition has been occurring since early in the Cretaceous Period, with the bulk of the deposition occurring in a marine environment. A maximum of only 3,000 feet of continental deposits has been laid down as a veneer over the marine sediments. During early Tertiary time, the Cretaceous sediments west of the valley were folded and uplifted, forming the Coast Ranges and isolating the Sacramento Valley from the ocean to the west.

Early- and middle-Tertiary sedimentation was primarily confined to the southern and eastern parts of the valley, with only those sediments adjacent to the Sierra Nevada being continental deposits. During late Tertiary time, continental deposits were laid down throughout the valley, and deposition continued into Quaternary time. These continental deposits include the Tehama, Tuscan, Laguna, and Mehrten Formations and form some of the most important aquifers in the valley. Also, near the end of the Tertiary Period, andesitic lava was extruded through the older marine sediments to form Sutter Buttes, a prominent volcanic neck in the middle of the Sacramento Valley.

During Pleistocene time, continental deposition continued throughout the valley. Alluvial fans and plains developed from sediments eroded from the Sierra Nevada to the east and the Coast Ranges to the west. Continued action of rivers flowing through the valley produced alluvial channel deposits and natural levees along the axis of the valley and produced flood basins adjacent to the rivers.

GEOMORPHIC UNITS

The Sacramento Valley is generally characterized by alluvial plains and fans bounded by rugged mountains. The geomorphic units described by Olmsted and Davis (1961) are (1) Sierra Nevada, (2) Coast Ranges, (3) Cascade Range, (4) low hills and dissected uplands, (5) alluvial plains and fans, (6) flood basins, (7) stream channels and natural levees, and (8) Sutter Buttes. In this section, the location and extent of the geomorphic units are described, and the geologic formations composing each unit discussed. Attention will be given to the lithology, mineralogy, and water-bearing characteristics of the geologic units where information is avaliable. The location of the geomorphic units are illustrated on plate 1*A*.

(1) *Sierra Nevada.* The Sacramento Valley is bounded on the east by the mountainous Sierra Nevada, a massive block of the Earth's crust that has been uplifted and tilted westward. The block extends under the sediments of the valley and underlies the eastern part at depth. The Sierra Nevada is composed of intrusive igneous rocks, metamorphosed volcanic rocks, and Paleozoic sedimentary rocks. The intrusive rocks are mainly granodiorite and quartz diorite with andesitic and rhyolitic extrusive rocks. In addition to the feldspars, quartz, and biotite of the igneous rocks, a wide variety of other minerals is present. These include cal-

cite, magnesite, barite, serpentine, metal sulfides, and others. The massive rocks of the Sierra Nevada contain little water, with the little that is available occurring in joints and fractures. The water quality of streams draining the Sierra Nevada is generally very good.

(2) *Coast Ranges.* The Coast Ranges, adjacent to the west of the valley, consist of Cretaceous marine sedimentary rocks folded and uplifted into ridges trending northwest-southeast, parallel to the valley. The Cretaceous rocks dip eastward and underlie much of the Sacramento Valley at depth. Also present in the Coast Ranges is the Franciscan Complex, which consists of highly metamorphosed marine sedimentary rocks of late Mesozoic age. The major rock type is this geologic unit is greywacke, interbedded with shales and minor limestone units. The primary minerals of the sedimentary rocks are plagioclase and quartz. Many lithic fragments present contain chert, chlorite, and mica. Ultramafic minerals have been metamorphosed to serpentine and magnesite. The marine sedimentary rocks are mostly consolidated and contain little water. Some units retain connate saline water, and streams draining the Coast Ranges may be contaminated by saline springs.

(3) *Cascade Range.* Between Oroville and Red Bluff, the northeastern part of the Sacramento Valley is bounded by the Cascade Range geomorphic unit. Adjacent to the valley, this unit is composed of the gently southwestward dipping Tuscan Formation of Pliocene age. On the surface, the Tuscan Formation is extensively eroded, and southwestward flowing streams have incised deep canyons. Beneath the valley, the Tuscan extends westward under younger valley sediments as far as the Sacramento River, and there the Tuscan interfingers with the Tehama Formation. The Tuscan is composed of volcanic breccia, coarse- to fine-grained tuffs, and volcanic sands, all of primarily andesitic composition. The most abundant mineral in the black sands found in wells drilled into this unit is plagioclase, and accessory quartz and pyroxenes. Volcanic glass is also abundant from the mudflow and tuff deposits. The Tuscan is an important aquifer in the northeastern part of the valley, and it contains fresh water at all depths.

(4a) *Low hills and dissected uplands, east side.* The dissected alluvial uplands leading up to the Sierra Nevada on the east side of the valley are composed of Tertiary and lower Quaternary sediments. This gently rolling terrain merges with the foothills of the Sierra Nevada to the east and the low alluvial plains to the west. The oldest rocks here are of the Eocene Ione Formation, overlain by the Oligocene, Miocene, and Pliocene volcanic deposits of the Valley Springs and Mehrten Formations. These units extend westward to the trough of the valley, but they are generally too deep to be tapped as aquifers except in the foothills area. Overlying the volcanic sediments are upper Tertiary and Quarternary continental deposits eroded from the Sierra Nevada. The older Tertiary volcanic sediments are composites of volcanic sands, ash and mudflows, and tuff layers of rhyolitic and andesitic composition. Particular minerals noted in these units include biotite, hornblende, orthoclase, plagioclase, and quartz. The Ione Formation contains kaolinitic clay layers. The younger deposits, the Laguna Formation and Fair Oaks Formation of Shlemon (1967), are sand, gravel, and silt deposits intercalated by clay layers. The Quaternary deposits are poorly sorted, and wells finished in these units produce only moderate quantities of water.

(4b) *Low hills and dissected uplands, northeast.* The low hills on the northeast margin of the valley consist of reworked sediments eroded from the underlying Tuscan Formation. The hills show the characteristic form of alluvial fans but are deeply trenched by the streams draining the Cascade Range. These fanglomerate deposits, as they are called, are mainly cemented sands, gravels, and silts, and have a mineral composition similar to that of the Tuscan Formation from which they are derived. The fanglomerate is also an important source of water in this area.

(4c) *Low hills and dissected uplands, west side.* The low hills on the west side of the valley are composed of the Tehama Formation of Pliocene age. These deposits extend from Red Bluff on the north almost as far south as Fairfield. The Tehama is made up of poorly sorted fluviatile sediments, primarily beds of sandy silt and silty clay with some lenses of crossbedded sands and gravels. Many of the coarser layers are cemented by calcium carbonate that reduces their permeability. The Tehama extends eastward to about the middle of the valley and is generally within 150 to 200 feet of land surface. Tectonic activity since deposition has folded the Tehama into a number of structures such as the Dunnigan Hills, Corning Ridge, and Plainfield Ridge along the valley margin. Sediments originated in the Coast Ranges and are rich in plagioclase and magnesium silicates, such as chlorite and serpentine. The Tehama is an important potential aquifer, although currently most water is the area is being pumped from more permeable alluvial fan deposits nearer the surface.

(5a) *Alluvial plains and fans, east side.* The alluvial plain on the east side of the valley is referred to as the Victor Plain by Olmsted and Davis (1961). The Victor Formation[2] of Olmsted and Davis (1961), which

[2]Recent work of Marchand and Allwardt (1981, p. 207) virtually eliminates the use of the Victor Formation for the northeastern part of the San Joaquin Valley. However, because no similar recent work has been done in the Sacramento Valley, the Victor Formation as defined and mapped by Olmsted and Davis (1961, p. 93) is used in this report.

ranges in thickness from 50 to 100 feet, covers the surface throughout the area and overlies the Laguna Formation, a Pleistocene continental deposit. The plain extends from the northern San Joaquin Valley to north of Chico, where it pinches out between the fanglomerate of the Cascade Range and the Sacramento River flood plain. The Victor Formation is composed of alluvial sediments carried down from the Sierra Nevada and contains numerous channel deposits. The sediments become generally finer grained towards the west with bluish- and greenish-gray clays indicating reducing deposition environments near the center of the valley. Opposite the Sierra Nevada, the material contains extensively weathered feldspars, quartz, mica, biotite, and layers of arkosic sandstones. Opposite the Cascade Range, the Victor Formation is composed of reworked volcanic detritus from the Tuscan Formation. Water is generally available throughout the Victor Formation, though many high-capacity irrigation wells also tap the underlying Laguna Formation.

(5b) *Alluvial plains and fans, west side.* The low alluvial fans on the west side of the valley have been laid down by streams draining the Coast Ranges. The fans are aggrading and have poorly developed soil horizons. The northernmost fan is that of Stony Creek, which extends from the valley margin to the Sacramento River. South of this fan, a series of small fans built up by ephemeral streams extends only a short distance away from the Coast Ranges. Cache Creek and Putah Creek, south of the Dunnigan Hills, also have developed rather large fans which coalesce to form Putah Plain. The lithology of these fans is varied but generally is coarse-grained and poorly sorted. The mineralogy reflects the source areas in the Coast Ranges. The alluvial fans are generally good aquifers, especially where old stream channel deposits are penetrated.

(6) *Flood basins.* Low areas adjacent to the Sacramento River were subject to frequent flooding before extensive construction of levees in modern times. In these basins, fine-grained sediments have settled out of flood waters to form poorly permeable deposits. Deposits between 50 and 170 feet thick of yellow clay, indicating oxidizing conditions, overlie blue clays reflecting reducing conditions at depth. Few wells are drilled in these areas, and the only water generally available is in tongues of sand and gravel from old channel deposits.

In Sutter Basin, ground water contains high chloride concentrations and is unsuitable for irrigation purposes. The origin of this high chloride water is thought to be from Cretaceous marine sedimentary rocks brought closer to the surface by faulting associated with the formation of Sutter Buttes.

(7) *Stream channels and natural levees.* Along the major rivers and streams throughout the valley, Holocene alluvial deposits form flood plains and natural levees. The levees slope gently away from the channels and merge into the surrounding flood basin deposits. The deposits are generally coarse grained and poorly sorted. The varied mineralogy reflects the many sources from which these sediments are derived. Wells drilled in these deposits are hydraulically connected to the adjacent rivers and can produce large quantities of water.

(8) *Sutter Buttes.* Sutter Buttes, a volcanic neck of late Tertiary age, rises abruptly 2,100 feet above the surrounding plains. The core of the buttes is andesite, surrounded by alluvial fans created from the erosion of the igneous rocks. The deposits are poorly sorted and contain tuff, volcanic breccia, and sands. Some Cretaceous marine sedimentary rocks exposed at the buttes were forced upwards by the rising lava. The volcanic rocks yield little water, but the adjoining alluvium produces moderate amounts.

HYDROGEOLOGY

The direction of ground-water movement can be determined from the configuration of the water table where ground water occurs in saturated sediments and is not confined. Ground-water movement is influenced by gravity, and so is downhill as determined by the altitude of the water table. Plate 1*B* is a map showing lines of equal altitude of the water table for the Sacramento Valley in the spring of 1975. Although extensive changes occurred in some areas during the drought of 1976 and 1977, the 1975 map reflects the general conditions throughout the valley as they existed when most of the water-quality samples were collected during the mid-1970's.

In the north part of the valley, ground waters flow to the south and away from the valley walls. The Sacramento River is a gaining stream north of Colusa and is a major ground-water discharge zone in the north part of the valley. Stony Creek alluvial fan is a particularly important area for recharge. South of Colusa, the Sacramento River becomes a losing stream, contributing water to the adjacent sediments. In the west-central part of the valley, between Colusa and Woodland, recharge from the west infiltrates the valley sediments and moves toward pumping depressions east of the Dunnigan Hills. In the east-central part of the valley, from Oroville to Marysville, the Feather, Yuba, and Bear Rivers recharge the ground water near the valley margin. Once on the valley floor, the Feather River becomes a gaining stream east of Sutter Buttes, but below Marysville it begins to lose water to pumping depressions to the east and west. A large pumping depression in the southeast draws water from the Ameri-

can and Sacramento Rivers in the vicinity of Sacramento. In the southwest, much ground-water recharge occurs in the Cache and Putah Creek alluvial fans. This water moves eastward toward pumping depressions near Woodland and Davis. Some recharge from Cache Creek flows around the end of the Dunnigan Hills to pumping depressions north of Woodland.

The water table in the Sacramento Valley is generally close to the surface, and in only a few places is it more than 80 feet below the surface. Depth to water in the flood basins and alluvium along the Sacramento and Feather Rivers ranges from 10 to 20 feet. This very shallow water table extends eastward to include much of the western part of the Victor Plain. In the alluvial fans along the west side of the valley, the depth to water is between 10 and 40 feet. Lowering of water levels in pumping depressions north of Woodland and south of Davis, however, has increased the depth to water in those places. Along the southeast margin of the valley, the depth to water increases from less than 10 feet, near the flood basins, to more than 80 feet in the foothills. In the fanglomerate of the Cascade Range around Chico, the depth to water is generally 10 to 40 feet.

The valley boundary illustrated on plate 1*B* is the approximate boundary of the principal alluvial aquifers currently used in the Sacramento Valley. There is no single definition of the Sacramento Valley, and different boundaries are drawn for different purposes. The boundary shown is approximately that used in a ground-water-flow model of the Sacramento Valley (California Department of Water Resources, 1978a, Appendix A). However, the definition of the Sacramento Valley ground-water basin by the State of California encompasses a much larger area. The boundary is a reference shape to show continuity among illustrations.

On the east side of the valley, the margin coincides with the contact between the alluvium of the low hills and dissected uplands geomorphic province, and the older rocks of the Sierra Nevada and Cascade Range provinces. On the west side, the division is at the contact between the younger alluvium of the alluvial fans and plains, and the older alluvium of the low hills and dissected uplands geomorphic province. This allows delineation of the Dunnigan Hills, and excludes a large, undeveloped and sparsely populated area to the northwest of the valley.

Some wells outside the principal alluvial aquifers were included in the data analysis, as the boundary of those aquifers is somewhat arbitrary. Because these wells lie in recharge zones, their characteristics are important to an understanding of ground-water chemistry in the rest of the valley, even though they are outside the area of the principal alluvial aquifers.

HYDROCHEMICAL FACIES

The concept of hydrochemical facies as described by Back (1966) is used to designate zones or areas in which ground waters share unique chemical characteristics. The differences between facies reflect different controls on water chemistry from the lithology and mineralogy of, flow patterns in, and sources of recharge to an aquifer. The prefix "hydro" is used as a modifier of "chemical" to emphasize the interdependence of chemistry and hydrology. The ground water in the Sacramento Valley shows a great diversity in chemical compositions. By dividing the valley into hydrochemical facies, the differences can be better related to differences in the sedimentary matrix holding the water and the sources of ground-water recharge.

CRITERIA AND PROCEDURE FOR DIVISION

While hydrochemical facies have commonly been defined in terms of water types (as determined by the predominance of ions in terms of equivalents per million; Back, 1966), the definition of hydrochemical facies can be based on any unique chemical signature. For the Sacramento Valley, this division was accomplished using differences in the concentrations of some of the dissolved chemical constituents.

An initial division of the valley was attempted by studying maps showing the geomorphic units, the water table, and the distribution of individual chemical constituents. Outlines of these areas were drawn up to the nearest quarter township, and a tentative hydrochemical facies was determined for each well. This initial division broke the valley into three areas extending northwest-southeast, parallel to the axes of the valley—along the west side, the east side, and in the central basins. Each of these areas was divided into a northern and southern part resulting in six tentative divisions.

After this initial division, these six areas were tested to determine if they could be successfully differentiated on the basis of their chemistries. Linear discriminant function analysis (Davis, 1973; Drake and Harmon, 1973) was used for this purpose. In linear discriminant function analysis, a linear combination of variables is used to distinguish between previously defined groups. After the function is defined, it can be used to classify new samples of unknown origin into one of the original groups.

To determine which chemical constituents would be the best to use in the discriminant analysis, the amount of variation in the major chemical species associated with the differences between hydrochemical facies was determined. The results of this analysis of variance are shown in table 1. The first five species in this table

TABLE 1.—*Variation in chemical constituents explained by variations between hydrochemical facies*

Constituent	Percent variation explained
Silica	62.7
Boron	48.5
Sodium	44.7
Bicarbonate	39.4
Nitrate	36.8
Chloride	30.1
Magnesium	27.2
Calcium	15.1
Sulfate	9.6

were picked for the analysis. Because chloride is closely associated with sodium in the valley, it was passed over and magnesium added to give a total of six chemical constituents to use in the discriminant analysis.

Of the 671 chemical analyses available, only 340 had measurements for all the species and could therefore be used in the analysis. Most of the reduction in sample size was due to the much smaller number (358) of silica analyses. However, because silica showed by far the greatest amount of variation between the tentative hydrochemical facies, it was decided to use silica at the cost of reducing the number of samples that could be classified using the discriminant function. Samples, which lack measurements of all six of the chemical species used, were subsequently classified on the basis of nearby wells.

About one-fifth of the eligible samples were used to define the discriminant functions for the six hydrochemical facies. Using these functions, the remaining eligible samples were classified using the chemistry, and this classification was compared to the prior classification from the map data. Misclassified observations were of two types. Type 1 misclassifications were scattered throughout other facies and showed no pattern nor were particularly close to the boundary between two areas. Type 2 misclassifications were clustered in an adjacent hydrochemical facies near the boundary. In the latter case, the boundaries were redrawn and the chemical analyses reclassified.

The discriminant functions were recalculated several times with adjustments in boundaries between each calculation. The final analysis showed that 76 percent of the samples could be correctly classified by hydrochemical unit using the six chemical species. Thirteen percent of the samples were misclassified into the adjacent northern or southern portion in the same part of the valley, indicating an association between west side, east side, and basin pairs. On the basis of the classification of wells in a quarter township, each quarter township was assigned to its final hydrochemical facies. Other wells missing some of the chemical species used for the classification were classified by their quarter township location.

The discriminant analysis showed that enough chemical variation existed among the six hydrochemical facies to consider them chemically distinct. The final boundaries of the hydrochemical facies are shown on plate 1*B*. On the east side of the valley, one of the facies lies opposite the Cascade Range, and one opposite the Sierra Nevada. The flood basins along the axis of the valley are divided into two more facies, one in Butte Basin and including Sutter Buttes, the second in the Colusa, Sutter, and American Basins. The final two hydrochemical facies are opposite the Coast Ranges and are divided north and south near Colusa. In the next section, the chemical characteristics of the six hydrochemical facies are presented and compared, and differences in chemistry are discussed.

DESCRIPTIONS OF HYDROCHEMICAL FACIES

Table 2 shows the geometric mean, minimum, and maximum of chemical concentrations for each of the hydrochemical facies. To determine if the average concentrations of chemical species in the hydrochemical facies are significantly different, the differences between geometric means were tested using a t test. The results of these comparisons are illustrated quantitatively in the same table.

TUSCAN VOLCANIC ROCKS

The Tuscan volcanic rocks hydrochemical facies is along the northeastern margin of the Sacramento Valley (pl. 1*B*) adjacent to the Cascade Range. The geologic formations in this area are the Tuscan Formation and more recent alluvial sediments derived from erosion of the Tuscan. Recharge is from the Cascade Range geomorphic province, and ground water is either discharged to the Sacramento River or moves into Butte Basin south of Chico. The Tuscan and its derivatives contain andesitic sands and extensive tuff deposits. Volcanic glass and plagioclase are abundant in these sediments.

The chemistry of ground water in the area reflects the low concentrations of dissolved solids carried by recharge from the Cascade Range, having low mean concentrations of magnesium, sodium, bicarbonate, sulfate, and chloride. Silica concentrations are high due to solution of volcanic glass, and the facies has the highest average nitrate-nitrogen concentration of the six. The maximum boron concentration is rather high, although the mean concentration is only moderate. Boron in excess of 1.0 mg/L occurs in only three wells, all to the east of the Sacramento River northeast of Red Bluff.

TABLE 2.—*Geometric mean, minimum, and maximum of chemical concentrations for each of the hydrochemical facies, Sacramento Valley*

[Figure above line refers to geometric mean; figures below line refer to minimum-maximum range. H, high; L, low; VH, very high; VL, very low. NOTE.—These comparisons are relative to the other hydrochemical facies and do not necessarily describe the absolute values. Labels were assigned only where the difference between two geometric means tested significant at the 95 percent level]

Chemical species	Tuscan volcanic rocks	Victor Plain	Butte Basin	Sutter Basin	North alluvial fans	South alluvial fans
Dissolved solids (mg/L)	L 231 137–571	L 220 137–1100	290 129–723	H 400 97–2040	280 108–1170	H 400 175–1420
Calcium (mg/L)	26 14–75	L 21 5.7–170	32 5.5–98	32 6.9–220	H 39 8.2–99	H 39 13–140
Magnesium (mg/L)	L 19 9.1–60	VL 12 3.6–120	24 5.0–93	24 2.2–160	24 7.6–70	H 33 3.5–140
Sodium (mg/L)	L 14 3.9–68	19 7.2–180	20 6.3–93	H 55 5.9–360	22 7.5–240	H 52 15–320
Potassium (mg/L)	1.3 0.3–5.9	1.3 0.4–4.5	H 1.9 0.6–5.0	H 1.7 0.3–5.4	L 0.8 0.4–2.1	1.2 0.2–7.0
Bicarbonate (mg/L)	L 170 98–400	VL 130 68–504	230 44–522	H 270 70–897	240 83–560	VH 310 130–1060
Sulfate (mg/L)	L 8.1 0.0–71	L 8.0 0.2–140	12 0.5–150	17 0.3–590	18 1.6–400	21 1.8–180
Chloride (mg/L)	VL 6.5 0.9–97	15 2.0–380	L 11 1.0–210	H 31 2.4–920	15 2.7–170	H 37 2.2–580
Fluoride (mg/L)	0.11 0.1–0.3	0.18 0.1–10.0	0.12 0.1–0.3	0.11 0.0–0.4	0.16 0.0–0.6	H 0.29 0.1–1.0
Nitrate - N (mg/L)	H 2.7 0.2–27	0.81 0–61	1.0 0–20	L 0.12 0–14	1.7 0.01–11	1.8 0–12
Phosphate - P (mg/L)	0.05 0.0–0.31	0.11 0.01–0.39	0.11 0.01–0.45	0.15 0.01–0.50	0.06 0.02–0.30	0.07 0.01–0.42
Silica (mg/L)	H 51 35–67	H 55 25–74	H 51 31–75	39 23–73	L 26 8.5–52	L 28 12–54
Iron (µg/L)	4.8 0–170	5.2 0–600	8.0 0–1900	H 11 0–520	9.7 0–280	8.0 0–180
Manganese (µg/L)	3.4 0–10	5.5 0–280	9.1 0–1700	H 75 0–2300	8.0 0–70	2.8 0–2000
Arsenic (µg/L)	1.2 0–4	2.2 0–20	H 5.5 0–50	H 5.8 0–100	1.7 0–6	2.3 0–31
Boron (mg/L)	0.066 0–1.50	L 0.023 0–0.60	L 0.034 0–0.37	H 0.140 0–1.10	0.068 0–0.58	VH 0.400 0–8.10

The source of the high boron water is Tuscan Spring, located along Salt Creek in Tehama County in section 32 of township 28 N., range 2 W. (Waring, 1965).

VICTOR PLAIN

The Victor Plain hydrochemical facies is along the east and southeast margin of the valley, and extends westward to near the Feather and Sacramento Rivers. Recharge is primarily from the Sierra Nevada to the east, although pumping depressions southeast of Marysville and north of Sacramento induce recharge from the rivers. North of Marysville, water is discharged into the Feather River or passed into Butte Basin. South of Marysville, most of the ground-water discharge seems to be by pumping. Along the valley margin, the aquifers are volcanic sands with associated tuffaceous deposits. In the central and western parts of this facies, the volcanic units dip under the Victor Formation composed of alluvium from the Sierra Nevada.

The Victor Plain facies has a low average dissolved-solids content reflecting recharge from the Sierra Nevada. Concentrations of calcium, magnesium, bicarbonate, boron, and sulfate are all low in this area. Silica

is high, reflecting the volcanic material present in the sediments.

BUTTE BASIN

The Butte Basin hydrochemical facies roughly coincides with the Butte flood basin east of the Sacramento River. The basin extends from Chico on the north to Yuba City on the south and lies between the Feather and Sacramento Rivers. Sutter Buttes is included in this facies as too few chemical analyses were available from this area to justify a separate facies. The basin receives recharge from the Tuscan volcanic rocks facies and from Victor Plain to the east. A small amount of recharge also occurs in the vicinity of Sutter Buttes. Ground water leaves the Butte Basin facies to enter the Sacramento River and to enter the Sutter Basin facies east of Sutter Buttes. In the flood basins the sediments are fine grained and reducing.

Ground water in the Butte Basin facies has a somewhat higher average dissolved-solids concentration than the two eastern margin facies possibly reflecting longer subsurface residence times or a change in sediment lithology. Chloride and boron are the only two species that have low average concentrations in this facies. The high silica concentrations may be a result of recharge from the Tuscan volcanic rocks facies and from volcanic material around Sutter Buttes. High arsenic concentrations imply deposition in a reducing environment (Garrels and Christ, 1965). This facies has the highest average potassium concentration, which may reflect the longer residence times or a change in mineralogy of the sediments.

Information on the variation in water chemistry with depth was obtained from a U.S. Geological Survey test well drilled in section 32 of township 19 N., range 1 W. Three piezometer tubes were installed at different depths and isolated by cement packers. Data on the shallow water at the site are available from a previous study (Fogelman, 1976).

Analyses from the three piezometers and from the shallow water are shown in table 3. The percent composition of the major ionic species in terms of milliequivalents per liter are provided in figure 3. Between 80 and 595 feet, a decrease in magnesium is balanced by an increase in sodium, with calcium remaining about the same. There is a slight increase in the percent of chloride in the ground water over this same interval, but the net change in anion composition is very small. Below 595 feet, however, calcium and magnesium decrease, both in percent composition and concentration, and sodium increases. Chloride also increases, becoming the dominant anion by a depth of 968 feet. Even at 1,333 feet, however, the dissolved-solids concentration of the water is only moderate, at 526 mg/L, and the boron concentration remains low.

SUTTER BASIN

The Sutter Basin hydrochemical facies is between the Sacramento and Feather Rivers south of Sutter Buttes. This facies extends west of the Sacramento River near Colusa to include part of Colusa Basin and includes some of the American Basin east of the Feather River. Recharge comes from Sutter Buttes, from the Butte Basin hydrochemical facies east of Sutter Buttes, and from both the Sacramento and Feather Rivers. Sediments in the flood basins are generally fine grained and reducing at depth.

The Sutter Basin facies is tied with the south alluvial fans facies for the highest average dissolved-solids concentration. This facies is also high in sodium, chloride, bicarbonate, potassium, and boron. The effects of reducing conditions are evident in the relatively higher concentrations of iron, manganese, and arsenic in this area, all of which are more soluble in reducing environments (Garrels and Christ, 1965). The very low average nitrate concentration in this facies is also indicative of reducing conditions, where nitrate can be removed by denitrification reactions.

The origin of the high dissolved-solids water is thought to be connate marine water moving upward along fault zones created when Sutter Buttes was emplaced (Curtin, 1971). Throughout much of the southern part of Sutter Basin, water of very high salinity (specific conductance greater than 3,000 micromhos) is located within 400 feet of the surface.

TABLE 3.—*Chemical composition of water from wells of various depths, section 32 of township 19 N., range 1 W.*

Sample No. (fig. 3)	Site identification	Depth of well (feet)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Bicarbonate (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Nitrate-N (mg/L)	Boron (mg/L)	Dissolved solids (mg/L)
1	19N/01W-32A01M	80	28	24	34	260	12	12	0.59	0.12	276
2	19N/01W-32G03M	595	25	4.4	62	210	12	22	.03	.15	276
3	19N/01W-32G02M	968	12	2.6	110	150	3.6	110	.02	.18	340
4	19N/01W-32G01M	1,333	15	2.8	160	110	3.4	230	.12	.24	526

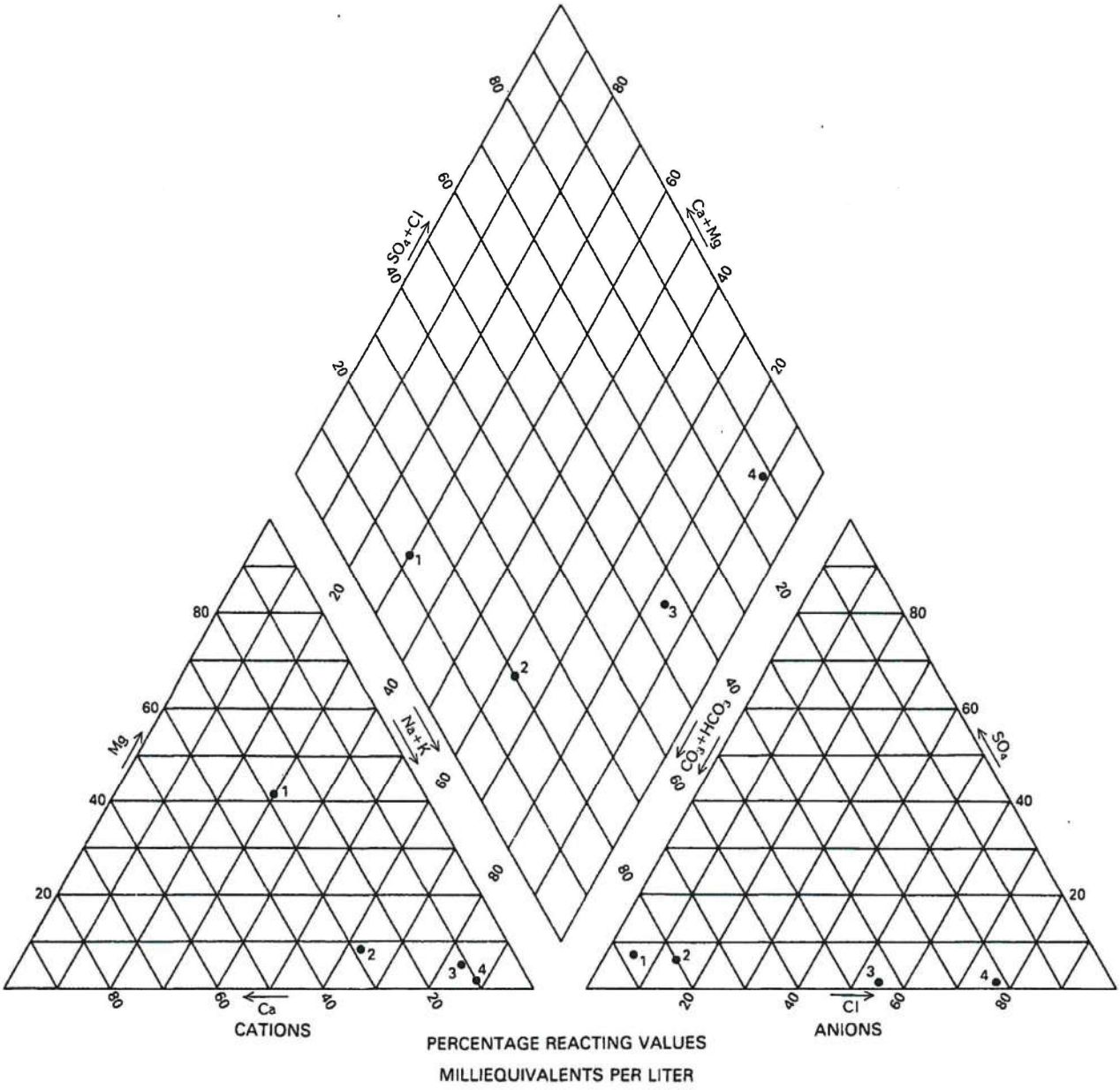

FIGURE 3.—Major-ion composition of water from wells of various depths in section 32 of township 19 N., range 1 W. Numbers refer to sample numbers in table 3.

NORTH ALLUVIAL FANS

The north alluvial fans hydrochemical facies is along the northwestern margin of the valley. Ground water occurs primarily in alluvial fan deposits and is recharged by streams draining the Coast Ranges. The alluvial fan of Stony Creek is a major source of recharge in this area, with flow radiating away from the fan to the north, east, and south. Ground-water flow in this facies is generally east and south. Most of the water is discharged to the Sacramento River along the eastern margin of the facies, although some moves into Colusa Basin along the southern boundary. Sediments in the alluvial fans are primarily derived from Mesozoic marine rocks of the Coast Ranges with sediments derived from Franciscan metamorphic rocks carried down by some of the larger streams.

The average dissolved-solids concentration in the north alluvial fans facies is moderate, and most of the chemical-constituent averages fall between those of the

other facies. Calcium is the only species with a high average concentration in this facies; this is from the waters of Stony Creek, which are high in calcium. Silica is much lower in waters on the west side of the valley, and this is shown by the low average silica concentration.

SOUTH ALLUVIAL FANS

Located along the southwestern margin of the valley in alluvial fans adjacent to the Coast Ranges, the south alluvial fans hydrochemical facies extends from Putah Creek north to township 15 N. Recharge from the Coast Ranges is provided by numerous ephemeral streams north of township 10 N., and by Cache and Putah Creeks in townships south of 11 N. Recharge from Cache Creek moves around the end of the Dunnigan Hills to pumping depressions north of Woodland. Some recharge is also drawn from the Sacramento River to these same pumping depressions.

The south alluvial fans hydrochemical facies is distinguished by having high average concentrations for many of the chemical species measured. Dissolved solids, calcium, magnesium, sodium, chloride, and fluoride all have high average concentrations here. Boron and bicarbonate concentrations in this facies average very high. With little volcanic material to provide silica, its average concentration is low, as in the north alluvial fans.

Boron and chloride concentrations in the ground water of this facies average the highest in the valley, and boron concentrations as high as 8.1 mg/L have been measured in township 11 N., range 2 E. The source of the chloride and boron has been attributed to the streams draining the Coast Ranges (Bertoldi, 1976). Information obtained from a deep test well drilled by the U.S. Geological Survey in section 34 of township 12 N., range 1 E., indicated another possible source. The test well 12N/01E–34Q was drilled to a total depth of 2,400 feet and piezometers tubes installed at 942 feet, 1,396 feet, and 2,120 feet. No sample was obtained from the 942-foot depth, but analyses from the two deeper piezometers are shown in table 4. At a depth of 2,120 feet, water containing 12 mg/L boron and 660 mg/L chloride was encountered. Piezometric heads in the test well indicate upward movement of water, which may be contaminating the shallow water.

The source of boron and chloride in the streams draining the Coast Ranges is warm saline springs, a number of which occur in the Clear Lake area. Partial chemical analyses from these springs are also shown in table 4. Boron concentrations are as high as 310 mg/L in these springs. To determine the source of the high boron concentrations in the ground water in township 11 N., range 2 E., the percent composition in milliequivalents per liter of the wells in this township were plotted along with the deep well water and the warm spring water (fig. 4). The Wilbur Oil Test is a wildcat oil well that produces cold water also high in boron and chloride.

TABLE 4.—*Data for wells and springs plotted in figures 4 and 5*

[Samples 1–2 from U.S. Geological Survey test well; 3–9, reported by Fogelman (1976); 10, average for 1960–76; 11–15, reported by White and others (1973), with locations as indicated therein]

Sample No. (fig. 4)	Site identification	Depth to first opening (feet)	Dissolved solids (mg/L)	Chloride (mg/L)	Boron (mg/L)	Temperature (°C)
1	12N/01E–34Q01M	2,120	1,310	660	12	21.0
2	12N/01E–34Q02M	1,396	482	95	1.1	21.5
3	11N/02E–20K06M	387	1,060	210	3.7	20.0
4	11N/02E–18R01M	264	321	39	1.4	18.5
5	11N/02E–18C02M	205	1,470	210	8.1	18.0
6	11N/02E–23N02M	200	746	66	2.5	21.0
7	11N/02E–14B03M	198	307	37	1.1	17.5
8	11N/02E–30C01M	184	741	96	3.3	18.0
9	11N/02E–29A02M	151	816	140	4.8	18.0
10	Cache Creek at Capay	---	268	36	1.5	---
11	Wilbur Springs	---	27,134	9,700	310	55.0
12	Elgin Mine Spring	---	28,872	11,000	240	68.5
13	Abbott Mine Spring	---	7,250	1,900	56	≈30
14	Grizzly Spring	---	12,400	3,940	178	17.5
15	Wilbur Oil Test	---	19,080	11,400	23	21.3

From figure 4 there is no clear indication of whether the water in the wells (sample Nos. 3–9) is derived from the thermal springs (sample Nos. 11–14) or from deep ground water in the area (sample No. 1). Two of the thermal springs, Wilbur Oil Test well and the deep well, are very high in percent sodium. Two of the thermal springs show an increase in percent magnesium, but the percent calcium remains very low.

The deep ground water and the Wilbur Oil Test well have a much higher percentage of chloride than the thermal springs, which are enriched in carbon dioxide from metamorphism at depth (Barnes and others, 1973). As no clear trends emerged in the plot of the percent compositions in milliequivalents per liter, a second plot of chloride versus boron concentrations was made (fig. 5). The dashed diagonal line in figure 5 represents the dilution of Wilbur Springs water with water containing no boron or chloride. The thermal springs all plot very close to this line, having both high chloride and boron concentrations. The shallow wells in township 11 N., range 2 E., all plot very close to the the line representing dilution of Wilbur Springs water, as does the average composition of Cache Creek. Wilbur Oil Test well and the deep wells in the valley plot to the right of the dilution line, which indicates more chloride relative to boron in these waters. From figure 5 the source of the high chloride and boron concentrations is confirmed as water from the thermal springs in the Coast Ranges carried into the valley by streams, such as Cache Creek. Distinct differences between the cold waters,

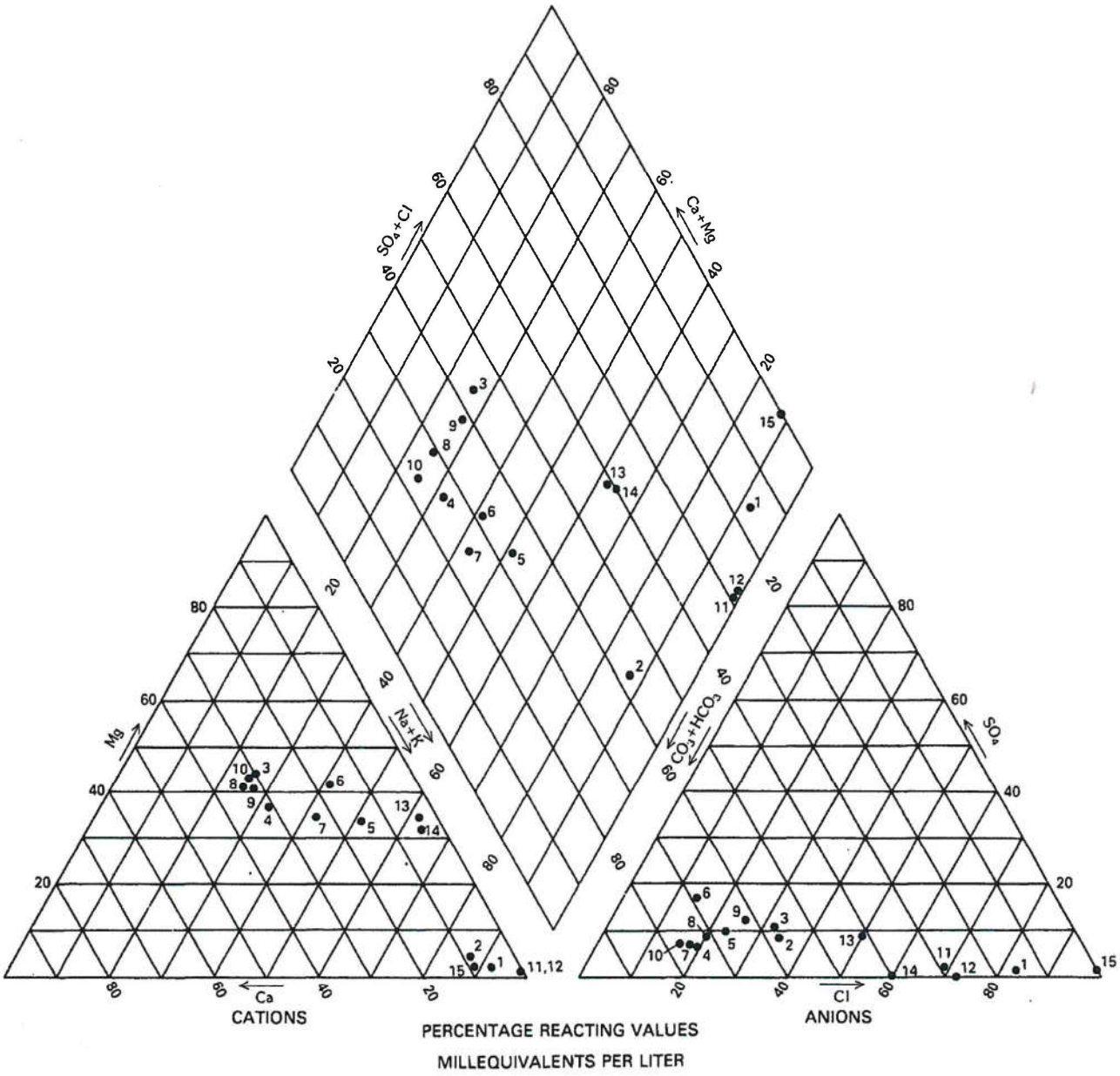

FIGURE 4.—Major-ion composition of water from springs in the Clear Lake area and from wells in a high boron area northwest of Woodland. Numbers refer to sample numbers in table 4.

such as Wilbur Oil Test and well 12N/01E–34Q01, and the thermal waters can be found in the boron-to-chloride ratio and the percent of bicarbonate ion in the waters. The hot waters probably receive inputs of carbon dioxide and boron from a gas phase produced during metamorphism of the marine sediments at depth. Cold waters are not enriched in volatile components and therefore have lower boron-to-chloride ratios and lower percent bicarbonate contents. The shallow wells in township 11 N., range 2 E., have the higher boron-to-chloride ratios indicative of a thermal water source.

TEMPORAL CHANGES

Ground-water-quality degradation may be occurring in the Sacramento Valley because of increasing development accompanied by more intensive agriculture and denser habitation. Such effects have been noted in the

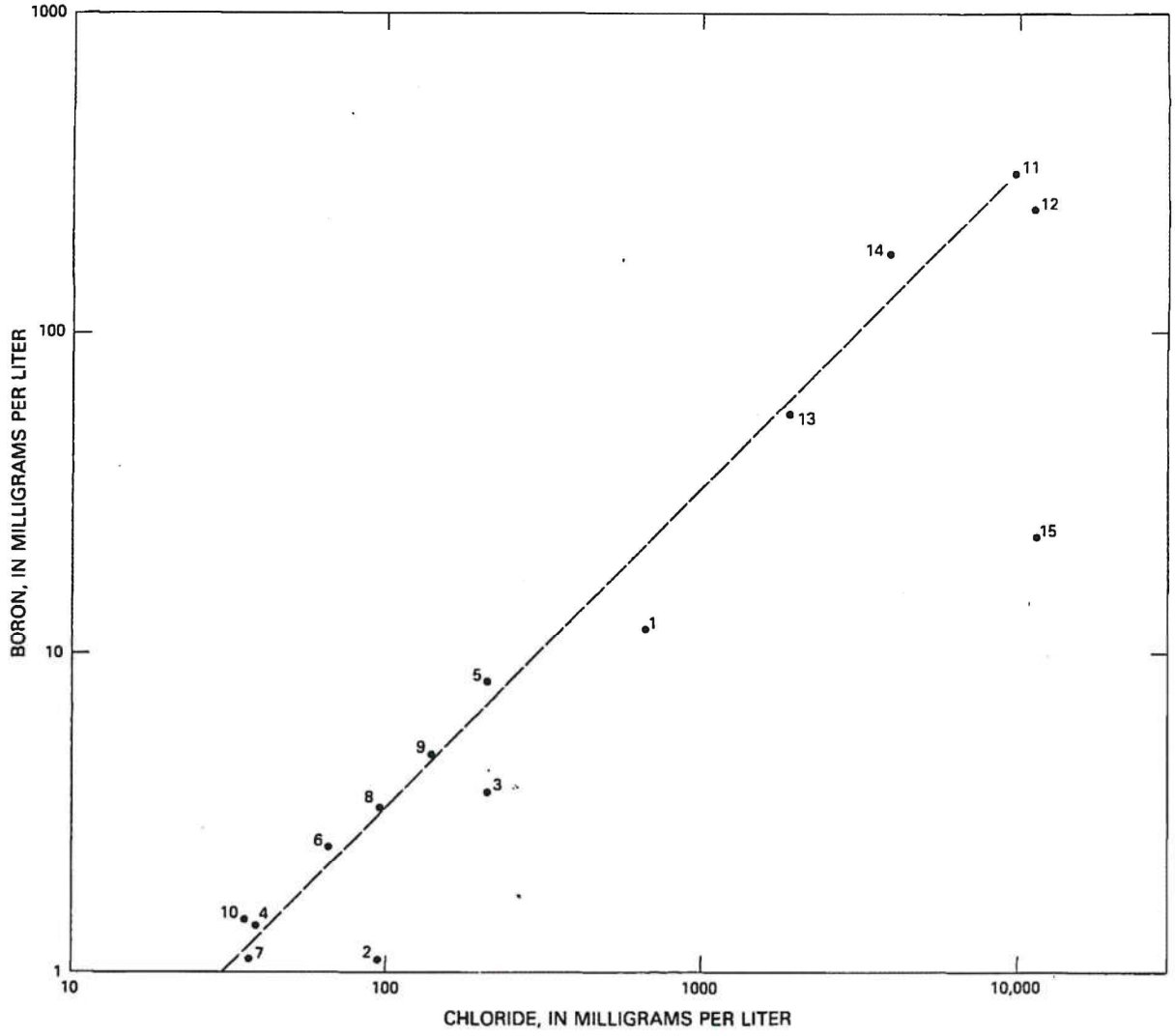

FIGURE 5.—Plot of chloride versus boron for springs in the Clear Lake area and for wells in a high boron area northwest of Woodland. Numbers refer to sample numbers in table 4. Dashed line indicates dilution of Wilbur Springs water with water containing no boron or chloride.

San Joaquin Valley (Kern County Water Agency, 1979), in San Bernardino County (Klein and Bradford, 1979), and in the Colorado River Basin (El-Ashry, 1980). Much of the problem is related to infiltrating irrigation water that (1) has been concentrated by evapotranspiration, (2) has dissolved salts added as fertilizers and soil conditioners, and (3) has leached natural salts from the unsaturated zone. Additional degradation can occur from nonagricultural activities, such as the disposal of sewage and industrial wastes.

In this section, water-quality data from the Sacramento Valley are examined for linear trends with time. Data in each of the hydrochemical facies are combined to derive an average trend for each of the areas. Individual wells are also examined for temporal changes to show more localized variations. The locations of wells used to study the temporal changes are plotted on a map of the valley, and those wells showing significant changes are labeled with symbols indicating the direction of change (pl. 2).

Two variables are used in this study, dissolved-solids and nitrate concentrations. Dissolved solids measures the total amount of dissolved chemicals in a water, and it gives a general indication of overall water quality. Nitrate is derived from a number of potential pollution sources, such as fertilizers and sewage. Increases in nitrate would indicate specific influences of man's activities. These two variables will give a fairly com-

prehensive evaluation of any temporal changes that may be occurring.

METHODS OF DATA ANALYSIS

To determine the average changes occurring in a hydrochemical facies, some technique was needed so that wells with different average dissolved-solids or nitrate concentrations could be compared. This was accomplished by standardizing the data for each well to have a mean of zero and a standard deviation of one. Data from all the wells for each year could then be averaged with equal weight being given to each well. This data manipulation procedure produced a data set with one observation per year for the period of record in each hydrochemical facies. The yearly observations represented the average for all the wells for which data were available in each hydrochemical facies.

Trends in the chemistry of the facies were then studied using a linear regression of the standardized and averaged dissolved-solids or nitrate concentrations versus time. One of the fundamental assumptions of regression analysis is that the observations are independently distributed. For sequences of data collected over time, this requirement is sometimes violated because the data are autocorrelated. Because of memory effects in natural processes, measurements taken at one time may be correlated to measurements taken at previous times.

To test the extent to which the dissolved solids and nitrate data suffered from autocorrelation problems, lag one serial correlations were calculated, and cumulative frequency histograms of these autocorrelations compiled. Matalas, Slack, and Wallis (1975) have generated a series of empirical cumulative frequency histograms for data sequences having a range of serial correlations. By comparing the cumulative frequency histograms for dissolved solids and nitrate in the Sacramento Valley to these empirical histograms, the probable population autocorrelations were determined to be about 0.3 for dissolved solids and between 0.3 and 0.5 for nitrate.

Serial correlations of this magnitude indicate a tendency for subsequent values to be positively correlated to previous values. As a result, the trends determined from the regression analyses may not be as strong as indicated. Positive autocorrelations of this magnitude, however, will not significantly affect the conclusions of the temporal study.

The equations describing the average temporal changes for the hydrochemical facies were transformed back to concentrations by destandardizing the regression equations. For each hydrochemical facies, the average of the means and standard deviations of the individual wells was calculated. By multiplying the regression equations by these average standard deviations and adding the average means, equations were obtained that give the average trend in a facies in terms of concentrations. This equation describes what might be observed in a typical well in each facies, and no individual well can be expected to show the same relation.

The equations produced by this analysis are not predictive equations, but merely reflect the average rate of change over the period of record, from about 1955 to 1977. An example of the problems that can arise if they are used as predictive equations is demonstrated by considering what happens if some of the equations are used to estimate past concentrations. The equation describing the average changes in nitrate-nitrogen concentrations for the Victor Plain hydrochemical facies indicates negative concentrations in the ground water prior to 1939. This is a physical impossibility and arises because the equation was used for a purpose for which it was not intended. While predictions of future concentrations of dissolved solids and nitrate-nitrogen may not produce negative results, the values obtained could be just as meaningless.

In addition to testing for average trends throughout a hydrochemical facies, individual wells were examined for temporal variations. Where a significant trend was noted for an individual well, the equation was recorded and the well's location plotted on a map of the valley with a symbol indicating the direction of the trend (pl. 2).

Few wells in the valley have multiple observations over time. To minimize the effects of random fluctuations, only wells with seven or more observations for dissolved solids and six or more observations for nitrate were used. There was no attempt to assure a random distribution of wells throughout the valley, and all wells in the valley or along the margins having a sufficient number of observations were used. Time is measured as the year minus 1900. For example, for the year 1975, time is equal to 1975–1900 or 75.

DISSOLVED SOLIDS

Dissolved solids is a measure of the total amount of dissolved chemicals in water. An increase in any of the individual constituents will be reflected by an increase in the dissolved solids. While not many historical dissolved-solids measurements are available, many specific-conductance measurements have been made. Specific conductance is proportional to the quantity and valence of ionized chemicals in a water. Because almost all the major dissolved chemical constituents in a water are ionized, dissolved solids and specific conductance are closely related.

It was felt that dissolved solids would have more meaning for most users of this report; therefore, specific conductivities were transformed to dissolved-solids concentrations. The relation between dissolved solids and specific conductance will depend on the specific ionized species present and the amount of uncharged species, mainly silica, present in the water. For this reason, separate equations were derived for different parts of the valley. These areas do not exactly coincide with the hydrochemical facies as they were finally defined, but the division follows the same basic pattern. Thus, the effects of different water chemistries on the relation between dissolved solids and conductance were taken into account during the transformation.

Equations that describe the relation between dissolved solids and specific conductance were derived from a linear regression on data from about 650 wells having measurements of both dissolved solids and conductance. A linear equation with both slope and intercept terms was used rather than a ratio. The intercept terms of all the linear equations were significantly different from zero, which indicates that the linear equations better fit the data than ratios.

Because the calculation of dissolved solids from conductance is a simple linear transformation, the calculation in no way affects the presence of trends in the data. All dissolved-solids values for a well were estimated from conductance measurements even if some measured dissolved-solids concentrations were available. This prevented any changes that might be induced by using dissolved-solids data from different sources.

Locations of wells examined for trends in dissolved solids are shown on plate 2A. The changes for each hydrochemical facies are discussed in the next section and coefficients for the equations describing the average temporal changes are given in table 5. Coefficients for individual wells are summarized in table 6.

HYDROCHEMICAL FACIES

Dissolved solids in the Tuscan volcanic rocks hydrochemical facies show an average annual increase of 0.95 mg/L. The trend line accounts for 31 percent of the variation in the standardized dissolved-solids data averaged over all wells by year. A plot of the trend line is shown in figure 6. Temporal variations are significant in five of the 19 wells for which historical data are available (table 6). Two of these wells show rising trends and three show decreasing trends.

TABLE 5.—*Analyses of variance and coefficients for the regression of average yearly dissolved solids with time for the six hydrochemical facies in the Sacramento Valley*

[t=(year–1900); for example, t=(1980–1900)=80. NS, linear trend not significant at the 90 percent confidence level]

Hydrochemical facies	Number of wells	Source	Degrees of freedom	Sum of squares	F ratio	Probability of exceeding F ratio	r^2	MODEL Dissolved solids=A+Bt: A	90 percent confidence limit	B	90 percent confidence limit
Tuscan volcanic rocks	19	Model	1	1.52	8.89	0.01	0.31	194	±36	0.95	±0.55
		Error	20	3.43							
		Total	21	4.95							
Victor Plain	20	Model	1	2.50	13.91	<0.01	.38	236	±48	1.61	±0.74
		Error	23	4.13							
		Total	24	6.63							
Butte Basin	12	Model	1	1.17	12.55	<0.01	.41	197	±45	1.37	±0.67
		Error	18	1.68							
		Total	19	2.85							
Sutter Basin Basin	10	Model	1	.03	.05	.83	.00	---	---	NS	---
		Error	23	15.21							
		Total	24	15.24							
North alluvial fans	62	Model	1	1.05	14.11	<0.01	.43	222	±31	1.02	±.46
		Error	19	1.41							
		Total	20	2.46							
South alluvial fans	18	Model	1	7.41	65.16	<0.01	.76	184	±67	4.75	±1.01
		Error	21	2.39							
		Total	22	9.80							

TABLE 6.—*Wells showing significant trends in dissolved-solids concentration*

[For the model: Dissolved solids=A+Bt, where t is the year minus 1900]

Well	A	Standard error	Student's *t*	B	Standard error	Student's *t*	Probability of exceeding t for B
TUSCAN VOLCANIC ROCKS							
23N/01W–09L01M	–24.6	73.2	0.34	5.72	1.12	5.12	<0.01
25N/02W–16P01M	666.4	174.5	3.82	–6.09	2.42	2.52	.01
26N/02W–09E01M	909.5	257.0	3.54	–7.44	3.56	2.09	.04
27N/03W–15N01M	1055.6	288.1	3.66	–9.56	3.92	2.44	.02
27N/03W–22B01M	–122.4	223.1	.55	6.30	3.06	2.06	.04
VICTOR PLAIN							
06N/07E–23A01M	892.6	373.4	2.39	–10.32	5.61	1.84	0.07
18N/04E–28M01M	325.8	209.4	1.56	22.03	3.02	7.29	.01
BUTTE BASIN							
16N/04E–09D01M	–389.3	181.4	2.15	8.57	2.80	3.06	<0.01
17N/01W–30K03M	1833.2	515.4	3.56	–21.27	7.04	3.02	<0.01
SUTTER BASIN							
15N/03E–15H04M	–910.0	485.4	1.87	20.92	6.82	3.07	<0.01
16N/02W–25B02M	2428.1	395.1	6.15	–24.98	5.56	4.49	<0.01
NORTH ALLUVIAL FANS							
17N/03W–33R01M	383.2	76.6	5.01	3.24	1.13	2.87	<0.01
18N/02W–01E01M	–716.6	77.8	9.21	16.37	1.16	14.16	<0.01
18N/04W–02F01M	–817.1	112.5	7.26	22.73	1.74	13.07	<0.01
19N/02W–23N01M	–464.2	77.8	5.97	14.03	1.16	12.14	<0.01
20N/02W–22E01M	–618.4	442.7	1.40	11.31	5.97	1.89	.06
21N/02W–15C01M	–241.0	84.5	2.85	8.77	1.25	7.04	<0.01
21N/03W–02Q01M	–121.4	84.6	1.43	7.41	1.25	5.95	<0.01
22N/01W–29C01M	40.2	87.8	.46	3.98	1.30	3.06	<0.01
22N/02W–03A01M	125.3	77.8	1.61	3.37	1.16	2.91	<0.01
22N/02W–04C02M	–459.7	376.8	1.22	10.53	5.11	2.06	.04
22N/03W–06H01M	–922.3	553.3	1.67	20.71	7.62	2.72	<0.01
22N/03W–22Q01M	20.0	77.8	.26	3.88	1.16	3.35	<0.01
23N/03W–35B01M	–69.5	84.3	.82	3.40	1.25	2.73	<0.01
24N/03W–24P01M	–724.6	364.0	1.99	16.36	4.95	3.30	<0.01
25N/03W–31R01M	89.9	77.8	1.16	3.49	1.16	3.02	<0.01
SOUTH ALLUVIAL FANS							
06N/01E–19L02M	–661.9	209.8	3.15	18.11	3.15	5.76	<0.01
06N/01E–19Q01M	101.0	207.1	.49	5.94	3.05	1.95	.05
06N/01W–01B04M	–166.4	280.1	.59	7.48	4.04	1.85	.07
07N/02E–34C02M	–152.3	185.0	.82	10.56	2.81	3.75	<0.01
09N/04E–33L01M	–740.0	169.8	4.36	28.96	2.75	10.55	<0.01
13N/01W–07A01M	335.8	139.7	2.40	7.43	2.04	3.64	<0.01
13N/01W–36Q02M	–32.3	117.0	.28	4.67	1.74	2.68	<0.01
14N/03W–11H01M	7.9	166.3	.05	4.45	2.46	1.81	.07

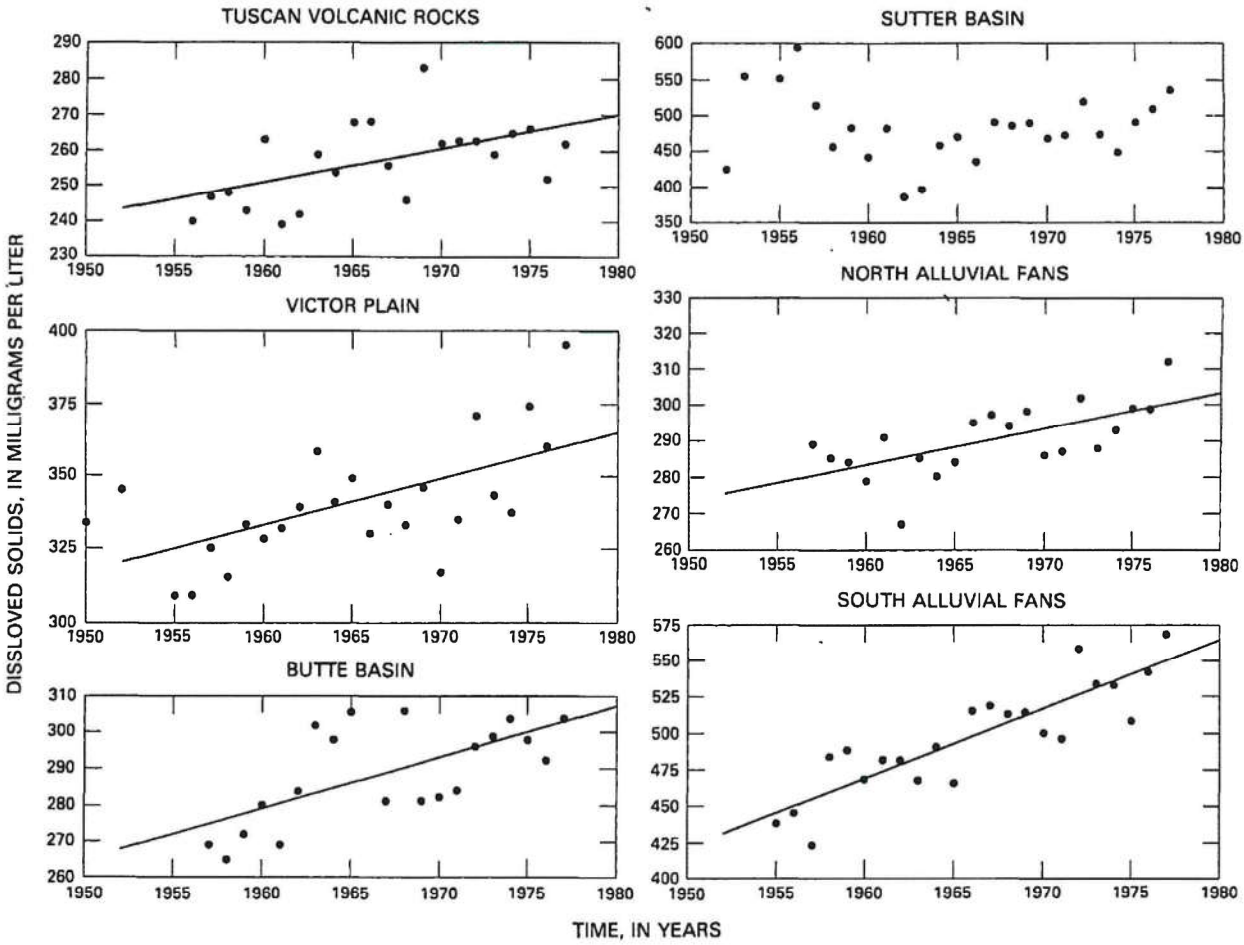

FIGURE 6.—Average yearly dissolved-solids concentrations versus time for the six hydrochemical facies in the Sacramento Valley. The coefficients and significance tests for the trend lines are given in table 5. If no line is shown, then the slope of the trend line is not significantly different from zero at the 90 percent confidence level. The technique by which the average yearly dissolved-solids values were derived is explained in the text.

The average yearly increase in dissolved solids for the Victor Plain facies is 1.61 mg/L. The trend line, which explains 38 percent of the variation in the standardized data, is shown in figure 6. Only two of the 20 wells studied in this facies showed significant changes, one of which showed an increase, and the other a decrease with time.

For Butte Basin, a temporal trend having a slope of 1.37 (mg/L)/yr explains 41 percent of the variation in the averaged data. In this facies also, two wells showed significant trends. One well demonstrated an increase and the other a decrease in dissolved solids with time.

Sutter Basin is the only hydrochemical facies to show no significant temporal change in average dissolved-solids concentration. Two of the 10 wells did show significant trends, but in opposite directions.

An increase in the average dissolved-solids concentration of the north alluvial fans facies of 1.02 (mg/L)/yr explains 43 percent of the variation in the yearly average data. A plot of the trend line is shown in figure 6. Of 62 wells that have seven or more observations in this area, 15 show significant upward trends, and none decrease.

Seventy-six percent of the variation in the average yearly dissolved-solids data are explained by a linear trend in the south alluvial fans facies. The slope is very steep 4.75 (mg/L)/yr and indicates a very rapid increase in dissolved solids (fig. 6). Of the 18 wells examined in this facies, 8 had significant increases in dissolved solids. There were no wells that showed decreases.

NITRATE

A certain amount of nitrate is present in precipitation, and chemical reactions in the soil zone may add to this amount. Thus, even under natural conditions, a finite amount of nitrate will exist in ground water. An estimate of natural nitrate concentrations in the Sacramento Valley can be made from data gathered during the period 1912–13 (Bryan, 1923). The median nitrate-nitrogen concentration in these 43 samples is 0.67 mg/L. The highest nitrate-nitrogen concentration measured was 14 mg/L, which suggests some wells were polluted as long as 70 years ago. From the frequency histogram of the 1912–13 nitrate data (fig. 7), it is estimated that under natural conditions, no more than about 3 mg/L nitrate-nitrogen would be expected in the ground water.

By the period 1974–78, the median nitrate-nitrogen concentration had more than doubled to 1.6 mg/L. The maximum observed nitrate-nitrogen concentration also increased, with two wells containing 27 mg/L and one well 61 mg/L. These increases likely reflect the influences of man's activities, and the extent of temporal changes was, therefore, investigated to determine the magnitude of the problem.

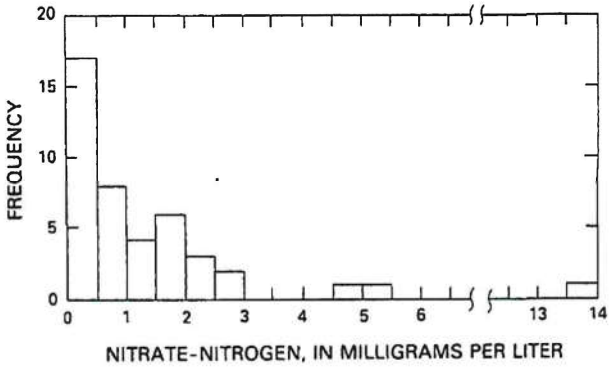

FIGURE 7.—Frequency histogram of dissolved nitrate-nitrogen concentrations in wells, 1912–13. Data from Bryan (1923).

Locations of wells examined for trends in nitrate are shown on plate 2*B*. The changes for each hydrochemical facies are discussed further and coefficients for the equations describing the average temporal changes are given in table 7. Coefficients for individual wells are summarized in table 8.

TABLE 7.—*Analyses of variance and coefficients for the regression of average yearly nitrate-nitrogen concentrations with time for the six hydrochemical facies in the Sacramento Valley*

[t=(year–1900); for example, t=(1980–1900)=80. NS, linear trend not significant at the 90 percent confidence level]

								MODEL Nitrate nitrogen=A+Bt			
Hydrochemical facies	Number of wells	Source	Degrees of freedom	Sum of squares	*F* ratio	Probability of exceeding *F* ratio	r^2	A	90 percent confidence limit	B	90 percent confidence limit
Tuscan volcanic rocks	5	Model	1	0.88	1.25	0.28	0.08	---	---	NS	---
		Error	15	10.57							
		Total	16	11.45							
Victor Plain	13	Model	1	6.05	29.31	<0.01	.63	–1.402	±0.751	0.036	±0.012
		Error	17	3.51							
		Total	18	9.56							
Butte Basin	3	Model	1	.69	1.85	.20	.12	---	---	NS	---
		Error	14	5.26							
		Total	15	5.95							
Sutter Basin	2	Model	1	.65	.84	.38	.08	---	---	NS	---
		Error	10	7.77							
		Total	11	8.42							
North alluvial fans	26	Model	1	5.02	49.67	<0.01	.73	–3.786	±1.625	.099	±0.024
		Error	18	1.82							
		Total	19	6.84							
South alluvial fans	13	Model	1	2.03	7.72	.01	.30	–0.506	±1.514	.036	±0.023
		Error	18	4.73							
		Total	19	6.76							

TABLE 8.—*Wells showing significant trends in nitrate-nitrogen concentration*

[For the model: Nitrate-nitrogen = A + Bt, where t is the year minus 1900]

Well	A	Standard error	Student's *t*	B	Standard error	Student's *t*	Probability of exceeding t for B
TUSCAN VOLCANIC ROCKS							
23N/01W–09L01M	–25.33	3.82	6.63	0.53	0.06	8.78	<0.01
25N/02W–07K01M	–7.96	3.74	2.13	.17	.06	2.89	<0.01
VICTOR PLAIN							
10N/05E–06M02M	–6.58	1.62	4.06	0.12	0.03	4.85	<0.01
11N/06E–16M01M	–9.38	1.35	6.96	.18	.02	8.56	<0.01
13N/05E–13D01M	–3.98	2.09	1.90	.08	.03	2.31	.02
14N/05E–32R03M	–14.48	2.19	6.60	.23	.03	7.38	<0.01
18N/04E–07A01M	–0.81	1.09	.75	.03	.02	1.87	.06
BUTTE BASIN							
None							
SUTTER BASIN							
None							
NORTH ALLUVIAL FANS							
18N/04W–02F01M	–73.57	6.37	11.54	1.38	0.10	13.96	<0.01
20N/03W–02D01M	–11.39	7.49	1.52	.23	.12	1.95	.05
21N/02W–15C01M	–15.47	5.62	2.75	.29	.08	3.43	<0.01
21N/03W–02Q01M	–33.53	7.80	4.30	.58	.12	4.89	<0.01
22N/01W–29C01M	–8.35	6.41	1.30	.17	.10	1.70	.09
22N/02W–03A01M	–10.26	6.16	1.67	.28	.10	2.92	<0.01
25N/03W–31R01M	–10.34	6.88	1.50	.24	.10	2.30	.02
SOUTH ALLUVIAL FANS							
09N/02E–10D01M	26.38	6.93	3.81	–0.38	0.11	3.44	<0.01
13N/01W–07A01M	–10.19	2.66	3.84	.21	.04	5.26	<.01
13N/01W–08B01M	–11.80	2.36	5.00	.22	.04	6.13	<.01
14N/03W–11H01M	–4.40	2.75	1.60	.10	.04	2.33	.02
14N/03W–14Q02M	–25.22	5.95	4.24	.38	.08	4.55	<.01

HYDROCHEMICAL FACIES

No significant average trend was found for the Tuscan volcanic rocks hydrochemical facies. However, two of the five wells examined did show significant upward trends in nitrate concentrations.

A linear trend with a slope of 0.036 (mg/L)/yr explains 63 percent of the temporal variation in the average yearly nitrate-nitrogen concentrations in the Victor Plain facies. A plot of this trend line is shown in figure 8. Of 13 wells in this area that had 6 or more observations, 5 showed significiant upward trends. None of the wells showed a significant decrease.

Neither Butte nor Sutter Basin had a significant average trend in nitrate. Also, there were no individual wells in either that showed any significant changes. However, with only three wells in Butte Basin and two in Sutter Basin having six or more observations, there are too few samples for the results of the test to be conclusive.

The nitrate-nitrogen concentrations in the north alluvial fans hydrochemical facies show a distinct upwards

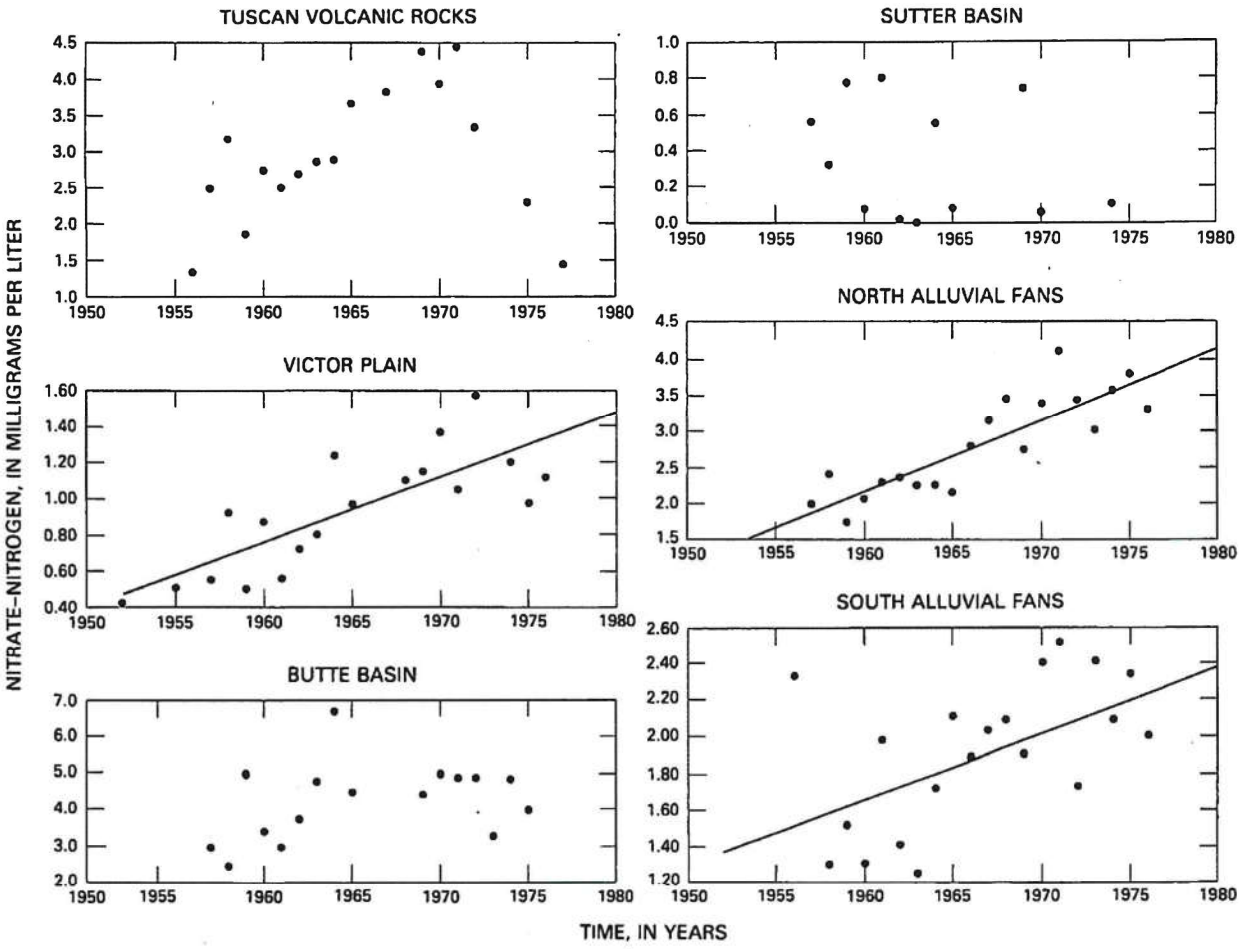

FIGURE 8.—Average yearly nitrate-nitrogen concentrations versus time for the six hydrochemical facies in the Sacramento Valley. The coefficients and significance tests for the trend lines are given in table 7. If no line is shown, then the slope of the trend line is not significantly different from zero at the 90 percent confidence level. The technique by which the average yearly nitrate-nitrogen values were derived is explained in the text.

trend with a slope of 0.099 (mg/L)/yr. Seven of the 26 wells in this facies showed significant upwards trends. The plot of the trend in figure 8 shows that the average concentration of nitrate-nitrogen in this facies has exceeded 3.0 mg/L, the maximum expected under natural conditions.

For the south alluvial fans hydrochemical facies, a linear trend having a slope of 0.036 (mg/L)/yr explains 30 percent of the temporal variation in the average annual nitrate-nitrogen concentrations. Thirteen wells had six or more observations over time, and 5 of them show significant temporal changes. Four have upwards trends, and 1 a downwards trend.

HYPOTHESIS TESTING

Because trends in the data for the individual wells were tested at the 90 percent confidence level, there is a 10 percent chance that no significant trend exists in the valley. The significant slopes that were observed could result from normally distributed random fluctuations about a true true slope of zero. If this were the case, 5 percent of the wells could show a significant increase, and 5 percent a significant decrease, although no real trend existed. If more than 5 percent of the dissolved-solids or nitrate wells show significant trends in the same direction, then it can be concluded that there has been a significant change for that species.

Of 140 wells in the Sacramento Valley tested for trends in dissolved solids, 28 (20 percent) showed an increase and 7 (5 percent) showed a decrease with time. Under the null hypothesis that no change in dissolved solids is occurring at the 90 percent confidence level, it would be expected that by random variation, 7 of the wells would show a significant decrease and 7 would

show a significant increase. For dissolved solids, the number of wells showing increases exceeds the number expected by random variation, and the increase in dissolved solids is significant.

Of 62 wells tested for trends in nitrate, 18 (29 percent) showed increases, but only 1 (2 percent) showed a decrease with time. Under the null hypothesis of no change, 3 can be expected to increase and 3 to decrease by random variation at the 90 percent confidence level. Because 29 percent of the wells showed significant increases in nitrate, the null hypothesis can be rejected, which indicates significant increases in nitrate are occurring in the Sacramento Valley.

PROCESSES CONTROLLING GROUND-WATER CHEMISTRY

Differences in the chemical composition of ground water among the six hydrochemical facies in the Sacramento Valley indicate that either different processes control the water chemistry in different areas, or that there are spatial variations in the same process. In this section, the major controlling processes are delineated from the chemical data using principal components analysis. Factor scores are than calculated for each well that reflect the magnitude of each component in that well. By studying the spatial trends in the factor scores using trend surface analysis, the areal variations in processes can be determined. Contour maps of these surfaces show the spatial distributions of the more important processes controlling ground-water chemistry.

METHODS OF DATA ANALYSIS

PRINCIPAL COMPONENTS ANALYSIS

Principal components analysis (Rummel, 1970; Davis, 1973) is used to separate the variance of a data matrix into common and unique components. Variables, in this case dissolved chemical species, that are controlled by the same process will share a common variance structure. Principal components analysis will group the variables on the basis of this shared variation and will calculate a correlation between variables and components. These components represent independent sources of variation in a data matrix and can be interpreted in terms of controlling processes using knowledge of geochemical principles.

From the correlations, or loadings as they are termed, between variables and components, factor scores can be calculated for each well that measure the intensity of a component in that well. These factor scores are a composite of all the chemical species that load on a component and summarize similar behavior in a number of different species. Where several of the chemical species are controlled by the same process, this transformation to factor scores reduces the number of variables needed to account for the significant variation in the data. The factor scores can be further analyzed as any other numerical variable.

TREND SURFACE ANALYSIS

Trend surface analysis (Davis, 1973) is a technique for separating variation in geographically distributed data into regional and local parts. Either of these parts might be the goal of a particular study. For the distribution of processes in the Sacramento Valley, however, the regional variation is of interest. A trend surface is delineated by a polynomial equation that predicts the magnitude of some variable in terms of the geographic coordinates of a set of observations. The criteria for fitting the polynomial is to minimize the squared deviations about the surface. In this study, the trend surface represents the spatial variation in processes controlling ground-water chemistry. By contouring the surface, maps can be prepared that show the spatial variation in the magnitude of the process.

PROCESSES AND THEIR SPATIAL VARIATION

For the Sacramento Valley, 15 variables (table 9) were included in the principal components analysis. A major assumption of components analysis is that the data are normally distributed. This requirement was reasonably well met by using logarithmic transformations of the chemical concentrations. Four principal components explained 73 percent of the total variation in the data and accounted for all the significant common variation (that is, only these four components had eigenvalues greater than one). The four individual components explained 36, 17, 11, and 9 percent of the total variation. Because neither the third nor fourth component yielded clear interpretations that could be attributed to processes, only the first two components are presented. These two components, however, explain

TABLE 9.—*Chemical variables included in the principal components analysis of the Sacramento Valley*

Dissolved solids	Potassium	Silica	Nitrate
Calcium	Manganese	Bicarbonate	Phosphate
Magnesium	Arsenic	Sulfate	Fluoride
Sodium	Boron	Chloride	

TABLE 10.—*Results of principal components analysis on chemical data from the Sacramento Valley*

[All loadings with absolute values less than 0.30 have been omitted for clarity]

	Components		Communalities
	1	2	
Dissolved solids	0.94		0.93
Calcium	.76		.60
Magnesium	.81		.67
Sodium	.83		.76
Bicarbonate	.85		.72
Chloride	.76		.62
Sulfate	.63		.41
Boron	.65		.42
Fluoride	.30	−0.46	.30
Silica	−0.54	.42	.46
Potassium		.67	.48
Nitrate		−0.71	.52
Phosphate		.50	.30
Manganese		.63	.41
Arsenic		.62	.38
Percent variation explained	36	17	
Cumulative percent variation explained	36	53	

over 50 percent of the variation in the chemical data from the Sacramento Valley.

Table 10 shows the results of the principal components analysis. On component one, dissolved solids, calcium, magnesium, sodium, bicarbonate, chloride, sulfate, boron, and fluoride all have positive loadings. Silica is the only species to have a significant negative loading on this component. The inverse loadings of dissolved solids and silica indicate that low silica concentrations tend to be found in conjunction with high dissolved-solids concentrations, and vice versa. The positive loadings of all the major chemical species on this factor indicate a source high in calcium, magnesium, sodium, bicarbonate, chloride, and sulfate. This source is also high in fluoride and boron, and low in silica.

The trend surface map of this component (fig. 9) shows a distinct linear trend across the valley, which accounts for 36 percent of the spatial variation in component one. Low values of component one along the eastern margin and in the northern end of the valley indicate low dissolved-solids and high silica concentrations. In the southwestern corner, high concentrations of dissolved species and boron are indicated. This distribution in the ground water is very similar to the distribution of water chemistry in surface streams draining into the valley. Table 11 shows the average concentrations of dissolved species in streams entering the valley from certain areas. East side streams are low in dissolved solids, and contain twice as much silica as streams from the southwestern margin. The silica in east side streams is likely from the weathering of volcanic detritus in the Sierra Nevada and Cascade Range. High dissolved-solids concentrations in the southwest originate in thermal springs in the Coast Ranges.

The first principal component represents the effects of the chemistry of recharge to the valley on the chemistry of the ground water. This process is active along both margins of the valley and produces fairly uniform chemical compositions along the eastern side. Along the western margin, changes in surface-water chemistry from north to south induce changes in ground-water chemistry. The effects of recharge chemistry are the single most important control on ground-water chemistry, accounting for over one-third of the total variation in the chemical data.

The second principal component (table 10) explains 17 percent of the variation in the chemical data, and contains positive loadings of silica, potassium, phosphate, manganese, and arsenic. Nitrate and fluoride have negative loadings on this component. The trend surface for component two (fig. 10) explains 38 percent of the spatial variation in this component. The pattern indicates high factor scores in the center of the valley with low values along the margins. The occurrence of high factor scores in wells in the flood basins suggests that the fine-grained sediments and reducing conditions in the basins are an important control on water chemistry.

Measurements of dissolved oxygen in the ground water in the south alluvial fans facies (table 12) show an average of 3.8 mg/L of dissolved oxygen. Although no data are available for other parts of the valley, it is reasonable to assume that the coarse-grained sediments along the valley margins would contain some dissolved oxygen. In the flood basins, where sediments are water saturated and fine grained, reducing conditions probably exist. The increase in manganese and arsenic, and decrease in nitrate, support an oxidation-reduction effect. The solubility of manganese and arsenic increases in reducing conditions, and nitrate could be removed by denitrification.

Longer residence times in the fine-grained sediments of the flood basins and weathering of volcanic detritus from Sutter Buttes could supply the higher silica and potassium concentrations indicated by component two. The inverse relation between phosphate and fluoride probably reflects spatial differences in their sources rather than equilibrium with a mineral phase, such as apatite. Phosphate, introduced along with nitrate, would not be removed by reduction reactions and would persist in the ground water. Fluoride is probably derived from thermal springs in the hills surrounding the valley and lacks a source in the central basins.

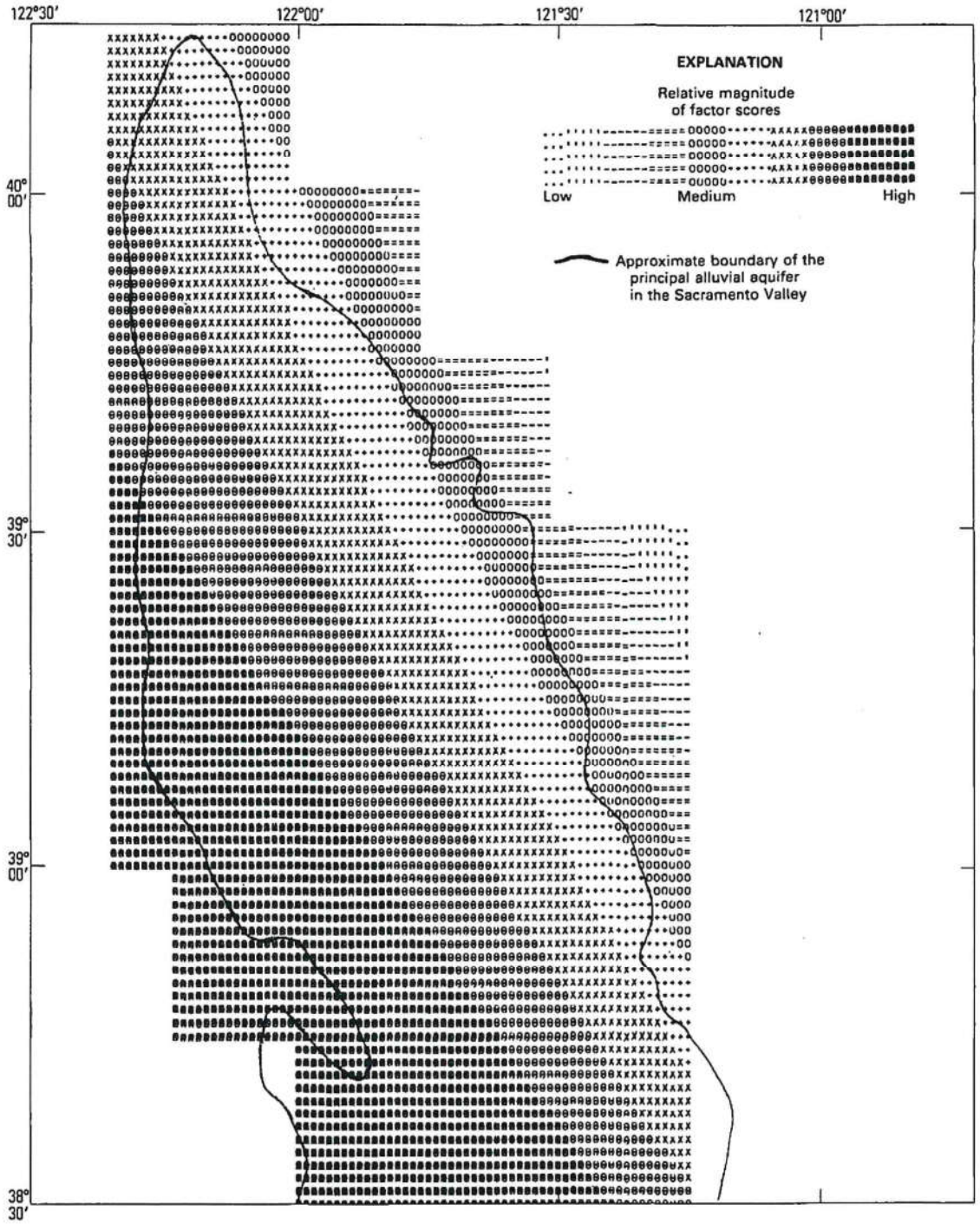

FIGURE 9.—Trend surface of factor scores for component one.

Principal components analysis shows that two components account for over 50 percent of the variation in the chemical data from the Sacramento Valley. While other processes will affect water chemistry, they seem to be either more localized or much less important than the two discussed. Recharge from the valley margins

TABLE 11.—*Average chemical compositions of surface water entering the Sacramento Valley*

Species (mg/L)	East side	Northern west side	Southern west side
Dissolved solids	85	215	592
Calcium	11	36	53
Magnesium	4.7	12	40
Sodium	6.3	13	101
Bicarbonate	55	164	314
Chloride	5.4	16	150
Sulfate	7.0	28	82
Boron	.10	.07	.51
Fluoride	.08	.08	.4
Silica	22	14	11

EXPLANATION OF LOCALITIES

East side: Antelope Creek, Mill Creek, Big Chico Creek, Butte Creek, Feather River, Yuba River, Bear River, and American River.

Northern west side: Red Bank Creek, Elder Creek, Thomes Creek, and Stony Creek.

Southern west side: Stone Corral Creek, Lurline Creek, Freshwater Creek, Salt Creek (west of Williams), Cortina Creek, Sand Creek, Oat Creek, Cache Creek, and Putah Creek.

is the most important control on ground-water chemistry, with reactions in the flood basin sediments also being important.

MINERAL STABILITY RELATIONS

Sediments deposited in the Sacramento Valley have been derived from erosion of the surrounding mountains. These mountains contain igneous and metamorphic rocks which were formed at higher temperatures and (or) pressures than are found at shallow depths in the valley sediments. Because the environment of deposition is radically different from that of formation, these minerals are generally not in equilibrium with their surroundings. As a result, the minerals react with the ground water, which dissolves the unstable primary minerals and forms secondary minerals that are more stable. Reaction rates may be very slow, so the process is gradual and can take tens of millions of years or longer. During this diagenesis, phases, such as pyroxenes, feldspars, micas, and volcanic glass, weather to more stable phases, such as clay minerals and iron hydroxides.

Water chemistry will be affected by water-rock interactions, and the three parts of the system (primary minerals, aqueous solution, and secondary minerals) are interdependent. Using thermodynamic calculations, the mineral phases that will be stable in equilibrium with solutions of various compositions can be predicted. It cannot be justifiably presumed, however, that the mineral assemblage and the ground-water chemistry are in thermodynamic equilibrium, particularly where aluminosilicate minerals are involved. Water chemistry may reflect incomplete reactions or partial equilibrium with metastable phases.

In this section, the relations between water chemistry and aquifer mineralogy are examined. Mineralogy is presented from two U.S. Geological Survey test wells. Mineral saturation indices are examined to determine any likely phases that may be controlling water chemistry. Finally, stability and metastability fields of mineral phases are compared to measured water chemistry to determine what secondary minerals will be most stable in contact with Sacramento Valley ground water.

MINERALOGY OF SEDIMENTS

Sidewall samples were collected from various depths in two test wells drilled by the U.S. Geological Survey during 1979. Data from two wells do not provide a comprehensive evaluation of sediment mineralogy, but they do provide a partial guide to what minerals may be present. Not all the samples have been analyzed as of the time of this writing and additional mineralogic data will be published in the future as basic data reports.

WELL 12N/01E–34Q

The mineralogy of sidewall samples from well 12N/01E–34Q was determined by optical microscope identification of the 0.5- to 0.125-mm size fraction. Table 13 shows the percent compositions of minerals, in this size range, for five samples collected from 323 feet to 897 feet. Data from an additional sample at 1,845 feet is also given. Feldspars compose an average of about two-thirds of the mineral grains, with about one-fifth being quartz and one-tenth being rock fragments. In all the shallower samples, the percent plagioclase having an anorthite content greater than 34 percent is smaller in the fine fraction than in the medium. The sample from 1,845 feet has an unusually small amount of anorthite-rich plagioclase in the medium fraction. The albitic plagioclase component increases between medium and fine fractions in all but one sample. The smaller size fractions, which are chemically more reactive, are dominated by albitic plagioclase.

Lithic fragments from a gravel at 1,856 feet, having a distinct greenish hue, were examined by X-ray diffraction. The sample near this depth was unusually rich in heavy lithic fragments (table 13). X-ray analysis of these fragments indicates that the composition is quartz, plagioclase, and chlorite (Ivan Barnes, U.S. Geological Survey, personal commun., 1979). The mineralogy of the sediments determined by optical methods may not reflect the complete mineralogy, especially where some minerals are contained in rock fragments which are not differentiated mineralogically. Mineral phases identified in samples from this well are shown in table 14.

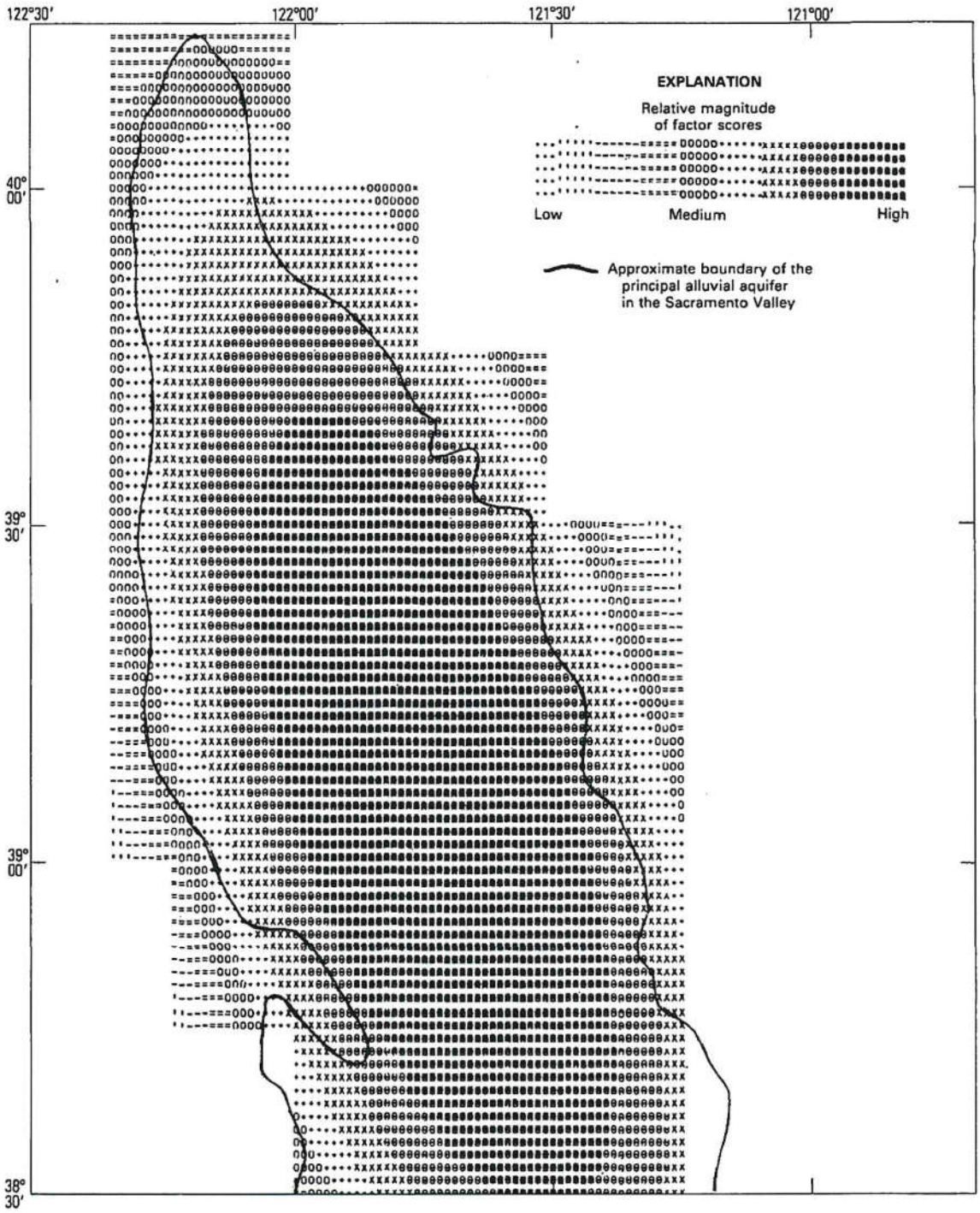

FIGURE 10.—Trend surface of factor scores for component two.

WELL 19N/01W–32G

The mineralogy of a number of fine-grained layers was determined by X-ray diffraction analysis of sidewall samples from well 19N/01W–32G. The results of the analyses are shown in table 15. Below a depth of about 562 feet, a large component of X-ray amorphous material is present in the sediments. Whether this is primary volcanic glass or an intermediate weathering

TABLE 12.—*Dissolved-oxygen concentrations in well water in the south alluvial fans facies*

Well	Date	Dissolved oxygen (mg/L)
08N/03E–05N04M	08–01–79	1.9
08N/03E–06M01M	08–01–79	2.0
08N/01E–06B01M	07–31–79	5.9
08N/01E–17C01M	07–26–79	5.0
09N/03E–31L01M	08–01–79	2.0
09N/02E–18N01M	07–31–79	4.4
09N/02E–33E01M	07–31–79	7.8
09N/01E–35H02M	07–31–79	3.8
09N/01W–25M01M	07–31–79	3.2
10N/02E–03E01M	07–25–79	2.8
11N/01W–01D01M	07–25–79	3.5
Mean		3.8

product, such as an amorphous aluminosilicate (Paces, 1978) was not investigated. The two clay minerals present in quantity are halloysite and illite. The presence of halloysite rather than kaolinite was determined using transmission electron microscopy. Figure 11 shows an electron micrograph of sediments from the 407-foot depth. The tubular structures at the center and top of the figure are halloysite, with poorly formed flakes of illite also visible. The dark, blocky particles are fine-grained quartz and plagioclase.

Optical examination of sand-size grains shows that the mineralogy is consistent with an andesitic sand. The major mineral is plagioclase, which is zoned and shows etching. Some pyroxenes are present and are clear to light green. Many of the grains are stained by ferric hydroxides.

SATURATION INDICES

According to the law of mass action, when an aqueous solution is in equilibrium with a mineral, the ion-activity product for that mineral will equal the thermodynamic equilibrium constant. The degree of saturation of a water can be represented by the saturation index (*SI*), which is the logarithm of the quotient of the ion-activity product (*IAP*) divided by the equilibrium constant (*K*):

$$SI = \text{Log}\,\frac{IAP}{K}, \tag{1}$$

where

SI=saturation index
IAP=ion-activity product, and
K=thermodynamic equilibrium constant.

The saturation index has a value of zero when the solution is in equilibrium with a solid phase. A positive saturation index indicates supersaturation and a negative index undersaturation with respect to some mineral. Minerals that are present in an aquifer and have negative saturation indices can dissolve. Minerals that have positive saturation indices may precipitate from solution, although whether this actually occurs depends on additional factors. By examining the saturation indices of water samples collected from the Sacramento Valley, some idea can be obtained about which minerals may be influencing ground-water chemistry.

TABLE 13.—*Mineralogic compositions of sidewall samples from U.S. Geological Survey test well 12N/01E–34Q*

c—coarse >0.5 mm.
m—medium 0.5–0.25 mm.
f—fine 0.25–0.125 mm.
vf—very fine 0.125–0.0625 mm.
p—pan <0.0625 mm.

VAB—very abundant, from 25–50 percent of the heavy minerals.
AB—abundant, from 10–25 percent of the heavy minerals.
SP—sparse, from 1–4 percent of the heavy minerals.

Sample depth, in feet	323		467		685		788		897		1845	
Texture, in percent c/m/f/vf/p	7/2/41/34/17		2/2/8/43/45		3/5/19/38/36		60/22/10/3/5		8/52/28/4/8		59/18/6/4/12	
Size interval	m	f	m	f	m	f	m	f	m	f	m	f
Composition, in percent:												
Potassium feldspar	12	13	6	16	27	13	15	14	15	12	10	12
Plagioclase (Anorthite<34)	25	44	40	33	22	32	21	36	28	39	19	24
Plagioclase (Anorthite>34)	28	10	24	14	25	16	23	12	23	14	3	13
Quartz	20	23	20	28	20	26	21	18	7	13	31	18
Lithic fragments	11	10	7	6	4	10	14	13	21	12	21	11
Heavy minerals[1]	3	1	3	3	2	2	5	6	6	13	15	23
Nonopaque heavy grains:												
Sausserite	VAB		VAB		VAB		VAB		AB		AB	
Uralite	VAB		VAB		VAB		VAB		AB		AB	
Goethite	VAB		VAB		VAB		VAB		AB		AB	
Lithic fragments	AB		SP		SP		AB		AB		VAB	

[1]Heavy minerals have specific gravities greater than 2.9.

TABLE 14.—*Minerals identified in sidewall samples from U.S. Geological Survey test well 12N/01E–34Q, in alphabetical order*

Actinolite-tremolite (series)[1]	Glaucophane
Amphiboles	Graphite
Analcite	Hematite (some specular)
Apatite	Hercynite
Augite-ferroaugite (series)[1]	Hornblende (green, brown, and oxy-varieties)
Basic glass	Hypersthene
Biotite	Lawsonite
Bronzite-ferrohypersthene (series)[1]	Marcasite
Chlorite	Pigeonite
Chromite	Plagioclase (series)[1]
Chrysotile	Potash feldspar (undifferentiated)
Clinozoisite	Pumpellyite
Cordierite	Richterite (part of series)[1]
Cummingtonite	Riebeckite
Diopside-hedenbergite (series)[1]	Serpentine (?)
Enstatite-bronzite (series)[1]	Sideromelane
Epidote	Sphene (titanite)
Fluorite	Spinel
Garnet (red)	Staurolite
Glauconite	Zircon
	Zoisite

[1]"Series" means several varieties within the series were found.

Saturation indices were calculated for 271 water analyses selected from those published by Fogelman (1975, 1976) and Fogelman and Rockwell (1977). Of the 271, 153 had aluminum analyses and 183 had iron analyses. Temperature, pH, and alkalinity were determined in the field. Samples for cation determinations were passed through a 0.1-micrometer filter and acidified with concentrated nitric acid. Some controversy exists as to the validity of aluminum and iron data gathered in this manner; however, the possible error introduced is generally small (Kennedy and others, 1974; Barnes, 1975). Some of the supersaturation in the aluminosilicate and iron minerals may be due to particulate iron and aluminum passing through the filter. Saturation indices were calculated using WATEQF (Plummer, and others, 1978).

Table 16 shows the mean, minimum, and maximum saturation indices for selected mineral phases along with log equilibrium constants at 20°C, the average temperature of ground waters in the Sacramento Valley. Although many minerals, such as the feldspars and montmorillonite, show variations in chemical composition, saturation indices were calculated for ideal mineral phases. Therefore, stability calculations for these minerals only approximate actual conditions, but they do provide useful indicators of the types of reactions that may be occurring.

TABLE 15.—*Percent mineral composition of sidewall samples from U.S. Geological Survey test well 19N/01W–32G*

[Tr, trace; unid., unidentified; inter., intermediate; ND, not detected]

Depth (feet)	Quartz	Plagioclase	Amorphous	Halloysite	Illite	Other
260	35–45	25–35	ND	15–20	5–10	Tr unid.
353	40	15–20	ND	10–15	ND	Tr minor.
407	35–40	20–25	ND	10–15	2–5	Tr minor.
478	35–40	25–30	ND	10–15	5–10	5–10 Chlorite.
562	10–20	15–25	Major	5–15	2–5	ND.
630	20–25	15–20	Inter.	5–10	2–10	Tr unid.
930	15–20	10–15	Inter.	10–15	5–10	ND.
984	5–15	5–10	Major	10–15	1–5	Tr unid.
1,098	5–10	5–10	Major	5–10	1–5	ND.
1,193	5–15	5–10	Major	5–10	1–5	Tr minor.
1,390	5–10	2–5	Major	2–5	2–5	ND.

Most waters are close to saturation with respect to silicaglass, as might be expected from the volcanic detritus in the sediments. All samples were supersaturated with respect to amorphous ferric hydroxide, which may reflect the variability in solubility with particle size or particulate iron passing through the 0.1-micrometer filter during sampling. The waters tend to be at saturation with respect to gibbsite and slightly below saturation with respect to amorphous aluminum hydroxide.

Ground water is fairly close to saturation with respect to the carbonate minerals, calcite, dolomite, and magnesite. No carbonate minerals were recorded in sediments from either of the wells examined for mineralogy. Apparently, the formation of secondary carbonate minerals is of limited extent despite a number of samples indicating supersaturation with respect to calcite.

Potassium and sodium feldspars, which are abundant in the sediments, average close to saturation in Sacramento Valley ground water. Dissolution of these phases probably contributes to water chemistry where ground water is undersaturated with respect to these feldspars. All water samples are undersaturated with respect to anorthite, which is less abundant in the sediments. Halloysite is the only clay mineral with which the ground water is not supersaturated. Any of the other clay minerals could potentially form from most of the waters. When stability fields are considered, however, only one phase will be the most stable. These phase relations can be illustrated using activity diagrams.

ACTIVITY DIAGRAMS

Activity diagrams can be used to illustrate the phase relations among primary and secondary minerals and to predict the most stable secondary phases as a function of water chemistry. Such diagrams have been used by Feth, Roberson, and Polzer (1964), Tardy (1971) and White (1979) to depict weathering reactions in ground



FIGURE 11.—Electron micrograph of sediments from the 407-foot depth of well 19N/01W–32G. (Photograph by Technology of Materials, Santa Barbara, Calif.)

waters. The technique for calculating such diagrams is given in Garrels and Christ (1965), and Helgeson, Brown, and Leeper (1969) give numerous examples of such diagrams. A slightly different type of diagram, though basically similar, was presented by Kittrick (1969), and it depicts equilibrium between solid phases and an aqueous solution.

As an example of the calculation of the equilibrium boundary between two phases, the calculation of the phase boundary between illite and montmorillonite is given below. Formulas for these minerals are taken from WATEQF (Plummer, and others, 1978). For the reaction illite ⇆ montmorillonite, the chemical equation is written

TABLE 16.—*Mean, minimum, and maximum saturation indices in Sacramento Valley ground water for selected mineral phases*

Phase[1]	n	[2]Log K at 20 °C	Saturation index		
			Mean	Minimum	Maximum
Silica glass	271	-3.07	-0.14	-0.58	0.16
$Fe(OH)_3$ amorph.	183	4.885	1.31	.62	3.67
$Al(OH)_3$ amorph.	153	-31.77	-1.13	-2.32	.03
Gibbsite	153	-32.95	.05	-1.15	1.22
Fluorite	269	-11.02	-2.38	-3.50	-0.10
Hydroxyapatite	270	-59.57	-2.22	-7.57	1.64
Strengite	183	-26.37	-0.61	-2.06	1.05
Calcite	271	-8.45	-0.33	-1.80	.50
Dolomite	271	-16.92	-0.54	-3.37	1.24
Magnesite	271	-8.16	-0.53	-1.96	.43
Adularia	153	-20.96	.22	-1.81	1.66
Albite	153	-18.32	-0.82	-2.93	.47
Anorthite	153	-19.55	-3.27	-5.95	-1.77
Halloysite	153	-33.38	-0.89	-3.76	1.38
Kaolinite	153	-37.52	3.26	.32	5.58
Illite	153	-40.99	2.31	-1.33	4.53
Montmorillonites:					
1. Calcium	153	-45.73	3.40	-0.37	5.84
2. Belle Fouche.	95	[3]-34.97	7.49	4.04	9.01
3. Aberdeen	95	[3]-29.69	6.69	3.43	8.10
Muscovite	153	-49.94	1.35	-3.12	4.61
Chlorite	153	-91.29	-1.83	-12.11	3.52

[1]Chemical formulas for these phases are as written in WATEQF (Plummer and others, 1978.)

[2]Data from the latest version of WATEQF.

[3]The log equilibrium constant at 25°C is used because no enthalpy is given in WATEQF.

$$(K_{0.6}Mg_{0.25}Al_{2.3}Si_{3.5}O_{10}(OH)_2)+2.48H_4SiO_4 +0.52Fe^{+3}+0.45Mg^{+2} \leftrightarrows 3.13H_2O+0.6K^{+1}+1.86H^{+1} +1.56(H_{0.42}Mg_{0.46}Fe_{0.34}Al_{1.47}Si_{3.82}O_{10}(OH)_2). \quad (2)$$

At the phase boundary, the ion-activity product for this reaction will equal the equilibrium constant (K):

$$\frac{[K^{+1}]^{0.6}[H^{+1}]^{1.86}}{[H_4SiO_4]^{2.48}[Fe^{+3}]^{0.52}[Mg^{+2}]^{0.45}}=K. \quad (3)$$

Brackets denote free ion activities, which are concentrations corrected for the nonideality of aqueous solutions. Rewriting in terms of log activities gives the equation:

$$0.61 \log [K^{+1}]/[H^{+1}]-0.52 \log [Fe^{+3}]/[H^{+1}]^3 -0.45 \log [Mg^{+2}]/[H^{+1}]^2-2.48 \log [H_4SiO_4]=\log K. \quad (4)$$

To plot this line on a two-dimensional graph, the equation must be reduced to two variables. The assumptions that may be considered when plotting phase diagrams include (1) controlling the concentration of a component by equilibrium with a solid phase, (2) conserving a component in solid phases during phase transformations, and (3) assigning a specified concentration for a species in solution, commonly the average for that species in the study area.

In all plots below, it is assumed that the logarithm of the activity quotient of free ferric iron to hydrogen cubed (log $[Fe^{+3}]/[H^{+1}]^3$) is controlled by the solubility of amorphous ferric hydroxide at 4.885 (Plummer and others, 1978). The average for the log activity ratio of potassium to hydrogen (log $[K^{+1}]/[H^{+1}]$) in the valley is 2.75, and ratio of magnesium to hydrogen squared (log $[Mg^{+2}]/[H^{+1}]^2$) is 11.25. The average log activity of silica in ground waters is -3.21. The use of these averages where a concentration must be assumed in the calculation of a phase transformation does not significantly affect the depicted relations between data points and phase boundaries in the following activity diagrams.

For the equilibrium between illite and montmorillonite, log $[Fe^{3}]/[H^{+1}]^3$ is assumed to be controlled by the solubility of ferric hydroxide, and log $[H_4SiO_4]$ is assigned a value of -3.21. Replacing these quantities in equation 4 gives the following equation for the phase boundary between illite and montmorillonite:

$$\log [K^{+1}]/[H^{+1}]=0.122+0.743 \log [Mg^{+2}]/[H^{+1}]^2. \quad (5)$$

Two types of diagrams are presented here to illustrate phase relations in the system MgO-K_2O-Fe_2O_3-Al_2O_3-SiO_2-H_2O. The diagrams depart, to some extent, from the traditional presentation in that metastable phases are included. Recent work by Paces (1973, 1978) and Busenberg (1978) indicates that during the weathering of feldspars, the initial solids formed are amorphous to poorly crystalline aluminosilicates which may be reversible with respect to the aqueous solution. Subsequent crystallization results in the formation of a metastable aluminosilicate commonly called halloysite. Eventually, the thermodynamically most stable mineral will form. This pathway between primary and secondary minerals generally follows Ostwald's Rule (Darken and Gurry, 1953), which states that when a system is proceeding from a less to a more stable state, the final most stable state is not necessarily reached directly but may be attained through a series of intermediate states. Neither halloysite nor illite are stable with respect to montmorillonite or kaolinite, yet they are present in the sediments. Activity diagrams showing metastable states indicate the intermediate steps, as well as the final secondary minerals that are expected to form.

All minerals included in the following diagrams are from WATEQF and have formulas and log equilibrium constants from that program. Because no information is available on the chemistry of clay minerals from the Sacramento Valley, particularly illite and montmorillonite, no better substitute is available. This use of surro-

gate minerals will introduce some uncertainty in the exact locations of phase boundaries in the diagrams. Considering the uncertainty in the knowledge of thermodynamic data on montmorillonites and illites, it is doubtful if full knowledge of mineral chemistry would improve the situation. The montmorillonite used in all the diagrams is Aberdeen montmorillonite (Kittrick, 1971) with modifications by Truesdell and Jones (1974).

Figure 12 shows the stability fields of minerals as a function of $pH-\frac{1}{3}pAl^{+3}$ and $p[H_4SiO_4]$, where p stands for -log as in $pH=-\log [H^{+1}]$, and $pAl^{+3}=-\log [Al^{+3}]$. This diagram depicts the formation of secondary minerals from an aqueous solution. The solution, in this case, is assumed to have the average ion activity ratios and silica activity observed in the Sacramento Valley. No solid phase will form from solutions with low aluminum to hydrogen ratios and low silica concentrations (bottom right corner of figure 12). At higher aluminum to hydrogen ratios, the stable solid phase changes from gibbsite to kaolinite to montmorillonite with increasing silica. Halloysite and amorphous aluminum hydroxide phase boundaries are dashed to emphasize that they are both metastable phases. A solution in equilibrium with halloysite will be supersaturated with respect to montmorillonite or kaolinite. All samples from the valley plot in the montmorillonite stability field. Only 10 percent of the samples are supersaturated with respect to halloysite.

Regression analysis was used to determine if any significant linear relation exists between aluminum and silica. Each hydrochemical facies was treated separately to preserve as much detail as possible. Only two of the regression equations were significant, those for the Tuscan volcanic rocks and the Sutter Basin facies.

The equation for the Tuscan volcanic rocks facies is

$$pH-\tfrac{1}{3}pAl^{+3}=2.10+0.39p\,[H_4SiO_4] \qquad (6)$$

with r^2 equal to 0.26 and coefficients and their 90 percent confidence limits of

$$2.10 \pm 0.83$$

and

$$0.39 \pm 0.27.$$

Rewriting the equation in terms of log activities gives

$$0.33 \log [Al^{+3}]/[H^{+1}]^3=2.10-0.39 \log [H_4SiO_4]. \qquad (7)$$

The inverse relation between the aluminum to hydrogen ratio and silica is indicative of control by a mineral phase. As silica increases in solution, $\log [Al^{+3}]/[H^{+1}]^3$ decreases to compensate.

The slope is close to and not significantly different from 0.33. Assuming that it is 0.33 and rearranging gives

$$\frac{[Al^{+3}][H_4SiO_4]}{[H^{+1}]^3}=10^{6.31}. \qquad (8)$$

The solution of halloysite or kaolinite is given by the equation:

$$\tfrac{1}{2}Al_2Si_2O_5(OH)_4+3H^{+1} \leftrightarrows \tfrac{1}{2}H_2O+Al^{+3}+H_4SiO_4. \qquad (9)$$

The ion activity product is

$$\frac{[Al^{+3}][H_4SiO_4]}{[H^{+1}]^3}=K. \qquad (10)$$

For halloysite log K equals 6.83 and for kaolinite, 4.76. The close agreement between the ion activity product of halloysite in ground water from the Tuscan volcanic rocks facies with the equilibrium constant is strong evidence that halloysite is controlling the aluminum and silica concentrations in ground water.

The Sutter Basin hydrochemical facies also showed a significant relation between $pH-\frac{1}{3}pAl^{+3}$ and $p[H_4SiO_4]$.

$$pH-\tfrac{1}{3}pAl^{+3}=6.13-0.92p[H_4SiO_4] \qquad (11)$$

with r^2 equal to 0.27 and coefficients and their 90 percent confidence limits of

$$6.13 \pm 2.91$$

and

$$0.92 \pm 0.91.$$

Rewriting the equation in terms of log activities gives

$$0.33 \log [Al^{+3}]/[H^{+1}]^3=6.13+0.92 \log [H_4SiO_4]. \qquad (12)$$

The positive slope is indicative of solution control of water chemistry, with both aluminum and silica increasing as some mineral phase is attacked by hydrogen ion. The slope is close to and not significantly different from one. This gives an aluminum to silica ratio in the dissolving phase of 1 to 3. The most likely minerals are, therefore, potassium and sodium feldspars, which have an aluminum to silica ratio of 1 to 3. This aluminum to silica ratio, along with the etched surfaces of feldspar grains observed under the microscope, may reflect stoichiometric dissolution of feldspars as found by Holdren and Berner (1979) and Berner and Holdren (1979).

Figure 13 shows the phase stability fields for minerals in terms of the log activity ratios of magnesium to

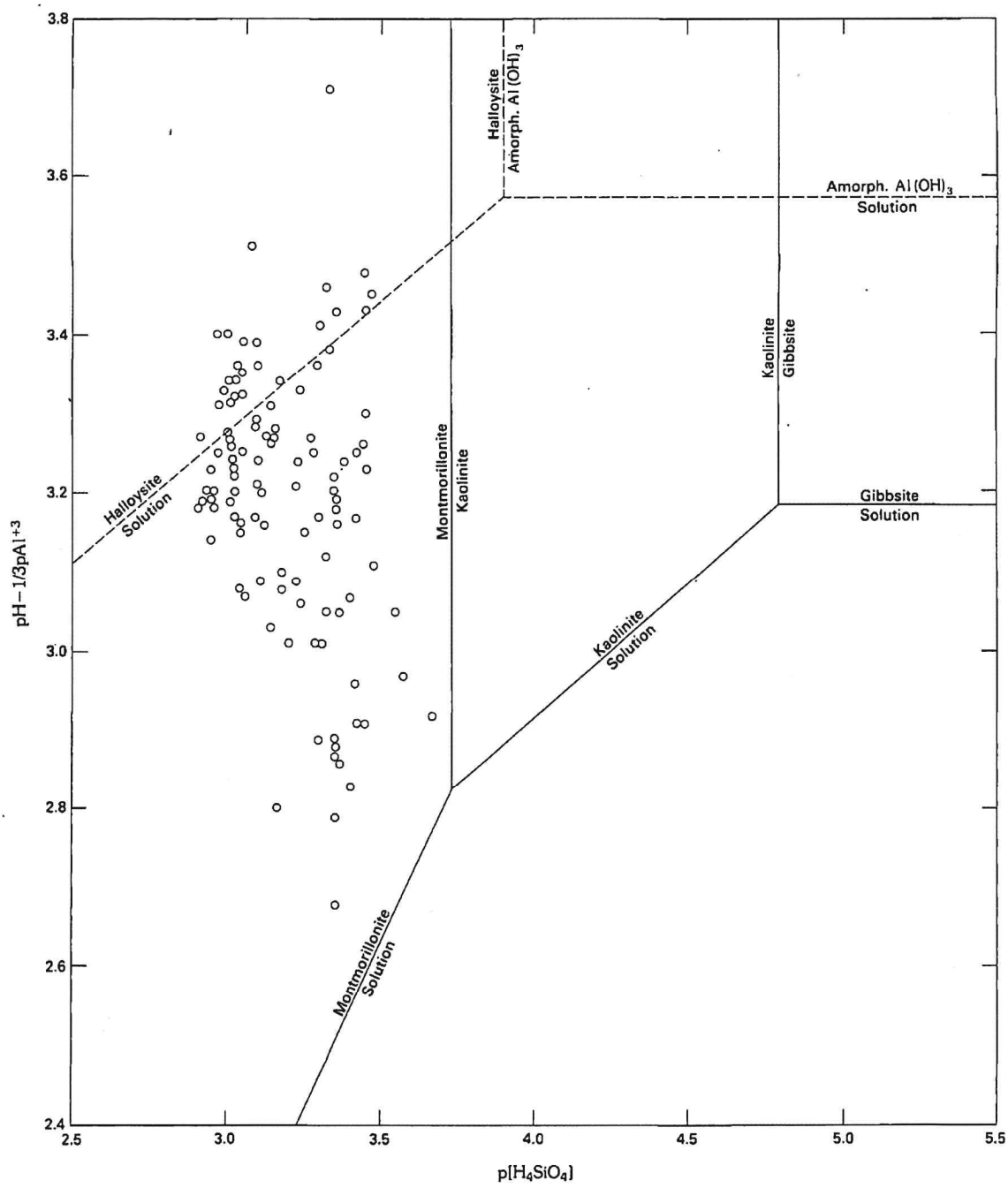

FIGURE 12.—Phase relations among minerals and aqueous solution in terms of pH-⅓pAl^{+3} and p[H_4SiO_4] at 20°C. (NOTE.—The aqueous solution is assumed to have the following ion activity ratios: log [Fe^{+3}]/[H^{+1}]^3 =4.885, log [K^{+1}]/[H^{+1}]=2.75, and log [Mg^{+2}]/[H^{+1}]^2=11.25.)

hydrogen squared and potassium to hydrogen. Aluminum is assumed to be strictly conserved in solid phases during phase transformations. Assumptions about iron and silica activities are as described at the beginning of this section on activity diagrams.

Figure 13 is actually two diagrams superimposed, so that illite, a metastable phase, can be shown. Illite is unstable with respect to montmorillonite or adularia if the three phases are considered simultaneously. The solid lines represent phase relations among the minerals

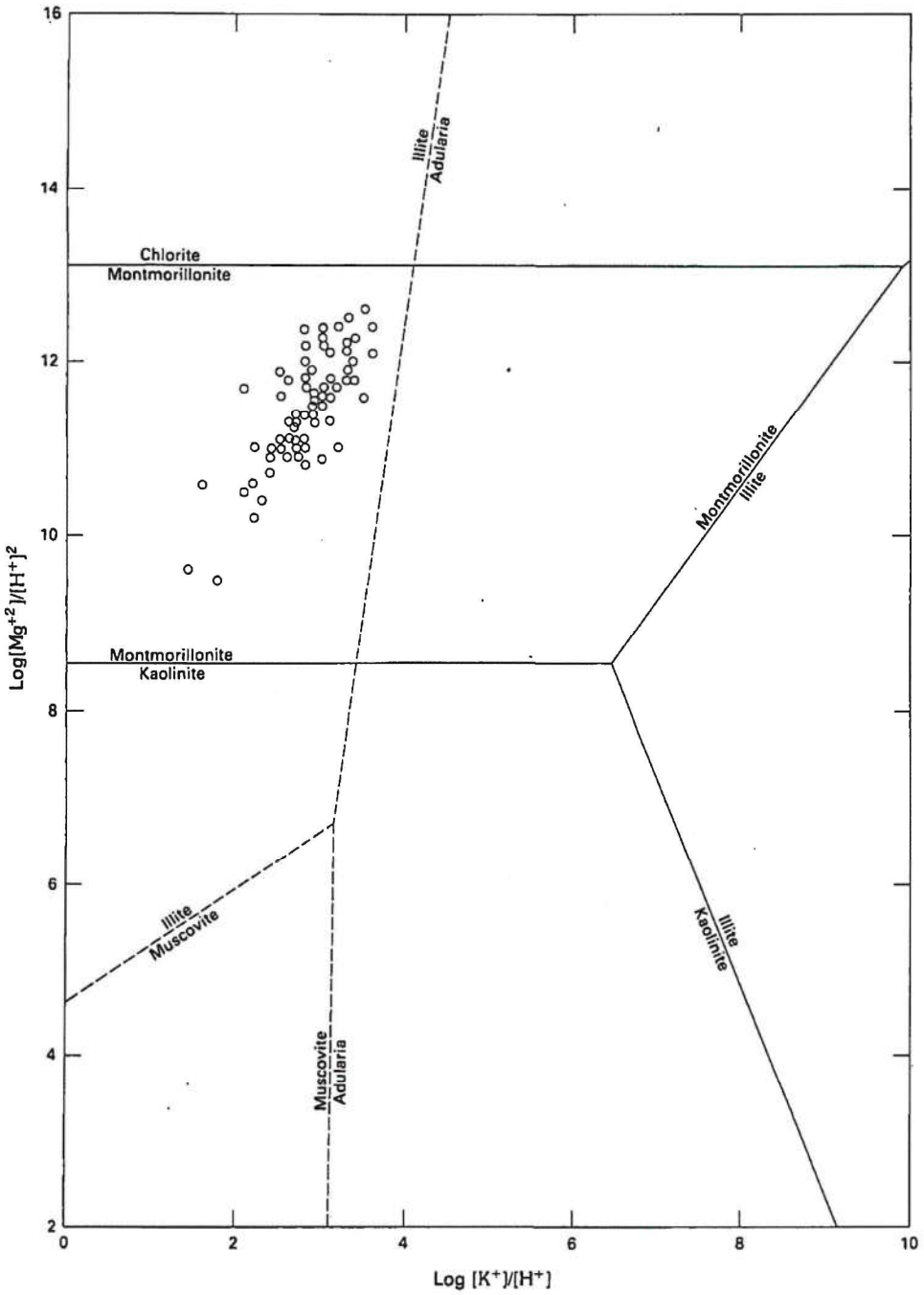

FIGURE 13.—Phase relations among minerals and coexisting aqueous solution in terms of log $[Mg^{+2}]/[H^{+1}]^2$ and log $[K^{+1}]/[H^{+1}]$ at 20°C. (NOTE.—Phase relations among chlorite, montmorillonite, illite, and kaolinite are shown by solid lines, and among illite, adularia, and muscovite by dashed lines. The aqueous solution is assumed to have the following activities of dissolved species: log $[Fe^{+3}]/[H^{+1}]^3$=4.885, log $[H_4SiO_4]$=-3.21.)

chlorite, montmorillonite, illite, and kaolinite. Among these minerals, montmorillonite is the most stable phase in equilibrium with ground water in the valley. The dashed lines represent phase relations among adularia, muscovite, and illite. Of these three minerals, illite is the most stable in contact with Sacramento Valley ground waters.

Illite is highly resistant to weathering (Berner, 1971),

and most of the illite found in samples from well 19N/01W-32G is probably detrital. Some of the illite may have formed from the weathering of primary minerals. Illite has been reported to form from orthoclase (Stumm and Morgan, 1970) and from muscovite (Berner, 1971).

Log activities from ground water in the Sacramento Valley plot in the stability field of a montmorillonite having the formula and stability of Aberdeen montmorillonite. Differences in activity ratios of ions in solution will probably produce montmorillonites of somewhat different composition in the Sacramento Valley, but some form of montmorillonite will be the most stable phase. Metastable phases either form as intermediate steps during the diagenesis of primary minerals (halloysite) or persist due to resistance to weathering (illite).

SUMMARY AND CONCLUSIONS

Shallow sediments in the Sacramento Valley were laid down as alluvial deposits in a freshwater environment. These sediments, from which ground-water samples were collected, have always been in contact with freshwater. Sediments along the valley margins are coarse grained, poorly sorted, and oxidized. In the central part of the valley, flood-basin deposits are finer grained and reduced. Most of the streams entering the valley are losing streams, at least over part of their courses, and much of the ground-water recharge is from this source.

The chemistry of ground water in the valley is greatly influenced by the chemistry of this recharge from the valley margins. Approximately one-third of the variation in ground-water chemistry can be attributed to this effect. The reducing conditions and finer grained sediments in the midvalley flood basins also influence ground-water chemistry. These processes have distinct spatial patterns that produce spatial variations in the chemical character of ground water in different areas.

Six areas, or hydrochemical facies, were delineated on the basis of geology, hydrology, and distinctions in chemical composition of ground water. Two of the facies lie along the eastern margin and receive recharge from the Cascade Range and Sierra Nevada. These waters are low in dissolved solids and high in silica. Two facies are located in the midvalley flood basins, and reducing conditions there produce higher concentrations of iron, manganese, and arsenic in the ground water. While the relative concentrations of these species are higher in the flood basins than in the rest of the valley, the absolute concentrations remain fairly low. Upwelling of saline water from underlying marine sediments contributes to high dissolved-solids concentrations in ground water in the southern parts of the flood basins.

Water along the west side of the valley is low in silica, and the water grades from moderate dissolved-solids levels in the north to high dissolved-solids levels in the south. Ground water in the southwest of the valley is also high in boron. The source of the high boron and dissolved-solids concentrations is thermal springs in the Coast Ranges. Two facies were delineated along the western margin to separate the waters having moderate and high dissolved solids. Because of the heterogeneity of ground-water chemistry in the valley, division into areas having more uniform chemical compositions provides additional detail in any investigation of water chemistry.

Dissolved-solids and nitrate concentrations were examined for linear trends with time for each of the hydrochemical facies. Significant increases in both were observed in parts of the valley. On the east side of the valley, the Tuscan volcanic rocks facies showed a significant increase in dissolved solids of 0.95 (mg/L)/yr but no significant change in nitrate concentrations. The Victor Plain facies showed significant increases in both dissolved solids [1.6 (mg/L)/yr] and nitrate-nitrogen [0.036 (mg/L)/yr]. Neither Butte Basin nor Sutter Basin hydrochemical facies, in the midvalley flood basins, showed a significant trend in nitrate with time. There were very few wells with multiple nitrate measurements, however, and the lack of significant changes may be due to the small sample size. Dissolved-solids concentrations in Butte Basin have been increasing at an average rate of 1.37 (mg/L)/yr, but are unchanged in Sutter Basin.

Both the north and south alluvial fans facies, adjacent to the Coast Ranges, show significant upward trends in dissolved solids and nitrate. The south alluvial fans facies has the greatest rate of increase for dissolved solids [4.75 (mg/L)/yr] of all the facies, and the north alluvial fans facies has the greatest rate of increase for nitrate-nitrogen [0.099 (mg/L)/yr]. The midvalley basins have fine-grained poorly permeable soils that protect the ground water from contamination. Infiltration rates are slow, and reducing conditions permit the removal of nitrate by denitrification reactions. Along the valley margins, however, significant increases in dissolved solids and nitrates have occurred since the mid-1950's.

Alkali feldspars and halloysite appear to be the most significant aluminosilicate minerals affecting water chemistry. Where waters are undersaturated, dissolution of feldspars takes place, bringing the water to near saturation with respect to adularia and albite. There is a general parallel increase in aluminum and silica reflecting the solution of aluminosilicates by ground water. In Sutter Basin, the relation between log $[Al^{+3}]/[H^{+1}]^3$ and log $[H_4SiO_4]$ indicates an increase in both aluminum and silica at a ratio 1 to 3. In the Tuscan

volcanic rocks facies, the relation between log $[Al^{+3}]/[H^{+1}]^3$ and log $[H_4SiO_4]$ is inverse. Rearranging the regression equation yields the same equation as for equilibrium between halloysite and an aqueous solution. The regression constant is very close to the equilibrium constant for halloysite, which supports the theory of solubility control by halloysite. Illite and halloysite were identified in sediments from the Sacramento Valley. Neither of these clay minerals is stable in the ground-water environment. The most stable clay minerals in equilibrium ground water of the valley is montmorillonite. Halloysite occurs as a mestastable intermediate step in the weathering of primary minerals to stable secondary minerals.

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Orchard Irrigation in Sutter-Yuba Area

STATE OF CALIFORNIA
EARL WARREN
GOVERNOR

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LETTER OF TRANSMITTAL

EARL WARREN
GOVERNOR



STATE OF CALIFORNIA
STATE WATER RESOURCES BOARD
PUBLIC WORKS BUILDING
SACRAMENTO 5, CALIFORNIA

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A. D. EDMONSTON, STATE ENGINEER
SECRETARY

August 27, 1952

ADDRESS ALL COMMUNICATIONS TO THE SECRETARY

HONORABLE EARL WARREN, *Governor, and*
Members of the Legislature of
the State of California

GENTLEMEN: I have the honor to transmit herewith Bulletin No. 6 of the State Water Resources Board, entitled "Sutter-Yuba Counties Investigation," as authorized by Chapter 1514, Statutes of 1945, as amended.

Under provisions of the cited statute, an agreement dated October 7, 1947, was entered into between the State Water Resources Board, the Counties of Sutter and Yuba, and the Department of Public Works acting through the agency of the State Engineer. The agreement provided for

> ". . . investigation and report on the underground water supply of the valley floor in the Counties of Sutter and Yuba, including quality, replenishment and utilization thereof, and, if possible, a method or methods of solving the problems involved . . .",

and authorized funds to meet the costs of the investigation for one year. A supplemental agreement executed by the same parties on December 3, 1948, authorized funds to complete the investigation and report.

The Sutter-Yuba Counties Investigation was conducted and Bulletin No. 6 was prepared by the Division of Water Resources of the Department of Public Works, under the direction of the State Water Resources Board. Funds to meet the cost of investigation and report were provided as follows: State of California (State Water Resources Board), $20,000; County of Sutter, $10,000; and County of Yuba, $10,000. Additional funds provided by the Legislature have been expended by the State Water Resources Board in connection with the current State-Wide Water Resources Investigation, certain results of which were used in connection with the Sutter-Yuba Counties Investigation.

Bulletin No. 6 contains an inventory of the underground and surface water resources of the valley floor in the Counties of Sutter and Yuba, estimates of present and probable ultimate water utilization, estimates of present and probable ultimate supplemental water requirements, and preliminary plans and cost estimates for water development works.

Very truly yours,

C. A. Griffith
Chairman

ACKNOWLEDGMENT

Valuable assistance and data used in the investigation were contributed by agencies of the Federal Government, cities, counties, public districts, and by private companies and individuals. This cooperation is gratefully acknowledged.

Special mention is also made of the helpful cooperation of the Boards of Supervisors of the Counties of Sutter and Yuba, the Sutter County Water Council, the Yuba County Water Development Association, the Yuba County Farm Advisor, the California Water Service Company, and the Pacific Gas and Electric Company.

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CHAPTER I

INTRODUCTION

In common with many other parts of California, the area under this investigation has recently experienced an increase in water utilization, and as a result is confronted with a need for more complete conservation of its water resources. An accelerated increase in ground water use in recent years, combined with progressive lowering of pumping levels and deterioration in quality of water at a number of wells, has brought about local concern regarding the adequacy of the ground water resources of Sutter and Yuba Counties.

AUTHORIZATION FOR INVESTIGATION

In consideration of the adverse ground water situation in Sutter and Yuba Counties, members of the Sutter County Water Council and the Yuba County Water Development Committee appeared before the State Water Resources Board at Sacramento on August 1, 1947, and proposed a state-county cooperative survey of ground water supplies of valley floor lands of the two counties. The Board referred the request to the State Engineer for preliminary examination and report on the need for such an investigation, and an estimate of its scope, duration, and cost.

The State Water Resources Board on September 5, 1947, approved a recommendation by the State Engineer, based on findings of the preliminary examination, for a two-year cooperative investigation, and authorized negotiation of an agreement with local agencies. The agreement, between the State Water Resources Board, the Counties of Sutter and Yuba, and the State Department of Public Works acting through the agency of the State Engineer, was executed on October 7, 1947. It provided that the work under the agreement "shall consist of investigation and report on the underground water supply of the valley floor lands in the Counties of Sutter and Yuba, including quality, replenishment and utilization thereof, and, if possible, a method or methods of solving the problems involved." This agreement authorized the provision of funds to meet the costs of investigation for one year. A supplemental agreement executed by the same parties on December 3, 1948, authorized funds to complete the investigation and report.

Funds to meet the costs of the investigation and report to the extent of $40,000 were provided as follows: State of California (State Water Resources Board), $20,000; County of Sutter, $10,000; and County of Yuba, $10,000. Additional funds have been expended in investigation of the Sutter-Yuba Area by the State Water Resources Board in connection with the current State-wide Water Resources Investigation, certain results of which have been used in connection with the Sutter-Yuba Counties Investigation.

Copies of the two agreements between the State Water Resources Board, the Counties of Sutter and Yuba, and the Department of Public Works, are included in Appendix A.

RELATED INVESTIGATIONS AND REPORTS

The following reports of prior investigations, containing information pertinent to evaluation of ground water problems in Sutter and Yuba Counties, were reviewed in connection with the current investigation:

"Soil Survey of the Marysville Area, California, 1909," by A. T. Strahorn, W. W. Mackie, L. C. Holmes, H. L. Westover, and Cornelius Van Duyne. Bureau of Soils, United States Department of Agriculture. October 25, 1911.

"Geology and Ground Water Resources of the Sacramento Valley, California," by Kirk Bryan. United States Geological Survey, Water-Supply Paper 495. 1923.

"Preliminary Report on the Proposed Sutter Irrigation District," by Milo B. Williams, Consulting Engineer. Typewritten. March 12, 1931.

"Report on Ground Water Conditions in the Proposed Sutter Irrigation District," by S. T. Harding, Consulting Engineer. Unpublished. November, 1931.

"Sacramento River Basin," Bulletin No. 26, Division of Water Resources, California State Department of Public Works. 1931.

"Memorandum on Ground Water Conditions in Area of Proposed Sutter Irrigation District During 1932," by S. T. Harding, Consulting Engineer. Unpublished. February, 1933.

"Sacramento Valley Water Investigations — Agricultural Aspects," Bureau of Agricultural Economics, United States Department of Agriculture. Mimeographed. March, 1944.

"Salt-Balance Conditions of Reclamation District No. 1500 in Sutter Basin for the Year Ending December 31, 1946," by L. V. Wilcox. Mimeographed. June, 1947.

"Salt-Balance Conditions of Reclamation District No. 1500 in Sutter Basin for the Year Ending December 31, 1947," by L. V. Wilcox. Mimeographed. April, 1948.

"Water Resources of California," Bulletin No. 1, California State Water Resources Board. 1951.

The Division of Water Resources is presently conducting surveys and studies for the State-wide Water Resources Investigation, authorized by Chapter 1541, Statutes of 1947. This investigation, under direction of the State Water Resources Board, has as its objective the formulation of The California Water Plan for full conservation, control, and utilization of the State's water resources to meet present and future water needs for all beneficial purposes and uses in all parts of the State insofar as practicable. Surveys and studies are also being conducted by the Division of Water Resources for the Survey of Mountainous Areas, authorized by Chapter 30, Statutes of 1947. This investigation, which is coordinated with the state-wide investi-

gation, has as its primary objective the determination of probable ultimate water requirements of certain counties of the Sierra Nevada, and the formulation of plans for projects which will meet those requirements. Results of both of the foregoing investigations will have direct bearing on solutions to the water problems of the Sutter-Yuba Area, particularly with regard to plans to meet supplemental water requirements of the area under ultimate conditions of cultural development.

SCOPE OF INVESTIGATION AND REPORT

It has been stated that under provisions of the authorizing agreements the general objectives of the Sutter-Yuba Counties Investigation included investigation and study of the underground water supply of valley floor lands in the investigational area, including quality, replenishment and utilization thereof, and, if possible, a method or methods of solving the water problems involved. In attaining these objectives it was necessary that the scope of the investigation include full consideration of surface as well as ground water supplies, and that it involve determination of present and ultimate water utilization and supplemental water requirements.

Field work in the investigational area, and office studies, as authorized by the initial and supplemental cooperative agreements, commenced in October, 1947, and continued into 1952.

In the course of the investigation, available precipitation and stream flow records were collected and compiled in order to evaluate water supplies available to the investigational area. Five new stream gaging stations were installed and maintained to supplement the available hydrographic data. These stations were on Pleasant Grove Creek at Lincoln Road, Auburn Ravine at Highway 99E, Coon Creek at Highway 99E, Dry Creek near Waldo, and South Honcut Creek at La Porte Road.

In order to determine ground water storage capacity and yield, geologic features of the ground water basin underlying the investigational area were investigated and reported on by the Ground Water Branch of the United States Geological Survey, under terms of a cooperative agreement with the Department of Public Works. This survey included the collection and study of about 700 well logs throughout the area. The report of the Geological Survey is included as Appendix B.

The effects of draft on and replenishment of the ground water basin were determined by measurements of static ground water levels made at about 850 wells during each spring and fall of the period of investigation. These wells were chosen to form a comprehensive measuring grid over the entire area. In addition, measurements to determine monthly fluctuations of water levels were made at approximately 90 control wells.

Present land use in the investigational area was determined by a complete survey of all culture on valley floor lands. This survey was conducted in 1948, and checked in 1949 to determine changes. The total area surveyed was about 327,000 acres. The cultural survey data were used in conjunction with available data on unit water use to determine total present water utilization in the investigational area.

In order to determine future water utilization, all valley floor lands were classified with regard to their suitability for irrigated agriculture. This involved collection, field checking, and re-evaluation of land classification data from the United States Bureau of Reclamation, supplemented by data from field surveys conducted by the Division of Water Resources.

Current irrigation practices in the investigational area were surveyed in order to determine unit application of water to important crops on lands of various soil types. During the 1948 irrigation season records of application of water were collected at 35 plots, and during the following season at 21 plots. The data collected included records of pump discharge, acreage served, crops irrigated, number and period of irrigations, and amount of water applied.

Studies were made of the mineral quality of surface and ground waters, in order to evaluate their suitability for irrigation use, and to determine the cause of degradation in their mineral quality during recent years. Data used in these studies included some 200 partial and 38 complete mineral analyses of ground water from wells. In addition, a large number of analyses of surface water supplies, covering the period since 1943, were collected and studied.

Field reconnaissance surveys, including geologic examinations, were made to locate and evaluate possible dam and reservoir sites for conservation of surface runoff. Reconnaissance surveys were also made of possible routes for conveyance of water to areas of use.

Results of the Sutter-Yuba Counties Investigation are presented in this report in the four ensuing chapters. Chapter II, "Water Supply," contains evaluations of precipitation, surface and subsurface inflow and outflow, and imports of water. It also includes results of investigation and study of the ground water basin, and contains data regarding mineral quality of surface and ground waters. Chapter III, "Water Utilization and Supplemental Requirements," includes data and estimates of present and probable ultimate land use and water utilization, and contains estimates of present and probable ultimate supplemental water requirements. It also includes available data on demands for water with respect to rates, times, and places of delivery. Chapter IV, "Plans for Water Development," describes preliminary plans for conservation and utilization of available water supplies to meet supplemental water requirements, including operation and yield studies, design considerations and criteria, and

cost estimates. Chapter V, "Conclusions and Recommendations," includes conclusions and recommendations resulting from the investigation and studies.

AREA UNDER INVESTIGATION

The area under investigation comprises those portions of the valley floor of Sutter and Yuba Counties which are in whole or in part served by ground water, and has been designated the "Sutter-Yuba Area." It includes the portions of Sutter County situated east of Feather River, Sutter By-pass, and a north-south line through the center of Sutter Buttes. It includes the portion of Yuba County lying on the Sacramento Valley floor from Feather River on the west to a line marking the approximate limit of the ground water service area near the base of the foothills on the east.

The Sutter-Yuba Area is situated on the east side of the central portion of the Sacramento Valley, and its southern boundary is about 10 miles north of the City of Sacramento. The area extends north and south for a distance of about 39 miles, varying in width from about 6 to about 19 miles. Its location is indicated on Plate 1, "Location of Sutter-Yuba Area," and the area is shown in greater detail on Plate 2, entitled "Hydrologic Zones and Organized Water Agencies, 1952."

In order to facilitate reference to its several parts, the Sutter-Yuba Area was divided into four principal zones, based on geographical considerations and on respective types of water service and sources of water supply. These were designated "West Side Zone," "Northeast Zone," "East Central Zone," and "South Side Zone," and are shown on Plate 2. The West Side Zone embraces the area between the Butte-Sutter county line and Nicolaus, and west of Feather River. The Northeast Zone consists of lands between Honcut Creek and Yuba River, and east of Feather River. Similarly, the East Central Zone consists of lands between the Yuba and Bear Rivers, and east of Feather River. The South Side Zone comprises those lands lying between Bear River and the Sutter-Sacramento county line, and east of the Feather and Sacramento Rivers. As shown on Plate 2, the West Side Zone was further subdivided into the area generally devoted to orchards and served by ground water, herein designated the "Peach Bowl," and the remainder of the zone which is largely served by surface water.

Drainage Basin

The eastern portion of the Sutter-Yuba Area comprises a gently rolling plain, which merges into nearly flat land over a large part of the central and western portions. The general ground surface slopes gently from east to west. Included valley floor lands lie below an elevation of about 100 feet. The Sutter Buttes, located in the northwest corner of the area, rise to 2,132 feet above sea level.

All watersheds on the west slope of the Sierra Nevada that head between Donner and Fredonyer Passes are tributary to the Sutter-Yuba Area. Their combined drainage areas total about 5,600 square miles. In order of importance, the principal tributary stream systems are those of the Feather, Yuba, and Bear Rivers. Minor tributary streams include Honcut, Dry, Coon, and Pleasant Grove Creeks, and Markham and Auburn Ravines. The extent of the various drainage basins is shown in the following tabulation:

Drainage basin	*Area, in square miles*
Feather River, above Oroville gaging station	3,611
Yuba River, above Smartville gaging station	1,194
Bear River, above gaging station near Wheatland	294
Minor streams, above valley floor, from Wyman Ravine to Pleasant Grove Creek	500
TOTAL	5,600

The tributary watersheds are in a zone of relatively heavy precipitation, and their aggregate mean seasonal natural runoff during the 53-year period from 1894-95 to 1946-47 is estimated to have approximated 1,360 acre-feet per square mile.

The Feather River traverses and roughly bisects the Sutter-Yuba Area from north to south, and joins the Sacramento River near Verona. The Yuba and Bear Rivers are tributary to the Feather within this reach, as are Honcut Creek and Nigger Jack Slough. Reeds, Hutchinson, and Dry Creeks, drain the East Central Zone and are tributary to Bear River within the area. Coon and Pleasant Grove Creeks and Markham and Auburn Ravines drain into Sacramento River near Verona by way of the Cross Canal. Gilsizer Slough, which flows more or less parallel to the Feather River through the West Side Zone and into Sutter By-pass, and Nigger Jack Slough are important as natural surface drains. Wadsworth Canal and its tributaries, together with other minor channels, drain the portion of the West Side Zone outside the Peach Bowl, discharging into Sutter By-pass.

Climate

The climate of the Sutter-Yuba Area is characterized by dry summers with high daytime temperatures and warm nights, and wet winters with moderate temperatures. More than 80 percent of the precipitation occurs during the five-month period from November to March, inclusive. The growing season is long, the 40-year recorded average for Marysville, centrally located in the area, being 273 days between killing frosts. Temperatures at Marysville have ranged from 16° F. to 118° F., and the monthly average for the period from 1871 to 1948 ranges from 46.9° F. in January to 79.3° F. in July.

Geology

The geologic formations of the Sutter-Yuba Area include pre-Cretaceous metamorphic and igneous rocks

of the Sierra Nevada block, which extends beneath the valley fill, overlain principally by Tertiary sedimentary formations derived from these and other rocks which are exposed in the Sierra Nevada to the east. The sedimentary rocks are of both marine and continental origin and are frequently interbedded with tuff-breccias. Volcanic rocks are also represented in the area in and about the Sutter Buttes, which are erosional remnants of an extinct Pliocene volcano. Only the sedimentary rocks can be considered as being water-bearing to any appreciable degree. The principal aquifers are composed of continental sediments of Pleistocene and Recent age. These consist of as much as 100 feet of Pleistocene sands and gravels overlain by up to 125 feet of Recent alluvial fan, flood plain, and stream channel deposits.

Soils

Soils of the Sutter-Yuba Area vary in their chemical and physical properties in accordance with differences in parent material, drainage, and age or degree of development since their deposition. The soils may be divided into two broad groups: (1) those derived from recent alluvial depositions, and (2) those derived from old alluvial fans or terraces. The first group may be further divided into stream bottom soils and basin soils.

Stream bottom soils occupy the flood plains immediately adjacent to stream channels generally throughout the area. They consist of unmodified to slightly modified alluvial deposits. These soils are highly productive and suited to a wide variety of crops, and have the highest agricultural value.

Basin soils of the Sutter-Yuba Area occupy large flat basin-like areas in the southwest portion of the West Side Zone and western portion of the South Side Zone. These basin soils are derived largely from fine-grained depositions by flood flows, and have developed under poor drainage conditions. Those areas of basin soils that have been drained and protected by levees from flooding are suitable for production of rice and other shallow-rooted crops.

Soils that have developed from old alluvial fans or terraces occupy most of the remainder of the Sutter-Yuba Area. These soils have undergone considerable physical and chemical change since their deposition and are entirely underlain by hardpan. They are restricted in their agricultural use by the depth of soil over the hardpan, and are only suited to the production of shallow-rooted crops.

Present Development

Development of the eastern portion of the Sacramento Valley has centered in the Sutter-Yuba Area since the first settlements early in the Nineteenth Century. Marysville became an important transportation center during the Gold Rush period, being the head of river traffic to the mining areas. The Counties of Sutter and Yuba embrace a rich agricultural region, and both irrigation and dry farming are of major importance.

The 1950 federal census showed that the population of Sutter County was 26,140, and that of Yuba County 24,240. The principal urban centers, Marysville and Yuba City, are situated only about two miles apart, near the confluence of the Yuba and Feather Rivers, and account for some 31 percent of the total population of the two counties. The 1950 census enumerated 7,856 persons in Yuba City, while 7,777 were counted in Marysville. Wheatland and Live Oak are the largest of a number of small communities, and the rural population is distributed generally throughout the area.

Agricultural development in the Sutter-Yuba Area is said to have begun with the growing of grain about 1845 near the site of Captain John A. Sutter's Hock Farm, south of Yuba City. Early agriculture on the valley floor was stimulated by the influx of settlers during and after the gold rush, but for many years was largely restricted to the growing of dry-farmed grain crops and stock raising. By 1865, a large portion of the area was given over to the production of wheat. Irrigation developed slowly, but it is probable that the first lands on the east side of the Sacramento Valley to receive irrigation water were near the confluence of Honcut Creek and Feather River. Diminishing profits from grain farming, together with the development of more satisfactory pumping plants, gave impetus to the increase in irrigated acreage after 1910. The transition from dry farming to irrigated cropping has continued to this time.

A survey conducted in 1949 as a part of the current investigation showed that irrigated lands in the Sutter-Yuba Area totaled about 149,000 acres, while approximately 140,000 acres were dry-farmed or fallow. Principal irrigated crops, in order of acreage devoted to each crop, were deciduous orchard consisting largely of peaches, and rice, permanent pasture, beans, and alfalfa. Principal dry-farmed crops were barley and wheat.

Industry in the Sutter-Yuba Area is supported largely by agricultural production. About 100 plants are operated during the harvest seasons to can and dehydrate fruits and vegetables, and to dry fruits, nuts, rice, and seed crops. Packing houses for packing fresh fruits and melons, and cold storage and refrigeration plants, have also been established. Several lumber reprocessing and molding plants near Marysville produce finished lumber and by-products. Sand and gravel works supply local demand for aggregates, while concrete pipe, generally used in irrigation distribution systems, is manufactured locally. A large gold dredging field is situated near the edge of the valley floor at Hammonton, south of Yuba River. Electric energy is available from nearby hydroelectric installations.

Water service agencies in the Sutter-Yuba Area are described in Chapter III. However, many public agencies have been organized in the area to deal with the problems of land reclamation and drainage. The provisions of California reclamation district laws have been used extensively to effect the unwatering of low lands and their protection from overflow. Active reclamation districts in the area and data concerning them are listed in the following tabulation:

Reclamation district	*Year organized*	*County*	*Gross area of district, in acres*
No. 10	1913	Yuba	11,300
No. 777	1907	Sutter	12,500
No. 784 (Plumas Lake)	1908	Yuba	19,600
No. 803 (Rideout)	1909	Sutter	2,000
No. 817	1910	Yuba	3,120
No. 823 (Marcuse)	1911	Sutter	2,800
No. 1000 (Natomas)	1911	Sutter, Sacramento	55,100
No. 1001 (Natomas)	1911	Sutter, Placer	31,200
No. 2054	1921	Sutter, Butte	12,900
No. 2056	1921	Sutter, Butte	9,100
No. 2066 (Abbott Lake)	1924	Sutter	600

Portions of Sutter and Yuba Counties are within the boundaries of the Sacramento and San Joaquin Drainage District, which comprises practically all swamp and overflow lands of both the Sacramento and San Joaquin Valleys. This large district was formed in 1911. Two levee districts in Sutter County, organized during the period of early agricultural development, built levees to protect eastern Sutter Basin lands from floods and overflow of Feather River. These districts, Sutter County Levee District No. 1, organized in 1873, and Sutter County Levee District No. 2, organized in 1879, contain 44,000 and 17,500 acres, respectively. The Sutter By-pass, and levees of the Feather and Yuba Rivers, are parts of the Sacramento River Flood Control Project. The function of Sutter By-pass is to receive and convey excess flood waters of Sacramento River and Butte Basin through Sutter Basin.

Areas included within the boundaries of the foregoing agencies, together with water service agencies in the Sutter-Yuba Area, are shown on Plate 2.

CHAPTER II

WATER SUPPLY

The sources of water supply of the Sutter-Yuba Area are direct precipitation on overlying lands, tributary surface and subsurface inflow, and imports by surface canals of water for irrigation. The water supply of the area is considered and evaluated in this chapter under the general headings "Precipitation," "Runoff," "Imported and Exported Water," "Underground Hydrology," and "Quality of Water."

The following terms are used as defined in connection with the discussion of water supply in this report:

Annual—This refers to the 12-month period from January 1st of a given year through December 31st of the same year, sometimes termed the "calendar year."

Seasonal—This refers to any 12-month period other than the calendar year.

Precipitation Season—This refers to the 12-month period from July 1st of a given year through June 30th of the following year.

Runoff Season—This refers to the 12-month period from October 1st of a given year through September 30th of the following year.

Investigational Seasons—This is used in reference to the two runoff seasons of 1947-48 and 1948-49, during which most of the field work on the Sutter-Yuba Counties Investigation was performed.

Mean Period—This is used in reference to periods chosen to represent conditions of water supply and climate over a long period of years.

Base Period—This is used in reference to periods chosen for detailed hydrologic analysis because prevailing conditions of water supply and climate were approximately equivalent to mean conditions, and because adequate data for such hydrologic analysis were available.

In studies for the current State-wide Water Resources Investigation it was determined that the 50 years from 1897-98 to 1946-47, inclusive, constituted the most satisfactory period for estimating mean seasonal precipitation generally throughout California. Similarly, the 53-year period from 1894-95 to 1946-47, inclusive, was selected for determining mean seasonal runoff. In studies for the Sutter-Yuba Area, conditions during these periods were considered representative of mean conditions of water supply and climate.

Studies were made to select a base period for hydrologic analysis of the Sutter-Yuba Area during which conditions of water supply and climate would approximate mean conditions, and for which adequate data on inflow, outflow, and ground water levels would be available. It was determined that the nine-year period from 1939-40 to 1947-48, inclusive, was the most satisfactory in this respect. Conditions during this chosen base period so closely approached conditions prevailing during the mean period that they were considered to be equivalent. For this reason, determined relationships between base period water supply and present and probable ultimate water utilization were assumed to be equivalent to corresponding relationships which might be expected under mean conditions of water supply and climate.

PRECIPITATION

The Sutter-Yuba Area lies within the southern fringe of storms which periodically sweep inland from the North Pacific during winter months. Although the rainfall resulting from these storms is moderate on the average, direct precipitation provides a substantial portion of the water supply of the area.

Precipitation Stations and Records

Fifteen precipitation stations in or adjacent to the Sutter-Yuba Area have unbroken records of 10 years duration or longer. These stations are fairly well distributed areally and their records were sufficient to provide an adequate pattern of precipitation. All of the records of precipitation have been published in bulletins of the United States Weather Bureau, with exception of the record obtained by the Sutter Basin Corporation for the station at Robbins. The Robbins record is included as Appendix C to this report. Locations of the precipitation stations are shown on Plate 3, "Lines of Equal Mean Seasonal Precipitation," with map reference numbers corresponding to those utilized in State Water Resources Board Bulletin No. 1, "Water Resources of California." The stations and map reference numbers are listed in Table 1, together with elevations of the stations, periods and sources of record, and mean, maximum, and minimum seasonal precipitation. In those instances where it was necessary, precipitation records were extended to cover the 50-year mean period by comparison with records of nearby stations having records covering this period.

Precipitation Characteristics

Because of the uniformity of the general precipitation pattern in the Sutter-Yuba Area, as indicated on Plate 3, and the central location of Marysville, precipitation at Marysville was considered to be fairly representative of rainfall over the area. A record of precipitation at Marysville was available from a United States Weather Bureau station maintained since

TABLE 1

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION AT SELECTED STATIONS IN OR NEAR SUTTER-YUBA AREA

Map reference number	Station	Elevation, in feet	Period of record	Source of record	Mean seasonal precipitation, in inches	Maximum and minimum seasonal precipitation	
						Season	Inches
5-69	Biggs	98	1899-1916	USWB	*21.04	1913-1914 1911-1912	21.20 12.29
5-76	Camptonville	2,850	1907-1951	USWB	*64.17	1908-1909 1923-1924	108.30 30.13
5-75	Chute Camp.	1,250	1907-1940	USWB	*54.74	1937-1938 1923-1924	78.17 23.87
5-73	Colgate	700	1907-1951	USWB	*39.92	1940-1941 1923-1924	56.61 18.51
5-82	Colusa	60	1871-1951	USWB	15.89	1940-1941 1938-1939	31.65 6.78
5-74	Dobbins	1,650	1904-1946	USWB	*41.03	1906-1907 1923-1924	64.28 20.13
5-70	Gridley	97	1884-1951	USWB	24.00	1889-1890 1897-1898	47.00 12.34
5-97	Marysville	61	1871-1951	USWB	20.68	1889-1890 1884-1885	38.91 8.15
5-107	Nicolaus	46	1912-1951	USWB	*18.32	1940-1941 1912-1913	32.46 7.07
5-62	Oroville	250	1884-1951	USWB	27.27	1889-1890 1930-1931	49.64 14.71
5-71	Palermo	213	1891-1914	USWB	*23.29	1904-1905 1897-1898	32.77 10.94
5-106	Robbins	20	1926-1951	SBCo	*16.81	1940-1941 1930-1931	31.93 9.51
5-120	Rocklin	239	1870-1951	USWB	23.14	1906-1907 1923-1924	38.63 10.42
5-131	Sacramento	69	1849-1951	USWB	16.37	1852-1853 1850-1851	36.35 4.71
5-98	Wheatland	84	1887-1945	USWB	*20.84	1889-1890 1887-1888	33.69 11.07

* Estimated.
SBCo—Sutter Basin Corporation.
USWB—United States Weather Bureau.

1871-72. Recorded seasonal precipitation at this station is presented in Table 2 and shown on Plate 4, "Recorded Seasonal Precipitation at Marysville, 1871-72 Through 1950-51."

Precipitation in the Sutter-Yuba Area consists almost entirely of rainfall and snowfall is rare. It increases generally from west to east, as is shown on Plate 3, except on the Sutter Buttes where a sharp rise in elevation probably results in relatively heavy precipitation. Mean seasonal depth of precipitation ranges from about 18 inches along the western boundary of the area to about 23 inches at its extreme easterly limit. At Nicolaus in the southern portion of the area mean seasonal precipitation is about 18 inches, whereas at Biggs, about eight miles north of the area, it is approximately 21 inches.

Precipitation varies over wide limits from season to season, ranging from less than 40 percent of the seasonal mean to nearly 200 percent. Maximum seasonal precipitation at Marysville occurred in 1889-90 when 38.91 inches of rain were recorded. In 1884-85, the minimum season at this station, precipitation was only 8.15 inches. Long-term trends in precipitation in the Sutter-Yuba Area are indicated on Plate 5, "Accumulated Departure From Mean Seasonal Precipitation at Marysville."

More than 80 percent of the seasonal precipitation in the Sutter-Yuba Area occurs during the five months from November through March on the average, and the summers are dry. Mean monthly distribution of precipitation as recorded at Marysville is presented in Table 3.

TABLE 2

RECORDED SEASONAL PRECIPITATION AT MARYSVILLE 1871-72 THROUGH 1950-51

(In inches)

Season	Precipitation	Season	Precipitation	Season	Precipitation
1871-1872	21.57	1899-1900	28.07	1929-1930	20.81
73	13.10	01	24.02	31	12.40
74	27.74	02	20.54	32	17.35
		03	21.26	33	12.64
1874-1875	13.68	04	22.50	34	14.10
76	17.36				
77	12.16	1904-1905	26.50	1934-1935	23.33
78	23.74	06	27.76	36	22.79
79	15.76	07	32.25	37	21.88
		08	16.91	38	28.26
1879-1880	18.93	09	20.72	39	9.76
81	17.43				
82	14.38	1909-1910	19.48	1939-1940	27.32
83	15.25	11	26.42	41	33.28
84	15.28	12	11.76	42	29.13
		13	13.76	43	21.43
1884-1885	8.15	14	28.54	44	20.02
86	22.27				
87	12.86	1914-1915	27.57	1944-1945	19.72
88	14.28	16	21.69	46	17.33
89	23.28	17	16.17	47	15.21
		18	12.56	48	17.60
1889-1890	38.91	19	21.52	49	15.51
19	15.72				
92	18.99	1919-1920	12.90	1949-1950	16.96
93	22.93	21	25.08	51	23.21
94	10.27	22	21.02		
		23	22.20	Average for 9-year base period, 1939-40 through 1947-48: 22.31	
1894-1895	26.83	24	11.53		
96	19.61				
97	17.77	1924-1925	25.82	Mean for 50-year period, 1897-98 through 1946-47: 20.68	
98	12.74	26	21.26		
99	16.53	27	26.59		
		28	17.28	Average for 80-year period of record, 1871-72 through 1950-51: 19.82	
		29	14.04		

TABLE 3

MEAN MONTHLY DISTRIBUTION OF PRECIPITATION AT MARYSVILLE

Month	Precipitation		Month	Precipitation	
	In inches	In percent of seasonal total		In inches	In percent of seasonal total
July	0.00	0.0	January	4.16	20.1
August	0.00	0.0	February	3.97	19.2
September	0.27	1.3	March	2.67	12.9
October	0.93	4.5	April	1.34	6.5
November	2.23	10.8	May	0.74	3.6
December	4.14	20.0	June	0.23	1.1
			TOTALS	20.68	100.0

Quantity of Precipitation

The mean seasonal quantity of precipitation in the Sutter-Yuba Area was estimated by plotting recorded or estimated mean seasonal depth of precipitation at stations in or near the area on a map. Lines of equal mean seasonal precipitation, or isohyets, were then drawn, as are shown on Plate 3. By planimetering the areas between these isohyets, the weighted mean seasonal depth and total quantity of precipitation were estimated.

In order to determine seasonal depth and quantity of precipitation during the base period and investigational seasons, the foregoing estimates for the mean period were adjusted on the basis of recorded precipitation at Marysville. The results of the estimates are presented in Table 4, which also shows the precipitation index for the base period and each of the investigational seasons. The term "precipitation index" refers to the ratio of the amount of precipitation during a given season to the mean seasonal amount, and is expressed as a percentage.

TABLE 4

ESTIMATED WEIGHTED SEASONAL DEPTH AND TOTAL QUANTITY OF PRECIPITATION ON SUTTER-YUBA AREA

Season	Precipitation index	Precipitation	
		Depth, in inches	Quantity, in acre-feet
1947-48	89	18.2	529,000
1948-49	76	15.4	448,000
Average for 9-year base period, 1939-40 through 1947-48	107	21.8	635,000
Mean for 50-year period, 1897-98 through 1946-47	100	20.3	592,000

RUNOFF

Runoff from the highly productive watersheds of the Sierra Nevada constitutes the most important source of water supply available to the Sutter-Yuba Area. The Feather River, which traverses the area from north to south, is the principal tributary of the Sacramento River. The Feather River system, including the Yuba and Bear Rivers which join the Feather within the area, is largely unregulated and undeveloped and is a potential source of water to meet future requirements not only in the Sutter-Yuba Area but in water-deficient areas in other parts of California.

Stream Gaging Stations and Records

Available records of runoff of the principal streams of the Sutter-Yuba Area were sufficient in number, length, and reliability for purposes of required hydrographic studies. With respect to certain of the smaller streams, however, records of runoff were nonexistent or confined principally to measurements made during the investigational seasons. By comparison with records of nearby stations on major streams, adequate estimates were made of runoff of these smaller streams.

Table 5 lists those stream gaging stations pertinent to the hydrography of the Sutter-Yuba Area, together with their map reference numbers, drainage areas above stations where significant, and periods and sources of records. These stations are also shown on Plate 3. The map reference numbers for the first 11 stations listed correspond to those used in State Water Resources Board Bulletin No. 1, "Water Resources of California." New map reference numbers were assigned to the remaining stations listed. The last five stations listed in Table 5 were installed, operated, and maintained as a part of the Sutter-Yuba Counties Investigation. Most of the runoff records listed in Table 5 have been published by the United States Geological Survey in its Water-Supply Papers or by the Division of Water Resources in its Reports of Sacramento-San Joaquin Water Supervision. The following records have not been published elsewhere and are included in Appendix D to this report:

Coon Creek at Highway 99E—November, 1947–December, 1948
Auburn Ravine at Highway 99E—November, 1947–December, 1948
Dry Creek near Waldo—November, 1947–May, 1949
South Honcut Creek at La Porte Road—November, 1947–December, 1948

Runoff Characteristics

An excellent continuous record of flow of the Feather River at or near Oroville is available for the period since January, 1902, when a stream gaging station was established at Oroville by the United States Geological Survey. The station was moved five miles upstream in October, 1934, but without appreciable effect on characteristics of the record. Although this record does not provide an exact measure of flow of the Feather River into the Sutter-Yuba Area, it is the most important record of the Feather River system, and does reflect characteristics of tributary mountain runoff to the Sutter-Yuba Area.

Flow of the Feather River to the valley floor is impaired by operation of Lake Almanor and several smaller upstream reservoirs, and by operation of hydroelectric power plants. An estimate of the natural runoff of the Feather River at Oroville, as it would be if unaltered by upstream diversion, storage, importation, and exportation, is included in State Water Resources Board Bulletin No. 1, "Water Resources of California." This estimate, together with recorded seasonal runoff of the Feather River at or near Oroville, is presented in Table 6. The

TABLE 5

STREAM GAGING STATIONS IN OR NEAR SUTTER-YUBA AREA

Map reference number	Stream	Station	Drainage area, in square miles	Period of record	Source of record
5-192	Feather River	at Oroville	3,640	1902-1934	USGS
5-191	Feather River	near Oroville	3,611	1934-1951	USGS and DWR
5-193	Feather River	near Gridley		1944-1951	DWR
5-244	Feather River	at Nicolaus		1921-1942 1943-1951	USGS and DWR
5-234	Feather River	below Shanghai Bend		1944-1951	DWR
5-194	Feather River	at Yuba City		1944-1951	DWR
5-222	Yuba River	at Narrows Dam	1,110	1941-1951	USGS and DWR
5-233	Yuba River	at Marysville		1939-1951	USGS and DWR
5-228	Yuba River	at Smartville	1,201	1903-1941	USGS
5-227	Deer Creek	near Smartville	83.5	1935-1951	USGS and DWR
5-238	Bear River	near Wheatland	295	1928-1951	USGS and DWR
SY-1	Sutter Butte Canal	at Diversion		1923-1951	DWR
SY-2	Wadsworth Canal	near Sutter		1929-1951	DWR
SY-3	Pleasant Grove Creek	at Lincoln Road	12.5	1950-1951	DWR
SY-4	Auburn Ravine	at Highway 99E	34.6	1947-1951	DWR
SY-5	Coon Creek	at Highway 99E	82.5	1947-1951	DWR
SY-6	Dry Creek	near Waldo	69.4	1947-1949	DWR
SY-7	South Honcut Creek	at La Porte Road	68.6	1947-1949	DWR

USGS—United States Geological Survey.
DWR—Division of Water Resources.

estimate of natural flow is also shown graphically on Plate 6, "Estimated Seasonal Natural Runoff of Feather River at Oroville."

Estimates of natural flow of streams of the Feather River system indicate that average seasonal runoff during the nine-year base period approximated the seasonal mean during the 53-year period. For the Feather, Yuba, and Bear Rivers these estimates were obtained from State Water Resources Board Bulletin No. 1. Natural flow of minor streams, including those tributary to the Sutter-Yuba Area but not in the Feather River system, were estimated during the current investigation. The estimates of natural flow are presented in Table 7, together with runoff indices for the combined natural flow of the Feather River system. The term "runoff index" refers to the ratio of the amount of runoff during a given season to the mean seasonal amount, and is expressed as a percentage.

Discharge of streams of the Sierra Nevada which are tributary to the Sutter-Yuba Area varies between wide limits from season to season, and within the season. This is indicated by flow of the Feather River at

TABLE 6

RECORDED SEASONAL AND ESTIMATED NATURAL SEASONAL RUNOFF OF FEATHER RIVER AT OROVILLE

(In acre-feet)

Season	Recorded runoff at or near Oroville	Estimated natural runoff at Oroville	Season	Recorded runoff at or near Oroville	Estimated natural runoff at Oroville
1894-1895		7,093,000	1924-1925	2,780,000	3,114,000
1895-1896		7,786,000	1925-1926	2,870,000	3,126,000
1896-1897		5,440,000	1926-1927	5,000,000	5,679,000
1897-1898		2,304,000	1927-1928	3,650,000	4,142,000
1898-1899		2,872,000	1928-1929	2,010,000	1,910,000
1899-1900		6,788,000	1929-1930	3,590,000	3,984,000
1900-1901		6,281,000	1930-1931	1,490,000	1,485,000
1901-1902		4,048,000	1931-1932	2,810,000	3,351,000
1902-1903	4,430,000	4,555,000	1932-1933	1,640,000	1,986,000
1903-1904	9,330,000	9,451,000	1933-1934	1,840,000	2,071,000
1904-1905	4,490,000	4,606,000	1934-1935	3,864,000	4,253,000
1905-1906	6,710,000	6,833,000	1935-1936	4,079,000	4,328,000
1906-1907	9,340,000	9,504,000	1936-1937	2,821,000	3,175,000
1907-1908	3,490,000	3,651,000	1937-1938	8,175,000	8,547,000
1908-1909	7,380,000	7,527,000	1938-1939	1,773,000	1,912,000
1909-1910	4,500,000	4,651,000	1939-1940	5,275,000	5,672,000
1910-1911	6,980,000	7,136,000	1940-1941	6,116,000	6,516,000
1911-1912	2,090,000	2,276,000	1941-1942	6,258,000	6,662,000
1912-1913	2,600,000	2,785,000	1942-1943	5,296,000	5,638,000
1913-1914	6,540,000	6,928,000	1943-1944	2,622,000	2,830,000
1914-1915	5,200,000	5,422,000	1944-1945	3,412,000	3,767,000
1915-1916	5,910,000	6,156,000	1945-1946	3,996,000	4,185,000
1916-1917	4,380,000	4,637,000	1946-1947	2,273,000	2,579,000
1917-1918	2,450,000	2,684,000	1947-1948	3,368,000	3,401,000
1918-1919	3,390,000	3,621,000	1948-1949	2,495,000	2,590,000
1919-1920	2,050,000	2,231,000	1949-1950	3,465,000	3,837,000
1920-1921	5,600,000	5,940,000	1950-1951	5,403,000	5,676,000
1921-1922	4,730,000	5,040,000			
1922-1923	2,890,000	3,112,000	Mean seasonal natural runoff for 53-year mean period, 1894-95 through 1946-47: 4,596,000		
1923-1924	1,180,000	1,317,000			

TABLE 7

ESTIMATED SEASONAL NATURAL FLOW OF STREAMS OF THE FEATHER RIVER SYSTEM, 1939-40 THROUGH 1947-48

(In acre-feet)

Season	Runoff index	Feather River at Oroville	Yuba River at Smartville	Bear River at Wheatland	Minor streams	Combined flow
1939-1940	124	5,672,000	2,860,000	406,000	293,000	9,231,000
1940-1941	142	6,516,000	3,209,000	483,000	339,000	10,547,000
1941-1942	145	6,662,000	3,407,000	502,000	355,000	10,926,000
1942-1943	123	5,638,000	3,133,000	464,000	328,000	9,563,000
1943-1944	62	2,830,000	1,395,000	191,000	141,000	4,557,000
1944-1945	82	3,767,000	2,112,000	289,000	211,000	6,379,000
1945-1946	91	4,185,000	2,401,000	323,000	239,000	7,148,000
1946-1947	56	2,579,000	1,365,000	170,000	131,000	4,245,000
1947-1948	74	3,401,000	1,510,000	216,000	156,000	5,283,000
Average for 9-year base period, 1939-40 through 1947-48	100	4,583,000	2,377,000	339,000	244,000	7,542,000
Mean for 53-year period, 1894-95 through 1946-47	100	4,596,000	2,415,000	356,000	248,000	7,615,000

or near Oroville, where the maximum recorded seasonal runoff occurred in 1906-07 and amounted to more than 9,300,000 acre-feet. The minimum seasonal runoff recorded at this station occurred in 1923-24 and was less than 1,200,000 acre-feet. Maximum recorded instantaneous discharge was 230,000 second-feet on March 19, 1907, and the estimated minimum discharge was about 300 second-feet on November 9, 1931. Estimated mean monthly distribution of natural flow of the Feather River at Oroville is presented in Table 8.

TABLE 8

ESTIMATED MEAN MONTHLY DISTRIBUTION OF NATURAL FLOW OF FEATHER RIVER AT OROVILLE

Month	Runoff, in acre-feet	Percent of seasonal total
October	101,000	2.2
November	188,000	4.1
December	290,000	6.3
January	423,000	9.2
February	556,000	12.1
March	722,000	15.7
April	873,000	19.0
May	744,000	16.2
June	368,000	8.0
July	152,000	3.3
August	101,000	2.2
September	78,000	1.7
TOTALS	4,596,000	100.0

Quantity of Runoff

Available records of stream flow, including those obtained from measurements made in connection with the investigation, were sufficient to permit fairly reliable determination of surface inflow to and surface outflow from the Sutter-Yuba Area during the nine-year base period and during the two seasons of the investigation.

Surface inflow to the Sutter-Yuba Area from the Feather and Bear Rivers was directly measured at the stations near Gridley and near Wheatland, respectively. Inflow from Yuba River was determined by recorded flow at Smartville until the season of 1940-41, after which season that station was discontinued and inflow was determined as the combined flow of Yuba River at Narrows Dam and Deer Creek near Smartville. For seasons when records of inflow from South Honcut Creek at La Porte Road and French Dry Creek near Browns Valley were not available, inflow was estimated by correlation with the combined flow of Yuba River at Narrows Dam and Deer Creek near Smartville. Inflow to the area from Dry Creek near Waldo, Coon Creek at Highway 99E, Auburn Ravine at Highway 99E, and Pleasant Grove Creek at Lincoln Road, was estimated for seasons when records were not available by correlation with the flow of Bear River near Wheatland. Inflow to the area through the Sutter

TABLE 9

MEASURED AND ESTIMATED SEASONAL SURFACE INFLOW TO AND OUTFLOW FROM SUTTER-YUBA AREA, 1939-40 THROUGH 1948-49

(In acre-feet)

Source	Season										Average for 9-year base period, 1939-40 through 1947-48
	1939-40	1940-41	1941-42	1942-43	1943-44	1944-45	1945-46	1946-47	1947-48	1948-49	
Inflow											
Feather River	4,634,000	5,103,000	5,581,000	4,326,000	1,536,000	2,208,000	3,106,000	1,724,000	2,751,000	1,742,000	3,441,000
Yuba River	2,364,000	2,550,000	2,778,000	2,562,000	948,000	1,583,000	1,877,000	924,000	1,503,000	1,063,000	1,899,000
Bear River	411,000	505,000	516,000	494,000	149,000	314,000	368,000	151,000	208,000	197,000	346,000
Deer Creek	125,000	137,000	162,000	155,000	72,000	111,000	105,000	54,000	52,000	50,000	108,000
South Honcut Creek*	48,000	53,000	57,000	52,000	23,000	35,000	40,000	23,000	25,000	29,000	40,000
French Dry Creek†	91,000	102,000	108,000	100,000	45,000	67,000	76,000	44,000	48,000	35,000	76,000
Dry Creek*	39,000	46,000	48,000	44,000	18,000	28,000	31,000	16,000	21,000	18,000	32,000
Coon Creek*	35,000	42,000	43,000	40,000	17,000	25,000	28,000	15,000	19,000	36,000	29,000
Auburn Ravine*	71,000	85,000	88,000	81,000	34,000	51,000	57,000	30,000	38,000	47,000	59,000
Pleasant Grove Creek†	9,000	11,000	12,000	11,000	4,000	7,000	8,000	4,000	5,000	4,000	8,000
Snake Slough†	49,000	49,000	55,000	40,000	44,000	49,000	47,000	39,000	38,000	39,000	46,000
Sutter Butte Canal†	111,000	112,000	130,000	153,000	161,000	167,000	186,000	163,000	136,000	160,000	147,000
Minor Drainage†	10,000	11,000	12,000	11,000	4,000	7,000	8,000	4,000	5,000	5,000	8,000
TOTALS	7,997,000	8,806,000	9,590,000	8,069,000	3,055,000	4,652,000	5,937,000	3,191,000	4,849,000	3,425,000	6,239,000
Outflow											
Feather River	7,104,000	9,827,000	9,703,000	7,268,000	3,326,000	5,026,000	5,999,000	2,784,000	4,737,000	3,234,000	6,197,000
Wadsworth Canal	95,000	119,000	105,000	72,000	93,000	106,000	102,000	67,000	53,000	62,000	90,000
Drainage into Sutter By-Pass†	13,000	18,000	19,000	17,000	0	7,000	10,000	0	0	0	9,000
Cross Canal†	32,000	35,000	37,000	34,000	0	18,000	25,000	0	0	0	20,000
TOTALS	7,244,000	9,999,000	9,864,000	7,391,000	3,419,000	5,157,000	6,136,000	2,851,000	4,790,000	3,296,000	6,316,000

* Partially estimated.
† Estimated.

Butte Canal was estimated by adjusting measured diversions from Feather River on the basis of acreages of crops served each season within and outside the area. Inflow to the area from Snake Slough at Sanders Road during seasons of no record was estimated by correlation with flow in the Sutter Butte Canal. Inflow from minor unmeasured drainage areas was estimated by correlation with the flow of Bear River near Wheatland.

Surface outflow from the Sutter-Yuba Area in Feather River and the Wadsworth Canal was directly measured during the nine-year base period and during the investigational seasons at the stations at Nicolaus and near Sutter, respectively. Estimates of the net amount of outflow as drainage to the Sutter By-pass were based on partial records of pumping to and from the by-pass at pumping plants operated by the Division of Water Resources. Outflow from the Cross Canal was estimated by correlation with measured runoff of streams tributary to the canal, corrected for measured pumping diversions from the canal.

Measured and estimated seasonal surface inflow to and outflow from the Sutter-Yuba Area during the base period and during 1948-49 are presented in Table 9.

IMPORTED AND EXPORTED WATER

Water is imported to the Sutter-Yuba Area through the Sutter Butte Canal system for irrigation of lands in that portion of the West Side Zone outside of the Peach Bowl. This water is diverted from the Feather River at a point about 14 miles upstream from the north boundary of the area, and is conveyed in unlined canals through a service area situated along the right bank of the Feather River both inside and outside the Sutter-Yuba Area. The estimated amount of the import was 160,000 acre-feet during the 1948-49 season, and the estimated seasonal average during the base period was 147,000 acre-feet. These estimates are shown in Table 9. For purposes of current studies the Sutter Butte Canal import was considered to be a part of surface inflow to the Sutter-Yuba Area.

So far as was determined during the investigation, there is no record of export of water from the Sutter-Yuba Area.

UNDERGROUND HYDROLOGY

The Sutter-Yuba Area overlies a portion of the ground water basin of the Sacramento Valley, and water pumped from storage in the basin presently serves nearly two-thirds of the lands irrigated in the area. Percolation of rainfall, stream flow, and drainage from adjacent hills, and of the unconsumed portion of applied irrigation water, is the most important source of ground water replenishment.

The term "free ground water," as used in this report, generally refers to a body of ground water not overlain by impervious materials and moving under control of the water table slope. "Confined ground water" refers to a body of ground water overlain by material sufficiently impervious to sever free hydraulic connection with overlying water, and moving under pressure caused by the difference in head between intake and discharge areas of the confined water body. In areas of free ground water, the ground water basin provides regulatory storage to smooth out fluctuations in available water supplies, and changes in ground water storage are indicated by changes in ground water levels.

Data and information collected during the Sutter-Yuba Counties Investigation indicated that free ground water exists in present zones of pumping, although there may be some temporary or partial confinement in certain depth zones. Study of historic fluctuation of the water table in the Sutter-Yuba Area, under varying conditions of draft and replenishment, permitted a determination of changes in ground water storage in the basin, and its safe yield of water under stated conditions. Underground hydrology is discussed in this section under the following headings: "Ground Water Geology," "Specific Yield and Ground Water Storage Capacity," "Ground Water Levels," "Change in Ground Water Storage," "Subsurface Inflow and Outflow," "Yield of Wells," "High Water Table Areas," and "Safe Ground Water Yield."

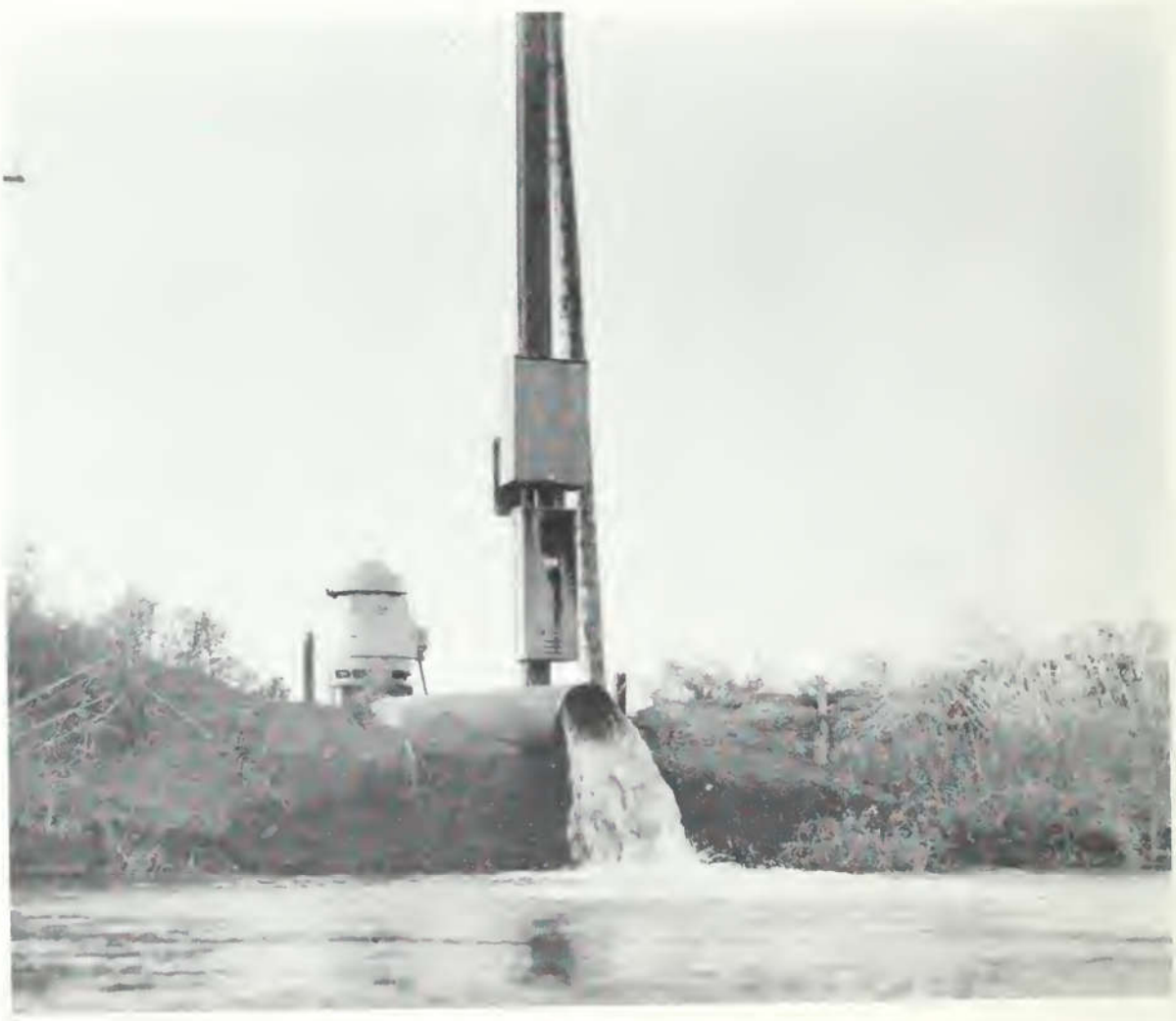
Ground Water Geology

Geologic features of the ground water basin underlying the Sutter-Yuba Area were investigated by the Ground Water Branch of the United States Geological Survey, under terms of an agreement between that agency and the State Department of Public Works. Appendix B comprises a detailed report by the Geological Survey on ground water storage capacity, within given pumping lifts, and on geologic features of the Sutter-Yuba Area, with a general geologic map, four geologic cross-sections, and a map showing ground water storage units, prepared under the direction of Joseph F. Poland, District Geologist, by G. H. Davis and F. H. Olmsted. Portions of an abstract of the geologic report follow:

"The Sutter-Yuba area occupies the east-central Sacramento Valley and part of the western foothills of the Sierra Nevada. The Sacramento Valley is a trough that has been receiving sediments from both sides since the middle part of Cretaceous time. Most of the sediments in the Sutter-Yuba area have been derived from the Sierra Nevada on the east, which is a block mountain range tilted about 1½° westward. Evidence indicates that the block continues westward beneath the sediments of the valley trough.

"The Sutter Buttes, erosional remnants of a Pliocene volcano, occupy a circular area about 10 miles in diameter near the center of the Sacramento Valley.

"Rocks exposed in the Sutter-Yuba area range in age from pre-Cretaceous metamorphic and igneous rocks of the Sierra Nevada block to Recent alluvium still undergoing deposition. The rocks may be divided into two general categories: (1) the basement complex of the Sierra Nevada, which extends beneath the Sacramento Valley at depth, and (2) the superjacent rocks; a sedimentary blanket of marine and continental deposits transported from the Sierra Nevada and deposited in the Great Valley trough.



Deep Well and Turbine Pump Installation in Sutter-Yuba Area

"The water-bearing deposits considered in this report are included in the superjacent rocks, although weathered and fractured zones in the basement complex contain small quantities of ground water. The marine sediments of Cretaceous and Tertiary age are penetrated by water wells in only a few places in the Sutter-Yuba area. Where marine sediments are encountered they are generally impervious and contain water of poor chemical quality.

"Volcanic activity in the Sierra Nevada during the Tertiary period produced tuff-breccia of mud-flow origin which are impermeable and yield little water, but interbedded volcanic sands and gravels are moderately permeable and yield water to deep wells in the Marysville, Wheatland, Roseville, and Camp Beale districts.

"Local volcanic activity at Sutter Buttes during the Pliocene epoch produced two principal groups of rocks: (1) intrusive rhyolite and andesite and vent tuffs of the central core; and (2) andesitic tuff-breccias that encircle the core. The core is hard and impervious, but sands and gravels interbedded with the tuff-breccias yield some water to wells in the Pennington and Sutter City district.

"Following the close of volcanic activity in the Sierra Nevada the streams deposited predominantly fine-grained sediments during the remainder of the Pliocene epoch. These old alluvial deposits underlie the dissected uplands or 'red lands' along the valley margin and extend westward beneath younger alluvial deposits. Poorly sorted alluvium composed of silt, clay, and cemented sand and gravel as much as 350 feet thick represent this time interval. Many wells penetrate thick sections of these materials, but well yields are low to moderate.

"Uplift of the Sierra block at the beginning of the Pleistocene epoch caused the deposition of coarser materials. Alluvium of Pleistocene age as much as 100 feet thick underlies the low plains of the Sutter-Yuba area. These deposits are moderately permeable throughout and tongues of sand and gravel provide large supplies of water to irrigation wells.

"Recent alluvium, defined as those materials undergoing deposition, falls into three general categories: (1) alluvial fans of the Sutter Buttes, (2) basin deposits, and (3) stream-channel deposits. Most of the alluvial-fan deposits of Sutter Buttes are poorly sorted and groundwater yields from them are low. Basin deposits consist of an accumulation of relatively impermeable clays and silts which have been laid down by overflow waters of the Sacramento and Feather Rivers. Generally these deposits produce little water. Stream-channel deposits of the major streams contain well sorted sands and gravels to depths of 125 feet. Well defined channels are found beneath the flood plains of the Feather, Yuba, and Bear Rivers. Wells penetrating these coarse deposits are highly productive."

Specific Yield and Ground Water Storage Capacity

The term "specific yield," when used in connection with ground water, refers to the ratio of the volume of water a saturated soil will yield by gravity to its own volume, and is commonly expressed as a percentage. Ground water storage capacity is estimated as the product of the specific yield and the volume of material in the depth intervals considered.

In its investigation of the Sutter-Yuba ground water basin, the United States Geological Survey estimated specific yield of different depth zones after study of some 700 well logs. The estimates were based on previously determined characteristics of the various types of material classified in the well logs. Ground water storage capacity of the Sutter-Yuba Area was determined by the Geological Survey for depth intervals from 20 to 50 feet, 50 to 100 feet, 100 to 200 feet, and for the entire interval from 20 to 200 feet below ground surface. However, in an area of saline ground water centered near the southern end of the West Side Zone, where storage capacity in the 100- to 200-foot depth interval was considered not usable under present conditions, the determination was limited to the 20- to 50-foot, and 50- to 100-foot depth intervals.

Storage capacity of the ground water basin underlying the Sutter-Yuba Area and the weighted average specific yield, as estimated by the United States Geological Survey, are shown in Table 10.

TABLE 10

ESTIMATED SPECIFIC YIELD AND GROUND WATER STORAGE CAPACITY, SUTTER-YUBA AREA

Depth interval, in feet from ground surface	Weighted average specific yield, in percent	Ground water storage capacity, in acre-feet
20 to 50	7.4	840,000
50 to 100	6.9	1,290,000
100 to 200	6.0	1,760,000
20 to 200	6.6	3,890,000

Ground Water Levels

The first indication of a cone of depression in the water table in the Sutter-Yuba Area was found by Kirk Bryan and reported in 1913 in United States Geological Survey Water-Supply Paper 495. At that time a small cone had developed along Gilsizer Slough southwest of Shanghai Bend.

In 1931, in a "Report on Proposed Sutter Irrigation District," S. T. Harding described a study of ground water conditions in the eastern portion of Sutter County. A fully developed depression cone was found in the water table existing at that time. In discussing the growth of pumping draft in the Peach Bowl up to 1931, the author wrote:

"Draft in 1920 was probably double that in 1913, much of the orchards being young in 1920 less water would be used. From 1920 there has been a continual increase in area and draft. Since 1924 the annual draft has probably varied more largely with variations in rainfall than of area. For the past five years there has been little new orchard planting and the existing orchards have been sufficiently mature to represent full draft.

"These conclusions correspond generally with the ground water record. Some lowering occurred prior to 1920 but this was not sufficient to cause concern. Lowering appears to have attracted attention in 1924 and to have increased in below normal years since 1924 being particularly marked in the last 3 years."

The Division of Water Resources has measured fall water levels at a series of control wells throughout the Sacramento Valley during most years from 1929 through 1940, and each year from 1947 to date. Forty of these control wells are in or adjacent to the Sutter-Yuba Area. The Sutter County Farm Adviser furnished data on water levels at 25 additional wells in the area which were measured several times annually from 1931 through 1941. The Pacific Gas and Electric Company has made frequent measurements since 1946 at approximately 25 wells in or adjacent to the Sutter-Yuba Area. This company also furnished records of

TABLE 11

MEASURED FALL DEPTHS TO GROUND WATER AT REPRESENTATIVE WELLS IN ZONES OF SUTTER-YUBA AREA

(In feet)

Year	West Side Zone			Northeast Zone		East Central Zone		South Side Zone	
	Well number								
	17N/3E-30F1	14N/3E-3P1	13N/3E-14C2	16N/4E-8A1	16N/4E-27N1	14N/4E-15C3	14N/4E-28N1	13N/4E-33R1	12N/4E-33L3
1929	4.7	28.3	15.4	18.4	10.4	15.4	10.5	20.7	15.4
1930	3.3	32.4	15.6	17.6	7.8	14.9	10.4	20.1	16.0
1931	6.2	33.8	15.4	19.5	10.8	15.4	11.0	20.8	16.4
1932	5.4	32.4	15.2	19.2	.....	14.7	11.1	20.1	12.7
1933	5.6	33.4	16.3	19.6	.....	10.0	11.2	20.5	15.6
1934	5.4	34.1	16.7	19.8	.....	.....	11.5	20.5	16.3
1936	.....	28.4	13.4	18.1	.....	9.7	11.9	22.7	12.5
1937	3.7	26.2	11.8	17.8	.....	14.8	12.0	24.8	9.4
1938	6.4	20.4	10.8	15.7	.....	11.1	9.2	19.0	8.9
1940	3.1	24.0	8.2	16.8	4.8	14.3	10.9	.....	3.4
1947	7.8	33.8	14.8	18.1	7.5	23.2	13.1	23.4	11.5
1948	9.3	34.2	14.2	21.0	12.0	24.3	13.4	25.3	11.0
1949	7.6	36.0	15.5	22.1	11.7	28.2	15.5	19.6	13.4
1950	8.6	39.1	15.5	23.6	8.8	29.7	14.6	28.1	13.0
1951	.....	32.0	.....	23.0	10.5	33.1	.....	23.3	.....

standing and operating water levels measured during pump tests, together with results of the tests.

A complete series of measurements of static ground water levels at approximately 850 wells in the Sutter-Yuba Area was made in the spring and fall of each year during the period of investigation, beginning with the fall of 1947 and continuing through 1951. The wells were chosen to form a comprehensive grid covering the entire area. In addition, monthly measurements were made at approximately 90 control wells during the first half of 1948 and through 1949, in order to observe behavior of the ground water table under conditions of draft and recharge. Available records of depth to ground water at wells in or adjacent to the Sutter-Yuba Area are included as Appendix E to this report.

Depths to ground water throughout the Sutter-Yuba Area, as measured each fall from 1947 through 1951, were plotted on maps and lines of equal depth drawn. These are shown on Plates 7 to 11, inclusive, "Lines of Equal Depth to Ground Water." Plate 12, "Lines of Equal Elevation of Ground Water, Fall 1949," was prepared from the data used for Plate 9, depths to ground water being subtracted from elevations of the measuring points above sea level to obtain elevations of the water table.

Table 11 shows depths from the surface of the ground to the water table at selected representative wells in the several zones of the Sutter-Yuba Area during the fall of most years from 1929 through 1951. The measurements were made following the summer period of irrigation pumping draft and prior to recovery in ground water storage resulting from winter rains. The wells are numbered in accordance with the system utilized by the United States Geological Survey, and described in Appendix B. Fluctuations in depth to ground water at a representative well in each zone of the Sutter-Yuba Area are depicted graphically on Plate 13, "Measured Fall Depths to Ground Water at Representative Wells."

From study of all available well measurements, estimates were made of the approximate average depth to ground water in the Sutter-Yuba Area in the fall of each year from 1929 through 1951. These estimates, which constitute arithmetical averages of available measurements, are presented in Table 12 and are illustrated graphically in Plate 14, entitled "Average Fall Depth to Ground Water."

TABLE 12

ESTIMATED AVERAGE FALL DEPTH TO GROUND WATER IN SUTTER-YUBA AREA

(In feet)

Year	Depth to ground water	Year	Depth to ground water
1929	15.9	1940	12.3
		1941	12.0
1930	16.1	1942	11.9
1931	17.7	1943	11.6
1932	16.6	1944	13.1
1933	17.6		
1934	17.2	1945	14.2
		1946	16.2
1935	16.8	1947	17.6
1936	16.4	1948	18.3
1937	15.2	1949	19.8
1938	15.2		
1939	14.5	1950	21.7
		1951	21.8

It is indicated that a moderate lowering of the water table over the Sutter-Yuba Area occurred from 1929 until 1931, followed by a slight rise in 1932, and a lowering again in 1933. Although 1935 marked the end of a series of dry years, ground water levels rose in 1934 because of reduced pumping. The water table continued to rise during a generally wet series of years until 1943, and in that year the estimated average depth to ground water was the least during the entire period from 1929 through 1951. Since 1943, coincidental with dry years and expansion of irrigation, a continuous lowering of the water table has occurred, reaching its greatest average depth during the entire period in the fall of 1951.

In order to estimate weighted average changes in ground water elevations in the Sutter-Yuba Area during the nine-year base period and each investigational season, maps were drawn showing lines of equal change in elevation during these periods. An example of these maps is presented as Plate 15, "Lines of Equal Change in Ground Water Elevation from Fall of 1947 to Fall of 1951." By planimetering the areas between lines of equal change, the weighted average change in elevation of water levels was estimated for each zone of the Sutter-Yuba Area. The results of these estimates are presented in Table 13.

TABLE 13

ESTIMATED WEIGHTED AVERAGE SEASONAL CHANGES IN FALL GROUND WATER ELEVATION IN ZONES OF SUTTER-YUBA AREA

(In feet)

Zone	1939-40 to 1947-48	1947-48	1948-49
West Side			
Peach Bowl	−0.7	−0.7	−1.5
Outside Peach Bowl	+0.1	+0.1	−0.2
Northeast	+0.1	+0.3	−1.0
East Central	−0.7	−1.2	−2.3
South Side	−0.6	−1.3	−2.1

Change in Ground Water Storage

In an area of free ground water, the volume of soil unwatered or resaturated over a period of time, when multiplied by the specific yield, measures the change in ground water storage during that time. Available data on fluctuations of water levels at wells in the Sutter-Yuba Area were sufficient to estimate the volume of soil unwatered or resaturated during the base period, and during the two investigational seasons. Changes in ground water storage were estimated for each zone of the area by multiplying changes in elevation of ground water, presented in Table 13, by the area of each zone and by the average value of specific yield of 7.4 percent, found by the Geological Survey for the depth interval from 20 to 50 feet below ground surface. The results of these estimates are presented in Table 14.

TABLE 14

ESTIMATED WEIGHTED AVERAGE SEASONAL CHANGES IN GROUND WATER STORAGE IN ZONES OF SUTTER-YUBA AREA

(In acre-feet)

Zone	Area, in acres	1939-40 to 1947-48	1947-48	1948-49
West Side				
Peach Bowl	61,400	−3,000	−3,000	−7,000
Outside Peach Bowl	62,370	+500	0	−1,000
Northeast	42,860	+300	+1,000	−3,000
East Central	77,870	−4,000	−7,000	−13,000
South Side	82,460	−4,000	−8,000	−13,000
TOTALS	326,960	−10,200	−17,000	−37,000

It is indicated that an average seasonal net decrease in ground water storage in the Sutter-Yuba Area of about 10,000 acre-feet occurred during the nine-year base period, in which conditions of water supply and climate were approximately equivalent to conditions during the mean periods. The estimated net decrease in ground water storage during the two investigational seasons was approximately 17,000 acre-feet in 1947-48, and 37,000 acre-feet in 1948-49. It may be noted that the decrease in storage was substantial in the Peach Bowl portion of the West Side Zone, and in the East Central and South Side Zones. In the high water table lands of the Sutter Butte Canal service area in the West Side Zone, and in the Northeast Zone, changes in ground water storage were of minor importance.

Subsurface Inflow and Outflow

Lines of equal elevation of ground water in the Sutter-Yuba Area in the fall of 1949 are shown on Plate 12. Slopes of the water table as defined by these ground water contours, together with information on the permeabilities of the various subsurface geologic formations, indicate that the greater portion of subsurface inflow to the area probably came from the east, and a smaller amount from the north between Sutter Buttes and the eastern foothills. It is probable that about half of the subsurface inflow from the east entered from Placer County south of the historic Bear River flood plain, and that the other half moved across the investigational boundary from the east in Yuba

County, including the whole of the historic Bear River flood plain.

The ground water gradients shown on Plate 12 indicate that there was little subsurface outflow from the Sutter-Yuba Area during or immediately following the 1949 season of heavy pumping draft. Sufficient data were not available to depict ground water contours in the area during the wet years from 1939 to 1943, when there was substantial ground water replenishment and when subsurface outflow may have been significant. Study of available data, however, does show that average seasonal subsurface outflow from the Sutter-Yuba Area during the nine-year base period was probably small.

The ground water contours shown on Plate 12 indicate the presence of a depression cone in the water table extending approximately north and south through the Peach Bowl during 1949. There was a general convergence of ground water around the perimeter of the depression and into the trough, showing that such ground water movement as may have occurred was inflow to the cone, rather than outflow.

The northern and western portions of the West Side Zone, and adjacent areas outside of the Sutter-Yuba Area, are served with surface water supplies, and ground water levels have been fairly stable and close to the ground surface even in dry years. However, during dry years, ground water levels in the Peach Bowl have lowered as a result of increased pumping. These conditions have probably resulted in relatively greater subsurface inflow to the Peach Bowl during such dry years, owing to the steeper gradients existing in the water table.

An indirect method was used to estimate the net effect of subsurface inflow to and outflow from the Sutter-Yuba Area. This involved evaluation of the difference between subsurface inflow and outflow as the item necessary to effect a balance between water supply and disposal. The sum of the items comprising the water supply of a given hydrologic unit or area must be equal to the sum of the items of water disposal. This is a statement of what is referred to as the "equation of hydrologic equilibrium." In the case of the Sutter-Yuba Area, values for pertinent items other than the difference between subsurface inflow and outflow, including surface inflow and outflow, precipitation, change in ground water storage, and consumptive use of water, were quantitatively measured or estimated. Determination of values for consumptive use of water is explained in Chapter III. Retention of subsurface inflow, or the difference between subsurface inflow and outflow, was the remaining unknown quantity in the equation of hydrologic equilibrium. Table 15 sets forth this equation for the Sutter-Yuba Area.

Certain of the values in the equation of hydrologic equilibrium presented in Table 15 are of large magnitude as compared to the derived excess of subsurface inflow over subsurface outflow. Small percentage errors in these larger quantities might introduce relatively large errors in the derived remainders. In this connection, independent geologic analysis of the cross section of the perimeter of the Sutter-Yuba ground water basin, including consideration of the porosity of the aquifers, indicated that with existing slopes of the water table the derived values for net subsurface inflow might be excessive. However, study of disposal of water supplies in areas adjacent to the Sutter-Yuba Area tended to corroborate the derived values.

TABLE 15

ESTIMATED EXCESS OF SEASONAL SUBSURFACE INFLOW OVER SUBSURFACE OUTFLOW IN SUTTER-YUBA AREA

(In acre-feet)

Item	Average for 9-year base period 1939-40 through 1947-48	1947-48	1948-49
WATER SUPPLY			
Precipitation	635,000	529,000	448,000
Surface inflow	6,239,000	4,849,000	3,425,000
Decrease in ground water storage	10,000	17,000	37,000
TOTALS	6,884,000	5,395,000	3,910,000
WATER DISPOSAL			
Surface outflow	6,316,000	4,790,000	3,296,000
Consumptive use of water	710,000	764,000	794,000
TOTALS	7,026,000	5,554,000	4,090,000
REMAINDER — EXCESS OF SUBSURFACE INFLOW OVER SUBSURFACE OUTFLOW	142,000	159,000	180,000

Yield of Wells

Yield of wells is an important factor in the use of ground water in the Sutter-Yuba Area. In certain small portions of the area ground water is not utilized for irrigation because of inability to obtain wells of adequate capacity to meet the agricultural requirements. On the other hand, throughout most of the area adequate agricultural wells can generally be obtained.

Yield of wells in the Sutter-Yuba Area was analyzed by the United States Geological Survey, as reported in Appendix B, utilizing data obtained from well pumping tests made by the Pacific Gas and Electric Company during the period from 1933 through 1948. Results of the Geological Survey's analysis are summarized in Table 16, which shows for each zone of the Sutter-Yuba Area the number of wells tested, and their average discharge, specific capacity, depth, and yield factor. The term "specific capacity" refers to the number of gallons of water per minute produced by a pumping well per foot of drawdown. "Drawdown" refers to the lowering of the water level in a well caused by pumping, and is measured in feet. The "yield factor" reflects

the production of water per foot of depth of well, and is determined by multiplying the specific capacity by 100 and dividing by the depth of the well, in feet.

TABLE 16

ESTIMATED AVERAGE YIELD OF WELLS IN ZONES OF SUTTER-YUBA AREA

Zone	Number of wells tested	Average discharge, in gallons per minute	Average specific capacity, in gallons per minute per foot of drawdown	Average depth of wells, in feet	Average yield factor
West Side					
Peach Bowl	249	728	47	182	25.7
Outside Peach Bowl	48	878	54	320	16.8
Northeast	28	838	60	201	29.8
East Central	109	846	48	292	16.7
South Side	104	960	47	324	14.7

Insofar as may be determined from consideration of Table 16, it is indicated that the better wells of the Sutter-Yuba Area are located in the Peach Bowl and in the Northeast Zone. While wells of adequate capacity may generally be obtained throughout the remainder of the area, it is usually necessary to drill to greater depths for equivalent yields. However, although not apparent from the foregoing data, it was determined during the investigation that in the southeastern portion of the East Central Zone there is an area of approximately 3,400 acres of irrigable land upon which efforts to obtain wells of sufficient capacity to support irrigation demands have been unsuccessful.

High Water Table Areas

Under about 8,000 acres in the Northeast Zone, ground water was less than 10 feet from the ground surface continuously from November, 1947, through 1951, as was also the case under about 23,000 acres in the West Side Zone north of the East and West Intercepting Canals. Under about 1,000 acres of such lands in the Northeast Zone, and 4,500 acres in the West Side Zone, depth to the water table ranged from 0 to 5 feet from the ground surface.

The foregoing high water table lands were entirely irrigated by surface waters. It was indicated that the perennially high water table was largely caused by heavy applications of the abundant surface water supply to crops of rice and permanent pasture. The geologic investigations showed that the lands overlie good water-bearing formations which are capable of being developed by wells of relatively high yield, and that increase in use of ground water would probably result in lowering of ground water levels.

Studies indicated that the high water table lands would be suitable for a much wider range of crops than at present, if ground water levels were held at greater depths, and that an existing drainage problem would be eliminated. Furthermore, it is probable that consumptive use of water on these lands, as evidenced by heavy growth of native vegetation, is substantially in excess of such use on similar nearby lands where ground water levels are lower. The term "consumptive use of water," as used in this report, refers to water consumed by vegetative growth in transpiration and building of plant tissue, and to water evaporated from adjacent soil, from water surfaces, and from foliage. It also refers to water similarly consumed and evaporated by urban and nonvegetative types of culture.

Safe Ground Water Yield

The term "safe ground water yield" refers to the maximum rate of extraction of water from a ground water body which, if continued over an indefinitely long period of years, will result in the maintenance of certain desirable fixed conditions. Commonly, safe ground water yield is determined by one or more of the following criteria:

1. Mean seasonal extraction of water from the ground water body does not exceed mean seasonal replenishment to the body.

2. Water levels are not so lowered as to cause harmful impairment of the quality of the ground water by intrusion of other water of undesirable quality, or by accumulation and concentration of degradants or pollutants.

3. Water levels are not so lowered as to imperil the economy of ground water users by excessive costs of pumping from the ground water body.

Safe ground water yield, as derived in this report, was measured by net extraction of water from the Sutter-Yuba ground water basin, as differentiated from total pumpage from the basin. Since the Sutter-Yuba Area overlies a free ground water body, the unconsumed portion of total pumpage may return to the ground water body and become available for re-use. The net rate of extraction, therefore, was considered to be only that portion of total pumpage from the ground water basin which was consumptively used.

Under natural conditions, ground water is expended by consumptive use from seep lands and from lands where the water table is close to the ground surface, by effluent stream flow, and by subsurface outflow. Artificial development and utilization of ground water salvages all or a portion of such natural disposal, by lowering ground water levels. This, in turn, affords opportunity for additional replenishment of ground water.

With the present general patterns of water utilization in the Sutter-Yuba Area, the extraction of water from the ground water basin might be increased. Such increase in draft would undoubtedly be accompanied by recession of ground water levels in areas of pumping. However, this lowering of the water table would induce increased subsurface inflow to the areas of pumping and reduce natural disposal of the ground water, the probable effects of which would be to increase replenishment in an amount approximately equal to the increase in draft. This would probably hold true even in a series of dry years because of the continuous availability of large amounts of ground water in adjacent areas, maintained by percolation from relatively large surface water supplies. For this reason, the first of the foregoing criteria for determination of safe yield was not considered to be applicable in the Sutter-Yuba Area.

Because of expressed local concern over recent progressive lowering of pumping levels and deterioration in mineral quality of the ground water, the second and third of the foregoing criteria for determination of safe ground water yield were adopted as applicable to the Sutter-Yuba Area. It was therefore arbitrarily assumed that seasonal net extraction of ground water in 1948-49, with ground water levels prevailing at that time, defined the desirable limit beyond which net extraction should not be increased at the expense of further lowering of ground water levels.

As previously stated, consumptive use of ground water was considered to be equal to net extraction of water from the Sutter-Yuba ground water basin. An estimate of average seasonal consumptive use of ground water in the area during the nine-year base period is presented and explained in Chapter III. After correction for average seasonal change in ground water storage, this value was considered to represent average seasonal replenishment of the ground water basin during the base period. When further corrected for the increase in replenishment during 1948-49, over and above the base period average, as measured by increase in subsurface inflow, the value was considered to be equal to safe seasonal ground water yield.

The estimate of safe seasonal ground water yield is presented in Table 17.

Certain of the items included in the estimate of safe ground water yield are based on the assumption that present practice of irrigation by surface water supplies in and adjacent to the Sutter-Yuba Area will continue indefinitely. Under such circumstances adjacent ground water basins will remain the sources of sufficient subsurface inflow to areas of ground water pumping in the Sutter-Yuba Area to meet increases in pumping draft. While there is no assurance that surface irrigation practices will continue indefinitely as at present, there is reason to believe that any changes will not be of material significance to the estimated yield for many years in the future.

TABLE 17

ESTIMATED SAFE SEASONAL GROUND WATER YIELD IN SUTTER-YUBA AREA

Item	Acre-feet
Average seasonal consumptive use of ground water for 9-year base period, 1939-40 through 1947-48	158,100
Average seasonal decrement in ground water storage for base period	10,000
Average seasonal replenishment of ground water basin for base period	148,100
Increase in replenishment in 1948-49 over base period seasonal average	38,000
SAFE SEASONAL GROUND WATER YIELD	186,100

The foregoing estimate of safe seasonal ground water yield may be considered to represent the net seasonal extraction from the ground water basin that might be maintained without permanent lowering of the water table and degradation of mineral quality of the ground water beyond conditions prevailing in 1948-49. Having so chosen the determining criteria, estimated safe seasonal ground water yield may be considered to be a property of the ground water basin, not affected by changes in irrigation efficiency, patterns, or practices.

QUALITY OF WATER

The surface water supplies of the Sutter-Yuba Area are of excellent mineral quality and well suited from that standpoint for irrigation and other beneficial uses. With respect to ground water supplies, however, salinity sufficient to impair use of the ground water for irrigation, domestic, and many industrial uses has been observed at scattered wells throughout the area for many years. In the Peach Bowl, in the adjacent southern portion of the West Side Zone, and in the western portion of the South Side Zone this salinity of ground water has been general. The principal objectives of the water quality investigation, therefore, were to evaluate these conditions and to determine the extent of the area presently affected and the source of the saline ground waters.

It is desirable to define certain terms commonly used in connection with discussion of quality of water:

Contamination—This refers to impairment of the quality of water by sewage or industrial waste to a degree which creates a hazard to public health through poisoning or spread of disease.

Degradation—This refers to any impairment in the quality of water due to causes other than disposal of sewage and industrial wastes.

Pollution—This refers to impairment of the quality of water by sewage or industrial waste to a degree which does not create a hazard to public health, but which adversely and unreasonably affects such water for beneficial uses.

Quality of Water—This refers to those inherent characteristics of water affecting its suitability for beneficial uses.

The term "mineral analysis" refers to the quantitative determination of inorganic impurities or dissolved mineral constituents in the water. The complete mineral analysis included a determination of three cations, consisting of calcium, magnesium, and sodium; four anions, consisting of bicarbonate, chloride, sulphate, and nitrate; total soluble salts; boron; and computation of percent sodium. The partial analysis included determination of chlorides and total mineral solubles only.

With the exception of boron, the concentrations of cations and anions in a water sample are expressed in this report in terms of "equivalents per million." This was done because ions combine with each other on an equivalent basis, rather than on basis of weight, and a chemical equivalent unit of measurement provides a better and more convenient expression of concentration. This is especially true when it is desired to compare the composition of waters having variable concentration of mineral solubles. In the case of boron, concentrations are expressed on a weight basis of "parts per million" of water. In order to convert equivalents per million to parts per million, the concentration, expressed in equivalents per million, should be multiplied by the equivalent weight of the cation or the anion in question. Equivalent weights of the common cations and anions are presented in the following tabulation:

Cation	*Equivalent weight*	*Anion*	*Equivalent weight*
Calcium	20.0	Bicarbonate	61.0
Magnesium	12.2	Chloride	35.5
Sodium	23.0	Sulphate	48.0
		Nitrate	62.0

Data used to determine the quality of water in the Sutter-Yuba Area included complete mineral analyses of eight surface water samples and complete mineral analyses of water samples collected from 38 wells. The data also included partial analyses of water samples collected from 226 wells during the 1948 irrigation season and partial analyses of samples collected from 296 wells during the 1949 irrigation season. Other data used during the course of the investigation included well water analyses that were obtained from the Federal Land Bank in Berkeley and the Rubidoux Laboratory of the United States Department of Agriculture at Riverside, California.

Standards of Quality for Water

Investigation and study of the quality of surface and ground waters of the Sutter-Yuba Area, as reported herein, were largely limited to consideration of mineral constituents of the waters, with particular reference to their suitability for irrigation use. However, it may be noted that, within the limits of the mineral analyses herein reported, a water which is determined to be suitable for irrigation may also be considered as being either generally suitable for municipal and domestic use, or susceptible to such treatment as will render it suitable for that purpose.

The major criteria which were used as a guide to judgment in determining suitability of water for irrigation use comprised the following: (1) chloride concentration, (2) total soluble salts, (3) boron concentration, and (4) percent sodium.

1. The chloride anion is usually the most troublesome element in most irrigation waters. It is not considered essential to plant growth, and excessive concentrations will inhibit growth.

2. Total soluble salts furnishes an approximate indication of the over-all mineral quality of water. It may be approximated by multiplying specific electrical conductance ($Ec \times 10^6$ at 25° C.) by 0.7. The presence of excessive amounts of dissolved salts in irrigation water will result in reduced crop yields.

3. Crops are sensitive to boron concentration, but require a small amount (less than 0.1 per million) for growth. They will usually not tolerate more than 0.5 to 2 parts per million, depending on the crop in question.

4. Percent sodium reported in the analyses is the proportion of the sodium cation to the sum of all cations, and is obtained by dividing sodium by the sum of calcium, magnesium, and sodium, all expressed in equivalents per million, and multiplying by 100. Water containing a high percent sodium has an adverse effect upon the physical structure of the soil by dispersing the soil colloids and making the soil "tight," thus retarding movement of water through the soil, retarding the leaching of salts, and making the soil difficult to work.

The following excerpts from a paper by Dr. L. D. Doneen, of the Division of Irrigation of the University of California at Davis, may assist in interpreting water analyses from the standpoint of their suitability for irrigation:

"Because of diverse climatological conditions, crops, and soils in California, it has not been possible to establish rigid limits for all conditions involved. Instead, irrigation waters are divided into three broad classes based upon work done at the University of California, and at the Rubidoux, and Regional Salinity laboratories of the U. S. Department of Agriculture.

"Class 1. *Excellent to Good*—Regarded as safe and suitable for most plants under any condition of soil or climate.

"Class 2. *Good to Injurious*—Regarded as possibly harmful for certain crops under certain conditions of soil or climate, particularly in the higher ranges of this class.

"Class 3. *Injurious to Unsatisfactory*—Regarded as probably harmful to most crops and unsatisfactory for all but the most tolerant.

"Tentative standards for irrigation waters have taken into account four factors or constituents, as listed below.

Factor	*Class 1 excellent to good*	*Class 2 good to injurious*	*Class 3 injurious to unsatisfactory*
Conductance (Ec × 10⁶ at 25° C.)	Less than 1000	1000–3000	More than 3000
Boron, ppm	Less than 0.5	0.5–2.0	More than 2.0
Percent sodium	Less than 60	60–75	More than 75
Chloride, epm	Less than 5	5–10	More than 10

(End of quotation)

Quality of Surface Water

Analyses of surface water samples, collected in March, 1949, from the Feather River and four of its tributaries, showed that at that time the waters in these streams were of excellent mineral quality and well suited for irrigation and other beneficial uses. The waters were characterized by a very low content of total mineral solubles, chloride, and boron, and by low percent sodium. The occurrence of excellent quality water in the Feather River is also indicated by analyses of water from that stream which are presented in the Sacramento-San Joaquin Water Supervision Reports of the Division of Water Resources dating from 1946. Analyses of drainage water samples collected from Sutter By-pass and Snake Slough indicated that both drainage waters contain higher concentrations of mineral solubles than waters of Feather River and its tributaries, but that they are well within the limits of Class 1 irrigation waters. Analyses of representative surface waters of the Sutter-Yuba Area, sampled in 1949, are presented in Table 18.

Quality of Ground Water

Although in the course of the present investigation surveys were made of the mineral quality of ground water throughout the Sutter-Yuba Area, particular emphasis was placed on those areas where saline degradation has been general, and of a degree sufficient to limit beneficial use of the ground water. Results of the surveys are presented and discussed in this section under the headings "Area of Degraded Ground Water" and "Source of Ground Water Salinity."

Area of Degraded Ground Water. Two comprehensive surveys of the average mineral quality of ground water in the Sutter-Yuba Area were made during the irrigation seasons of 1948 and 1949. Both surveys involved the partial analysis of water samples collected from numerous wells to determine total mineral solubles and chlorides. Results of the two surveys are summarized in Table 19, and show that in 1948 and 1949 the mineral quality of native ground water supplies was excellent or good in all zones of the Sutter-Yuba Area, except in that portion of the West Side Zone south of Oswald Road where abnormally high concentrations of chloride were found in many of the well water samples. The 1949 survey embraced a larger area than the 1948, and included lands south and west of Sutter By-pass. Results of this extended survey showed that high chloride salinity of ground water also occurred locally near the town of Robbins, some seven miles westerly from Nicolaus.

The foregoing present areas of comparatively high chloride salinity are shown on Plate 16, "Lines of Equal Concentration of Chlorides in Ground Water, July 1949." It may be noted that the concentration of chlorides in the ground water decreased progressively with distance from both of the affected areas, in the

TABLE 18

COMPLETE MINERAL ANALYSES OF REPRESENTATIVE SURFACE WATERS OF SUTTER-YUBA AREA

	Date of sample	Conductance, Ec × 10⁶ at 25° C.	Boron, in ppm	Mineral constituents in equivalents per million							Percent sodium
				Ca	Mg	Na	HCO_3 + CO_3	Cl	SO_4	NO_3	
Tributary Streams											
Feather River at Rednal Road	3/15/49	99	0.0	0.39	0.47	0.27	0.91	0.06	0.09	Trace	24
Feather River at Nicolaus	3/14/49	92	0.0	0.43	0.46	0.40	0.77	0.03	0.20	0.09	31
South Honcut Creek at La Porte Road	3/15/49	124	0.0	0.43	0.62	0.36	1.08	0.12	0.15	Trace	26
Dry Creek near Waldo	3/21/49	164	0.0	0.71	0.85	0.40	1.37	0.13	0.31	Trace	20
Coon Creek at Highway 99E	3/14/49	175	0.0	0.70	0.93	0.36	1.51	0.16	0.32	0.06	18
Auburn Ravine at Highway 99E	3/14/49	143	0.0	0.54	0.69	0.39	1.04	0.16	0.28	0.10	24
Drainage Waters											
Sutter By-pass at Colusa Highway	7/19/49	400	0.09	1.49	1.79	1.35	3.94	0.52	0.21	Trace	28
Snake Slough at Sanders	7/19/49	380	0.09	1.29	1.80	1.80	3.88	0.38	0.08	Trace	26

TABLE 19

SUMMARY OF PARTIAL MINERAL ANALYSES OF GROUND WATERS IN ZONES OF SUTTER-YUBA AREA, SUMMERS OF 1948 AND 1949

Zone	Number of samples		Chlorides, in equivalents per million				Conductance, Ec × 10^6 at 25° C.	
			Average		Range			
	1948	1949	1948	1949	1948	1949	1948	1949
West Side								
North of Oswald Road	41	25	1.5	0.84	0.3- 4.8	0.3- 2.1	600	730
South of Oswald Road	129	159	5.13	6.10	0.3-28.7	0.3-62.5	1,010	1,300
Northeast	4	2	0.8	0.73	0.3- 1.1	0.3- 1.1	340	280
East Central	31	14	0.7	0.7	0.3- 1.7	0.3- 1.7	300	210
South Side	21	6	1.1	1.0	0.6- 4.8	0.5- 2.0	500	380

West Side Zone south of Oswald Road and near the town of Robbins. It may be inferred from this condition that, when hydraulic conditions are favorable, saline ground water from these two areas may move laterally, thus causing degradation in the mineral quality of remaining fresh ground water resources of surrounding areas.

The areas delimited by the lines of equal chloride concentration on Plate 16 indicate that at the present time wells on approximately 4,500 acres of land in the West Side Zone south of Oswald Road yield water containing chlorides in amounts exceeding 10 equivalents per million, which amount is considered to be the upper limit for safe irrigation use. When such saline waters are used for irrigation, quantities of water exceeding normal crop demands are commonly applied in order to dilute the soil solution and leach accumulations of excess salts away from the root zone.

Source of Ground Water Salinity. The presence of saline ground waters in and adjacent to the Sutter-Yuba Area has been observed to exist for many years, and was remarked upon in reports of salt balance studies conducted by the Division of Soil Management and Irrigation of the United States Department of Agriculture. These studies, which were made in cooperation with the Sutter Mutual Water Company during 1931, 1932, 1933, 1946, and 1947, showed that the amount of dissolved solids in water drained from lands adjacent to and west of the southern portion of the Sutter-Yuba Area greatly exceeded the amount brought onto the lands in irrigation water. The salt output during each of the five years, expressed as a proportion of the input, is reported to have ranged between 248 and 655 percent, and the average was about 407 percent.

The opinion was expressed in a report on the foregoing 1947 salt balance study that the salt in the drainage waters was probably derived from saline waters underlying the area. Preliminary studies made by the Division of Water Resources similarly indicated that the chloride salinity in many of the wells was due to admixture of deep-seated brines with native fresh ground waters. There is evidence that such brines may underlie aquifers of good quality water throughout large areas of the Sacramento and San Joaquin Valleys, and that they may have originated during past geologic time when the floor of the valley was inundated by the ocean. Such brines sometimes appear in water pumped from the deeper wells in the two valleys, or from areas wherein the fresh ground water levels are markedly lowered through overdraft. In many instances these relatively deep-seated brines are under considerable pressure and readily rise to the surface through defective, abandoned, or improperly constructed wells. A case in point is a natural gas well located near the town of Robbins which yields water under artesian and/or gas pressure, at a rate of about 200 gallons a minute. The water from this well, No. 12N/2E-18, has a conductivity of about 8,600, a chloride content of about 100 equivalents per million, and about 10.8 parts per million of boron.

A geochemical study was made to determine whether salinity of ground water in the Sutter-Yuba Area was caused principally by a common degradant, and whether the foregoing deep-seated brines constituted that degradant. The study to identify the degradant was made on the basis of complete mineral analyses of water samples collected from 38 scattered wells located in the West Side Zone south of Oswald Road and in adjacent lands to the west. These water samples were first classified into eight groups according to the range in concentration of total anions. For purposes of the study it was considered that native fresh ground waters contained total anions in amounts less than about 7 equivalents per million, chlorides in amounts less than about 2.5 equivalents per million, and that degradation had occurred if these amounts were ex-

ceeded. A discussion of the characteristics of each group follows:

Group 1. This comprised unaltered normal ground water. Four analyses were available for Group 1 water. The wells which yielded this water were located within the present zone of high chloride concentration, and the samples were taken and analyses made in 1934 and 1935 prior to recent degradation of ground water in the zone. The water had total anions ranging from 4.72 to 6.31 equivalents per million, and chlorides from 0.85 to 2.06 equivalents per million. Its mineral quality was excellent.

Group 2. This group comprised waters containing a trace of salinity. Total anions ranged from 8.95 to 10.68 equivalents per million, and chlorides from 5.45 to 6.39 equivalents per million. Four analyses repre-

TABLE 20

COMPLETE MINERAL ANALYSES OF GROUND WATERS IN AREA OF SALINE DEGRADATION IN AND ADJACENT TO SUTTER-YUBA AREA, GROUPED IN ACCORDANCE WITH TOTAL ANIONS

Ground water group	Well location or number	Date of sample	Conductance, Ec × 10⁶ at 25° C.	Boron, in ppm	Mineral constituents, in equivalents per million							Percent sodium
					Ca	Mg	Na	HCO_3 + CO_3	Cl	SO_4	NO_3	
1	N½ Sec. 9, T13N, R3E	5/31/34	483		1.40	1.81	1.51	3.30	1.33	0.09		32
	S½ Sec. 10, T14N, R3E	1/ 2/35	543		1.70	1.97	1.43	4.25	0.85	Trace		28
	NE¼ Sec. 15, T14N, R3E	1/15/35	515		1.50	2.13	1.54	3.70	1.47	Trace		30
	NW¼ Sec. 28, T14N, R3E	4/30/34	635		2.10	2.30	1.91	4.20	2.06	0.05		30
	Average		544		1.67	2.05	1.59	3.86	1.43	0.03		30
2	11N/3E-2B1	7/ /49	944	0.16	2.80	2.24	4.31	3.02	5.90	0.03	0.0	46
	13N/3E-3D1	7/ /49	980	0.09	3.59	5.02	2.05	4.20	6.39	0.09	0.0	19
	14N/3E-28R1	7/ /49	1,000	0.12	2.71	5.62	2.58	3.94	6.38	0.13	Trace	24
	14N/3E-33A2	7/ /49	1,037	0.0	2.98	4.29	3.32	5.09	5.45	0.03	0.0	31
	Average		990	0.09	3.02	4.29	3.06	4.06	6.03	0.07	Trace	30
3	13N/3E-2P3	7/ /49	1,317	0.17	3.13	3.39	6.46	3.78	9.21	0.04	0.0	50
	13N/3E-5K1	7/ /49	1,353	0.07	3.70	5.53	4.07	4.15	9.14	0.09	0.0	31
	13N/3E-10A1	7/ /49	1,190	0.05	4.40	5.83	2.13	3.91	8.06	0.22	0.0	17
	14N/3E-27E1	7/ /49	1,361	0.0	4.51	5.94	3.38	5.53	7.86	0.45	Trace	24
	14N/3E-29Q1	7/ /49	1,390	0.14	4.14	5.33	4.47	3.23	10.15	0.02	Trace	32
	14N/3E-34J1	7/ /49	1,087	0.0	4.05	5.76	2.57	6.84	3.40	2.01	0.10	21
	Average		1,283	0.07	3.99	5.31	3.85	4.54	7.97	0.14	0.02	29
4	13N/3E-2E1	7/ /49	1,503	0.49	2.96	3.05	8.75	3.78	11.11	0.03	0.0	59
	13N/3E-11D1	7/ /49	1,408	0.06	5.21	7.34	1.96	4.17	9.34	0.81	0.0	13
	13N/3E-14G1	7/ /49	1,307	0.06	4.43	6.85	3.44	6.20	7.49	0.71	0.06	23
	13N/3E-23H1	7/ /49	1,408	0.03	5.45	6.73	2.92	4.98	10.23	0.17	0.0	19
	13N/3E-24D1	7/ /49	1,460	1.64	3.23	2.15	9.05	3.90	11.68	0.03	0.0	63
	14N/3E-33A1	7/ /49	1,460	0.0	4.88	6.99	2.82	5.11	9.44	0.09	0.0	19
	Average		1,425	0.36	4.36	5.52	4.86	4.52	9.88	0.31	0.01	33
5	13N/3E-5C1	7/ /49	1,835	0.21	4.83	6.00	6.70	3.52	14.08	0.03	0.0	38
	13N/3E-11F1	7/ /49	1,710	0.85	3.29	4.51	9.40	3.26	13.04	0.28	0.0	55
	13N/3E-14J1	7/ /49	1,710	0.31	4.68	8.18	4.87	4.12	12.78	0.43	0.0	27
	14N/3E-28G2	7/ /49	1,653	0.0	5.18	6.92	4.51	5.21	10.95	0.37	0.0	27
	14N/3E-32F1	7/ /49	1,640	0.24	4.90	7.36	4.77	4.35	12.37	0.03	0.0	28
	Average		1,709	0.32	4.58	6.59	6.05	4.09	12.64	0.23	0.0	35
6	11N/3E-3B1	7/ /49	2,162	0.93	4.63	2.98	13.94	3.42	18.08	0.03	0.0	65
	13N/3E-2N1	7/ /49	1,802	0.07	5.71	6.31	6.02	4.63	13.61	0.15	Trace	33
	13N/3E-14R1	7/ /49	1,870	0.72	5.35	6.68	6.89	4.88	14.06	0.26	0.0	36
	13N/3E-16R1	7/ /49	2,222	0.03	5.96	8.25	7.27	4.24	17.42	0.03	0.0	34
	13N/3E-32L1	7/ /49	2,062	0.21	5.27	10.09	5.75	2.64	17.26	0.30	0.0	27
	Average		2,059	0.39	5.38	6.86	7.97	3.95	16.09	0.15	Trace	39
7	13N/3E-6K1	7/ /49	2,550	0.28	6.62	11.33	8.81	5.08	20.42	0.05	0.0	33
	13N/3E-23B1	7/ /49	3,390	0.0	11.83	16.80	6.71	5.50	29.04	0.34	Trace	19
	14N/3E-31J1	7/ /49	2,425	0.0	7.28	11.08	6.20	5.06	19.26	0.26	Trace	25
	14N/3E-31R1	7/ /49	2,552	0.07	7.36	11.09	6.97	4.98	20.44	0.12	0.0	27
	14N/3E-32L2	7/ /49	2,776	0.27	7.40	9.30	9.84	2.82	23.52	0.04	0.0	37
	14N/5E-21A1	8/ 3/49	2,702	1.71	10.78	4.17	12.60	1.72	22.94	2.01	Trace	46
	Average		2,732	0.39	8.55	10.63	8.52	4.19	22.60	0.47	Trace	31
8	SE¼ Sec. 2, T12N, R2E	7/ 9/49	10,000	0.60	30.37	35.30	39.90	4.10	99.45	0.05	0.0	38
	SW¼ Sec. 18, T12N, R2E	3/14/47	8,600	10.8	19.83	7.22	76.12	2.71	99.92	0.08		74
	Average		9,300	5.7	25.10	21.26	58.01	3.40	99.67	0.05		56

senting wells yielding Group 2 waters were available. These waters were classed as of good mineral quality and suitable for general irrigation use.

Group 3. This group comprised slightly saline ground waters. Total anions ranged from 12.19 to 13.40 equivalents per million, and chlorides ranged from 3.40 to 10.15 equivalents per million. Six analyses were available for wells yielding Group 3 waters. These waters were considered to be generally satisfactory for irrigation use.

Group 4. This group comprised moderately saline ground waters, with total anions ranging from 14.32 to 15.38 equivalents per million, and chlorides ranging from 7.49 to 11.68 equivalents per million. Six analyses were available for wells yielding Group 4 waters. These waters were classed as usable with caution for general irrigation under most conditions.

Group 5. This group comprised saline ground waters with total anions ranging from 16.53 to 17.63 equivalents per million, and chlorides ranging from 10.95 to 14.08 equivalents per million. Five analyses were available for wells yielding Group 5 waters. These waters would normally be considered usable for irrigation only after dilution with water of better mineral quality.

Group 6. This group comprised saline ground waters having total anions ranging from 18.35 to 21.69 equivalents per million, and chlorides ranging from 13.61 to 18.08 equivalents per million. Five analyses were available for wells yielding Group 6 water. This water was classed as unsuitable for irrigation use.

Group 7. This group comprised highly saline ground waters, having total anions ranging from 25.54 to 34.88 equivalents per million, and chlorides ranging from 19.26 to 29.04 equivalents per million. Analyses were available for six wells yielding Group 7 waters. These waters were not considered usable for irrigation or domestic purposes.

Group 8. This group comprised briny ground waters. Group 8 waters were yielded in June 1949 by a reputedly shallow well, and in April 1930 and March 1947 by a nearly 1500-foot abandoned gas well, both located near Robbins to the west of the Sutter-Yuba Area. These waters had total anions in excess of 100 equivalents per million. Chlorides accounted for about 95 per cent or more of the anions.

Results of complete mineral analyses of ground waters in the zone of degradation, segregated into the foregoing groups, are presented in Table 20.

The character formula of a water expresses the percent of each cation and anion of mineral constituents of the water with respect to their total, and is useful in comparing mineral quality characteristics of several waters. In order to compare the groups of saline ground waters in and adjacent to the Sutter-Yuba Area, the average equivalents per million of each cation and anion in unaltered normal ground water, represented by Group 1, were first subtracted from corresponding average mineral constituents in ground water of each of the other groups, with exception of those of Group 8. The character formulae of waters of Groups 2 to 7 were then derived as determined by use of these remainders. Both the character formulae of these differences and the mineral constituents are shown in Table 21. They may be considered to represent the mineral characteristics of the ground water degradant as they were prior to alteration through mingling of the degradant with fresh ground water, but after being subjected to base exchange during movement of the degradant from its source. It may be noted that both the concentration and composition of waters in Group 8 were taken directly from the average analysis presented in Table 20. This was done on the assumption that the brines of that group were not significantly diluted with fresh water.

TABLE 21

AVERAGE MINERAL CHARACTER AND CONSTITUENTS OF SALINE GROUND WATERS IN AND ADJACENT TO SUTTER-YUBA AREA

(Corrected for effects of dilution with unaltered normal ground water)

Ground water group	Mineral constituents in equivalents per million and character formulae in percent					
	Ca	Mg	Na	HCO_3	Cl	SO_4
2	1.35 13.3%	2.24 22.2%	1.47 14.5%	0.20 2.0%	4.60 47.6%	0.04 0.4%
3	2.32 14.0%	3.26 20.8%	2.26 14.4%	0.68 4.6%	6.54 44.6%	0.11 0.8%
4	2.69 14.3%	3.47 18.4%	3.27 17.3%	0.66 3.5%	8.45 45.0%	0.28 1.5%
5	2.91 12.2%	4.54 19.1%	4.46 18.7%	0.23 1.0%	11.21 48.1%	0.20 0.9%
6	3.71 13.7%	4.81 15.6%	6.38 20.7%	0.09 0.3%	14.66 49.3%	0.12 0.4%
7	6.88 15.4%	8.58 19.1%	6.93 15.5%	0.33 0.8%	21.17 48.2%	0.44 1.0%
8	25.10 21.0%	21.26 10.0%	58.01 28.0%	3.40 1.7%	99.67 48.0%	0.06 0.3%

Table 21 shows that, irrespective of variations in concentration, the character formula of the degradant in each of the ground water Groups 2 through 7 is strikingly similar to that of the brines comprising Group 8. This is especially true of the anions which are not subject to base exchange reactions. This similarity in composition, together with apparent absence of any other like degradant, indicates that degradation of the native ground waters is due to admixture of deep-seated brines of the type exemplified by Group 8.

Although the chloride content of water from wells in the area of saline ground water is generally high, it is quite variable with respect to the depth of wells. Examination of analyses of water from 33 wells of known depth in the West Side Zone south of Oswald Road did not indicate any correlation between chloride content of the water and depth. The wells studied for this purpose ranged in depth from about 50 to 300 feet, and the average depth was of the order of 145 feet. The lack of any significant correlation in this matter cannot be fully explained on the basis of data compiled during the course of the present investigation. However, it is probable that the explanation may lie in precise identification of the aquifers which contribute water to the respective wells. For example, wells pumping from both fresh and saline aquifers would probably yield water containing lower concentrations of chlorides than wells pumping only from saline aquifers. In this connection it is noted that additional more detailed investigation of the quality of the water resources of the Sutter-Yuba Area is in progress under the provisions of Section 229 of the Water Code. This work is being conducted by the Division of Water Resources in connection with its assigned responsibilities for a state-wide survey of quality of surface and ground waters, the results of which will be published at a later date.

Studies to date of saline ground water conditions in the Sutter-Yuba Area indicate that the brines of Group S may migrate upward into fresh water aquifers both through permeable zones in the alluvium and through unplugged test wells and abandoned, defective, or improperly constructed water wells. Furthermore, when the water table is lowered by heavy irrigation pumping, it is probable that upward movement of the brines is accelerated. Possible subsequent lateral movement of the brines may be inferred from the observed progressive decrease in ground water chloride concentrations with distance from the two areas of high chloride salinity, in the West Side Zone south of Oswald Road and near Robbins.

CHAPTER III

WATER UTILIZATION AND SUPPLEMENTAL REQUIREMENTS

The nature and extent of water utilization and requirements for supplemental water in the Sutter-Yuba Area, both at the present time and under probable conditions of ultimate development, are considered in this chapter. In connection with the discussion, the following terms are used as defined:

Water Utilization—This term refers to the sum of consumptive use of water and those irrecoverable losses of water incidental to its beneficial use.

Consumptive Use of Water—This term refers to water consumed by vegetative growth in transpiration and building of plant tissue, and to water evaporated from adjacent soil, from water surfaces, and from foliage. It also refers to water similarly consumed and evaporated by urban and nonvegetative types of culture.

Supplemental Requirement—This term refers to the amount of water, over and above the sum of safe ground water yield and safe surface water yield, which must be developed to satisfy water utilization.

Ultimate—This term refers to an unspecified but long period of years into the future when cultural development will be essentially stabilized. (It is realized that any present forecasts of the nature and extent of such ultimate cultural development, and resultant water utilization, are inherently subject to possible large errors in detail and appreciable error in the aggregate. However, such forecasts, when based upon best available data and present judgment, are of value in establishing long-range objectives for development of water resources. They are so used herein, with full knowledge that their re-evaluation after the experience of a period of years may result in considerable revision.)

Present water utilization in the Sutter-Yuba Area was estimated by the application of appropriate unit consumptive use of water factors to the present cultural pattern. Probable ultimate water utilization was similarly estimated, by the use of an ultimate cultural pattern projected from the present pattern on the basis of land classification data, the assumption being made that under ultimate conditions of cultural development all irrigable lands would be irrigated. As indicated by the foregoing definition, supplemental requirements for water were estimated as the differences between derived values of safe yield and utilization, under both present and ultimate conditions of cultural development.

Water utilization is considered and evaluated in this chapter under the general headings "Present Water Supply Development," "Land Use," "Unit Use of Water," "Past and Present Water Utilization," "Probable Ultimate Water Utilization," and "Demands for Water." Supplemental water requirements are similarly treated under the two general headings "Present Supplemental Requirements" and "Probable Ultimate Supplemental Requirements."

WATER UTILIZATION

Of the total amount of water presently utilized in the Sutter-Yuba Area, approximately 65 percent is consumed in the production of irrigated crops, while the remainder is consumed by dry-farmed crops and fallow lands, native vegetation, and miscellaneous culture including domestic and municipal. It is considered probable that the predominant importance of irrigated agriculture, as related to utilization of water in the area, will continue to prevail in the future.

Present Water Supply Development

Approximately two-thirds of the acreage under water service in the Sutter-Yuba Area is presently supplied by water pumped from the underlying ground water basin. Irrigated lands utilizing ground water are generally served by individually owned wells and pumps. Because of this fact and the extensive ground water utilization, the amount of water developed for irrigation use by individuals is larger than by organized agencies. As of April 1, 1949, there were 2,198 wells and pumping plants of heavy draft, powered with motors of more than five horsepower, and of this number 2,159 were used for irrigation. The 39 remaining wells supplied water for urban and industrial uses. A number of additional wells of light draft supplied limited amounts of water for noncommercial gardens and orchards, and for domestic purposes. Lands served principally with ground water comprise the Peach Bowl, the East Central Zone, and the portion of the South Side Zone adjacent to and south of Bear River.

Surface diversions for irrigation in the Sutter-Yuba Area are made from the Sacramento and Feather Rivers and tributary streams, and from the Wadsworth and Natomas Canals, various surface drains, and the Sutter By-pass. The major diversions are made by irrigation companies and districts, with service to the lands being largely by means of open ditch transmission and distribution systems. Minor surface diversions are made for the most part by individuals whose lands are adjacent to the surface supplies. The Sutter Butte Canal Company is the principal diverter of water from Feather River, serving lands in the West Side Zone outside of the Peach Bowl. The joint diversion of the Hallwood Irrigation Company and the

Cordua Irrigation District is the largest of a number of irrigation diversions from Yuba River, and serves water to lands in the Northeast Zone. The Nevada Irrigation District supplies some surface water to lands in the South Side Zone through ditches diverting from Auburn Ravine. Lands served principally by surface waters comprise the Northeast Zone, the West Side Zone outside the Peach Bowl, and the west portion of the South Side Zone.

Water used for municipal, industrial, and domestic purposes in the Sutter-Yuba Area is obtained almost entirely from wells. The greater part of such use is in the Cities of Marysville and Yuba City, and is scattered and of relatively minor significance throughout the remainder of the area.

The City of Marysville is served by the California Water Service Company, a public utility which pumps water from wells into storage tanks, from which it is delivered to consumers by gravity. Water services are metered. The quantity of water pumped for use in Marysville in the calendar year 1948 was 506,000,000 gallons, or 1,550 acre-feet. With an approximate population of 7,500 in July, 1948, the daily production averaged about 185 gallons per capita.

Yuba City is served by the Yuba City Municipal Water Works, which charges for water on a flat-rate basis. It was estimated that the quantity of water pumped for use in Yuba City in the calendar year 1948 was about 750,000,000 gallons, or 2,300 acre-feet. With an approximate population of 6,300 in March, 1948, the daily per capita production was about 330 gallons.

In addition to the foregoing figures regarding ground water pumped in 1948 under the municipal systems of Marysville and Yuba City, it was estimated that approximately 1,000 acre-feet was pumped and used by industries operating their own wells within the cities. Wheatland has a community water system that distributes water from a storage tank supplied by two wells. The estimated amount of water pumped in Wheatland during the calendar year 1948 was approximately 200 acre-feet. Assuming that the per capita water production in remaining small towns and communities in the Sutter-Yuba Area was about 200 gallons per day, it was estimated, on the basis of 1948 population estimates, that total annual pumpage from ground water for these communities was about 700 acre-feet.

The respective areas within the several zones of the Sutter-Yuba Area served by ground water and surface water are shown in Table 22. The data presented for the two investigational seasons resulted from field surveys during the current investigation, while the averages for the base period were largely based on records of crop surveys made by the Division of Water Resources in connection with the Sacramento-San Joaquin Water Supervision, and on pumping power consumption records furnished by the Pacific Gas and Electric Company.

TABLE 22

GROUND AND SURFACE WATER SERVICE AREAS IN ZONES OF SUTTER-YUBA AREA

(In acres)

Zone	Ground water		Surface water	
	1948	1949	1948	1949
West Side	48,990	44,650	18,750	21,590
Northeast	6,050	8,240	11,540	11,850
East Central	24,230	33,140	2,500	990
South Side	11,280	10,770	15,420	18,070
TOTALS	90,550	96,800	48,210	52,500
Averages for 9-year base period, 1939-40 through 1947-48	68,490		42,810	

Table 23 lists the principal water service agencies, together with notations on their sources of water supply, locations of service areas within the Sutter-Yuba Area, and acreages within the area irrigated by water served by each agency in 1948. Areas included within the boundaries of these agencies are shown on Plate 2.

TABLE 23

PRINCIPAL WATER SERVICE AGENCIES SUTTER-YUBA AREA

Agency	Source of water supply	Service area, by zones	Acreage irrigated in 1948
California Water Service Company	Ground water	Northeast	Municipal use in Marysville
Camp Far West Irrigation District	Bear River	East Central	1,580
Cordua Irrigation District	Yuba River	Northeast	4,736
Farm Lands Investment Company	Feather River	East Central	1,833
Feather River Water Company	Feather River	West Side	0
Garden Highway Mutual Water Company	Feather River	West Side	2,075
Hallwood Irrigation Company	Yuba River	Northeast	6,365
Natomas Central Mutual Water Company	Sacramento River	South Side	11,298
Natomas Northern Mutual Water Company	Sacramento River	South Side	*
Nevada Irrigation District	Yuba and Bear Rivers	South Side	1,240
Oswald Water District	Feather River	West Side	608
Sutter Butte Canal Company	Feather River	West Side	12,840
Sutter Extension Water District	Feather River	West Side	Formed in 1949
Yuba City Municipal Water Works	Ground water	West Side	Municipal use

* Included in acreage of Natomas Central Mutual Water Company.



Rice Field in Sutter-Yuba Area

Land Use

As a first step in estimating the amount of water utilization in the Sutter-Yuba Area during the base period and investigational seasons, determinations were made of the nature and extent of land use prevailing during these periods. Similarly, the probable nature and extent of ultimate land use, as related to water utilization, was forecast on the basis of land classification survey data which segregated lands of the area in accordance with their suitability for irrigated agriculture.

Past and Present Cultural Patterns. In connection with the Sacramento-San Joaquin Water Supervision, the Division of Water Resources for some 25 years has made annual crop surveys of those lands in the Sutter-Yuba Area utilizing surface water. In 1946 the United States Bureau of Reclamation made a complete crop survey of the area. A comprehensive cultural survey was made during the season of 1947-48 as a part of the current investigation. Additional data on culture were obtained in 1948-49 from a supplementary survey made in order to determine any changes in land use since the preceding season.

Data available from the foregoing surveys were sufficient to estimate the average cultural pattern in the Sutter-Yuba Area during the nine-year base period. For purposes of this report, the cultural pattern existing during the 1948-49 season was considered to represent "present" conditions of culture and development in the area, and is so referred to in subsequent discussion.

Summaries of the results of the cultural surveys of 1947-48 and 1948-49 and the estimated average cultural pattern for the base period are presented in Table 24. The Sutter Buttes, comprising some 22,300 acres of waste land in the West Side Zone, are not included in the tabulation. Lands irrigated in the Sutter-Yuba Area during the 1947-48 season are shown on Plate 17, "Irrigated and Irrigable Lands, 1948."

The most significant indicated recent trend in irrigated agriculture in the Sutter-Yuba Area is toward increased plantings of rice and permanent pasture. The data presented in Table 24 show that the area of rice increased from an estimated average of some 25,500 acres during the base period to over 44,000 acres in 1948-49. At the same time, permanent pasture increased from some 17,500 to 25,500 acres. Deciduous orchard, which had long been the largest irrigated crop in the area on an acreage basis, showed an increase of less than 3,000 acres in 1948-49 over the base period average, and was surpassed by the acreage of rice during the latter season. The foregoing increases in irrigated agriculture were largely reflected by corresponding decreases in acreage of dry-farmed and fallow lands. Table 24 shows that there was moderate increase in farmstead and urban development in 1948-49 over the base period averages, but no very significant changes in remaining types of culture in the Sutter-Yuba Area.

Probable Ultimate Cultural Pattern. Classification of lands of the Sutter-Yuba Area with respect to their suitability for irrigated agriculture was largely accomplished by other agencies prior to the Sutter-Yuba Counties Investigation. Many valuable data on land classification were available from and furnished by the United States Bureau of Reclamation. The available data were supplemented and checked as required in the course of field surveys conducted as a part of the investigation.

On the basis of their suitability for irrigation, agricultural lands of the Sutter-Yuba Area were segregated into the following five classes:

Class 1. This class comprises lands that are highly desirable in every respect for continuous irrigated agricultural use, and capable of producing all climatically adapted crops. The soils are deep, with good surface and subsoil drainage, of medium to fairly fine texture, and of good water-holding capacity. The soil structure is such as to permit easy penetration of roots, air, and water, and the land surface is smooth and gently sloping.

Class 2. This class comprises lands that are generally limited in their use to climatically adapted crops of medium root depths. Restrictive features with regard to use of the lands are soil depth and, to some extent, topography or drainage.

Class 3. This class comprises lands that are generally limited in their use to climatically adapted shallow-rooted crops, owing to deficiencies in soil depth, topography, or drainage characteristics. This class of lands is suitable for development under irrigation, but because of shallow soil depths, greater care and skill are required in the application of water than are necessary in the case of lands of Classes 1 and 2.

Class 4. This class comprises lands that fail to meet the standards of Classes 1, 2, and 3, as to topography, drainage, and depth of soil. These lands are generally suitable only for permanent pasture or similar crops.

Class 6. This class comprises all lands that do not meet the minimum requirements of suitability for irrigation use.

In addition to agricultural lands, 5,550 acres in the Sutter-Yuba Area were classified as urban, and 22,270 acres comprising the waste lands of the Sutter Buttes were not otherwise classified. Results of the land classification of the Sutter-Yuba Area, summarized by zones, are presented in Table 25.

By use of the land classification data a probable ultimate cultural pattern for the Sutter-Yuba Area was forecast. The general assumption was made that under

TABLE 24

PAST AND PRESENT CULTURAL PATTERNS IN ZONES OF SUTTER-YUBA AREA

(In acres)

Class and type of culture	West Side Zone			Northeast Zone			East Central Zone			South Side Zone			Totals		
	Estimated base period average, 1939-40 through 1947-48	1947-48	Present, 1948-49	Estimated base period average, 1939-40 through 1947-48	1947-48	Present, 1948-49	Estimated base period average, 1939-40 through 1947-48	1947-48	Present, 1948-49	Estimated base period average, 1939-40 through 1947-48	1947-48	Present, 1948-49	Estimated base period average, 1939-40 through 1947-48	1947-48	Present, 1948-49
Irrigated lands															
Deciduous orchard	30,610	32,660	31,820	3,830	4,380	4,410	3,190	3,970	4,080	3,050	3,220	3,190	40,680	44,230	43,500
Rice	9,200	13,480	13,120	1,170	3,440	4,320	3,350	7,800	12,080	11,800	13,630	14,920	25,520	38,350	44,440
Permanent pasture	5,750	8,760	8,530	5,030	6,710	7,580	3,860	5,130	5,860	2,800	3,330	3,560	17,440	23,940	25,530
Beans	3,470	3,610	3,700	1,270	1,460	1,140	3,640	4,190	5,680	1,330	1,390	1,870	9,700	10,650	12,390
Alfalfa	3,100	3,780	3,770	780	1,030	1,630	1,430	1,940	2,210	2,760	3,310	3,530	8,070	10,060	11,140
Truck	2,950	3,060	3,010	210	230	250	510	600	650	680	1,000	930	4,350	4,890	4,840
Tomatoes	980	1,020	1,000	70	80	140	180	210	600	320	70	140	1,550	1,370	1,880
Corn	350	370	300	190	220	270	310	350	550	370	390	410	1,230	1,330	1,530
Hops	520	540	540				560	650	650				1,080	1,190	1,190
Sugar beets	240	250	190	10	10	180	560	640	640	210		40	1,020	900	1,050
Olives	50	40	40	20	20	20	240	290	280				310	350	340
Vines	140	150	150				70	80	80		10	10	200	240	240
Miscellaneous	20	20	70			150	810	890	770	310	350	240	1,140	1,260	1,230
Subtotals	57,380	67,740	66,240	12,580	17,580	20,090	18,710	26,740	34,130	23,630	26,700	28,840	112,300	138,760	149,300
Dry-farmed and fallow lands	53,980	42,610	44,110	24,700	19,150	16,640	47,440	38,440	31,050	53,810	50,120	47,980	179,920	150,310	139,770
Native vegetation	3,580	3,580	3,580	2,750	2,750	2,750	5,280	5,280	5,280	1,400	1,400	1,400	13,010	13,010	13,010
Miscellaneous															
Farmsteads	2,320	2,690	2,690	460	590	590	1,080	1,460	1,460	1,070	1,380	1,380	4,930	6,120	6,120
Roads	2,320	2,690	2,690	460	590	590	1,080	1,460	1,460	1,070	1,380	1,380	4,930	6,120	6,120
Urban	1,840	2,110	2,110	900	1,190	1,190	1,850	2,060	2,060	190	190	190	4,780	5,550	5,550
Water surface	1,350	1,350	1,350	470	470	470	1,040	1,040	1,040	130	130	130	2,990	2,990	2,990
Railroads and highways	720	720	720	380	380	380	660	660	660	690	690	690	2,450	2,450	2,450
Airfields				160	160	160	590	590	590				750	750	750
By-pass overflow lands										470	470	470	470	470	470
Tules	160	160	160				20	20	20				180	180	180
By-pass levees	120	120	120										130	130	130
Waste lands							120	120	120				120	120	120
Subtotals	8,830	9,840	9,840	2,380	3,380	3,380	6,440	7,410	7,410	3,620	4,240	4,240	21,730	24,880	24,880
TOTALS	*123,770	*123,770	*123,770	42,860	42,860	42,860	77,870	77,870	77,870	82,460	82,460	82,460	*326,960	*326,960	*326,960

* Excluding 22,270 acres of waste lands in Sutter Buttes.

TABLE 25

CLASSIFICATION OF LANDS IN ZONES OF SUTTER-YUBA AREA

(In acres)

Zone	Land classes						
	1	2	3	4	6	Urban	Totals
West Side	45,520	41,040	27,440	220	7,440	2,110	*123,770
Northeast	4,240	18,420	13,190	190	5,630	1,190	42,860
East Central	8,330	14,070	44,450	1,270	7,690	2,060	77,870
South Side	10,200	30,880	36,770		4,420	190	82,460
TOTALS	68,290	104,410	121,850	1,680	25,180	5,550	*326,960

* Excluding 22,270 acres of waste lands in Sutter Buttes.

an increasing pressure of demand for agricultural products all irrigable but presently dry lands would eventually be provided with irrigation service. Provision was also made for probable increase in lands devoted to farmsteads, roads, urban, and other miscellaneous purposes under conditions of probable ultimate development.

The estimated ultimate cultural pattern of the Sutter-Yuba Area, summarized by general classes of culture and by zones of the area, is presented in Table 26. Irrigable lands, as determined by the land classification survey data and as indicated by the probable ultimate cultural pattern, are shown on Plate 17.

TABLE 26

PROBABLE ULTIMATE CULTURAL PATTERN IN ZONES OF SUTTER-YUBA AREA

(In acres)

Class of culture	West Side Zone	Northeast Zone	East Central Zone	South Side Zone	Totals
Irrigated lands	100,000	31,200	54,000	64,700	249,900
Dry-farmed lands	9,600	5,100	9,300	11,100	35,100
Native vegetation	3,600	2,700	5,300	1,400	13,000
Miscellaneous	10,600	3,900	9,300	5,200	29,000
TOTALS	*123,800	42,900	77,900	82,500	*327,000

* Excluding waste lands in Sutter Buttes.

Unit Use of Water

The second step in evaluation of water utilization involved the determination of unit values of consumptive use of water for each type of water consuming culture. Estimates of these unit values were largely based on the results of prior investigations and studies in other areas.

A procedure suggested by Harry F. Blaney and Wayne D. Criddle of the Soil Conservation Service, United States Department of Agriculture, in their reports entitled "A Method of Estimating Water Requirements in Irrigated Areas from Climatological Data," dated December, 1947, and "Determining Water Requirements in Irrigated Areas from Climatological and Irrigation Data," dated August, 1950, was generally utilized for adjustment of available data on unit consumptive use by irrigated crops in other localities to correspond with conditions existing in the Sutter-Yuba Area. This method involved correlation of the data on the basis of variations in average monthly temperatures, monthly percentages of annual daytime hours, precipitation, and lengths of growing season. It disregarded certain generally unmeasured factors such as wind movement, humidity, etc. Average monthly temperatures at Marysville were considered representative of the Sutter-Yuba Area. Monthly percentages of annual daytime hours were determined for latitude 39° N., which passes approximately through the center of the area.

The following is an outline of the procedure utilized for estimating unit values of consumptive use:

1. The unit value for each irrigated cultural type during its growing season was taken as the product of available heat and an appropriate coefficient of consumption, where: (a) the available heat was the product of average monthly temperature and monthly percent of daytime hours, and (b) the coefficient of consumption was one which had been selected as appropriate for California by Harry F. Blaney as a result of his studies for the Soil Conservation Service. Certain exceptions involved the use of coefficients estimated from consumptive use data available from other sources.

2. The unit value for each irrigated cultural type during its nongrowing season was taken as the amount of precipitation available, but not exceeding one to two inches of depth per month, depending upon the type of culture and cover crop.

3. The seasonal unit value for each irrigated cultural type was taken as the summation of values determined under items 1 and 2 for that type.

4. Unit seasonal values for native annual grasses were taken as equal to the available precipitation up to but not exceeding 1.3 feet in depth.

5. Unit seasonal values for native vegetation other than annual grasses were estimated on the basis of available data on corresponding consumptive use in similar localities, due consideration being given to density and type of vegetation and depth to ground water.

6. Unit seasonal values for free water surfaces were estimated from available records of evaporation at Gridley.

7. Unit seasonal values for remaining miscellaneous types of culture were estimated on the basis of available data on corresponding consumptive use in similar localities.

Estimated unit seasonal values of consumptive use of water in the Sutter-Yuba Area, including consumption of precipitation, are presented in Table 27. In view of the indicated water supply and climatological similarities of the mean and base periods, the estimated average unit seasonal values of consumptive use for the base period were considered to approximate corresponding values for the mean period.

TABLE 27

ESTIMATED UNIT VALUES OF SEASONAL CONSUMPTIVE USE OF WATER IN SUTTER-YUBA AREA

(In feet of depth)

Class and type of culture	Average for 9-year base period, 1939-40 through 1947-48	1947-48	1948-49
Irrigated lands			
Deciduous orchard	2.7	2.5	2.7
Rice	5.0	5.0	5.0
Permanent pasture	3.7	3.3	3.6
Beans	2.0	2.0	1.8
Alfalfa	4.0	3.6	3.9
Truck	2.3	2.3	2.2
Tomatoes	2.3	2.3	2.2
Corn	2.8	2.7	2.6
Hops	3.0	2.9	3.0
Sugar beets	3.1	3.0	3.0
Olives	2.7	2.5	2.7
Vines	2.0	2.0	1.9
Miscellaneous	2.4	2.3	2.2
Dry-farmed and fallow lands	1.3	1.3	1.2
Native vegetation			
Heavy brush, trees, grass	4.5	4.5	4.5
Medium brush, trees, grass	3.8	3.8	3.8
Light brush, grass	2.8	2.8	2.8
Sparse brush, grass	1.3	1.3	1.3
Miscellaneous			
Farmsteads	2.0	2.0	2.0
Roads	1.0	1.0	1.0
Urban	2.0	2.0	2.0
Water surfaces	5.0	5.0	5.0
Railroads, highways	1.0	1.0	1.0
Airfields	1.3	1.3	1.3
By-pass overflow lands	4.0	4.0	4.0
Tules	5.0	5.0	5.0
By-pass levees	1.0	1.0	1.0
Waste lands	0.5	0.5	0.5

Past and Present Water Utilization

The total amount of utilization of water in the Sutter-Yuba Area was estimated by multiplying the acreage of each type of culture by its respective unit value of consumptive use of water. The results of the estimates of seasonal water utilization during the base period and investigational seasons are presented in Table 28, summarized by general classes of culture. These estimates include consumptive use of precipitation.

TABLE 28

ESTIMATED SEASONAL UTILIZATION OF WATER IN SUTTER-YUBA AREA DURING BASE PERIOD AND INVESTIGATIONAL SEASONS

(In acre-feet)

Class of culture	Average for 9-year base period, 1939-40 through 1947-48	1947-48	1948-49
Irrigated lands	382,000	469,000	524,000
Dry-farmed and fallow lands	234,000	195,000	171,000
Native vegetation	49,000	49,000	49,000
Miscellaneous	45,000	51,000	50,000
TOTALS	710,000	764,000	794,000

Mean seasonal water utilization in the Sutter-Yuba Area was also estimated as it would be with present cultural development but under mean conditions of water supply and climate. The estimate was based on the cultural pattern determined by the 1949 survey, and on estimated average unit seasonal values of consumptive use of water for the nine-year base period which were considered to approximate those for the mean period. The estimate, which includes consumptive use of precipitation, is presented in Table 29, summarized for the four zones of the area and segregated by general cultural classes.

In order to facilitate certain phases of the analysis of ground water hydrology, presented in Chapter II, it was desirable to estimate seasonal utilization of ground water in the Sutter-Yuba Area. Unit seasonal values of consumptive use of ground water were derived by subtracting the amount of available precipitation, up to but not exceeding 1.3 feet of depth, from the appropriate unit seasonal values presented in Table 27. The corrected values were then multiplied by the acreages of each cultural type served by ground water during the respective periods. These included native vegetation in high water table areas. The 1949 cultural pattern was considered representative of present conditions, and average unit seasonal values of consumptive use for the base period were considered to be equal

to corresponding mean period values. The estimates of utilization of ground water are summarized by general classes of culture in Table 30.

TABLE 29

ESTIMATED MEAN SEASONAL UTILIZATION OF WATER IN ZONES OF SUTTER-YUBA AREA UNDER PRESENT CULTURAL DEVELOPMENT

(In acre-feet)

Class of culture	West Side Zone	Northeast Zone	East Central Zone	South Side Zone	Totals
Irrigated lands	219,100	73,400	125,500	120,100	538,100
Dry-farmed and fallow lands	57,300	21,600	40,400	62,400	181,700
Native vegetation	13,600	10,400	20,000	5,300	49,300
Miscellaneous	20,700	7,100	15,300	5,900	49,000
TOTALS	310,700	112,500	201,200	193,700	818,100

TABLE 30

ESTIMATED SEASONAL UTILIZATION OF GROUND WATER IN SUTTER-YUBA AREA

(In acre-feet)

Class of culture	Average for 9-year base period, 1939-40 through 1947-48	1947-48	1948-49	With present culture under mean conditions of water supply and climate
Irrigated lands	119,400	165,600	222,400	224,600
Native vegetation	31,900	31,900	31,900	31,900
Miscellaneous	6,800	8,200	8,200	8,200
TOTALS	158,100	205,700	262,500	264,700

Probable Ultimate Water Utilization

The total seasonal amount of water utilization in the Sutter-Yuba Area was estimated as it would be under probable ultimate conditions of cultural development and under mean conditions of water supply and climate. This was accomplished by multiplying acreages of cultural types derived in the forecast of the ultimate cultural pattern by corresponding average unit seasonal values of consumptive use of water for the base period. It was considered that unit consumptive use during the base period was equal to that under mean conditions of water supply and climate. The estimate of probable ultimate water utilization is summarized in Table 31 by general cultural classes and by zones of the Sutter-Yuba Area. The estimate includes consumptive use of precipitation.

TABLE 31

PROBABLE ULTIMATE MEAN SEASONAL UTILIZATION OF WATER IN ZONES OF SUTTER-YUBA AREA

(In acre-feet)

Class of culture	West Side Zone	Northeast Zone	East Central Zone	South Side Zone	Totals
Irrigated lands	336,300	111,500	205,000	249,300	902,100
Dry-farmed lands	12,400	6,700	12,100	14,400	45,600
Native vegetation	13,600	10,400	20,000	5,300	49,300
Miscellaneous	22,000	7,600	18,400	9,300	57,300
TOTALS	384,300	136,200	255,500	278,300	1,054,300

Demands for Water

The term "demands for water," as used in this report, refers to those factors pertaining to rates, times, and places of delivery of water, imposed by the control, development, and use of the water for any and all beneficial purposes. Certain possible present or future nonconsumptive demands for water in the Sutter-Yuba Area, such as those for hydroelectric power generation, flood control, conservation of fish and wildlife, recreation, etc., were considered to be outside the scope of the current investigation. Since they would have little significance in preliminary design of works to meet supplemental requirements for water in the Sutter-Yuba Area, they are not further discussed herein.

Irrigation practice in the Sutter-Yuba Area, as determined by rates of application, gross diversions, monthly demands, and permissible deficiencies in application of water, must be given consideration in preliminary design of works to meet supplemental water requirements. These demand factors, which were not measured or considered in the foregoing estimates of water utilization, are discussed in the following sections.

Application of Water. The term "applied water," as used in this report, refers to that water other than precipitation which is delivered to a farmer's headgate in the case of irrigation use, or to an individual's meter in the case of urban use, or its equivalent. During each of the two seasons of the investigation measurements were made of the amount of water applied for irrigation of selected plots of principal crops grown on various soil types in the Sutter-Yuba Area. Records of such application of water pumped from wells were obtained for 35 plots during 1948, and 21 plots during 1949. For each well the pump discharge, acreage of each type of crop irrigated, number of irrigations, periods of irrigation, and amounts of water applied in each irrigation were recorded. From these data, monthly and total seasonal applications of water to

each crop were determined. Results of these studies, which may be considered representative of prevailing irrigation practice in the Sutter-Yuba Area, are summarized in Table 32. Detailed results of the plot studies are presented in Appendix F, and location of the plots is indicated on Plate 17.

TABLE 32

MEASURED AVERAGE SEASONAL APPLICATION OF IRRIGATION WATER ON REPRESENTATIVE PLOTS OF PRINCIPAL CROPS IN SUTTER-YUBA AREA

Crop	Number of plots			Applied water, in feet of depth		
	1948	1949	Total	1948	1949	Weighted average for the two seasons
Alfalfa	2	3	5	5.69	6.14	5.98
Almonds	3	2	5	1.07	1.71	1.29
Beans	2	1	3	1.21	0.95	1.15
Cherries	2	0	2	2.29	--	2.29
Clover	1	0	1	4.29	--	4.29
Corn	1	1	2	2.62	1.76	1.91
Flax	1	0	1	0.87	--	0.87
Hops	1	1	2	0.92	0.87	0.89
Irrigated pasture	1	3	4	2.18	6.50	5.19
Peaches	9	5	14	2.46	2.68	2.53
Prunes	4	1	5	1.04	3.02	1.21
Rice	3	3	6	5.14	5.56	5.36
Sugar beets	1	0	1	1.45	--	1.45
Walnuts	4	1	5	2.04	1.90	2.00

Studies were made to determine the approximate average irrigation efficiency realized from application of ground water in the Sutter-Yuba Area during the 1947-48 season. "Irrigation efficiency" is defined as the ratio of consumptive use of applied water to the total amount of applied water, and is commonly expressed as a percentage.

In order to estimate the total amount of ground water applied for irrigation in the Sutter-Yuba Area in 1947-48, appropriate crop acreages, as mapped in the cultural survey, were multiplied by average seasonal values of depth of applied water for the several crops, as measured at the representative plots listed in Table 32. This computation resulted in an estimate of 347,000 acre-feet. As a check on this figure, the Pacific Gas and Electric Company furnished a corresponding estimate of 317,000 acre-feet based on records of electric power consumption for pumping. The company's estimate gave consideration to the relationship between pumping plant horsepower, drawdown, and power consumption per unit of water pumped at various lifts, as determined by pump performance tests conducted in the area by the company. In view of the nature of the basic data, the check furnished was believed to have been reasonably close.

By dividing the estimated value of 165,600 acre-feet for consumptive use of ground water on irrigated lands in the Sutter-Yuba Area in 1947-48, presented in Table 30, by the foregoing estimated value of 347,000 acre-feet, it was estimated that the irrigation efficiency realized from application of ground water in the Sutter-Yuba Area during 1947-48 was approximately 48 percent. This efficiency may be considered to be indicative of average irrigation practice in the Sacramento Valley. It was impracticable to make a corresponding estimate of irrigation efficiency realized from use of surface water in the Sutter-Yuba Area because of lack of sufficient data regarding application of surface water for irrigation purposes.

Gross Diversion of Water. The amount of the gross diversion for irrigation by ground water in the Sutter-Yuba Area was considered to be equivalent to the amount of applied ground water. As discussed in the preceding section, this was estimated to have totaled 347,000 acre-feet during 1947-48.

The gross diversion for irrigation by surface water in the Sutter-Yuba Area was estimated to have totaled about 362,000 acre-feet during 1947-48. This estimate was based on records of measurement of all surface diversions in the area, plus the estimate of importation by the Sutter Butte Canal system presented in Chapter II.

By subtracting from total consumptive use of water on irrigated lands the corresponding consumptive use of ground water and precipitation, the approximate amount of consumptive use of applied surface water was estimated. An estimate of total consumptive use of water on irrigated lands of the Sutter-Yuba Area in 1947-48, in the amount of 469,000 acre-feet, was presented in Table 28. Consumptive use of ground water on irrigated lands was estimated to have been 165,600 acre-feet in 1947-48, as shown in Table 30. It was further estimated that consumptive use of precipitation on the 138,700 acres of irrigated lands in the Sutter-Yuba Area in 1947-48 was equal to 1.3 feet of depth, or a total amount of 180,400 acre-feet. It follows that the estimated amount of consumptive use of surface water applied for irrigation in the area was approximately 123,000 acre-feet in 1947-48.

It is indicated from the foregoing that only about 123,000 acre-feet, or about 34 percent of the estimated 362,000 acre-feet of gross surface diversion for irrigation in the Sutter-Yuba Area in 1947-48, was actually consumed in production of crops. It should be noted that this figure is not comparable with estimated irrigation efficiency attained in connection with use of ground water in the area, evaluated in the preceding section, since it is based on the amount of gross diversion rather than the amount of applied water. Insufficient data were available to permit evaluation of transmission and other losses encountered in connection with use of surface water between points of diversion and places of use.

Monthly Demands for Irrigation Water. Because of the wide variety of crops produced in the Sutter-Yuba Area there is considerable variation in both rate and period of demand for irrigation water. On the

average, the irrigation demand occurs during the months of April through October. Studies of irrigation practice in the Sutter-Yuba Area indicated that for certain crops the maximum monthly demand might be as much as 45 percent of the seasonal total. Based on these studies, and on similar studies made in other areas, the estimated average monthly distribution of demand for irrigation water in the West Side Zone and in the remainder of the Sutter-Yuba Area is set forth in Table 33. Because of the predominance of orchard and truck crops in the West Side Zone, monthly distribution in that zone varies somewhat from that in the remainder of the area. Early applications to rice and irrigated pasture account for the greater part of the demand for water in April and May.

TABLE 33

ESTIMATED AVERAGE MONTHLY DISTRIBUTION OF DEMAND FOR IRRIGATION WATER IN SUTTER-YUBA AREA

(In percent of seasonal total)

	West Side Zone	Remainder of Sutter-Yuba Area
April	2	10
May	13	16
June	21	17
July	27	22
August	21	17
September	12	11
October	4	5
November		2
	100	100

Permissible Deficiencies in Application of Irrigation Water. Studies to determine deficiencies in the supply of irrigation water that might be endured without permanent injury to perennial crops were not made in connection with the Sutter-Yuba Counties Investigation. However, the results of past investigation and study of endurable deficiencies in the Sacramento River Basin are believed to be applicable to the Sutter-Yuba Area. In this respect, the following is quoted from Division of Water Resources Bulletin No. 26, "Sacramento River Basin," 1931.

"* * * A full irrigation supply furnishes water not only for the consumptive use of the plant but also for evaporation from the surface during application and from the moist ground surface, and for water which is lost through percolation to depths beyond the reach of the plant roots. Less water can be used in years of deficiency in supply by careful application and by more thorough cultivation to conserve the ground moisture. In these ways the plant can be furnished its full consumptive use with much smaller amounts of water than those ordinarily applied and the yield will not be decreased. If the supply is too deficient to provide the full consumptive use, the plant can sustain life on smaller amounts but the crop yield will probably be less than normal.

"It is believed from a study of such data as are available that a maximum deficiency of 35 per cent of the full seasonal requirement can be endured, if the deficiency occurs only at relatively long intervals. It is also believed that small deficiencies occurring at relatively frequent intervals can be endured. * * *"

SUPPLEMENTAL WATER REQUIREMENTS

The previously presented data, estimates, and discussion regarding water supply and utilization in the Sutter-Yuba Area indicate that present and probable future water problems of the area are largely limited to those connected with ground water and that their effects are largely related to irrigated agriculture. It is further indicated that ground water problems, including those created in various portions of the area by progressive lowering of water levels, degradation of mineral quality of ground water, and low yield of wells, may be eliminated or prevented if adequate supplemental water supplies are developed and utilized in the area. The estimated present and probable ultimate requirements for supplemental water in the Sutter-Yuba Area are discussed and evaluated in the following sections. As previously defined, requirement for supplemental water refers to the amount of water, over and above the sum of safe ground water yield and safe surface water yield, which must be developed to satisfy water utilization. Water utilization in turn refers to the sum of consumptive use of water and those irrecoverable losses of water incidental to its beneficial use.

Present Supplemental Requirement

The present requirement for supplemental water in the Sutter-Yuba Area was evaluated as the difference between safe yield of ground water and present consumptive use of ground water. It might be argued that this evaluation fails to give consideration to possible inadequacies in service of surface water to portions of the area. However, in the solution of the equation of hydrologic equilibrium, presented in Table 15, upon which the estimate of safe ground water yield was based, the unit consumptive use factors chosen assumed a full and sufficient application of water on all irrigated lands whether from surface sources or ground water. It follows that any possible present inadequacy in surface water service was taken into account and provided for in the estimate of safe ground water yield.

It was estimated in Chapter II that safe seasonal ground water yield in the Sutter-Yuba Area amounted to 186,100 acre-feet. This was determined as the seasonal net extraction of water from the ground water basin that might be maintained, under mean conditions of water supply and climate, without further progressive lowering of the water table below levels prevailing in 1948-49. Seasonal consumptive use of ground water in the area, with present culture and under mean conditions of water supply and climate, was estimated to be 264,700 acre-feet, as shown in Table 30. The estimated present requirement for supplemental water in the Sutter-Yuba Area, therefore, is 78,600 acre-feet per season. This estimate is presented in Table 34, which shows distribution of the supple-

mental water requirement among the several zones of the area. The distribution was based on the assumption that lowering of water levels which occurred during the season of 1948-49 would have been proportionately the same had mean water supply and climatic conditions prevailed.

TABLE 34

ESTIMATED PRESENT MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENT IN ZONES OF SUTTER-YUBA AREA

Zone	Acre-feet
West Side	
Peach Bowl	14,900
Outside Peach Bowl	2,100
Northeast	6,400
East Central	27,600
South Side	27,600
TOTAL	78,600

It was shown in Chapter II that an area of about 4,500 acres in the West Side Zone south of Oswald Road was irrigated in the summer of 1950 with ground water containing chlorides at or above the upper limit of safe use for irrigation. A substitute water supply is presently required for these lands, the amount of which may be determined by the required amount of applied water. This is true because any unconsumed portion of applied water would be so degraded after percolating to the underlying saline ground water as to preclude its re-use. Seasonal application of water to the orchard and truck crops grown in the Peach Bowl averages about 3.0 feet of depth, as determined by plot studies conducted during the investigation. However, if water of good mineral quality were substituted for the inferior ground water now used, leaching irrigations would not be required. It was estimated that under such conditions the seasonal application of water would be about 2.5 feet of depth, corresponding to average good practice in the Sutter-Yuba Area for irrigation of orchard and truck crops. On this basis the estimated amount of the substitute water supply presently required in the West Side Zone in lieu of ground water of excessive salinity is about 11,300 acre-feet per season. This is less than the estimated present supplemental requirement of 17,000 acre-feet per season required to prevent progressive and permanent lowering of water levels in the West Side Zone. Therefore, by furnishing a supplemental surface water supply to the West Side Zone sufficient to prevent progressive and permanent lowering of the water table, the present problem with respect to inferior mineral quality of the ground water would be eliminated.

Probable Ultimate Supplemental Requirement

The probable ultimate requirement for supplemental water in the Sutter-Yuba Area was evaluated as the difference between present and probable ultimate utilization of water, plus the present requirement for supplemental water. Development and utilization of a supplemental water supply in the amount of this forecast would assure an adequate supply of water for lands presently irrigated in the area, as well as for those irrigable lands not presently served with water. Furthermore, present problems resulting from progressive and permanent lowering of water levels, degradation of mineral quality of ground water, and low yield of wells would be eliminated.

Estimates of present and probable ultimate utilization of water in the Sutter-Yuba Area, under mean conditions of water supply and climate, were presented in Tables 29 and 31, respectively, and a corresponding estimate of the present requirement for supplemental water was developed in the preceding section. Utilizing these estimates, the forecast of probable ultimate seasonal requirement for supplemental water by zones of the Sutter-Yuba Area, under mean conditions of water supply and climate, is presented in Table 35.

TABLE 35

PROBABLE ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENT IN ZONES OF SUTTER-YUBA AREA

(In acre-feet)

Zone	1	2	3	4	5
	Present water utilization	Probable ultimate water utilization	Probable increase in water utilization (2 — 1)	Present supplemental water requirement	Probable ultimate supplemental water requirement (3 + 4)
West Side	310,700	384,300	73,600	17,000	90,600
Northeast	112,500	136,200	23,700	6,400	30,100
East Central	201,200	255,500	54,300	27,600	81,900
South Side	193,700	278,300	84,600	27,600	112,200
TOTALS	818,100	1,054,300	236,200	78,600	314,800

CHAPTER IV

PLANS FOR WATER DEVELOPMENT

It has been shown heretofore that the present basic water problems in the Sutter-Yuba Area are progressive and permanent lowering of ground water levels and attendant degradation of mineral quality of the ground water. Elimination of these problems, prevention of their recurrence in the future, and irrigation of irrigable lands not presently served with water will require further conservation development of available water supplies. In the preceding chapter, estimates were presented as to the amount of supplemental water required for these purposes both at the present time and under probable ultimate conditions of cultural development.

It has been shown that large surplus flows of water are presently available to the Sutter-Yuba Area from the highly productive watershed of the Feather River system, including the Yuba and Bear Rivers and minor tributary streams. This surface water is available during the snowmelt period of every season, and, in all but very dry seasons, flows sufficient to meet present supplemental requirements of the area are available into the summer months. Studies which are described in this chapter indicate that the surplus flows, if properly controlled and regulated, would more than supply the probable ultimate water requirements of the Sutter-Yuba Area.

As was stated in Chapter I, the Division of Water Resources is presently conducting surveys and studies for the State-wide Water Resources Investigation, under direction of the State Water Resources Board. This investigation has as its objective the formulation of The California Water Plan, for full conservation, control, and utilization of the State's water resources, to meet present and future water needs for all beneficial purposes and uses in all parts of the State, insofar as practicable. Surveys and studies are also being conducted by the Division of Water Resources for the Survey of Mountainous Areas. This investigation, which is coordinated with the state-wide investigation, has as its primary objective the determination of probable ultimate water requirements of certain counties of the Sierra Nevada, and the formulation of plans for projects which will meet those requirements. Although these investigations are still in progress, they are sufficiently advanced to permit tentative description of certain major features of The California Water Plan which would provide supplemental water to meet the probable ultimate requirements of the Sutter-Yuba Area. The projects would also provide supplemental water supplies for other water-deficient areas of California. In addition, benefits from the projects would include hydroelectric power, flood and salinity control, mining debris storage, and incidental benefits in the interests of recreation and the preservation of fish and wildlife.

In general, the major features of The California Water Plan, which were mentioned in the preceding paragraph, would be large multipurpose projects requiring relatively large capital expenditures. Their scope, with regard to both location of the works and benefits derived from their operation, would not be limited to the Sutter-Yuba Area, but would embrace other portions of California. Much additional study will be required to estimate costs and to determine possible means of financing these large projects. Under the Sutter-Yuba Counties Investigation, therefore, numerous surveys and studies were made in order to estimate costs of supplemental water supplies for the Sutter-Yuba Area under more localized plans that might be suitable for current financing, construction, and operation by appropriate local public agencies. These plans for initial development generally are such that the works could be integrated into future major projects. Their purposes are largely limited to conservation of new water supplies sufficient to meet the present requirements of the Sutter-Yuba Area and to provide for limited future growth in water demands of the area.

Major features of The California Water Plan which would be pertinent to solution of the ultimate water problems of the Sutter-Yuba Area are described in general terms in this chapter under the heading "The California Water Plan." These projects will be more specifically described in future reports of the State Water Resources Board. The several plans for possible initial local development of supplemental water supplies which were given consideration in connection with the Sutter-Yuba Counties Investigation are described in this chapter under the heading "Plans for Initial Local Development." All such plans considered would be subject to vested rights. Specific plans are presented for the more favorable of these local projects, together with estimates of capital and annual costs and unit costs of the developed supplemental water supplies. Location of the principal features of the several possible plans, for both initial and future construction, are shown on Plate 18, "Potential Water Storage Developments."

THE CALIFORNIA WATER PLAN

The Feather River Project, an adopted feature of The California Water Plan, is described in the following section, where it is shown that it will provide supplemental water to meet the probable ultimate

requirement of the West Side Zone. Several other major projects, which would involve multipurpose water resources developments on the Yuba and Bear Rivers and other tributaries of the Feather River, are briefly described in an ensuing section. These latter projects would provide supplemental water to meet the probable ultimate requirements of the Northeast, East Central, and South Side Zones, and are tentatively being considered as possible features of The California Water Plan.

Feather River Project

The probable ultimate supplemental water requirement in the West Side Zone could be met under a plan which would provide upstream regulatory storage on the Feather River to enhance and firm the summer flow of the stream. Such storage will be made available by construction of Oroville Dam and Reservoir, units of the Feather River Project, which are described in detail in a publication of the State Water Resources Board entitled "Report on Feasibility of Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of The California Water Plan," dated May, 1951. These projects were authorized and adopted by the 1951 Legislature in an act which authorized their construction, operation, and maintenance by the Water Project Authority of the State of California. Provision was made in the authorizing act for financing construction of the proposed works through issuance and sale of revenue bonds and through receipt of contributions from other sources. In May, 1952, the Legislature provided $800,000, by budgetary appropriation to the Division of Water Resources, for necessary investigations, surveys, and studies, and preparation of plans and specifications for the Feather River and Sacramento-San Joaquin Delta Diversion Projects.

The multipurpose Feather River Project contemplates construction of a gravity concrete dam, 710 feet in height above stream bed, at a point on the Feather River 1.7 miles below the junction of the North and Middle Forks and 5.5 miles above the City of Oroville. The dam will have an overpour spillway. It will create a reservoir of 3,500,000 acre-foot storage capacity, and will provide a large measure of control of the runoff of the Feather River for purposes of conservation, flood control, hydroelectric power generation, and other beneficial uses. Provision will be made for a power plant located at the dam, of 440,000 kilowatt capacity, and for an afterbay dam, and power plant of 25,000 kilowatt capacity, located four miles downstream from the main dam. The foregoing features of the Feather River Project are shown on Plate 18. The project also includes construction of a power transmission line from the Oroville power plants to Bethany, near Tracy in San Joaquin County, and a switch yard at the terminal. A channel crossing of the Sacramento-San Joaquin Delta will be required to carry Oroville Reservoir releases from the Sacramento River to the San Joaquin River Delta for subsequent transmission to water-deficient areas in other parts of California.

In studies for the cited feasibility report of the State Water Resources Board, Oroville Reservoir was operated to first meet the water requirements of the Feather River Service Area, shown on Plate 18. The West Side Zone of the Sutter-Yuba Area is contained within the described Feather River Service Area.

Under the plan of operation of Oroville Reservoir described in the foregoing feasibility report, releases of water would be made sufficient to meet gross demands of the Feather River Service Area under ultimate conditions of irrigation development. The estimate of seasonal gross demand for water under such conditions was 970,000 acre-feet, which, with an assumed irrigation efficiency of 65 percent, would provide for consumptive use of water, over and above effective rainfall, in the amount of 631,000 acre-feet per season. Of this estimated ultimate consumptive use of applied water in the Feather River Service Area, 311,000 acre-feet per season would be new water over and above present utilization. Studies indicate that the probable ultimate supplemental water requirement of the West Side Zone, estimated to be some 90,000 acre-feet per season, could readily be supplied from the foregoing 311,000 acre-feet of new water from Oroville Reservoir.

Detailed estimates of cost of the Feather River Project are presented in the feasibility report. A summary of estimated capital costs of the project is given in Table 36. The estimates of capital cost were based on prices prevailing in 1951, and included allowances of 10 percent for administration and engineering, 15 percent for contingencies, and 3 percent for interest during one-half of the estimated construction period.

TABLE 36

SUMMARY OF ESTIMATED CAPITAL COSTS OF FEATHER RIVER PROJECT

Oroville Dam and Reservoir	$342,626,000
Oroville Power Plant	64,509,000
Oroville Afterbay and Power Plant	14,146,000
Oroville Transmission Line	17,124,000
Terminal Switchyard	2,610,000
Delta Cross Channel	3,798,000
TOTAL	$444,813,000

It was assumed in the cost analyses presented in the feasibility report that the Federal Government would contribute to the Feather River Project the sum of $50,000,000, without reimbursement, in the interest of flood control. Substantial flood control benefits to land

and communities along the Feather River would result from operation of the project. There is well-established federal policy for such financial participation in projects of this character. It was also assumed that the State of California would contribute to the Feather River Project the sum of $86,926,000 in the interests of flood control and water development. This contribution would likewise be without reimbursement, and would be accomplished by assuming the costs of lands and improvements flooded and of necessary relocation of utilities. Such financial participation by the State would be justified under the policy set forth in the State Water Resources Act of 1945, as amended. If these federal and state contributions to the Feather River Project were forthcoming, capital costs shown in Table 36 would be reduced to $307,887,000. Based on this estimated capital cost, it was further estimated that annual costs of the project would be about $14,791,000 based upon 2 percent interest, and about $16,272,000 based on 3 percent interest. The annual costs included interest, repayment, replacement, operation and maintenance, insurance, and general expenses. In the cost analysis it was shown that annual costs based upon the 2 percent interest rate could be met under the schedule of revenues shown in the following tabulation, but that an annual deficit of some $1,426,000 would occur with the 3 percent rate.

Item	*Unit charge*	*Annual revenue*
311,000 acre-feet of new water delivered to Feather River Service Area (includes West Side Zone)	$1.00	$311,000
2,845,000 acre-feet of new water delivered to Delta	1.00	2,845,000
1,670,000,000 kilowatt-hours of electrical energy at terminal substation	0.007	11,690,000
TOTAL		$14,846,000

Based on the foregoing assumptions, the estimated cost of water from the Feather River Project to water users in the West Side Zone would be about $1 per acre-foot at the streamside. This estimate does not include costs for diverting the water from the Feather River and conveying it to and distributing it in areas of use in the West Side Zone. Studies indicate that a practicable means for diverting the water from the river would be by pumping plants strategically located along the river, discharging into appropriate conveyance and distribution systems. Diversion also could be made by gravity with construction of a diversion weir and headgates at a suitable upstream site.

Other Major Projects Under Consideration

Surveys and studies in connection with the Statewide Water Resources Investigation and the Survey of Mountainous Areas indicate that it would be feasible from the engineering standpoint to so regulate and conserve the relatively large flood flows of the Yuba and Bear Rivers and other tributaries of the Feather River as to yield firm water supplies considerably in excess of the probable ultimate supplemental water requirements of the Northeast, East Central, and South Side Zones. Existing water resources developments on these streams, together with tentative locations of possible future dams and reservoirs, are shown on Plate 18.

In addition to the studies by the Division of Water Resources, the Oroville-Wyandotte Irrigation District is currently investigating a plan for multipurpose development of the water resources of the South Fork of the Feather River. Principal features of this project, which is in an advanced planning phase, are delineated on Plate 19, "Plans for Development of South Fork of Feather River." The district is considering the diversion of waters of both the South Fork of the Feather River and Slate Creek through tunnels to the proposed Lost-Sly Creek Reservoir, to be created by construction of a dam immediately above the flow line of the existing Lost Creek Reservoir on the stream of that name. Conservation and regulatory storage would be created on the South Fork by construction of Little Grass Valley Reservoir, and on Slate Creek by construction of the small Slate Creek Reservoir. Water released from Lost-Sly Creek Reservoir would flow into Lost Creek Reservoir, and then through a proposed pressure tunnel to the penstock of the proposed Woodleaf Power House, to be located on the South Fork about one mile below its junction with Lost Creek. From the afterbay of this plant the water would flow through another tunnel to the penstock of the proposed Forbestown Power House, also to be located on the South Fork. Construction of a canal is proposed from the Forbestown Power House afterbay along the left or south bank of the South Fork of the Feather River to a point about two miles west of Lake Wyandotte, to serve lands of the Oroville-Wyandotte Irrigation District to the west of the canal. It is feasible from an engineering standpoint to extend the canal in a southerly direction a distance of some 25 miles to South Honcut Creek.

As a possible alternative to the Oroville-Wyandotte Irrigation District's project, the Division of Water Resources is studying another plan for multipurpose development of the South Fork of the Feather River. This plan contemplates construction of the proposed Little Grass Valley Reservoir on the South Fork, and diversion of the conserved water at a point about 1½ miles below the dam through a tunnel to Fall River. Water would also be diverted from South Branch of Middle Fork of Feather River to Fall River through a tunnel. A dam on Fall River would divert its own flows and water from the two foregoing diversions through a tunnel to the penstock of the proposed Lumpkin Power House on the South Fork of Feather River. A tunnel would convey the water from the afterbay of this plant to an enlarged Lost Creek Reservoir, which

would be created by construction of a higher dam approximately at the site of the existing structure. The plan also contemplates construction of a small reservoir on Canyon Creek, and a diversion tunnel to the proposed Slate Creek Diversion Dam. From this dam the Slate Creek water and water from Canyon Creek would be diverted through a tunnel to a point on Lost Creek above the proposed enlarged reservoir. Releases from Lost Creek Reservoir would be made through a tunnel to a diversion dam on Grizzly Creek and from this dam through a canal and siphons to the penstock of the proposed Golden Gate Power House, to be located on Golden Gate Canyon at the headwaters of French Dry Creek. From the afterbay of this plant, a conduit, including canal and siphon sections, would lead to the penstock of the proposed Brownsville Power House, to be located on French Dry Creek at Brownsville. A canal would lead from the afterbay of the Brownsville plant to a saddle between the drainage areas of French Dry and South Honcut Creeks. At this point the canal would divide, with one branch bearing generally westerly and discharging into the existing Forbestown Ditch and thence into Lake Wyandotte. The other branch would bear southwesterly and terminate at the penstock of the proposed Honcut Power House, to be located on South Honcut Creek below its confluence with Natchez Creek. From the afterbay of the Honcut Power House a canal would extend along the right bank of South Honcut Creek and then bear northerly, terminating east of Oroville. This canal would serve lands of the Oroville-Wyandotte Irrigation District and adjacent irrigable lands lying to the west of the canal. Construction of a dam on South Honcut Creek is contemplated under the plan to create a reservoir the flow line of which would extend to the Honcut Power House afterbay. Water released from South Honcut Creek Reservoir would be diverted at appropriate downstream points on South Honcut Creek to serve lands in Browns Valley and on the Sacramento Valley floor east of the Feather River. Other diversions for irrigation and other beneficial uses in remaining water service areas between the Feather and Yuba Rivers could be made from the system.

Tentative plans for ultimate development of the Yuba River contemplate increasing the storage capacity of the existing Bullards Bar Reservoir on the North Yuba River, or providing equivalent increased capacity upstream at Kellys Bar, together with hydroelectric power development of the upper North Yuba River. Construction of a dam and reservoir on the Middle Yuba River at Granite Point is also under consideration, together with a diversion tunnel to the existing afterbay of the Bullards Bar Power House. Waters of the South Yuba River would be diverted at Edwards Crossing and conveyed by a proposed tunnel to the Granite Point Reservoir. Both the Middle and South Yuba Rivers offer possibilities for construction of dams and reservoirs, principally in the interests of mining debris storage and flood control.

The State Water Plan, as adopted by the Legislature in 1941, contemplates a storage capacity in the Englebright Reservoir on the Yuba River of about 850,000 acre-feet, as compared to the 70,000 acre-foot capacity of the existing Englebright Reservoir. This additional capacity would provide substantial conservation, flood control, and hydroelectric power, but would inundate the existing Colgate Power House, recently enlarged by the Pacific Gas and Electric Company. As a possible alternative, construction of offstream storage for waters of the Yuba River at the Waldo site, on Dry Creek, about nine miles northeast of Wheatland, is under consideration. This plan would involve construction of a conduit, diverting from Englebright Reservoir at the spillway elevation, to convey flood waters of the Yuba River to the proposed Waldo Reservoir. Under the plan, Waldo Reservoir in turn would spill into the proposed enlarged Camp Far West Reservoir on Bear River, which is hereinafter described. Consideration is also being given to possible construction of one or more additional reservoirs at the Garden Bar, Parker, or Rollins sites, upstream from the Camp Far West site on the Bear River, to effect more complete conservation of flood waters of that stream.

Studies indicate that the Northeast Zone could be served with an ultimate supplemental water supply either from the South Fork of the Feather River under the plan of development hereinbefore described, or from the Yuba River. Service from the Yuba River could be made by enlargement of the existing Hallwood-Cordua system or by diversion from the Yuba River at a suitable site in the vicinity of Parks Bar, and distribution by gravity from a main conduit bearing in a northerly direction roughly along the eastern boundary of the zone. It has been estimated that the amount of the probable ultimate mean seasonal supplemental water requirement of the Northeast Zone will be about 30,000 acre-feet. A water supply in this amount, under an appropriate schedule of demands, could be made available to the Northeast Zone by construction of one or more of the previously described major upstream projects.

It is indicated that under ultimate conditions of development the East Central Zone could also be served with supplemental water from the Yuba River. It has been estimated that the amount of the probable ultimate mean seasonal water requirement of the zone will be about 82,000 acre-feet. A portion of the required supplemental supply could be diverted, under an appropriate schedule of demands, directly from the Yuba River above Hammonton, and conveyed in a southerly direction to Hutchinson Creek, by rehabilitation and extension of the abandoned Yuba River Ditch of the Yuba Consolidated Gold Fields. Conserved water of the Yuba River to meet the remainder of the ultimate

supplemental water requirement of the East Central Zone could be released from the proposed Waldo Reservoir for downstream diversion and conveyance to areas of use.

Studies also indicate that under ultimate conditions of development the South Side Zone could be served with a supplemental water supply released, under an appropriate schedule of demands, from the proposed Camp Far West Reservoir. It has been estimated that the amount of the probable ultimate mean seasonal supplemental water requirement of the zone will be about 112,000 acre-feet. A supply in this amount would be available in Camp Far West Reservoir, and would consist of waters of the Yuba and Bear Rivers and Dry Creek conserved jointly by the proposed Waldo Reservoir, Camp Far West Reservoir, and upstream reservoirs on the Bear River. It could be conveyed to points of use in the South Side Zone by an enlarged system similar to that described hereinafter in connection with the Camp Far West Project.

PLANS FOR INITIAL LOCAL DEVELOPMENT

Possible plans for initial local development of supplemental water supplies for the Sutter-Yuba Area, together with cost estimates, are described in this section. Design of features of the plans was necessarily of a preliminary nature and primarily for cost estimating purposes. More detailed investigation, which would be required in order to prepare plans and specifications, might result in designs differing in detail from those presented in this report. However, it is believed that such changes would not be significant.

Capital costs of dams, reservoirs, diversion works, conduits, pumping plants, and appurtenances, included in the considered conservation, conveyance, and distribution systems, were estimated from preliminary designs based largely on data from surveys made during the current investigation. Approximate construction quantities were estimated from these preliminary designs. Unit prices of construction items were determined from recent bid data on projects similar to those in question, or from manufacturers' cost lists, and are considered representative of prices prevailing in April, 1952. The estimates of capital cost included costs of rights of way and construction, and interest during one-half of the estimated construction period at 3 percent per annum, plus 10 percent for engineering, and 15 percent of construction costs for contingencies. Estimates of annual costs included interest on the capital investment at 3 percent, amortization over a 50-year period on a 3 percent sinking fund basis, replacement, operation, and maintenance costs, and costs of electrical energy for pumping.

Because of geographical considerations, and respective types of water service and water supplies in the several zones of the Sutter-Yuba Area, possible plans for initial water development are presented in this section separately for the West Side, Northeast, East Central, and South Side Zones.

West Side Zone

In Chapter III it was shown that the present requirement for supplemental water in the West Side Zone is about 17,000 acre-feet per season. However, in the design of projects for initial local development to meet this requirement, it was considered desirable to provide some capacity for future growth in water demand which would occur through development of irrigable lands not presently irrigated. This additional capacity was estimated at about 7,000 acre-feet per season, giving consideration to the extent of undeveloped irrigable lands that might readily be served, and to the available sources of water supply. For reasons hereinafter discussed it was considered that the new water supply would be applied to about 7,000 acres of land in the Peach Bowl, of which about 4,500 acres are presently irrigated by ground water containing chlorides at or above the safe limit for irrigation use, and 2,500 acres are irrigable lands not presently served with water. These lands are contained within a service area lying generally to the south of Oswald Road, and delineated on Plate 20, "Peach Bowl Project."

Three possible alternative plans of works for initial construction to provide supplemental water to the West Side Zone were considered. For reasons hereinafter mentioned, after preliminary investigation and study the first two plans were given no further consideration for present cost estimating purposes, but may warrant future study. The third plan is described in some detail later in this section.

Alternative Plans Considered. The first of the alternative plans considered for initial construction included salvage of water in high water table lands of the Sutter Butte Canal service area, and its conveyance to and use in the Peach Bowl. This would involve the installation of batteries of wells in the high water table area, conveyance of the pumped ground water to the Peach Bowl either in conduits or in the channel of the Feather River, and distribution of the water in a strategically situated service area of heavy ground water pumping draft in the Peach Bowl. The new water supply would largely replace ground water presently used in the Peach Bowl service area, thereby preventing progressive and permanent lowering of ground water levels and attendant degradation of mineral quality of the ground water throughout the Peach Bowl and adjacent ground water service areas. However, preliminary investigation and study indicated that changes in the crop pattern and in irrigation practice in the Sutter Butte Canal service area, which would be necessary for consummation of this plan, would be difficult to effect, and that cost of the salvaged water would be greater than for water yielded under the third plan



Feather River in the Vicinity of Starr Bend, Looking Upstream

herein described. For these reasons, this plan was given no further present consideration.

Consideration was also given to the provision of a supplemental water supply to the Peach Bowl service area from the Feather River, by extension of the conveyance and distribution system of the Sutter Butte Canal. As in the case of the first plan described, use of the new surface water supply would prevent progressive and permanent lowering of water levels, and attendant degradation of mineral quality of ground water, in the area served and in adjacent areas. Preliminary investigation and study of this second plan for initial construction indicated that existing diversion facilities might be adequate for such purpose, but that conveyance facilities would require enlargement. Furthermore, a canal to serve lands requiring supplemental water in the Peach Bowl would have to be constructed on a relatively flat slope over a long distance through highly developed orchard lands. The canal would also pass through urban areas lying immediately south and west of Yuba City. It was indicated from investigation and study that cost of the new water supply would be greater than under the third plan hereinafter described. For these reasons, this plan was given no further present consideration.

The third of the alternative plans considered for initial construction would provide for the present supplemental water requirement in the West Side Zone, and for growth in water utilization for a number of years in the future. It would include the construction of facilities for pumping water directly from the Feather River and for its conveyance to and distribution in the service area in the Peach Bowl. As in the case of the two previous plans, use of the new surface water supply would prevent progressive and permanent lowering of ground water levels and degradation of mineral quality of the ground water, in the area served and in adjacent areas. This plan is hereinafter referred to as the "Peach Bowl Project," and its principal features are delineated on Plate 20.

Peach Bowl Project. Satisfactory sites for a pumping plant to divert flow of the Feather River exist on the right or west bank of the river along the reach one-half mile north and south of the prolongation of Hutchinson Road. The site selected for cost estimating purposes is at a point about four miles south of Shanghai Bend, near the center of Section 26, Township 13 North, Range 3 East, M.D.B. & M. Conveyance and distribution of water pumped from the Feather River to the area of use would be accomplished by means of a combination system including lined and unlined canals, and ditches, and the utilization of existing individual distribution systems insofar as possible. The lands which would be irrigated with the new water supply comprise the aforementioned 7,000 acres within the service area shown on Plate 20, ranging in elevation from approximately 45 feet at the north boundary to approximately 30 feet in the southerly portion.

Since the Peach Bowl constitutes a free ground water area, water losses in conveyance and distribution of the new water supply would largely percolate to the ground water. For this reason it was assumed that these losses, plus the unconsumed portion of the new water supply applied to irrigation would be effective in preventing progressive and permanent lowering of ground water levels and degradation of mineral quality of the ground water. The acreage to be irrigated by the supplemental supply would depend on the amount of the gross diversion, water losses encountered in conveyance and distribution, and the requirement for application of water to the lands irrigated.

For cost estimating purposes the Peach Bowl Project was designed to provide a gross seasonal supplemental surface water supply of approximately 24,000 acre-feet, of which about 17,000 acre-feet is necessary to meet the present supplemental requirement, and the remainder would be available for additional development of irrigable lands. An estimate of the monthly distribution of demand for irrigation water in the West Side Zone was presented in Table 33. Based on these data, the monthly gross demand for water for the Peach Bowl Project would be as shown in Table 37.

TABLE 37

ESTIMATED MONTHLY DISTRIBUTION OF GROSS DEMAND FOR WATER FOR THE PEACH BOWL PROJECT

Month	Percent of seasonal total	Demand for water, in acre-feet
April	2	480
May	13	3,120
June	21	5,040
July	27	6,480
August	21	5,040
September	12	2,880
October	4	960
TOTALS	100	24,000

Based upon known soil characteristics in the Peach Bowl and upon irrigation experience elsewhere, it was assumed that water losses in conveyance and distribution of a new surface water supply would amount to about 25 percent of the gross diversion, leaving about 18,000 acre-feet per season for application to irrigated lands. Lands in the Peach Bowl to be served with the new water supply and presently irrigated by ground water comprise about 4,500 acres of highly developed orchard. From results of the plot studies of water application described in Chapter III, it was estimated that these orchard lands would require a

seasonal application of irrigation water in an amount of about 2.5 acre-feet per acre, or a total of about 11,000 acre-feet. The remaining 7,000 acre-feet of water per season available under the Peach Bowl Project, as designed, would serve about 2,500 acres of irrigable lands, presently not served with water, lying to the west of the foregoing orchard lands. If developed, it was considered that these irrigable lands would probably largely be devoted to truck and general row crops, with limited amounts of rice and irrigated pasture. Based on results of the cited plot studies, it was estimated that these lands would require a seasonal application of irrigation water in an amount of about 2.8 acre-feet per acre.

No record was available of flow in the Feather River at the proposed point of pumping diversion. However, records were available of monthly flow at Shanghai Bend some four miles upstream from the proposed diversion point, and at Nicolaus some 11 miles downstream therefrom. The Shanghai Bend record dated from 1940, while that for Nicolaus was continuous since 1921, although prior to 1939 records of stream flow at the latter station were obtained only during summer months of low flow. Studies were made of these records and of measurements of diversions from the Feather River in the reach between the two stations. These studies indicated that during the irrigation season probable flow at the proposed diversion for the Peach Bowl Project was greater than recorded flow in the Feather River at Nicolaus. Therefore, the assumption that flows available for the pumping diversion were equal to those measured at Nicolaus was considered to be conservative.

It was determined that during the critical months of July, August, and September, tributary inflow to the Feather River from the Bear River was negligible. For this reason, any future conservation development on this tributary would not adversely affect the assumption as to flow in the Feather River at the proposed point of diversion during the critical summer months. Furthermore, records of the Sacramento-San Joaquin Water Supervision indicated that the amount of existing diversions from the Feather River between Nicolaus and the confluence with the Sacramento River, during the critical summer months of low flow, is insufficient to materially affect the estimates of water supply available in the Feather River for diversion to the Peach Bowl.

Available records of monthly stream flow of the Feather River at Nicolaus during the irrigation season are presented in Table 38. Comparison of these recorded flows with the estimated monthly gross demands of the Peach Bowl Project, presented in Table 37, indicates that during the period from 1921 through 1950 ample water was available from the Feather River to meet demands of the project, as designed, except during the two seasons of 1924 and 1931. During these seasons irrigation deficiencies of approximately 40 and 25 percent, respectively, would have occurred. From past experience in the Sacramento Valley, it is considered probable that such deficiencies could be endured without permanent damage.

TABLE 38

MEASURED MONTHLY FLOW OF FEATHER RIVER AT NICOLAUS DURING THE IRRIGATION SEASON, 1921 THROUGH 1950

(In acre-feet)

Year	Runoff index	April	May	June	July	August	September	October
1921	129				61,870	23,195	25,035	49,140
1922	109				181,000	48,300	49,200	49,200
1923	67				111,000	52,100	72,000	126,000
1924	28			6,780	1,780	609	20,900	93,500
1925	67				55,600	33,400	49,000	106,000
1926	67			57,500	24,900	24,300	60,100	109,000
1927	122				99,000	43,600	61,300	131,000
1928	90			89,300	54,800	30,700	60,700	104,000
1929	40		371,000	160,000	49,700	70,100	104,000	132,000
1930	85		536,000	183,000	52,000	57,300	112,000	163,000
1931	32		68,900	17,700	935	5,070	32,800	68,200
1932	72		904,000	453,000	75,600	29,900	26,700	40,100
1933	42		418,000	331,000	34,900	18,300	25,100	61,100
1934	44		114,000	40,500	21,800	19,600	39,200	67,710
1935	93				84,430	69,850	70,070	123,400
1936	94			385,200	81,780	63,020	82,050	110,000
1937	69				66,950	18,130	38,780	129,000
1938	186				217,000	83,360	90,100	149,800
1939	41	359,700	107,800	27,070	9,870	19,660	57,700	77,200
1940	123	1,593,900	711,200	200,100	43,700	36,760	92,230	128,700
1941	141	1,416,200	1,467,000	548,000	191,300	52,800	54,500	99,400
1942	145	1,480,000	1,254,000	793,600	166,500	44,140	67,200	137,600
1943	122	1,220,600	663,300	314,800	57,350	22,040	32,360	119,000
1944	61	597,600	633,000	179,800	33,300	13,280	32,190	83,300
1945	82	726,800	736,100	262,900	40,890	27,620	53,160	106,800
1946	90	836,000	679,900	171,900	38,500	30,040	53,690	87,650
1947	55	573,300	124,000	74,330	16,780	24,640	40,820	135,600
1948	74	1,326,000	1,091,000	590,200	73,600	16,170	48,190	132,900
1949	57	809,700	533,500	98,060	13,920	9,230	27,480	39,430
1950	84	1,099,000	834,900	327,200	40,030	18,230	71,500	163,500

Studies indicated that the maximum monthly diversion for the Peach Bowl Project would occur in July, and that it would amount to about 27 percent of the total seasonal diversion of 24,000 acre-feet, equivalent to a continuous flow of about 105 second-feet throughout the month. For cost estimating purposes the pumping plant for the project was designed with a total pumping capacity of 135 second-feet. This installation would meet the estimated maximum rate of demand, provide additional capacity for shorter-term peaking in excess of the average monthly rate, and provide stand-by capacity to assure continuous service in case of breakdown.

Features of the pumping plant considered for the Peach Bowl Project are shown on Plate 20. In order to permit flexibility in operation of the project, design of the pumping plant was based on the installation of three electrically driven vertical axial-flow propellor type pumping units. Each of the units would comprise a 36-inch diameter pump with capacity of 45 second-feet, driven by a 100-horsepower motor. The pumps would operate at a maximum pumping head of about 15 feet, pumping from an estimated minimum water surface elevation in the river of about 31 feet to a discharge elevation of about 46 feet. The pumping units would be of the all-weather type, mounted on steel beams, and supported on concrete piles driven into the stream bed at the toe of the river face of the right bank levee of the Feather River. The battery of pumps would be operated from a corrugated metal control house, also mounted on the concrete piles, and would be served by a steel trestle from the levee crest. The units would pump from a reinforced-concrete sump into three 30-inch diameter steel pipes supported by ring girders and reinforced-concrete piers on the slopes of the levee. The pipes would pass through the levee five feet beneath the crest, and discharge into a reinforced-concrete sand trap at the landward base of the levee.

From the sand trap the water would be conveyed by gravity to areas of use by the system of lined and unlined canals shown on Plate 20. The main canal extending in a southerly direction along the levee would be concrete-lined, in order to prevent seepage which might otherwise damage orchards or the toe of the Feather River levee. This canal would be approximately 6.1 miles in length, and would be of trapezoidal section, with 1.5:1 side slopes, bottom width of 8.0 feet, depth of 3.4 feet, and 1.0 foot freeboard. The slope would be approximately 1.0 foot per mile, the velocity about 2.5 feet per second, and the capacity would be 100 second-feet. A second main canal would extend from the sand trap in a westerly direction a distance of approximately 0.7 mile to a concrete division box near the Southern Pacific Railroad right of way. This canal would have characteristics similar to the one already described. From the division box a lateral would extend south along the railroad right of way a distance of approximately 4.8 miles. This lateral would also be concrete-lined, to prevent possible damage by seepage to adjacent orchards and to the railroad. It would be of trapezoidal section, with 1.5:1 side slopes, bottom width of 6.0 feet, depth of 2.4 feet, and freeboard of 1.0 foot. The slope would be approximately 1.5 feet per mile, the velocity about 2.3 feet per second, and the capacity 50 second-feet. A second lateral from the division box would extend in a westerly and then southerly direction a distance of approximately 5.2 miles. This canal would be unlined, since seepage from it would probably result in no damage. The canal would be of trapezoidal section, with 2:1 side slopes, bottom width of 6.0 feet, depth of 3.2 feet, and freeboard of 1.0 foot. Its slope would be approximately 1.5 feet per mile, its velocity about 1.3 feet per second, and its capacity 50 second-feet. Cost estimates for the conveyance canals were based on preliminary designs utilizing data from field location surveys.

Detailed design of works for distribution of water from the conveyance canals was considered to be outside the scope of the current investigation. Existing pressure irrigation systems of individuals and agencies could be adapted to use of the new surface water supply by means of gravity diversions or individual low-head pumps, as required. Cost estimates for the distribution systems were based on known costs of similar irrigation works elsewhere in California, adjusted to correspond with conditions prevailing in the Sutter-Yuba Area.

Pertinent data with respect to general features of the Peach Bowl Project, as designed for cost estimating purposes, are presented in Table 39.

TABLE 39

GENERAL FEATURES OF PEACH BOWL PROJECT

Pumping Plant

- Pumps—3 each, vertical, propeller type, axial-flow, 45 second-foot capacity
- Estimated minimum water surface elevation in Feather River—31 feet
- Discharge elevation—46 feet
- Estimated maximum pumping head—15 feet
- Installed pumping capacity—135 second-feet
- Estimated maximum monthly demand—105 second-feet
- Estimated gross seasonal diversion—24,000 acre-feet
- Motors—3 each, all-weather type, 100 horsepower
- Pump support—steel beams on concrete pile structure
- Pumping sump—reinforced-concrete, 13 feet by 65 feet, 5 feet deep, equipped with trash racks
- Discharge lines—3 each, 30-inch diameter, welded-steel, supported on concrete piers by ring girders
- Sand trap—reinforced-concrete, 10 feet by 40 feet, 6 feet deep, equipped with baffles and sluice gates

Conveyance System

	Main canals	Central lateral	West lateral
Type	Trapezoidal, concrete-lined	Trapezoidal, concrete-lined	Trapezoidal, unlined
Length, in miles	6.8	4.8	5.2
Side slopes	1.5:1	1.5:1	2:1
Bottom width, in feet	8.0	6.0	6.0
Depth, in feet	3.4	2.4	3.2
Freeboard, in feet	1.0	1.0	1.0
Slope, in feet per mile	1.0	1.5	1.5
Velocity, in feet per second	2.5	2.3	1.3
Capacity, in second-feet	100	50	50



Daguerre Point Weir on Yuba River

Capital cost of the Peach Bowl Project, based on prices prevailing in April, 1952, was estimated to be about $1,384,900. Corresponding annual costs of the Peach Bowl Project were estimated to be about $100,900. Resultant estimated average unit cost of the 24,000 acre-feet of water per season diverted at the river was about $4.20 per acre-foot. The estimated average unit cost of the 18,000 acre-feet of water per season actually applied for irrigation was about $5.60 per acre-foot.

Estimated capital and annual costs of the Peach Bowl Project are summarized in the following tabulation. Detailed cost estimates are presented in Appendix H.

	Estimated costs	
	Capital	*Annual*
Pumping plant	$107,900	$16,000
Conveyance system	813,900	43,800
Distribution system	463,100	41,100
TOTALS	$1,384,900	$100,900

Northeast Zone

In Chapter III it was shown that the present requirement for supplemental water in the Northeast Zone is about 6,000 acre-feet per season. However, in the design of projects for initial local development to meet this requirement, it was considered desirable to provide some capacity for future growth in water demand which would occur through development of irrigable lands not presently irrigated. This additional capacity was estimated at about 6,000 acre-feet per season, giving consideration to the extent of undeveloped irrigable lands that might readily be served, and to the available sources of water supply as determined by engineering and economic limitations on size of the proposed conservation works. For reasons hereinafter discussed, it was considered that the new water supply would be applied to about 2,300 acres in the Northeast Zone, of which about 1,700 acres are presently irrigated by ground water and 600 acres are irrigable lands not presently served with water. These lands are contained within a service area adjoining and lying to the east and north of the Cordua Irrigation District, and delineated on Plate 21, "South Honcut Creek Project."

Three possible alternative plans of works for initial construction to provide supplemental water to the Northeast Zone were considered. For reasons hereinafter mentioned, after preliminary investigation and study, the first two plans were given no further consideration for present cost estimating purposes, but may warrant future study. The third plan is described in some detail in this section.

Alternative Plans Considered. The first of the alternative plans considered for initial construction involved the substitution of surface water from the Yuba River to replace ground water presently utilized in the foregoing service area. The substitute supply would be furnished by extension and enlargement of portions of the Cordua Irrigation District canal system. Its use would prevent progressive and permanent lowering of ground water levels in the described service area and in adjacent areas. The Cordua Irrigation District and the Hallwood Canal Company jointly divert from the Yuba River through a 1,200-foot tunnel with capacity of 325 second-feet, heading at the northwest end of the Daguerre Point Weir. Surface flow in the Yuba River at Daguerre Point during the peak of the irrigation season is generally not greater than present demands of the Cordua and Hallwood systems, and at times these demands cannot be met. Much of the surface flow in the Yuba River during such periods as measured at Marysville does not occur on the surface at the Daguerre Point Weir. Measurements indicate that this water is lost to surface flow by percolation in an extensive area of dredger tailings above the weir, and reappears at the Marysville gaging station. For this reason, a preliminary survey was made to determine the feasibility of diverting the Cordua-Hallwood water supply from the Yuba River at a site upstream from the area of dredger tailings. This would be excessively expensive because of the necessity for increasing capacity of the Cordua-Hallwood system, providing a diversion structure, and providing a closed conduit for the diverted water for a considerable distance until stable bank could be reached. For these reasons, and because of uncertainty regarding the available water supply, this plan was given no further present consideration.

The second of the alternative plans considered for initial construction involved the purchase of Feather River water from the Oroville-Wyandotte Irrigation District at a point of delivery on South Honcut Creek, diversion of the water from South Honcut Creek, and its conveyance to and distribution in the Northeast Zone. As in the case of the first plan described, use of the new surface water supply would prevent progressive and permanent lowering of ground water levels in the area served and in adjacent areas. The water purchased and utilized would be a portion of that which the district proposes to develop on the South Fork of the Feather River under the multipurpose project described earlier in this chapter, principal features of which are shown on Plate 19. The water would be delivered to South Honcut Creek at an elevation of about 600 feet, by the district. The amount of water that might be made available to the Northeast Zone would depend upon design of features of the proposed Oroville-Wyandotte Irrigation District project, and in turn upon the outcome of possible negotiations between the district and an agency representing interests of the Northeast Zone. For these reasons, features of the plan were not surveyed and studied in detail, nor estimates of cost prepared.

The third plan considered for initial construction would include the construction of a dam and reservoir on South Honcut Creek, facilities for diversion of flood



South Honcut Creek Dam Site Viewed From Point Within Reservoir Area

waters of French Dry Creek to the reservoir, and facilities for diversion of the conserved waters from South Honcut Creek below the dam, and for their conveyance to and distribution in both the Northeast Zone and the Browns Valley service area. This latter area, lying to the east of the Northeast Zone, is also in need of a supplemental water supply and could be advantageously served as indicated. As in the case of the two previous plans, use of the new surface water supply would prevent progressive and permanent lowering of ground water levels in the area served in the Northeast Zone and in adjacent areas. This plan is hereinafter referred to as the "South Honcut Creek Project," and its principal features are delineated on Plate 21.

South Honcut Creek Project. The proposed dam would be an earthfill structure with side channel spillway, located on South Honcut Creek near Sugar Loaf, in Section 25, Township 18 North, Range 5 East, M. D. B. & M., some 20 miles upstream from the confluence of Honcut Creek with the Feather River. The stream bed elevation at this point is about 730 feet. Flood waters of French Dry Creek would be diverted at a point on that stream at an elevation of approximately 2,125 feet, about one-half mile below Brownsville, and conveyed a distance of about two miles in a canal, discharging into a tributary of South Honcut Creek above the reservoir. The conserved waters of both South Honcut and French Dry Creeks, after release from the reservoir, would be diverted from South Honcut Creek at a point about two miles downstream from the dam and 300 feet downstream from the county bridge southeast of Bangor, at an elevation of about 600 feet. From this diversion point the waters would be conveyed by a conduit a distance of about 4.7 miles to a point about one mile northeast of Loma Rica, where the elevation is about 500 feet. Diversions could be made for the Browns Valley service area along the conduit and at its terminus. Water for the Northeast Zone would be conveyed from this terminus in a natural drainage channel, a short canal section, and the natural channel of Prairie Creek to a diversion point for the Northeast Zone on Prairie Creek about one mile upstream from its confluence with South Honcut Creek, at an elevation of approximately 135 feet. From this point the waters would be conveyed to and distributed in the Northeast Zone by means of an unlined canal and ditch system. The lands which would be served by the new water supply comprise the aforementioned 2,300 acres contained within the service area shown on Plate 21, ranging in elevation from about 150 feet along its eastern boundary to about 75 feet on the west.

As a first step in determination of size of the project, estimates were made of yield of the proposed works for various reservoir storage capacities. It was estimated that mean seasonal runoff of South Honcut Creek, from the approximately 24 square miles of watershed above the dam site, was about 23,400 acre-feet. Estimated mean seasonal runoff of French Dry Creek at the proposed point of diversion to South Honcut Creek was about 27,100 acre-feet, from some 22 square miles of watershed. Of these French Dry Creek waters, studies indicated that flood flows in an estimated mean seasonal amount of about 22,000 acre-feet could be diverted to the proposed South Honcut Creek Reservoir through a 200 second-foot capacity conduit, during the months from November to April, inclusive.

Based upon records and estimates of runoff during the critical dry period which occurred in the Sacramento Valley from 1920-21 through 1934-35, yield studies were made for five sizes of reservoir at the South Honcut Creek site. It was assumed that a seasonal irrigation deficiency up to 35 percent could be endured in one season of the period. Monthly demands on the reservoir were assumed to be proportional to the estimated distribution of irrigation demands in the Sutter-Yuba Area, as presented in Table 33. A summary of results of the yield studies is presented in Table 40.

TABLE 40

ESTIMATED SAFE SEASONAL YIELD OF SOUTH HONCUT CREEK RESERVOIR WITH FRENCH DRY CREEK DIVERSION, BASED ON CRITICAL DRY PERIOD FROM 1920-21 THROUGH 1934-35

(In acre-feet)

Reservoir storage capacity	Safe seasonal yield
12,000	12,800
20,000	16,400
30,000	20,900
38,000	24,300
70,000	27,100

After consideration of the results of the yield studies, together with topography of the dam site and cost analyses hereinafter discussed, a reservoir of 38,000 acre-foot storage capacity, with estimated safe seasonal yield of 24,300 acre-feet, was chosen for purposes of cost estimates to be presented in this report. The yield study for this size of reservoir is included in Appendix G.

Although the estimate of the present requirement for supplemental water in the Northeast Zone was only about 6,000 acre-feet per season, essentially all irrigable but presently nonirrigated lands in the zone would be physically susceptible of irrigation under the South Honcut Creek Project. However, a substantial acreage of irrigable lands lying in the Browns Valley service area could be developed with water from the South Honcut Creek Project. For this reason, studies of present utilization of water from the South

Honcut Creek Project were based on an assumed release of water for the Northeast Zone equal to approximately one-half of the estimated safe yield of the project. It was assumed that remaining safe yield of the project would be made available to the Browns Valley service area.

For design purposes it was assumed that minor losses of water released from South Honcut Creek Reservoir would occur in the stream channel between the dam and the downstream point of diversion and in the lined canal leading to the point of release north of Loma Rica, and would amount to about 300 acre-feet per season. Thus a gross supplemental water supply of approximately 12,000 acre-feet per season would be made available to the Browns Valley service area. It was estimated that losses in conveyance and distribution of this supply would be about 25 percent, leaving some 9,000 acre-feet per season for application to irrigation. On the assumption that the imported water would be largely used on irrigated pasture, with an estimated average unit seasonal application of about 3.5 acre-feet per acre, about 2,600 acres of irrigable but presently nonirrigated lands in the Browns Valley service area could be served by the new water supply.

It was assumed that seasonal losses by transpiration, evaporation, and percolation in conveying the new water supply to the point of diversion on Prairie Creek would be about 10 percent of the gross reservoir release, or about 1,200 acre-feet, leaving approximately 10,800 acre-feet for distribution in the zone. Since the Northeast Zone constitutes a free ground water area, water losses in the unlined canal and ditch system would largely percolate to the ground water. For this reason it was assumed that these losses, plus the unconsumed portion of the new water supply applied to irrigation, would be effective in preventing progressive and permanent lowering of ground water levels.

The acreage to be irrigated by the supplemental supply in the Northeast Zone would depend on the gross amount of the import, water losses encountered in conveyance and distribution, and the requirement for application of water to the lands irrigated. It was assumed that losses to be encountered in conveyance and distribution within the zone would be 25 percent of the gross import, or about 2,700 acre-feet per season, leaving some 8,100 acre-feet for application to irrigated lands. It was also assumed that water imported to the Northeast Zone would largely be used on irrigated pasture, and that the average seasonal application of the new water would be 3.5 acre-feet per acre. On this basis it was estimated that the imported supply would be applied to some 2,300 acres in a service area adjoining and lying to the east and north of the Cordua Irrigation District. Of the lands which would be served with the new water supply, about 1,700 acres are presently irrigated by ground water and 600 acres are irrigable lands not presently irrigated.

An estimate of the monthly distribution of demand for irrigation water in the Sutter-Yuba Area was presented in Table 33. Based on these data, the monthly demand on the South Honcut Creek Project would be as shown in Table 41.

TABLE 41

ESTIMATED MONTHLY DISTRIBUTION OF DEMAND FOR WATER FROM SOUTH HONCUT CREEK PROJECT

(In acre-feet)

Month	Percent of seasonal total	Reservoir release	Gross import to Northeast Zone	Gross import to Browns Valley
April	10	2,430	1,080	1,200
May	16	3,890	1,730	1,920
June	17	4,130	1,830	2,040
July	22	5,350	2,380	2,640
August	17	4,130	1,830	2,040
September	11	2,670	1,190	1,320
October	5	1,210	540	600
November	2	490	220	240
TOTALS	100	24,300	10,800	12,000

Plane table topographic surveys were made of the South Honcut Creek dam and reservoir sites by the Division of Water Resources in 1949. The reservoir site was mapped at a scale of 1 inch to 400 feet, and the dam site at a scale of 1 inch to 100 feet, both with 10-foot contour intervals. Storage capacities of South Honcut Creek Reservoir at various stages of water surface elevation are given in Table 42.

Based upon preliminary geological reconnaissance, the South Honcut Creek dam site is considered suitable for an earthfill dam of any height up to a maximum of 200 feet. Foundation rock at the site consists of a slightly metamorphosed series of igneous rocks, chiefly of volcanic origin. The original nature of the rocks ranged from basalt to gabbro. The bulk of the material is a blue-gray, hard, very slightly metamorphosed basalt. The entire mass has been intruded by a number of small dikes, of later origin, consisting of unmetamorphosed andesite and/or basalt. The foundation bedrock as a whole is relatively hard and unweathered where exposed in outcrops. Joints are prominently developed in several sets. The predominant set has a strike approximately parallel to the stream course and apparently controls the primary drainage pattern in the vicinity. Small shears are common throughout the rock mass but these have generally been recemented. Some of the joints also have been recemented by deposition of minerals from percolating waters. Seepage may be observed from remaining open seams in the bedrock in several places.

TABLE 42

AREAS AND CAPACITIES OF SOUTH HONCUT CREEK RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum, in feet	Water surafce area, in acres	Storage capacity, in acre-feet
0	730	0	0
20	750	3	25
40	770	26	226
60	790	62	1,090
80	810	132	2,980
100	830	256	6,530
119	849	344	12,000
120	850	355	12,300
138	868	484	20,000
140	870	512	20,900
156	886	634	30,000
160	890	691	32,800
168	898	720	38,000
180	910	801	47,600
200	930	933	65,000
205	935	976	70,000
220	950	1,070	85,100

Three hundred feet downstream from the axis a fault zone is encountered which follows the base of the right abutment longitudinally for an additional 200 feet before lensing out. The plane of this fault apparently has a dip of 55 degrees into the left abutment. The zone appears to die out rapidly in both upstream and downstream directions but at the point of maximum development it is eight feet in width. There is some gouge and much crushed rock along this fault. The inconsistency of the zone on the surface would seem to indicate that it may also lens out vertically at a relatively shallow depth. Indications are that there has been no recent movement on the fault. Special treatment of the dam foundation in the area of this fault would undoubtedly be necessary.

Stripping for the foundation of an earthfill type of dam at this site should not exceed, for the right abutment, five feet of overburden, consisting chiefly of soil, plus three feet of weathered bedrock, and for the left abutment, three feet of overburden plus three feet of weathered bedrock. These estimates apply only under the impervious section of an earthfill type of dam and are for any height of dam up to a maximum of 200 feet. Only the overburden would have to be stripped from under the pervious sections of such a dam. The stated depths are estimated normal to the surface. Stripping in the channel section should consist of about two feet of gravel and one foot of weathered bedrock.

A satisfactory location for a spillway for an earthfill dam at this site would be around the end of the structure, with the excavation being largely in hard bedrock. The material from such excavation, as well as the weathered rock stripped from the abutments, should prove about 80 percent recoverable for construction use as pervious fill, rockfill, or riprap. Tailings from former hydraulic mining operations which choke the channel one mile upstream from the dam site could also be used as pervious fill material. A small quantity of concrete aggregate could be recovered locally for use in appurtenant structures for an earthen dam, but large amounts would either have to be crushed at the site or imported. Soil suitable for use in the construction of an impervious embankment is available in limited quantities from sloping flats of the reservoir area. Although the depth of this material is probably not great, it is believed that enough could be obtained from this source to provide for a minimum impervious earth section.

As a result of yield studies, geologic reconnaissance, and preliminary economic analysis, an earthfill dam, 168 feet in height from stream bed to spillway lip, and with a crest elevation of 910 feet, was selected to illustrate estimates of cost of the South Honcut Creek Project. The dam would have a crest length of about 670 feet and a crest width of 30 feet, and 2.5:1 upstream and down-stream slopes. The central impervious core would have a top width of 10 feet and 0.8:1 slopes, and would be blanketed with sand and gravel filters. The outer pervious zones of the dam would consist of dredger tailings and materials excavated in construction of the spillway. The volume of the fill would be an estimated 919,000 cubic yards. The maximum depth of water above the spillway lip would be 8 feet, and an additional 4 feet of freeboard would be provided. The spillway would be of the side channel type, excavated from rock of the right abutment and concrete-lined. It would have a capacity of 10,000 second-feet, required for an assumed discharge of 400 second-feet per square mile of drainage area, and would discharge into South Honcut Creek below the dam. Outlet works would consist of a 42-inch diameter steel pipe placed in a trench excavated in rock beneath the dam, and encased in concrete. Releases from the dam would be controlled at the upstream end by two 30-inch hydraulically controlled high pressure slide gates located at a submerged inlet upstream from the dam, and operated by hydraulic controls from the crest of the dam. The outlet would be controlled at the downstream end by a Howell-Bunger valve.

The diversion works on French Dry Creek would be located approximately at the site of a former diversion weir, portions of which are still in existence. The site was examined and cross sections taken during the

course of the investigation. The proposed diversion weir would consist of a concrete gravity overpour section and apron, 7 feet in height above stream bed and some 55 feet in length. An opening at the right end of the weir would provide entrance to a side channel leading downstream about 100 feet to the headworks of the diversion canal. The side channel would have a concrete gravity parapet wall of the overpour type, and a 5- by 4-foot sluice gate would be provided for sand clearance. The headworks would consist of a concrete headwall across the end of the side channel, in which there would be two 5- by 4-foot slide gates. The diversion canal, which for a portion of its route would be aligned roughly along an abandoned canal, would be about 2.0 miles in length, discharging into an unnamed tributary of South Honcut Creek. Location of the canal was based on a map study, and was checked in the field. The canal chosen for cost estimating purposes would have a capacity of 200 second-feet, a shotcrete-lined trapezoidal section with 1:1 side slopes, bottom width and depth of 4.0 feet, and freeboard of 1.0 foot, and a slope of approximately 7.0 feet per mile. The velocity would be about 6.3 feet per second.

The diversion works on South Honcut Creek to serve Browns Valley and the Northeast Zone would be similar to those described for the French Dry Creek diversion, except that the weir would be 9 feet high and 84 feet in length, and the headworks would be located at the left end of the weir. The site was examined and cross-sectioned during the course of the investigation. The diversion conduit chosen for cost estimating purposes would have a capacity of 150 second-feet and would bear in a general southerly direction a distance of approximately 4.7 miles. Location of the conduit was based on a map study, and was checked in the field. For the most part the conduit would consist of a shotcrete-lined canal, but would include a steel pipe siphon, 5.5 feet in diameter and about 1,500 feet in length, across Tennessee Creek. The canal portion would have a trapezoidal section with 1:1 side slopes, bottom width of 5.0 feet, depth of 4.0 feet, and freeboard of 1.0 foot. Its slope would be approximately 4.0 feet per mile, and the velocity would be about 4.2 feet per second. Releases of water for use in Browns Valley could be made along the conduit and at its terminus.

From the terminus, about one mile northeast of Loma Rica, water for the Northeast Zone would be released to flow southerly in a tributary of Little Dry Creek for about 6,000 feet, and then would be diverted by temporary earthen works into a short unlined canal leading westerly and discharging into an unnamed tributary of Prairie Creek. The water would flow in Prairie Creek and its tributary a distance of about six miles to the point of diversion for the Northeast Zone. This diversion site and the route of the conduit to serve the Northeast Zone were surveyed during the course of the investigation. The diversion works would consist merely of a temporary earthen structure, replaced each season. The conduit from the diversion to the Northeast Zone would bear in a general southerly direction a distance of approximately 6.3 miles, terminating in a tributary of Nigger Jack Slough. It would be an unlined canal, having capacities of 75 second-feet at the diversion point and 25 second-feet at the terminus. At the diversion point the canal would have a trapezoidal section with 2:1 side slopes, bottom width of 4.0 feet,

TABLE 43

GENERAL FEATURES OF SOUTH HONCUT CREEK PROJECT

Earthfill Dam
- Crest elevation—910 feet
- Crest length—670 feet
- Crest width—30 feet
- Height, spillway lip above stream bed—168 feet
- Side slopes—2.5:1
- Freeboard, above spillway lip—12 feet
- Elevation of stream bed—730 feet
- Volume of fill—919,000 cubic yards

Reservoir
- Surface area at spillway lip—720 acres
- Capacity at spillway lip—38,000 acre-feet
- Drainage area
  - Honcut Creek—24 square miles
  - French Dry Creek—22 square miles
- Estimated mean seasonal runoff
  - Honcut Creek—23,400 acre-feet
  - French Dry Creek—27,100 acre-feet
- Estimated mean seasonal diversion from French Dry Creek—22,000 acre-feet
- Estimated safe seasonal yield—24,300 acre-feet
- Type of spillway—Side channel, concrete-lined
- Spillway capacity—10,000 second-feet
- Type of outlet—42-inch diameter steel pipe beneath dam

Diversion Works
- French Dry Creek—Concrete gravity weir, with ogee overpour section, 55 feet in length, and 7 feet high above stream bed elevation of about 2,125 feet; side channel diversion box, with overpour parapet wall, and 5- by 4-foot slide sluice gate; two 5- by 4-foot slide headgates in concrete headwall.
- South Honcut Creek—Concrete gravity weir, with ogee overpour section, 84 feet in length, and 9 feet high above stream bed elevation of 600 feet; side channel diversion box, with overpour parapet wall, and 5- by 4-foot slide sluice gate; two 5- by 4-foot slide headgates in concrete headwall.
- Prairie Creek—Temporary earthen structure, at stream bed elevation of 135 feet.

Conduits

	French Dry Creek Diversion	South Honcut Creek Diversion	Prairie Creek Diversion
Type	Trapezoidal, shotcrete-lined canal	Trapezoidal, shotcrete-lined canal, and 1,500 feet of 5.5-foot diameter steel pipe siphon	Trapezoidal, unlined canal
Length, in miles	2.0	4.7	6.3
Side slopes	1:1	1:1	2:1
Bottom width, in feet	4.0	4.0	1.0 (maximum)
Depth, in feet	4.0	5.0	3.7 (maximum)
Freeboard, in feet	1.0	1.0	1.0
Slope, in feet per mile	7.0	4.0	2.5
Velocity, in feet per second	6.3	4.2	1.7
Capacity, in second-feet	200	150	75 to 25

depth of 3.7 feet, and freeboard of 1.0 foot. Its slope would be approximately 2.5 feet per mile, and the velocity would be about 1.7 feet per second.

Cost estimates for the canals to convey water to the service areas in Browns Valley and the Northeast Zone were based on designs utilizing data obtained by reconnaissance field location surveys. Detailed design of the distribution systems in Browns Valley and the Northeast Zone, however, was considered to be outside the scope of the current investigation. Cost estimates for the systems were based on known costs of similar irrigation works elsewhere in California, adjusted to correspond with conditions prevailing in the Sutter-Yuba Area.

Pertinent data with respect to the general features of the South Honcut Creek Project, as designed for cost estimating purposes, are presented in Table 43.

The capital cost of the South Honcut Creek Project, based on prices prevailing in April, 1952, was estimated to be about $3,009,600. Corresponding annual costs of the South Honcut Creek Project were estimated to be about $154,200. The resultant estimated average unit cost of the 24,300 acre-feet of water per season conserved by South Honcut Creek Reservoir was about $6.40 per acre-foot. The estimated unit costs of water applied for irrigation in the Northeast Zone and in the Browns Valley service area were about $9.70 and $8.40 per acre-foot, respectively.

Estimated capital and annual costs of the South Honcut Creek Project are summarized in the following tabulation. Detailed cost estimates are presented in Appendix H.

	Estimated costs	
	Capital	*Annual*
Dam and reservoir	$2,225,600	$94,400
French Dry Creek diversion and conduit	151,100	8,100
South Honcut Creek diversion and conduit	379,100	20,500
Prairie Creek diversion and conduit	131,300	7,100
Browns Valley distribution system	65,000	14,400
Northeast Zone distribution system	57,500	9,700
TOTALS	$3,009,600	$154,200

East Central Zone

In Chapter III it was shown that the present requirement for supplemental water in the East Central Zone is about 28,000 acre-feet per season. However, in the design of projects for initial local development to meet this requirement, it was considered desirable to provide some capacity for future growth in water demand which would occur through development of irrigable lands not presently irrigated. This additional capacity was estimated at about 12,000 acre-feet per season, giving consideration to the extent of undeveloped irrigable lands that might readily be served, and to the available sources of water supply. For reasons hereinafter discussed it was considered that the new water supply would be applied to about 8,500 acres in the East Central Zone, of which about 3,300 acres are presently irrigated by ground water and 5,200 acres are irrigable lands not presently served with water. These lands are contained within a service area lying generally south of Hutchinson Creek and east of the Western Pacific Railroad, and delineated on Plate 22, "Camp Far West Project."

Four possible alternative plans of works for initial construction to provide supplemental water to the East Central Zone were considered. For reasons hereinafter mentioned, after preliminary investigation and study the first three plans were given no further consideration for present cost estimating purposes, but may warrant future study. The fourth plan is described in some detail in this section.

Alternative Plans Considered. The first of the alternative plans considered for initial construction involved the substitution of surface water from the Yuba River to replace ground water presently utilized in an area in the East Central Zone. The substitute supply would be diverted at a point on the Yuba River about four miles upstream from Daguerre Point by means of existing headworks of the Yuba River Ditch, owned by the Yuba Consolidated Gold Fields. The Yuba River Ditch, an abandoned canal some four miles in length, with a designed capacity of approximately 115 second-feet, would be rehabilitated and extended in a southerly direction to Hutchinson Creek. Use of the new surface water supply would prevent progressive and permanent lowering of ground water levels in the area served and in adjacent areas. During study of the plan it was determined that surplus flows are available in the Yuba River at the proposed point of diversion during the snowmelt period and into summer months in all but the driest years. However, during the peak of the irrigation season in many years, flows at the diversion point are no more than adequate to maintain the required downstream diversion at Daguerre Point for the Cordua and Hallwood systems. Until such time as additional upstream conservation storage and regulation of flood flows of the Yuba River are accomplished, excessive irrigation deficiencies would be experienced under this plan. For this reason the plan was given no further present consideration for initial construction.

The second of the alternative plans considered for initial construction would include the construction of a dam and reservoir at the Waldo site on Dry Creek, facilities for release of the conserved waters from the reservoir, and facilities for their downstream diversion, conveyance, and distribution in the East Central Zone. Preliminary studies indicated that this plan would not provide sufficient yield to meet the present requirement for supplemental water in the East Central Zone, and that the unit cost of the conserved water would be greater than the corresponding unit cost with the fourth plan described in this section. For these reasons the plan was given no further present consideration. Studies were also made of a plan which included a



Existing Camp Far West Dam and Reservoir

larger dam and reservoir at the Waldo site, together with facilities for diversion of flood waters of Yuba River to the larger reservoir. Yield studies and preliminary cost estimates indicated that this plan should probably be deferred for future development. It was indicated that only a portion of the yield of the enlarged project could be readily utilized in the Sutter-Yuba Area at the present time. The capital cost of the larger project would be more than twice that of the fourth plan for initial construction described in this section. Costs of developed water would be excessive until such time as the major portion of the yield could be put to beneficial use. For these reasons this plan was given no further present consideration for initial construction.

The third of the alternative plans considered for initial construction involved the possible purchase of water from the Nevada Irrigation District and conveyance to places of use in the natural channel of Dry Creek. Preliminary studies indicated that additional water could be supplied to the East Central Zone by development and extension of existing facilities of the district, including the China and Tarr Ditches. As in the case of the first plan described, use of the new surface supply would prevent progressive and permanent lowering of ground water levels in the area served and in adjacent areas. The amount of water that might be made available to the East Central Zone would depend upon construction and enlargement of works of the Nevada Irrigation District, and, in turn, upon the outcome of possible negotiations between the district and an agency representing interests of the Northeast Zone. For these reasons, features of the plan were not surveyed and studied in detail, nor estimates of cost prepared.

The fourth plan considered for initial construction would provide for the present supplemental water requirement in the East Central Zone and for growth in water utilization for a number of years in the future. In addition, it would provide corresponding benefits to the South Side Zone. The plan would include the construction of a larger dam and reservoir on the Bear River at the site of the existing Camp Far West Dam and Reservoir, and facilities for conveyance of the conserved water to and its distribution in both the East Central and South Side Zones. Use of the new surface water supply would prevent progressive and permanent lowering of ground water levels in the areas served and in adjacent areas. This plan is hereinafter referred to as the "Camp Far West Project," and its principal features are delineated on Plate 22.

Camp Far West Project. The proposed dam would be an earthfill structure with chute spillway, located on the Bear River, in Section 21, Township 14 North, Range 6 East, M. D. B. & M., some 16 miles upstream from the confluence with the Feather River, and 6.6 miles upstream from Highway 99E. Stream bed elevation at the site is 145 feet. The proposed dam would be superimposed upon an existing curved concrete gravity dam, 62 feet in height from stream bed to dam crest, which creates a reservoir of about 5,000 acre-foot capacity, and is owned by the Camp Far West Irrigation District. Flood waters of the Bear River conserved by the proposed reservoir would be released at an elevation of approximately 180 feet to canals serving the East Central and South Side Zones, respectively. The lands which would be served by the new water supply comprise the aforementioned 8,500 acres in the East Central Zone, and an additional 8,500 acres in the South Side Zone, in the respective service areas shown on Plate 22. Both service areas range in elevation from about 150 feet along their eastern boundaries to about 50 feet on the west.

In Chapter III it was estimated that the present requirement for supplemental water in the East Central Zone is about 28,000 acre-feet per season and in the South Side Zone an additional 28,000 acre-feet, a total of about 56,000 acre-feet per season. In the design of the Camp Far West Project for cost estimating purposes, it was considered necessary to provide about 10,000 acre-feet of water per season for the Camp Far West Irrigation District to replace yield of the existing reservoir. Based upon the area of lands irrigated by the district, this estimate is believed to be adequate. As has been stated, it was also considered desirable to provide some capacity for future growth in demand on the project, which would occur through development of irrigable lands not presently irrigated.

As a first step in determination of size of the project, estimates were made of yield of the proposed works for various storage capacities. It was estimated that mean seasonal runoff of the Bear River, from the approximately 280 square miles above the dam site, was 347,000 acre-feet. Based upon records and estimates of runoff during the critical dry period which occurred in the Sacramento Valley from 1920-21 through 1934-35, yield studies were made for three sizes of reservoirs at the Camp Far West site. It was assumed that a seasonal irrigation deficiency up to 35 percent could be endured in one season of the period. A summary of results of the yield studies is presented in Table 44.

TABLE 44

ESTIMATED SAFE SEASONAL YIELD OF CAMP FAR WEST RESERVOIR, BASED ON CRITICAL DRY PERIOD FROM 1920-21 THROUGH 1934-35

(In acre-feet)

Reservoir storage capacity	Safe seasonal yield
55,000	55,000
104,000	90,000
151,000	122,000

After consideration of the results of the yield studies, together with topography of the dam site and cost analyses hereinafter discussed, a reservoir of 104,000 acre-foot storage capacity, with estimated safe seasonal yield of 90,000 acre-feet was chosen for purposes of cost estimates to be presented in this report. The yield study for this size of reservoir is included in Appendix G.

For cost estimating purposes a tentative distribution of yield of the proposed Camp Far West Reservoir was made. Of the estimated 90,000 acre-feet of safe seasonal yield, 10,000 acre-feet per season was assigned to the Camp Far West Irrigation District. The remaining yield was divided equally between the East Central and South Side Zones, in the amount of 40,000 acre-feet per season to each zone.

Since the East Central Zone constitutes a free ground water area, water losses in the proposed canal and ditch system would largely percolate to the ground water. For this reason it was assumed that these losses, plus the unconsumed portion of the new water supply applied to irrigation would be effective in preventing progressive and permanent lowering of ground water levels. It was estimated that losses in conveyance and distribution of the 40,000 acre-feet of safe seasonal yield assigned to the East Central Zone would be about 25 percent, leaving some 30,000 acre-feet per season for application to irrigation. It was also assumed that water imported to the East Central Zone would be used largely on irrigated pasture, and that the average seasonal application of the new water would be 3.5 acre-feet per acre. On this basis it was estimated that the imported supply would be applied to some 8,500 acres in a service area lying generally south of Hutchinson Creek and east of the Western Pacific Railroad. Of the lands which would be served with the new water supply, about 3,300 acres are presently irrigated by ground water and about 5,200 acres are irrigable lands not presently irrigated.

An estimate of the monthly distribution of demand for irrigation water in the Sutter-Yuba Area was presented in Table 33. Based on these data, monthly demands on the Camp Far West Project would be as shown in Table 45.

A topographic survey of the Camp Far West reservoir site up to an elevation of 225 feet was made by the Camp Far West Irrigation District in 1922. This survey was extended to an elevation of 320 feet by the Division of Water Resources in 1930, and a map was drawn from both surveys at a scale of 1 inch equals 500 feet, with a contour interval of 10 feet. Storage capacities of the Camp Far West Reservoir at various stages of water surface elevation are given in Table 46.

Based upon preliminary geological reconnaissance, the Camp Far West dam site is considered suitable for an earthfill dam of any height up to a maximum of 180 feet. Bedrock at the site consists of a slightly

TABLE 45

ESTIMATED MONTHLY DISTRIBUTION OF DEMAND FOR WATER FROM CAMP FAR WEST PROJECT

Month	Percent of seasonal total	Gross release to Camp Far West Irrigation District, in acre-feet	Gross import to East Central Zone, in acre-feet	Gross import to South Side Zone, in acre-feet
April	10	1,000	4,000	4,000
May	16	1,600	6,400	6,400
June	17	1,700	6,800	6,800
July	22	2,200	8,800	8,800
August	17	1,700	6,800	6,800
September	11	1,100	4,400	4,400
October	5	500	2,000	2,000
November	2	200	800	800
TOTALS	100	10,000	40,000	40,000

TABLE 46

AREAS AND CAPACITIES OF CAMP FAR WEST RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	145	0	0
25	170	100	1,400
45	190	180	4,200
65	210	380	9,800
85	230	600	19,400
105	250	890	34,200
125	270	1,260	55,500
145	290	1,750	85,600
155	300	2,020	104,400
165	310	2,330	126,100
175	320	2,620	151,000

porphyritic, compact, and massive dark greenstone with gradations into coarse-grained phutonic rock. A complex joint system exists in this vicinity with joint cracks opened a few inches on the surface by weathering. The joints probably do not persist to appreciable depths other than as hairline cracks in the rock. However, some moderate grouting would be necessary. Shears are not abundant in the bedrock, and no serpentine was found locally. While slopes up to an elevation of about 160 feet above stream bed on

both abutments consist essentially of barren bedrock with scattered patches of overlying soil, the abutment slopes above 100 feet show only occasional bedrock outcrops with a much heavier mantle of overburden. Stripping under the impervious section of an earthfill type of dam at this site should not exceed four feet of depth of loose material up to 100 feet above stream bed on both abutments, and eight feet of depth above 100 feet on the abutments. Topographic considerations indicate that the spillway should be located across the ridge forming the right abutment of the dam, utilizing a natural saddle and drainage channel.

The material stripped from the foundation and abutments and excavated from the spillway should prove largely recoverable for construction use as pervious fill, rockfill, or riprap. Deposits of dredger tailings about two miles downstream from the dam, as well as sands and gravels accumulated in the existing reservoir, could be used as pervious fill material for the proposed dam. Soil suitable for use in the construction of an impervious embankment is available in limited quantities within a radius of about two miles from the dam. Although the depth of this material is probably not great, it is believed that enough could be obtained from several sources to provide for a minimum impervious earth section.

As a result of yield studies, geologic reconnaissance, and preliminary economic analysis, an earthfill dam, 155 feet in height from stream bed to spillway lip, and with a crest elevation of 311 feet, was selected to illustrate estimates of costs of the Camp Far West Project. The dam would have a crest length of about 2,980 feet and a crest width of 30 feet, and 3 :1 upstream and 2.5 :1 downstream slopes. The central impervious core would have a top width of 10 feet and 0.8 :1 slopes. The outer pervious zones of the dam would consist of stream bed gravels, dredger tailings, and salvaged material from stripping and excavation. A 3-foot blanket of gravel riprap would protect the upstream face of the dam. The volume of the fill would be an estimated 2,070,000 cubic yards. The spillway would be of the chute type, located across the ridge forming the right abutment, and concrete-lined. The maximum depth of water above the spillway lip would be 7 feet, and an additional 4 feet of freeboard would be provided. The spillway would have a capacity of 60,000 second-feet, required for an assumed discharge of 215 second-feet per square mile of drainage area. The spillway would discharge into a draw that joins the Bear River about 900 feet downstream from the toe of the dam. The outlet works would include a horseshoe type tunnel, 10 feet in diameter and 880 feet in length, excavated through the left abutment and concrete-lined. The tunnel would be used to divert flow of the Bear River during the construction period. After completion of the dam a concrete plug would be placed in the tunnel at the axis of the dam, and a 5- by 5-foot high pressure slide gate would be installed to control releases from the reservoir. A 66-inch diameter steel pipe, with capacity of 440 second-feet, would convey the water through the tunnel and terminate in a 60-inch diameter needle valve at a location about 250 feet downstream from the tunnel portal. This needle valve would discharge into a concrete-lined stilling basin, from which water would enter a concrete-lined canal at an elevation of 187 feet. Another needle valve, of 36-inch diameter, would be installed in the steel outlet pipe just outside of the tunnel portal, and would discharge directly into the Bear River.

The canal from the stilling basin would be of trapezoidal section, with 1 :1 side slopes, bottom width of 7.0 feet, depth of 6.0 feet, and freeboard of 1.0 foot. Its slope would be about 2.5 feet per mile, its velocity about 5.1 feet per second, and its capacity 400 second-feet. The canal would extend along the left bank of the Bear River a distance of about 8,000 feet, terminating in a concrete division box at an elevation of 183 feet. From this structure a steel pipe siphon, 66 inches in diameter and about 800 feet in length, with capacity of 200 second-feet, would convey water across the Bear River, discharging into a canal to serve the East Central Zone. The division box would also contain an outlet to a canal to serve the South Side Zone, and another outlet to a wasteway emptying into the Bear River.

The canals to serve both the East Central and South Side Zones would have capacities at their intakes of 200 second-feet. The canal to serve the East Central Zone would extend from the siphon outlet in a northwesterly direction a distance of approximately 3.6 miles, where about one-half of the water would be discharged into the channel of South Dry Creek to be diverted by downstream users. The remaining water would be carried a distance of about 0.8 mile and discharged into the channel of North Dry Creek for similar downstream rediversion. For an initial distance of about 3,500 feet from the Bear River siphon the canal would be shotcrete-lined and of trapezoidal section, with 1 :1 side slopes, bottom width of 6.0 feet, depth of 4.5 feet, and freeboard of 1.0 foot. The slope would be about 2.5 feet per mile, and the velocity about 4.3 feet per second. For the remainder of the distance to South Dry Creek the canal would be unlined and of trapezoidal section, with 2 :1 side slopes, bottom width of 8.0 feet, depth of 5.0 feet, and freeboard of 1.0 foot. The slope would be about 2.5 feet per mile, and the velocity about 2.2 feet per second. From South Dry Creek to North Dry Creek the canal would be unlined and of trapezoidal section, with 2 :1 side slopes, bottom width of 7.0 feet, depth of 3.7 feet, and freeboard of 1.0 foot. The slope would be about 2.5 feet per mile, and the velocity about 1.9 feet per second. Capacity of this portion of the canal would be 100 second-feet.

The canal to serve the South Side Zone would extend from the division box in a southerly direction a distance

of approximately 10.0 miles to Coon Creek, where about one-half of the flow would be discharged for rediversion by downstream users. The remaining water would be carried in a canal with capacity reduced to 100 second-feet, a distance of about 5.5 miles in a general southerly direction, where it would be similarly discharged into and conveyed in the natural channel of Markham Ravine for a distance of about 1.1 miles. The conserved water would be diverted from Markham Ravine by a flashboard dam and conveyed in a canal for a distance of about 1.2 miles where it would be discharged into Auburn Ravine for rediversion by downstream users. For an initial distance of about 1.0 mile from the division box the canal would be shotcrete-lined and of trapezoidal section, with 1:1 side slopes, bottom width of 6.0 feet, depth of 4.5 feet, and freeboard of 1.0 foot. The slope would be about 2.5 feet per mile, and the velocity about 4.3 feet per second. For the remainder of the distance to Coon Creek the canal would be unlined. It would be of trapezoidal section, with 2:1 side slopes, bottom width of 8.0 feet, depth of 5.0 feet, and freeboard of 1.0 foot. Its slope would be about 2.5 feet per mile, and its velocity about 2.2 feet per second. From Coon Creek to Auburn Ravine the constructed canal would be unlined and of trapezoidal section, with 2:1 side slopes, bottom width of 7.0 feet, depth of 3.7 feet, and freeboard of 1.0 foot. Its slopes would be about 2.5 feet per mile, and its velocity about 1.9 feet per second.

TABLE 47

GENERAL FEATURES OF CAMP FAR WEST PROJECT

Earthfill Dam
- Crest elevation—311 feet
- Crest length—2,980 feet
- Crest width—30 feet
- Height, spillway lip above stream bed—155 feet
- Side slopes—3:1 upstream; 2.5:1 downstream
- Freeboard, above spillway lip—11 feet
- Elevation of stream bed—145 feet
- Volume of fill—2,070,000 cubic yards

Reservoir
- Surface area at spillway lip—2,020 acres
- Capacity at spillway lip—104,000 acre-feet
- Drainage area—280 square miles
- Estimated mean seasonal runoff—347,000 acre-feet
- Estimated safe seasonal yield—80,000 acre-feet
- Type of spillway—Chute, concrete-lined
- Spillway capacity—60,000 second-feet
- Type of outlet—10-foot diameter pressure tunnel and 66-inch diameter steel pipe through left abutment

Conduits

	Outlet	Bear River Canal	Bear River Siphon	East Central Zone Conduit			South Side Zone Conduit		
Type	66-inch diameter steel pipe	Trapezoidal, concrete-lined	66-inch diameter	Trapezoidal			Trapezoidal		
				Lined section	Unlined section		Lined section	Unlined section	
Length, in miles	0.21	1.5	0.15	0.7	2.9	0.8	1.0	10.0	6.7
Side slopes		1:1		1:1	2:1	2:1	1:1	1:1	2:1
Bottom width, in feet		7.0		6.0	8.0	7.0	6.0	8.0	7.0
Depth, in feet		6.0		4.5	5.0	3.7	4.5	5.0	3.7
Freeboard, in feet		1.0		1.0	1.0	1.0	1.0	1.0	1.0
Slope, in feet per mile		2.5		2.5	2.5	2.5	2.5	2.5	2.5
Velocity, in feet per second	18.5	5.1	8.4	4.3	2.2	1.9	4.3	2.2	1.9
Capacity, in second-feet	440	100	200	200	200	100	200	200	100

Cost estimates for the canals to convey water to the service areas in the East Central and South Side Zones were based on designs utilizing data obtained by field location surveys. Detailed design of the distribution systems in the East Central and South Side Zones, however, was considered to be outside the scope of the current investigation. Cost estimates for the distribution systems were based on known costs of similar irrigation works elsewhere in California, adjusted to correspond with conditions prevailing in the Sutter-Yuba Area.

Pertinent data with respect to general features of the Camp Far West Project, as designed for cost estimating purposes, are presented in Table 47.

The capital cost of the Camp Far West Project, based on prices prevailing in April, 1952, was estimated to be about $5,592,900. The corresponding annual costs of the Camp Far West Project were estimated to be about $299,600. The resultant estimated unit cost of the 80,000 acre-feet per season of new water conserved by the Camp Far West Reservoir was about $3.70 per acre-foot. The estimated unit cost of water applied for irrigation in the East Central Zone was about $4.70 per acre-foot, and the estimate for water applied for irrigation in the South Side Zone was about $5.30 per acre-foot.

Estimated capital and annual costs of the Camp Far West Project are summarized in the following tabulation. Detailed cost estimates are presented in Appendix H.

	Estimated costs	
	Capital	*Annual*
Dam and reservoir	$3,979,900	$170,000
Bear River canal	233,000	12,600
East Central Zone canal and siphon	286,600	15,400
South Side Zone canal	668,400	36,000
East Central Zone distribution system	212,500	32,800
South Side Zone distribution system	212,500	32,800
TOTALS	$5,592,900	$299,600

South Side Zone

Three possible alternative plans of works for initial construction to provide supplemental water to the South Side Zone were considered. The first of these plans was the Camp Far West Project, which, as described in the preceding section, would provide supplemental water for both the East Central and South Side Zones. The second of the alternative plans con-

sidered for initial construction involved the possible purchase of water from the Nevada Irrigation District and conveyance to places of use in the natural channels of Coon Creek and Auburn Ravine. The amount of water that might be made available to the South Side Zone would depend upon design and construction of additional works of the Nevada Irrigation District, and in turn upon the outcome of possible negotiations between the district and an agency representing interests of the South Side Zone. For these reasons, features of the plan were not surveyed and studied in detail, nor estimates of cost prepared.

The third of the plans involved the construction of a dam and reservoir on Coon Creek, at a site approximately seven miles northeast of Lincoln, the utilization of an existing diversion works and ditch to convey flood flows of the Bear River to the reservoir, the reconstruction of existing abandoned facilities for diversion of the conserved waters from Coon Creek below the dam, and the construction of facilities for conveyance of the waters to and their distribution in the South Side Zone. This plan is hereinafter referred to as the "Coon Creek Project," and its principal features are delineated on Plate 23, "Coon Creek Project."

Under each of the alternative plans use of the new surface water supplies would prevent progressive and permanent lowering of ground water levels in the areas served and in adjacent areas. Each plan would provide for the present supplemental water requirement of the South Side Zone and for growth in water utilization for a number of years in the future.

Camp Far West Project. In the earlier description of the Camp Far West Project a reservoir of 104,000 acre-foot capacity, with estimated safe seasonal yield of 90,000 acre-feet, was chosen at the Camp Far West site on the Bear River for cost estimating purposes. A tentative distribution of this yield was made that would provide 40,000 acre-feet per season to the South Side Zone, some 12,000 acre-feet per season greater than the present requirement for supplemental water in the zone, which was estimated in Chapter III to be about 28,000 acre-feet per season. The 12,000 acre-feet per season of indicated present surplus yield was assigned to irrigation of irrigable lands not now served with water.

Since the South Side Zone constitutes a free ground water area, water losses in the proposed conveyance and distribution system for the new water supply would largely percolate to the ground water. For this reason it was assumed that these losses, plus the unconsumed portion of the new water supply applied to irrigation, would be effective in preventing progressive and permanent lowering of ground water levels. It was assumed that losses in conveyance and distribution of the 40,000 acre-feet per season of safe seasonal yield assigned to the South Side Zone would be about 25 percent, leaving some 30,000 acre-feet per season for application to irrigation. It was also assumed that water imported to the South Side Zone would largely be used on irrigated pasture and that the average seasonal application of the new water would be 3.5 acre-feet per acre. On this basis it was estimated that the imported supply would be applied to some 8,500 acres in a service area lying generally adjacent to Coon Creek and Auburn Ravine and easterly of the boundaries of Reclamation Districts 1000 and 1001. Elevation of this service area ranges from about 150 feet along the eastern boundary to about 50 feet on the west. Of the lands which would be served with the new water supply, about 3,300 acres are presently irrigated by ground water, and 5,200 acres are irrigable lands not presently irrigated. An estimate of monthly distribution of demand for the 40,000 acre-feet of gross seasonal import to the South Side Zone from the Camp Far West Project was presented in Table 45.

As described in the preceding section, direct releases would be made from Camp Far West Reservoir to the intake of a canal to serve the South Side Zone. The intake would be at a concrete division box, located on the left bank of the Bear River, about 1.5 miles downstream from Camp Far West Dam, at an elevation of 183 feet. From the intake the canal, with capacity of 200 second-feet, would extend in a southerly direction approximately 10.0 miles to Coon Creek. At this point about one-half of the flow would be discharged into Coon Creek for rediversion by downstream users. The remaining water would be carried in a general southerly direction an additional 5.5 miles, in a canal with capacity reduced to 100 second-feet, where it would be similarly discharged into and conveyed in the natural channel of Markham Ravine for a distance of about 1.1 miles. The conserved water would be diverted from Markham Ravine by a flashboard dam and conveyed in a canal for a distance of about 1.2 miles where it would be discharged into Auburn Ravine for rediversion by downstream users. Additional pertinent data with respect to general features of the Camp Far West Project, as designed for cost estimating purposes, were presented in Table 47.

The cost estimate for the canal to convey water to the South Side Zone was based on designs utilizing data obtained by field location surveys. Detailed design of the distribution system for the South Side Zone was considered to be outside the scope of the current investigation. The cost estimate for the distribution system was based on known costs of similar irrigation works elsewhere in California, adjusted to correspond with conditions prevailing in the Sutter-Yuba Area.

As stated in the preceding section, the capital cost of the Camp Far West Project, based on prices prevailing in April, 1952, was estimated to be about $5,592,900. Corresponding annual costs of the Camp Far West Project were estimated to be about $299,600. The resultant estimated unit cost of new water conserved by Camp Far West Reservoir was about $3.70 per acre-foot of safe seasonal yield. The estimated unit cost of

water applied for irrigation in the South Side Zone was about $5.30 per acre-foot, and the estimate for water applied for irrigation in the East Central Zone was about $4.70 per acre-foot. Detailed cost estimates for the Camp Far West Project are presented in Appendix H.

Coon Creek Project. The proposed Coon Creek Dam would be an earthfill structure, with two earthen auxiliary saddle dikes and a chute spillway. It would be located in Sections 8 and 17, Township 13 North, Range 6 East, M.B.D. & M., at a site on Coon Creek some 7.5 miles northeast of Lincoln and 8.3 miles upstream from Highway 99E. Stream bed elevation at this site is 345 feet. For cost estimating purposes, it was assumed that flood waters of the Bear River would be diverted by existing works, conveyed in the existing Upper Gold Hill and Combie-Ophir Canals for a distance of about 2.4 miles, and discharged into a tributary of Coon Creek above the proposed reservoir. These diversion works and the canals belong to the Nevada Irrigation District. The conserved waters of both Coon Creek and Bear River, after release from the proposed reservoir, would flow down Coon Creek for a distance of approximately six miles to an existing abandoned diversion structure. At this point about one-half of the released water would be diverted into a canal, and conveyed in a general southerly direction for a distance of some 5.5 miles where it would be discharged into and conveyed in the natural channel of Markham Ravine for a distance of about 1.1 miles. The conserved water would be diverted from Markham Ravine by a flashboard dam and conveyed in a canal for a distance of about 1.2 miles where it would be discharged into Auburn Ravine. The new water supply would be available in the natural channels of Coon Creek and Markham and Auburn Ravines for downstream diversion and use.

The lands which would be served by the new water supply comprise some 12,000 acres in a service area lying generally adjacent to Coon Creek and Auburn Ravine and easterly of the boundaries of Reclamation Districts 1000 and 1001. A portion of this service area, shown on Plate 23, is in Placer County and outside of the Sutter-Yuba Area. For reasons hereinafter discussed, it was assumed that water yielded by the Coon Creek Project would be entirely applied to irrigable lands not presently served with water. Use of the new surface water supply would prevent progressive and permanent lowering of ground water levels in the area served and in adjacent areas in the South Side Zone.

In Chapter III it was estimated that the present requirement for supplemental water in the South Side Zone is about 28,000 acre-feet per season. However, in design of projects for initial local development to meet this requirement, it was considered desirable to provide some capacity for future growth in water demand which would occur through development of irrigable lands not presently irrigated. In the case of the Camp Far West Project, described in the preceding section, this additional capacity was estimated to be 12,000 acre-feet per season. However, in connection with the Coon Creek Project, giving consideration to the extent of undeveloped irrigable lands that might readily be served, and to the available source of water supply, the corresponding additional capacity was estimated to be 28,000 acre-feet per season.

As a first step in determination of the size of the Coon Creek Project, estimates were made of yield of the proposed works for various reservoir storage capacities. It was estimated that mean seasonal runoff of Coon Creek, from the approximately 40 square miles of watershed above the dam site, was about 32,800 acre-feet. Of the Bear River waters, studies indicated that flood flows in an estimated mean seasonal amount of about 35,700 acre-feet could be diverted to the proposed Coon Creek Reservoir, through the existing Combie-Ophir Canal of about 106 second-foot capacity, during the months of November through April.

Based on records and estimates of runoff during the critical dry period which occurred in the Sacramento Valley from 1920-21 through 1934-35, yield studies were made of two sizes of reservoir at the Coon Creek site. The limited number of yield studies was largely determined by topographic considerations. It was assumed that a seasonal irrigation deficiency up to 35 percent could be endured in one season of the period. Monthly demands on the reservoir were assumed to be proportional to the estimated distribution of irrigation demands in the Sutter-Yuba Area, as presented in Table 33. A summary of the results of the yield studies is presented in Table 48.

TABLE 48

ESTIMATED SAFE SEASONAL YIELD OF COON CREEK RESERVOIR WITH BEAR RIVER DIVERSION, BASED ON CRITICAL DRY PERIOD FROM 1920-21 THROUGH 1934-35

(In acre-feet)

Reservoir storage capacity	Safe seasonal yield
25,500	34,000
59,000	56,000

After consideration of the results of the yield studies, together with topography of the dam site and cost analyses hereinafter discussed, a reservoir of 59,000 acre-foot capacity with estimated safe seasonal yield of 56,000 acre-feet was chosen for purposes of cost estimates to be presented in this report. The yield study for this size of reservoir is included in Appendix G.

Since the considered service area constitutes a free ground water area, water losses in the proposed canal

and ditch system would largely percolate to the ground water. For this reason it was assumed that these losses, plus the unconsumed portion of the new water supply applied to irrigation, would be effective in preventing progressive and permanent lowering of ground water levels in the area served and in adjacent areas in the South Side Zone.

It was assumed that seasonal losses in conveyance and distribution of the 56,000 acre-feet of safe seasonal yield would be about 25 percent, or 14,000 acre-feet, leaving some 42,000 acre-feet for application to irrigation. It was also assumed that the new water supply from the Coon Creek Project would largely be used on irrigated pasture, and that the average seasonal application of water would be 3.5 acre-feet per acre. On this basis it was estimated that the imported supply would be applied to some 12,000 acres in a service area lying generally adjacent to Coon Creek and Auburn Ravine and easterly of the boundaries of Reclamation Districts 1000 and 1001. Of the assumed average seasonal application of 3.5 acre-feet per acre, it was estimated that seasonal consumptive use would be about 2.3 acre-feet per acre, and that about 1.2 acre-feet per acre would be unconsumed. This unconsumed portion would aggregate about 14,400 acre-feet per season for the 12,000 acres which would be irrigated.

From the foregoing it was estimated that losses in conveyance and distribution of the new water supply, plus the unconsumed portion of the water actually applied to irrigation, both of which would largely percolate to ground water, would total about 28,400 acre-feet per season. Since the estimated present seasonal water requirement to prevent progressive and permanent lowering of ground water levels in the South Side Zone is about 28,000 acre-feet per season, no substitute water supply would have to be furnished lands presently irrigated by ground water in order to prevent such lowering. It was assumed, therefore, that lands to which the water supply from the Coon Creek Project would be applied would consist entirely of irrigable lands not presently served with water. In this connection, certain irrigable but unirrigated lands in Placer County lying immediately adjacent to the South Side Zone could readily and logically be served with water from the Coon Creek Project. For this reason the water service area shown on Plate 23 was extended outside the South Side Zone to include these lands.

An estimate of the monthly distribution of demand for irrigation water in the Sutter-Yuba Area was presented in Table 33. Based on these data, monthly demands on the Coon Creek Project would be as shown in Table 49.

TABLE 49

ESTIMATED MONTHLY DISTRIBUTION OF DEMAND FOR WATER FROM COON CREEK PROJECT

Month	Percent of seasonal total	Gross release to South Side Zone, in acre-feet
April	10	5,600
May	16	9,000
June	17	9,500
July	22	12,300
August	17	9,500
September	11	6,200
October	5	2,800
November	2	1,100
TOTALS	100	56,000

A topographic map of the Coon Creek dam and reservoir sites, at a scale of 1 inch equals 425 feet, with contour interval of 20 feet, was made by the Division of Water Resources in 1951, using photogrammetric methods. Topography of the dam site was shown on the map up to an elevation of 580 feet, while topography of the reservoir site was shown up to an elevation of 500 feet. Reservoir topography above that elevation was estimated. Storage capacities of Coon Creek Reservoir at various stages of water surface elevation are given in Table 50.

TABLE 50

AREAS AND CAPACITIES OF COON CREEK RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	345	0	0
15	360	5	50
35	380	25	300
55	400	65	1,200
75	420	110	3,000
95	440	180	5,800
115	460	260	10,300
135	480	360	16,600
155	500	500	25,500
175	520	610	37,600
195	540	740	51,000
205	550	810	58,000
207	552	820	59,000
215	560	880	65,000

Based upon preliminary geological reconnaissance, the Coon Creek dam site is considered suitable for an earthfill dam of any height up to a maximum of 220 feet. Foundation rock at the site consists essentially of

amphibolite schist. In the vicinity of the site the rock varies between schistose and massive material, striking across the channel and dipping vertically. The foundation bedrock as a whole is relatively hard and unweathered where exposed in outcrops. Joints are prominently developed in several sets, with a horizontal joint set predominating. Minor faulting may be involved at this site, as evidenced by the sharp change in attitude of the joint sets of the rock slightly downstream from the tentative axis position. The trend of such a possible fault may strike obliquely upstream into the right abutment where considerable talus material exists. There are no indications of recent movement in this area.

The stream at this site has cut through the resistant rib of rock, forming a narrow gorge with steep side slopes to an elevation of about 150 feet above stream bed. A dam of the height considered for cost estimating purposes would require a dike across the saddle south of the left abutment, and two dikes across smaller saddles north and east of the right abutment. However, it is indicated that the spillway could be located across the ridge forming the right abutment of the dam, utilizing one of the saddles and eliminating the need for construction of a dike therein.

It is probable that stripping under the impervious section of an earthfill dam at the Coon Creek site would be relatively heavy, due to the jointed blocky nature of the rock. On the left abutment no removal of overburden would be required for a height of about 50 feet above stream bed, while above that height stripping of overburden, consisting of earth and loose rock, should not exceed two feet of depth. On the right abutment for a height of about 60 feet above stream bed stripping of overburden, consisting of loose talus rocks but including occasional blocks in place, should not exceed 15 feet of depth. Above that height on the right abutment stripping of overburden, consisting of loose rock and earth, should not exceed three feet of depth. Beneath the described overburden on both abutments it is anticipated that required stripping would involve the removal of blocky hard rock to a maximum of 20 feet of depth.

For an earthfill dam at this site, a large proportion of the material obtained from stripping operations could be salvaged for use in the pervious sections of the dam or as riprap. Aggregates, particularly fines, are lacking in the area and might require hauling from the vicinity of the Bear River. Soil suitable for use in the construction of an impervious core is available in only limited quantities. Deposits of residual clay overburden are scattered and thin in the vicinity. However, based on a preliminary sampling program, sufficient material is believed to be available within two to three miles of the dam site to provide for a minimum impervious earth section. Materials for the pervious sections of the dam could be obtained from salvage from stripping, and from stream bed gravels of Coon Creek and the Bear River.

As a result of yield studies, geologic reconnaissance, and preliminary economic analysis, an earthfill dam 207 feet in height from stream bed to spillway lip, and with a crest elevation of 560 feet, was selected to illustrate estimates of cost of the Coon Creek Project. The dam would consist of three earthfill structures, a main dam across Coon Creek and two auxiliary saddle dams. The main dam would have a crest length of about 1,420 feet, a crest width of 30 feet, and 3:1 upstream and 2.5:1 downstream slopes. The south saddle dam would have a crest length of about 1,450 feet and a maximum height of about 64 feet. The north saddle dam would have a crest length of about 550 feet and a maximum height of about 39 feet. Both saddle dams would have crest widths of 20 feet, and 2.5:1 upstream and downstream slopes. The central impervious cores of all dams would have top widths of 10 feet and 0.8:1 slopes, and would be blanketed with sand and gravel filters. The outer pervious zones of the dams would consist of stream bed gravels and materials salvaged from stripping and excavation. The upstream face of the main dam would be protected by a 3-foot blanket of riprap, and similar blankets 2 feet in depth would protect the upstream faces of the saddle dams. The main dam would have an estimated volume of fill of 2,201,000 cubic yards, and the estimated volume of fill of the two saddle dams would be 449,000 cubic yards.

The concrete spillway would be of the ogee weir type, located in a saddle between the main dam and the north saddle dam. It would have a capacity of 14,000 second-feet, required for an assumed discharge of 350 second-feet per square mile of drainage area, and would discharge into a tributary of Coon Creek. The maximum depth of water above the spillway lip would be 4 feet, and an additional 4 feet of freeboard would be provided. Outlet works would consist of a 48-inch diameter steel pipe placed in a trench excavated in rock beneath the dam, and encased in concrete. Releases from the reservoir would be controlled at the upstream end by two 30-inch hydraulically controlled high-pressure slide gates, located at a submerged inlet upstream from the dam, and operated by hydraulic controls from a house on the left abutment. The outlet would be controlled at the downstream end by a Howell-Bunger valve.

The proposed diversion works on Coon Creek would incorporate remaining features of an abandoned diversion structure at a site approximately 3.3 miles upstream from Highway 99E. The site was examined and surveyed during the course of the investigation. The existing works consist of a concrete gate structure with concrete abutments. An earthen dike which formerly completed stream closure of the left abutment has been destroyed. Stream bed elevation at the site is 140 feet, and the gate structure is 17 feet in height above stream

bed. The gate opening is 35 feet in width, and contains seven bays to hold flashboards, each with an opening four feet in width.

For cost estimating purposes, it was planned to utilize the old concrete gate structure by installing removable flashboards to a height of 7 feet above stream bed elevation. The earthen dike would be replaced from the left abutment of the gate structure to the natural bank of Coon Creek, a distance of about 100 feet, to complete the stream closure. This embankment would be approximately 10 feet in height, with 2:1 side slopes and a crest elevation of 150 feet. A similar dike with crest elevation of 155 feet, portions of which are already in place, would extend upstream along the low left bank of Coon Creek for a distance of approximately 1,000 feet. At a point about 50 feet upstream from the main axis of the diversion structure a concrete headwall would be placed in the left side embankment, containing a 4- by 4-foot slide gate to control releases into a proposed canal. It was estimated that spillway capacity of the existing gate structure, after removal of the flashboards, would be in excess of 2,000 second-feet. It was considered that infrequent flood flows in Coon Creek in excess of this amount would wash out the closing earth embankment, and that the embankment would have to be replaced after such floods.

The proposed canal, with a capacity of 100 second-feet, would extend from the headgate in a general southerly direction a distance of approximately 5.5 miles to Markham Ravine. The conserved water would be conveyed in the natural channel of Markham Ravine for a distance of about 1.1 miles where it would be diverted by a flashboard dam and conveyed in a canal for a distance of about 1.2 miles and discharged into Auburn Ravine. For an initial distance of about 0.5 mile from the headgate the canal would be shotcrete-lined and of trapezoidal section, with 1:1 side slopes, bottom width of 4.0 feet, depth of 4.0 feet, and freeboard of 1.0 foot. Its slope would be approximately 2.5 feet per mile, and the velocity would be about 3.5 feet per second. The remaining portion of the constructed canal would be of an unlined trapezoidal section, with 2:1 side slopes, bottom width of 7.0 feet, depth of 3.7 feet, and freeboard of 1.0 foot. Its slope would be approximately 2.5 feet per mile, and the velocity would be about 1.9 feet per second. At a distance of about 1.3 miles before reaching Markham Ravine the conduit would cross Highway 99E and the Southern Pacific Railroad. The structure to carry the water underneath the highway and railroad tracks would be a steel pipe 48 inches in diameter.

Cost estimates for the canal were based on designs utilizing data obtained by a reconnaissance field location survey. Detailed design of the distribution system, however, was considered to be outside the scope of the current investigation. Cost estimates for the system were based on known costs of similar irrigation works elsewhere in California, adjusted to correspond with conditions prevailing in the Sutter-Yuba Area.

Pertinent data with respect to general features of the Coon Creek Project, as designed for cost estimating purposes, are presented in Table 51.

TABLE 51

GENERAL FEATURES OF COON CREEK PROJECT

Main Earthfill Dam
- Crest elevation—560 feet
- Crest length—1,420 feet
- Crest width—30 feet
- Height, spillway lip above stream bed—207 feet
- Side slopes—3:1 upstream
  2.5:1 downstream
- Freeboard, above spillway lip—8 feet
- Elevation of stream bed—345 feet
- Volume of fill—2,201,000 cubic yards

Auxiliary Earthfill Dams
- South saddle dam
  - Crest length—1,450 feet
  - Crest width—20 feet
  - Side slopes—2.5:1
  - Maximum height—64 feet
- North saddle dam
  - Crest length—550 feet
  - Crest width—20 feet
  - Side slopes—2.5:1
  - Maximum height—39 feet
- Volume of fill, both dams—449,000 cubic yards

Reservoir
- Surface area at spillway lip—820 acres
- Capacity at spillway lip—59,000 acre-feet
- Drainage area, Coon Creek—40 square miles
- Estimated mean seasonal runoff, Coon Creek—32,800 acre-feet
- Estimated seasonal diversion of Bear River water through Combie-Ophir Canal—35,700 acre-feet
- Estimated safe seasonal yield—56,000 acre-feet
- Type of spillway—Ogee weir, concrete-lined
- Spillway capacity—14,000 second-feet
- Type of outlet—48-inch diameter steel pipe beneath dam

Diversion Works
- Bear River—Existing concrete gravity weir, with overpour section, approximately 300 feet in length, and approximately 15 feet high above stream bed elevation of about 1,500 feet; side channel diversion box, with overpour parapet wall and sluice gate; headgates in concrete headwall.
- Coon Creek—Existing concrete diversion structure for flashboard control, with opening 35 feet in width and 17 feet in height above stream bed elevation of 140 feet; to be rehabilitated by installation of flashboards to height of 7 feet, construction of auxiliary earthen dikes, and installation of concrete headwall and 4- by 4-foot slide headgate.

Conduits
- Bear River Diversion—Existing conduit with estimated capacity of 106 second-feet, 2.4 miles in length, comprised of concrete-lined and unlined canal sections, wooden flume, and steel pipe siphons.

Coon Creek Diversion

Type	Trapezoidal, shotcrete-lined canal	Trapezoidal, unlined canal
Length, in miles	0.5	5.0
Side slopes	1:1	2:1
Bottom width, in feet	4.0	7.0
Depth, in feet	4.0	3.7
Freeboard, in feet	1.0	1.0
Slope, in feet per mile	2.5	2.5
Velocity, in feet per second	3.5	1.9
Capacity, in second-feet	100	100

The capital cost of the Coon Creek Project, based on prices prevailing in April, 1952, was estimated to be $5,303,500. The corresponding annual cost of the Coon

Creek Project was estimated to be about $254,100. The resultant estimated average unit cost of the 56,000 acre-feet per season of new water conserved by the Coon Creek Reservoir was about $4.50 per acre-foot. The estimated unit cost of water applied for irrigation in the service area considered for cost estimating purposes was about $6.10 per acre-foot. These estimates of cost do not include possible charges for use of the existing diversion works on the Bear River and the canals of the Nevada Irrigation District. They do, however, include estimated costs for acquiring the existing abandoned diversion structure on Coon Creek below the dam.

Estimated capital and annual costs of the Coon Creek Project are summarized in the following tabulation. Detailed cost estimates are presented in Appendix H.

	Estimated costs	
	Capital	*Annual*
Dam and reservoir	$4,773,700	$196,200
Coon Creek diversion and conduit	229,800	12,300
Distribution system	300,000	45,600
TOTALS	$5,303,500	$254,100

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

As a result of field investigation, and study and analyses of available data on the water resources and water problems of the Sutter-Yuba Area, the following conclusions and recommendations are made.

CONCLUSIONS

It is concluded that:

1. The present basic water problems in the Sutter-Yuba Area are progressive and permanent lowering of ground water levels and attendant degradation of mineral quality of ground water. Elimination of these problems, prevention of their recurrence in the future, and irrigation of irrigable lands not presently served with water will require further development of available water supplies.

2. Mean seasonal depth of precipitation over the Sutter-Yuba Area is about 20.7 inches, and precipitation contributes water to the area in a mean seasonal amount of about 590,000 acre-feet.

3. The highly productive tributary watersheds of the Sierra Nevada constitute the most important source of water supply available to the Sutter-Yuba Area, and mean seasonal surface inflow of water to the area from these sources is about 6,240,000 acre-feet.

4. The ground water basin underlying the Sutter-Yuba Area functions as a natural regulatory reservoir, and at the present time about two-thirds of the lands irrigated in the area are irrigated with water pumped from this reservoir. The gross extraction of ground water in the Sutter-Yuba Area during 1948 was about 350,000 acre-feet.

5. The storage capacity of the ground water basin underlying the Sutter-Yuba Area is about 3,890,000 acre-feet between the levels of 20 and 200 feet below the ground surface.

6. Because of the continuing development and extensive use of ground water in the Sutter-Yuba Area, a substantial cone of depression exists in the ground water plane, and the average level of ground water has fallen about 10 feet since 1943. This lowering of the ground water level has resulted in increased agricultural production costs, and in saline degradation of the ground water in portions of the area.

7. Hydraulic gradients existing in the plane of ground water at the present time result in a seasonal excess of subsurface inflow over subsurface outflow from the Sutter-Yuba Area of about 180,000 acre-feet. This water is an important source of replenishment to the ground water basin.

8. Satisfactory wells with yields sufficient for irrigation purposes may be obtained in all but certain small portions of the Sutter-Yuba Area.

9. High water table lands in certain portions of the Sutter-Yuba Area served with surface water would be suitable for a wider range of crops than at present if ground water levels were held at greater depths. Furthermore, existing drainage problems in these areas would be eliminated and some salvage of water now excessively consumed would result.

10. Safe seasonal yield of the ground water basin underlying the Sutter-Yuba Area, with average maintenance of ground water levels prevailing in 1949, is about 190,000 acre-feet.

11. The surface water supplies of the Sutter-Yuba Area are of excellent mineral quality.

12. The ground water supplies of the Sutter-Yuba Area are generally of excellent to good mineral quality. However, salinity sufficient to impair use of ground water for irrigation, domestic, and many industrial uses, has been observed at scattered wells throughout the area for many years. This condition is particularly prevalent in the Peach Bowl. Saline degradation of ground water in the Sutter-Yuba Area probably results from the upward migration and diffusion of deep saline brines through permeable zones in the alluvium, and through unplugged test wells and abandoned, defective, or improperly constructed wells. This upward and lateral movement of degraded water is probably accelerated when the ground water plane is lowered by heavy irrigation pumping.

13. Due to geographic and water service considerations, the Sutter-Yuba Area is naturally divided into four principal zones. These have been designated "West Side Zone," "Northeast Zone," "East Central Zone," and "South Side Zone," and are shown on Plate 2.

14. At the present time there are approximately 150,000 acres of irrigated land in the Sutter-Yuba Area. The present distribution of the irrigated land among the several zones is as follows: West Side Zone, 66,200 acres; Northeast Zone, 20,100 acres; East Central Zone, 34,100 acres; and South Side Zone, 28,800 acres.

15. The probable ultimate cultural pattern of the Sutter-Yuba Area will include about 250,000 acres of irrigated land. The probable ultimate distribution of irrigated land among the several zones is as follows: West Side Zone, 100,000 acres; Northeast Zone, 31,000 acres; East Central Zone, 54,000 acres; and South Side

Zone, 65,000 acres. This and subsequent conclusions set forth with reference to future conditions are based upon the general assumptions that: (a) All irrigable lands in the Sutter-Yuba Area will ultimately be brought under irrigation; (b) The type of irrigated crops and irrigation practice will not alter materially; (c) There will be no significant changes in irrigation practice in adjacent areas served with surface supplies; (d) Rainfall, water supply, and climatic conditions will have annual and secular variations as in the past.

16. Of the total amount of water, including rainfall, presently utilized in the Sutter-Yuba Area, approximately 65 percent is consumed in the production of irrigated crops. Dry-farmed and fallow lands, native vegetation, and miscellaneous culture including urban areas, consume the remaining 35 percent. At the present time mean seasonal utilization of water in the area is about 820,000 acre-feet. The estimated distribution of seasonal water utilization among the several zones is as follows: West Side Zone, 311,000 acre-feet; Northeast Zone, 113,000 acre-feet; East Central Zone, 201,000 acre-feet; and South Side Zone, 194,000 acre-feet.

17. Under conditions of ultimate development the mean seasonal utilization of water will probably increase to about 1,050,000 acre-feet. The probable distribution of this use among the several zones is as follows: West Side Zone, 384,000 acre-feet; Northeast Zone, 136,000 acre-feet; East Central Zone, 256,000 acre-feet; and South Side Zone, 278,000 acre-feet.

18. The present requirement for supplemental water in the Sutter-Yuba Area, in order to prevent progressive and permanent lowering of ground water levels and attendant degradation of mineral quality of the ground water, is about 79,000 acre-feet per season. The estimated distribution of the supplemental seasonal water requirement among the several zones is as follows: West Side Zone, 17,000 acre-feet; Northeast Zone, 6,400 acre-feet; East Central Zone, 27,600 acre-feet; and South Side Zone, 27,600 acre-feet. The distribution among the zones was based on the assumption that lowering of water levels which occurred during the season of 1948-49 would have been proportionately the same had mean water supply and climatic conditions prevailed.

19. Under ultimate conditions of development the corresponding requirement for supplemental water probably will be about 315,000 acre-feet per season. The estimated distribution of ultimate mean seasonal supplemental water requirement among the several zones is as follows: West Side Zone, 90,600 acre-feet; Northeast Zone, 30,100 acre-feet; East Central Zone, 81,900 acre-feet; and South Side Zone, 112,200 acre-feet. The estimate for each zone was determined as the sum of the probable increase in water utilization and the present supplemental water requirement.

20. Major features of The California Water Plan, which is presently being formulated under direction of the State Water Resources Board, will provide supplemental water to meet the probable ultimate requirements of the Sutter-Yuba Area. The Feather River Project, an adopted feature of The California Water Plan, will provide supplemental water to meet the probable ultimate supplemental water requirements of the West Side Zone. It is feasible from an engineering standpoint to so regulate and conserve the relatively large flood flows of the Yuba and Bear Rivers and other tributaries of the Feather River as to yield firm water supplies considerably in excess of the probable ultimate supplemental water requirements of the Northeast, East Central, and South Side Zones.

21. New water sufficient to meet the present supplemental requirement of the West Side Zone, together with additional water for growth in water demand for a number of years in the future, could be furnished by construction of facilities for pumping water directly from the Feather River and for its conveyance to and distribution in the Peach Bowl. Cost estimates indicate that the average unit cost of water diverted at the river would be about $4.20 per acre-foot, and that applied to irrigation would be about $5.60 per acre-foot.

22. Preliminary studies indicate that supplemental water could be furnished the Northeast Zone from a multipurpose development of the South Fork of the Feather River and tributaries of the North Fork of the Yuba River.

23. New water sufficient to meet the present supplemental requirement of the Northeast Zone, together with additional water for growth in water demands for a number of years in the future in both the Northeast Zone and the Browns Valley service area, could be furnished by construction of a dam and reservoir on South Honcut Creek, facilities for diversion of flood waters of French Dry Creek to the reservoir, and facilities for conveyance to and distribution of the conserved waters in the Northeast Zone and the Browns Valley service area. The estimated average unit cost of the water so developed and applied to irrigation would be about $9.70 per acre-foot in the Northeast Zone, and about $8.40 per acre-foot in the Browns Valley service area.

24. Preliminary studies indicate that supplemental water could be furnished both the East Central and South Side Zones from a development involving enlargement and extension of facilities of the Nevada Irrigation District.

25. New water sufficient to meet the present supplemental requirements of the East Central and South Side Zones, together with additional water for growth in water demands for a number of years in the future, could be furnished by construction of a larger dam and reservoir on the Bear River at the site of the existing Camp Far West Dam and Reservoir, and

facilities for conveyance of the conserved water to and its distribution in both the East Central and South Side Zones. The estimated average unit cost of the water so developed and applied to irrigation would be about $4.70 per acre-foot in the East Central Zone, and about $5.30 per acre-foot in the South Side Zone.

26. New water sufficient to meet the present supplemental requirement of the South Side Zone, together with additional water for growth in water demand for a number of years in the future, could be furnished by construction of a dam and reservoir on Coon Creek, utilization of existing facilities of the Nevada Irrigation District for diversion of flood waters of the Bear River to the proposed reservoir, and facilities for conveyance to and distribution of the new water in the South Side Zone. The estimated average unit cost of the water so developed and applied to irrigation would be about $6.10 per acre-foot.

27. The unit costs of water as given in the foregoing paragraphs are based on current prices of construction, and are illustrative of the cost of new water for the various zones of the Sutter-Yuba Area developed by works exclusively for water conservation purposes. The costs exceed that of surface water presently served within the area, and it is probable that under present conditions ground water pumping costs are somewhat less than the estimated costs of water developed by the considered conservation projects. It is indicated that in order to obtain new water at lower unit costs in the Sutter-Yuba Area, multipurpose developments providing other benefits and revenues in addition to water conservation will be required.

RECOMMENDATIONS

It is recommended that:

1. Public districts endowed with appropriate powers be created for the purposes of proceeding with further study of the local water problems and with financing, construction, and operation of projects found financially feasible.

2. Local development of water resources be accomplished by an orderly progression of phases of development, and in accordance with The California Water Plan. Successive steps in proposed plans should first develop those projects with indicated lowest capital and unit cost of water, and thence proceed in order of expense to phases of greater unit cost.

3. Additional engineering investigation and study be made for design, financing, and construction of the Peach Bowl Project.

4. Additional engineering investigation and study be made as required for design, financing, and construction of other local projects for initial development outlined in this report, when the financial feasibility of these projects has been determined.

5. A program be initiated for the acquisition of lands, easements, and rights of way necessary for construction of required local water conservation works.

6. Consideration be given to the implementation of plans for securing a firm ultimate supplemental water supply for the West Side Zone from the Feather River Project.

7. Continuing support be given to the investigation and study of major multipurpose developments under The California Water Plan, including those on the Feather, Yuba, and Bear river systems.

APPENDIX A

AGREEMENT, AND ITS SUPPLEMENT, BETWEEN THE STATE WATER RESOURCES BOARD, THE COUNTIES OF SUTTER AND YUBA, AND THE DEPARTMENT OF PUBLIC WORKS

AGREEMENT BETWEEN THE STATE WATER RESOURCES BOARD, THE COUNTIES OF SUTTER AND YUBA, AND THE DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quintuplicate, entered into by the State Water Resources Board, hereinafter referred to as the "Board"; the Counties of Sutter and Yuba, hereinafter referred to as the "Counties"; and the Department of Public Works, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer."

WITNESSETH:

WHEREAS, in the State Water Resources Act of 1945, as amended, the Board is authorized to make investigations, studies, surveys, hold hearings, prepare plans and estimates, and make recommendations to the Legislature in regard to water development projects, including flood control plans and projects; and

WHEREAS, by said act, the State Engineer is authorized to cooperate with any county, city, State agency or public district on flood control and other water problems and when requested by any thereof may enter into a cooperative agreement to expend money in behalf of any thereof to accomplish the purposes of said act; and

WHEREAS, each of the Counties desires and hereby requests the Board to enter into a cooperative agreement for the making of an investigation and report on the underground water supply of the valley floor lands in the Counties of Sutter and Yuba, including quality, replenishment and utilization thereof, and if possible, to incorporate findings in said report as to a method or methods of solving the problems involved; and

WHEREAS, the Board hereby requests the State Engineer to cooperate in making an investigation and report on the underground water supply of said valley floor lands in said Counties, including quality, replenishment and utilization thereof, and, if possible, to incorporate in said report a method or methods of solving the problems involved;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the Counties, and the State Engineer do hereby mutally agree as follows:

ARTICLE I—WORK TO BE PERFORMED:

The work to be performed under this agreement shall consist of investigation and report on the underground water supply of the valley floor lands in the Counties of Sutter and Yuba, including quality, replenishment and utilization thereof, and, if possible, a method or methods of solving the problems involved.

The Board by this agreement authorizes and directs the State Engineer to cooperate by making said investigation and report and by otherwise advising and assisting in making an evaluation of present and ultimate underground water problems in the valley floor lands of said Counties, and in formulating a solution or solutions of said problems.

During the progress of said investigation and report all maps, plans, information, data and records pertaining thereto which are in the possession of any party hereto shall be made fully available to any other party for the due and proper accomplishment of the purposes and objects hereof.

The work under this agreement shall be diligently prosecuted with the objective of completion of the investigation and report on or before December 31, 1949, or as nearly thereafter as possible.

ARTICLE II—FUNDS:

Each of the Counties, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Five Thousand Dollars ($5,000) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund (also known as the Water Resources Fund) in the State Treasury, for expenditure by the State Engineer in performance of the work provided for in this agreement. Also, upon execution of this agreement by the Board, the Director of Finance is requested to approve the transfer of the sum of Ten Thousand Dollars ($10,000) from funds appropriated either by the Budget Act of 1947, or by Chapter 1541, Statutes of 1947, or in part from each of said appropriations, to said Water Resources Board for expenditure by the State Engineer in performance of the work provided for in this agreement and the State Controller is requested to make such transfer.

If the Director of Finance, within thirty (30) days after receipt by the State Engineer of said sums from the Counties, shall not have approved the deposit thereof into said Water Resources Revolving Fund, together with the transfer of said sum of Ten Thousand Dollars ($10,000) from funds appropriated to said Board either by the Budget Act of 1947, or by Chapter 1541, Statutes of 1947, or in part from each of said appropriations, said Water Resources Revolving Fund for expenditure by the State Engineer in performance of the work provided for in this agreement, said sums contributed by said Counties shall be returned thereto by the State Engineer.

It is understood by and between the parties hereto that the sum of Twenty Thousand Dollars ($20,000) to be made available as hereinbefore provided is adequate to perform approximately half of the above specified work and it is the present intention of each of said Counties to make a further sum of Five Thousand Dollars ($5,000) available at the commencement of the second year of said investigation which will be subject to a matching or contribution in equal sums by said Board for the completion of said investigation and report.

The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for under this agreement any amount in excess of the sum of Twenty Thousand Dollars ($20,000) as made available hereunder and when said funds are exhausted, the Board and the State Engineer may discontinue the work provided for in this agreement and shall not be liable or responsible for the resumption and completion thereof until the further sums as specified in the preceding paragraph are made available.

Approved:

/s/ C. H. Purcell
Director of Public Works

Approval Recommended:

/s/ Spencer Burroughs
Principal Attorney
Division of Water Resources

Approved as to Form:

/s/ Loyd E. Hewitt
District Attorney
County of Sutter

/s/ Joseph L. Hennan
District Attorney
County of Yuba

Approved:

/s/ James S. Dean
Director of Finance

Approved as to Legality:

/s/ C. C. Carleton
Chief Attorney
Department of Public Works

Upon completion of and final payment for the work provided for in this agreement, the State Engineer shall furnish the Board and each of the Counties a statement of all expenditures made under this agreement. One-half of the total amount of all said expenditures shall be deducted from the sum advanced from funds appropriated to said Board, and one-fourth of the total amount of all said expenditures shall be deducted respectively, from the sum advanced by each of the Counties and any balances which may remain shall be returned to the Board, and to the counties, respectively.

ARTICLE III—EFFECTIVE DATE

This agreement shall become effective immediately upon its execution by all the parties hereto.

In Witness Whereof, the parties hereunto have affixed their signatures, the County of Sutter on the 22nd day of September, 1947, the County of Yuba on the 22nd day of September, 1947, the Board on the 6th day of October, 1947, and the State Engineer on the 7th day of October, 1947.

COUNTY OF SUTTER

By /s/ Ed. F. DaCosse
Chairman, Board of Supervisors

/s/ Albert B. Brown
Clerk, Board of Supervisors

COUNTY OF YUBA

By /s/ James R. Brown
Chairman, Board of Supervisors

/s/ Adrienne Conley
Clerk, Board of Supervisors

STATE WATER RESOURCES BOARD

By /s/ Royal Miller
Chairman

DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA

By /s/ Edward Hyatt
State Engineer

(Initialled)
LJK HA

Form	Budget	Value	Descript.

DEPARTMENT OF FINANCE
APPROVED
Oct. 23, 1947

SUPPLEMENTAL AGREEMENT BETWEEN THE STATE WATER RESOURCES BOARD, THE COUNTIES OF SUTTER AND YUBA, AND THE DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in sextuplicate, entered into by the State Water Resources Board, hereinafter referred to as the "Board"; the Counties of Sutter and Yuba, hereinafter referred to as the "Counties"; and the Department of Public Works of the State of California, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer":

WITNESSETH:

WHEREAS, by agreement heretofore entered into by and between the parties hereto, executed by the Counties on the 22nd day of September, 1947, by the Board on the 6th day of October, 1947, and by the State Engineer on the 7th day of October, 1947, the making by the State Engineer of an investigation and report on the underground water supply of the valley floor lands in the Counties of Sutter and Yuba, including quality, replenishment and utilization thereof and, if possible, a method or methods of solving the problems involved, was provided for; and

WHEREAS, it was the expressed intention in said agreement that at the commencement of the second year of said investigation said Counties would make available in equal proportion a further sum of Ten Thousand Dollars ($10,000) subject to a matching or contribution in equal amount by the Board for the completion of said investigation and report; and

WHEREAS, said additional funds are required to complete said investigation and report, and it is the desire of the parties hereto that an additional sum of Twenty Thousand Dollars ($20,000) shall be provided, Five Thousand Dollars ($5,000) by each of the Counties, and Ten Thousand Dollars ($10,000) by the Board;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the Counties, and the State Engineer do hereby mutually agree as follows:

1. Each of the Counties, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Five Thousand Dollars ($5,000) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental.

2. Upon execution of this agreement by the Board, the Director of Finance will be requested to approve the transfer of the sum of Ten Thousand Dollars ($10,000) from funds appropriated to the Board by Item 335 of the Budget Act of 1948 for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental, and the State Controller will be requested to make such transfer.

3. The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for in said prior agreement to which this agreement is supplemental any amount in excess of the sum of Forty Thousand Dollars ($40,000) as made available under said prior agreement and this supplemental agreement and if funds are exhausted before completion of said work the Board and the State Engineer may discontinue said work and shall not be liable or responsible for the completion thereof.

4. In so far as consistent herewith and to the extent adaptable hereto, all of the terms and provisions of said prior agreement to which this agreement is supplemental are hereby made applicable to this agreement and are hereby confirmed, ratified, and continued in effect.

5. This agreement shall become effective immediately upon its execution by all of the parties hereto.

In Witness Whereof, the parties hereunto have affixed their signatures, the County of Sutter on the 4th day of October, 1948, the County of Yuba on the 22nd day of November, 1948, the Board on the 3rd day of December, 1948, and the State Engineer on the 30th day of November, 1948.

Approved as to form:

/s/ Loyd E. Hewitt
District Attorney
County of Sutter

/s/ Joseph L. Hennan
District Attorney
County of Yuba

Approval Recommended:

/s/ Spencer Burroughs
Principal Attorney
Division of Water Resources

Approved as to Legality:

/s/ C. C. Carleton
Chief Attorney
Department of Public Works

Approved:

/s/ James S. Dean
Director of Finance

COUNTY OF SUTTER

By /s/ Ed. F. DaCosse
Chairman, Board of Supervisors

/s/ Albert B. Brown
Clerk, Board of Supervisors

COUNTY OF YUBA

By /s/ James P. Brown
Chairman, Board of Supervisors

/s/ Adrienne Conley
Clerk, Board of Supervisors

STATE WATER RESOURCES BOARD

By /s/ C. A. Griffith
Vice-Chairman

DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA

By /s/ C. H. Purcell
Director of Public Works

/s/ Edward Hyatt
State Engineer

APPENDIX B

GEOLOGIC FEATURES AND GROUND-WATER STORAGE CAPACITY OF THE SUTTER-YUBA AREA, CALIFORNIA

By G. H. Davis and F. H. Olmsted, under the direction of J. F. Poland, District Geologist

Ground Water Branch, Water Resources Division
UNITED STATES GEOLOGICAL SURVEY

Prepared in cooperation with the California Department of Public Works, Division of Water Resources

Dated May, 1950

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UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GROUND WATER BRANCH
2520 Marconi Avenue
SACRAMENTO 21, CALIFORNIA

May 22, 1950

Mr. A. D. EDMONSTON, *State Engineer*
Division of Water Resources
P. O. Box 1079, Sacramento 5, California

DEAR SIR: I take pleasure in transmitting herewith a report on "Geologic features and ground-water storage capacity of the Sutter-Yuba area, California" by G. H. Davis and F. H. Olmsted. This report has been prepared by the Geological Survey as a part of the program of cooperative ground-water investigations with the California Division of Water Resources.

The report has been approved by the Director of the Geological Survey for publication by the State Water Resources Board as an appendix to its Bulletin No. 6 entitled "Sutter-Yuba Counties Investigation."

Very truly yours,

(Signed) JOSEPH F. POLAND
District Geologist

GEOLOGIC FEATURES AND GROUND-WATER STORAGE CAPACITY OF THE SUTTER-YUBA AREA, CALIFORNIA

By G. H. Davis and F. H. Olmsted

INTRODUCTION

Purpose and Scope of Report

The Sutter-Yuba Area, as identified in this report, includes the parts of Sutter and Yuba Counties that are within the Sacramento Valley and the lower foothills of the Sierra Nevada, an area of 750 square miles. Its general physical and geomorphic features are shown by Plate 1. It is bounded on the east by the rugged Sierra Nevada, on the west by the Sacramento River, and is divided into two nearly equal parts by the southward flowing Feather River. Its importance as an agricultural area and its dependence on surface-water and ground-water supplies for existence and future development have been discussed in the main report by the California Division of Water Resources.

This report on the geology and ground-water storage capacity of the Sutter-Yuba Area has been prepared at the request of the Division of Water Resources, as one of the investigations of ground-water basins of the State now being made by the Geological Survey in accordance with the cooperative agreement with the State Water Resources Board entered into in March, 1948.

The geologic investigation of the Sutter-Yuba Area is in essence a part of a broader reconnaissance investigation of the geology and ground-water storage capacity of the Sacramento Valley which was begun by the Geological Survey in the spring of 1948 at the request of and in cooperation with the California Division of Water Resources. The findings of the valley-wide study are to be published in a separate bulletin under the title of "Geologic features and ground-water storage capacity of the Sacramento Valley, California." That bulletin is now being written.

This appendix has two principal purposes:

First, to describe the geology and general water-bearing character of the rocks. Treatment of the older, nonwater-bearing rocks is general and brief, but is a necessary element of the story because the sediments making up the water-bearing rocks are derived from the weathering and erosion of these older rocks and from their transportation from the Sierra Nevada to the Sacramento Valley. The water-bearing rocks of Tertiary and Quaternary age are described in considerable detail; those deposits are the important sources of ground water. Furthermore, certain geologic events which have uplifted, tilted, or folded the rocks or have produced volcanic deposits have been described because they have caused changes in the texture of sediments being transported to the valley by streams, by mud flows, or through the atmosphere, and thus have been primary factors in deposition of the coarse-grained water-bearing deposits.

Second, to describe the methods used and the results obtained in estimating the water-holding capacity of the water-bearing deposits considered to be within ultimate economic limits for pumping—that is, the deposits constituting the part of the underground reservoir that may be capable of dewatering and resaturation.

This appendix does not treat ground-water occurrence and movement, perennial yield, or chemical character of the ground waters because the hydrologic and water-quality phases of the problem have been carried out entirely by the State Division of Water Resources.

The investigation, which began in October, 1949, has been under the general direction of A. N. Sayre, geologist in charge of the Ground Water Branch, and under the immediate supervision of J. F. Poland, district geologist for California. The field work by the Geological Survey in the Sutter-Yuba area was confined chiefly to geologic mapping, which was done by G. H. Davis and F. H. Olmsted in October and November 1949. The geologic contacts actually traced in the field include the boundaries of the basement complex and of the Tertiary and Quaternary deposits near the basement-complex outcrop. The boundaries of the alluvial deposits of late Tertiary and Quaternary age were mostly drawn or modified on the basis of physiography, and from significant soil-type boundaries mapped by the United States Department of Agriculture, Bureau of Soils. The geology of the Sutter Buttes was taken from H. R. Johnson (1943) * "Marysville Buttes (Sutter Buttes) gas field."

Most of the information on subsurface geology and ground-water storage capacity of the water-bearing deposits was obtained from about 700 logs of water wells supplied by well drillers to the Bureau of Reclamation and the Geological Survey. The logs were turned over to the Division of Water Resources for field location. The cooperation of the well drillers in making available the well logs is greatly appreciated.

Numbers Applied to Wells

In its recent cooperative programs in California, the Geological Survey commonly has assigned well numbers that indicate locations according to the rectangular land surveys. For well 15 N 3E-21C1, for example, the

* References are listed at the end of this appendix alphabetically by the author's name and the year of publication.

first part of the number indicates the township and range (T. 15 N., R. 3 E., Mt. Diablo base line and meridian), the two digits following the hyphen indicate the section (Sec. 21), and the letter indicates the 40-acre subdivision as shown on the accompanying diagram.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Within each 40-acre tract the wells are numbered serially as indicated by the final digit or digits of the number. Thus well 21C1 is in the NE ¼ NW ¼ Sec. 21 and is the first well in that tract to be listed.

In the parts of the area that once were public lands, the official Federal land survey is followed. In the few areas that never were Federally surveyed, the net is projected.

GEOLOGY

General Features

North-central California, which includes the Sutter-Yuba Area, comprises parts of four geomorphic provinces as delimited by Jenkins (1943, pp. 83-88): the Great Valley of California, the Sierra Nevada, the Coast Ranges, and the Cascade Range. The area described in this report lies mostly within the Great Valley of California province, but includes a narrow strip of the Sierra Nevada province to the east. The southernmost extension of the Cascade Range lies more than 20 miles to the north, and the eastern margin of the Coast Ranges lies 20 miles to the west of the Sutter-Yuba Area.

The rocks exposed in the area range from Recent alluvial deposits to Mesozoic and Paleozoic crystalline rocks. Their areal extent is shown on Plate B-1 and their subsurface character on Plates B-2, B-3, and B-4. Their stratigraphy and physical and water-bearing character are summarized in the following table. These rocks may be assigned to two broad categories: the basement complex and the superjacent rocks. The basement complex is exposed in the Sierra Nevada and extends beneath the superjacent rocks in the Sacramento Valley. The superjacent rocks cap many of the interstream divides in the Sierra and comprise the thick and extensive deposits of the valley. The water-bearing rocks considered in this report are entirely within the superjacent rocks, although the basement complex yields small amounts of water to wells in weathered and fractured zones.

Pre-Cretaceous Crystalline Rocks

The basement complex consists of metamorphosed igneous and sedimentary rocks of late Paleozoic and early Mesozoic age and a series of igneous rocks ranging in composition from granite to peridotite which were intruded during the late Jurassic or early Cretaceous Nevadan orogeny.

The rocks exposed immediately east of the Sutter-Yuba Area are predominantly greenstones that probably are metamorphosed basic igneous rocks.

Cretaceous and Tertiary Nonwater-bearing Rocks

The older superjacent rocks are Upper Cretaceous and early Tertiary sediments. A section of unnamed Upper Cretaceous siltstone and sandstone totaling 4,350 feet thick crops out in the Sutter Buttes and has been found in gas wells in the Sacramento Valley. These sediments were deposited in a sea which at times extended eastward to or beyond the present western edge of the basement complex outcrop.

Eocene and possible Paleocene sediments underlie most of the Sutter-Yuba Area. A lower and middle Eocene marine section is exposed in the Sutter Buttes. Stewart (1949) has assigned the 300 feet of lower Eocene in the Buttes to the Meganos formation, and the 130 feet of middle Eocene to the Ione formation. The Ione formation, described in some detail by Allen (1929) is exposed in places along the east side of the valley. There it is usually a brackish-water or deltaic deposit consisting largely of light-colored anauxitic clays and sands, dark reddish or brownish ferruginous sandstones, and minor amounts of lignitic material.

The Ione formation interfingers to the east with river gravels deposited by old Sierra Nevada streams. The ancient Yuba River was the main stream entering the Sutter-Yuba Area in Eocene time.

About 250 to 300 feet of upper Eocene or Oligocene rocks, called the Wheatland formation by Clark and Anderson (1938), are exposed along the southeast bank of the Dry Creek flood plain northeast of Wheatland. A fossiliferous conglomerate containing andesitic pebbles is near the base of the formation which lies unconformably on basement complex. Some of the finer-grained sediments above the conglomerate also contain volcanic detritus.

The Upper Cretaceous and Eocene sediments are not significant as ground-water reservoirs in the Sutter-Yuba Area. Probably none of the water wells in the area penetrates Upper Cretaceous rocks. Several water wells near Wheatland apparently penetrate Eocene rocks, but impermeable shale, siltstone, and sandstone predominate, and the water in the more permeable zones is generally of poor quality. How much of the chloride contamination in parts of the area comes from connate waters in the Eocene rocks is not known. In

STRATIGRAPHY OF THE SUTTER-YUBA AREA AND VICINITY, CALIFORNIA

(Generalized section[1])

Geologic age		Rock unit and symbol on pl. B-1		Thickness (feet)	Physical and water-bearing character
QUATERNARY	Recent	Young alluvial deposits	Stream-channel deposits (Qrc)	0 - 130	Sand, gravel, and silt, in large part well-sorted, in present stream channels and beneath flood plains; yield water in large quantities to irrigation wells. Where the Feather and Sacramento Rivers border the Sutter Basin, they have constructed natural levees composed largely of silt and fine sand deposited during flood stages.
			Basin deposits (Qrb)	0 - 100±	Largely impervious clays and silts deposited in the overflow basins during flood stages of the Feather and Sacramento Rivers. Thin, discontinuous sands supply small domestic and stock wells in the northern part of Sutter Basin; in the southern part of the basin brackish waters are likely to be encountered in wells of any depth.
			Alluvial fans of the Sutter Buttes (Qrf)	0 - 80	Poorly sorted alluvial deposits of gravel and clay, sandy clay, or silt, of low to moderate permeability; yield small supplies of good quality water to stock and domestic wells along the flanks of Sutter Buttes.
	Pleistocene	Local unconformity			
		Intermediate alluvial deposits (Qpal)		0 - 110+	Silt, sand, and gravel, in part well-sorted; moderately permeable throughout. Tongues and layers of fluviatile sand and gravel are highly permeable and supply large quantities of irrigation water. Deposits are coarsest and most permeable near the present major streams and along abandoned Pleistocene channels of the Yuba and Feather Rivers.
		Unconformity			
		Old alluvial deposits (TQal)		0 - 350±	Poorly-sorted silt, clay, sand, and gravel of moderate to low permeability supply water of good chemical quality to domestic, stock, and a few small irrigation wells. Essentially impervious strata of cemented sand and gravel are common. Well-sorted permeable alluvial materials are rare.
TERTIARY	Pliocene	Volcanic rocks of the Sutter Buttes	Andesite tuff-breccia (Tat)	0 - 800±	Andesitic tuffs and tuff-breccias, unsorted and generally of low permeability; some beds may be impermeable. Permeable tongues and stringers of volcanic sand and gravel interbedded with mudflow tuffs and tuff-breccias yield water of good quality to irrigation wells in the Pennington and Sutter City areas.
			Unconformity		
			Rhyolite and andesite (Tra)		Impervious, hard lavas forming core of Sutter Buttes; possibly could provide small water supplies from fractured zones. No wells are known in these rocks.
			Unconformity		
	Pliocene Miocene Oligocene	Volcanic rocks from the Sierra Nevada (Tfa)		0 - 1,800±	Andesitic and rhyolitic tuffs, tuff-breccias, conglomerates, sands, and gravels deposited by inter-volcanic streams from the Sierra Nevada. Sands and gravels yield water of good quality to deep wells in the Marysville and Bear River areas. Fluviatile "black sands" are prolific water producers at many places in the Sacramento Valley. Tuff and tuff-breccia have low permeability and yield little water.
		Unconformity			
	Eocene	Undivided Eocene sediments (Te)		0 - 700±	Marine and non-marine clay, shale and sandstone beneath the Sacramento Valley interfingering along the eastern margin of the valley with Eocene river gravels. These gravels ordinarily are cemented and partially decomposed and probably would yield little water. Coarser sediments in southern Yuba and northwestern Placer counties yield saline waters of probable marine origin to some deep wells. In structurally high positions the marine connate waters have been flushed out of the permeable strata and fresh water is found.
		Unconformity			
CRETACEOUS	Upper Cretaceous	Unnamed Upper Cretaceous sediments (Ku)		0 - 4,350	Sandstone, siltstone, and shale; not penetrated by water wells in Sutter-Yuba area. Connate marine water high in chloride could be expected in wells penetrating these sediments in the Sacramento Valley.
		Unconformity			
PRE-CRETACEOUS		Pre-Cretaceous crystalline rocks (pK)			Hard, impervious metamorphic and igneous rocks. Stock and domestic wells produce small supplies of water of good chemical quality from fractured and partly decomposed zones near the land surface.

[1] Dotted lines are used to separate units that are considered to be contemporaneous.

structurally high positions, for example just west of the outcrops of Wheatland formation, the marine connate waters have been flushed out, and fresh water is found in the more permeable strata.

Tertiary and Quaternary Water-bearing Rocks

Volcanic Rocks From the Sierra Nevada (Eocene-Pliocene)

Tertiary fragmental volcanic rocks having a source near the present crest of the northern Sierra Nevada are exposed at several localities and are encountered in many of the deep wells in the Sutter-Yuba Area. The exposures are found at three principal localities: south of the Yuba River and about 10 miles east of Marysville, on the Camp Beale Military Reservation; at the clay quarries one to two miles northwest of Lincoln; and in an extensive area east of the Southern Pacific railroad and U. S. Highway 99E between Lincoln and Roseville. The last two areas are in Placer County.

Tertiary volcanic rocks do not crop out in the foothill region between Lincoln and the Camp Beale exposure south of the Yuba River. However, many water wells farther west penetrate volcanic rocks, and the original eastward extent of those volcanics was probably greater than it is at present.

GEOLOGIC EVENTS IN SIERRA NEVADA AND ON EAST SIDE OF SACRAMENTO VALLEY

(Read from bottom up)

Recent	Hydraulic mining in Sierra Nevada in late 19th century chokes channels of Feather, Yuba and Bear Rivers with debris. Deposition of stream-channel, alluvial-fan, and basin deposits contemporaneous with mild dissection of intermediate alluvial deposits (Qpal).
Pleistocene	Deposition of intermediate alluvial deposits (Qpal), contemporaneous with moderate to severe dissection of old alluvial deposits (TQal). Several stages of glaciation in Sierra. Truncation and planation of Pliocene alluvial deposits and older rocks, and deposition of thin blanket of course gravel in many areas adjacent to the Sierra Nevada (uppermost part of TQal). Last major uplift of Sierra Nevada with additional regional westward tilting.
Pliocene	Eruptions of Sutter Buttes volcano cover slopes with tuff-breccia deposits from mud-flows. Deposition of old alluvium from Sierra continues. Deposition of old alluvial deposits by streams of low gradient from Sierra Nevada. May be in part contemporaneous with deposition of uppermost Sutter formation and with subsequent volcanic activity at Sutter Buttes. Intrusion of Sutter Buttes central area as plug of plastic andesite porphyry. Andesite mass subsequently intruded by rhyolite porphyry. Valley sediments pierced by volcanic plug are folded and fractured around central area. Great andesitic volcanic activity in Sierra wanes; consequent streams erode volcanic materials and deposit them in Sacramento Valley.
Miocene and Oligocene	Great mud flows of andesitic detritus originating near the crest of the Sierra cover most of the western slope. Old drainage in Sierra almost completely disrupted. Streams begin to erode detritus and deposit it in valley. Faulting and westward tilting of Sierra block during andesite eruptions. Volcanic eruptions near present Sierra crest continue; rhyolitic debris moves westward down canyons, locally damming and diverting streams. Deposition of Sutter formation (non-marine) begins in Sacramento Valley; continues until uplift of Sutter Buttes.
Oligocene or Eocene	Earliest volcanic activity in Sierra Nevada (andesitic and some rhyolitic); sea finally withdraws from Sacramento Valley after extending as far northeast as Wheatland during uppermost Eocene or Oligocene.
Eocene	Marine sedimentation in Sacramento Valley during middle and lower Eocene. Middle Eocene Ione formation, largely non-marine clay and quartzose sand, deposited on the lower slopes of the Sierra Nevada and as deltaic deposits in Sacramento Valley embayment. Moderate uplift of Sierra Nevada or change of base level causes dissection of weathered rocks on west slope of Sierra. Tropical climate and gentle slopes cause deep weathering of rocks in place on west slope of Sierra Nevada.
Upper Cretaceous	Regional upwarping at end of Upper Cretaceous interrupts marine deposition on east side of Sacramento Valley. Great erosion in Sierra Nevada; shallow-water marine deposition in Sacramento Valley.
Lower Cretaceous	At end of Lower Cretaceous—ancestral Coast Ranges formed by folding, faulting, and uplift; Sacramento Valley trough first outlined, though axis somewhat west of present valley. Erosion in ancestral Sierra Nevada.
Lower Cretaceous and/or Upper Jurassic	Formation of folded mountain range of great height, the ancestral Sierra Nevada, by Nevadan orogeny.

The volcanic deposits are chiefly andesitic stream-laid conglomerate and sandstone, and tuff-breccia of mud-flow origin, together with some fine-grained rhyolitic material, all from the Sierra Nevada. As encountered in wells, the conglomerate and sandstone often are loosely consolidated and in such cases are logged by drillers as gravel and sand.

The large area of volcanic rocks at Camp Beale is underlain by andesitic conglomerate, sandstone, and tuff-breccia with interbedded rhyolitic ash. The age of these deposits is probably Eocene, which is somewhat older than most of the other volcanic deposits in the Sutter-Yuba Area on the east side of the Sacramento Valley (Clark and Anderson, 1938).

Andesite tuff-breccia one mile northwest of Lincoln overlies altered rhyolitic ash, and also clay of the Ione formation. The extensive volcanic surface east of U. S. Highway 99E between Lincoln and Roseville is underlain by the same andesite tuff-breccia interbedded with andesitic sandstone and conglomerate. The age of these deposits is not certainly known, but they are believed to be equivalent in age to andesitic deposits in the Mokelumne River Area (the Mehrten formation), which is probably Miocene and may be in part Pliocene (Piper and others, 1939).

The Sutter formation of the Sutter Buttes unconformably overlies Eocene rocks and is in turn overlain unconformably by andesitic and rhyolitic tuffs and breccias of Pliocene age derived from the Buttes volcano. The lower part of the Sutter formation is probably correlative with the volcanic rocks from the Sierra Nevada, although the upper portion may consist of later reworked deposits. The maximum exposed thickness of the Sutter formation is approximately 1,800 feet (Johnson, 1943, p. 614)—considerably thicker than the volcanics from the Sierra Nevada farther east which are probably not over 250 feet thick in outcrop (see Plate B-1). The Sutter rocks are thin-bedded to massive tuff, conglomerate, sand, and clay.

The permeable sand and gravel in the volcanic rocks from the Sierra Nevada probably yield water to deep wells in the Sutter-Yuba Area. Deep wells in Marysville obtain some water from the volcanic sediments, and wells on the Camp Beale Military Reservation 10 miles east of Marysville obtain yields of several hundred gallons a minute from volcanic sands and gravel. Several wells south of the Bear River also produce water from the volcanic rocks from the Sierra Nevada.

Volcanic Rocks of the Sutter Buttes (Pliocene)

The Pliocene volcanic rocks of the Sutter Buttes may be divided into two principal groups: the intrusive rhyolite and andesite and the vent tuffs of the central core; and the andesitic and rhyolitic tuff-breccia that forms the ring encircling the core.

The rocks of the first group are principally porphyritic rhyolite and andesite. These rocks form the sharp peaks in the central area. They are unimportant as a source of ground water.

The tuff-breccia consists of angular blocks of rhyolite and andesite that were swept down the slopes of the old volcano in great mud flows. Many water wells near the periphery of the Buttes encounter the tuff-breccia and intercalated volcanic sediments (see Plates B-1 and B-2). The estimated maximum thickness of the deposits is about 800 feet.

In general, the volcanic sand and gravel yields some water, but the tuff-breccia is tight and nonwater-bearing. North of the Buttes, in the vicinity of Pennington, irrigation wells obtain part of their yield from the volcanic sands and gravels.

Old Alluvial Deposits (Pliocene-Pleistocene)

Location and Extent. The old alluvial deposits, which overlie the volcanics from the Sierra Nevada and older rocks, are exposed in a semicontinuous belt along the east side of the valley, between the outcrop of the basement complex and the volcanics to the east and the younger sediments to the west. A few scattered outliers of old alluvium extend west of the main outcrop from the northern edge of the Sutter-Yuba Area to Wheatland.

Physical Character. The old alluvial deposits are identified physiographically as dissected uplands near the eastern valley margin. Peculiar "hog wallow" topography, consisting of small mounds and undrained or poorly drained depressions often less than 100 feet across, is a common and striking characteristic.

A capping gravel, presumably early Pleistocene in age, and seldom more than 30 feet thick, is extensive near the eastern edge of the outcrops of old alluvium. The underlying silts and sands are presumably Pliocene in age and may be correlative with the Laguna formation to the south, in the Mokelumne Area, described by Gale (Piper and others, 1939).

The gravels almost always have a silty or fine sandy matrix with a distinctive reddish color. Silty and fine-sandy loams, usually with a hardpan layer, are typical soils.

The old alluvial deposits are extremely heterogeneous, and it is difficult to distinguish them in most well logs from younger and older sediments.

Reddish to yellowish-brown silt and silty sand are abundant, but light-gray moderately well-bedded indurated siltstone and fine sandstone are more distinctive and diagnostic. Many of the sand and gravel beds are cross-bedded, indicating fluviatile origin. The gravel is rarely clean or well-sorted; the silty matrix greatly reduces the permeability and porosity. This gravel may be distinguished from that in the underlying volcanics from the Sierra Nevada by the relative scarcity of volcanic rocks, but this distinction is often hard to make, and many drillers do not mention the composition of the pebbles and cobbles.

Water-bearing Character. The poorly-sorted sediments of the old alluvium generally do not yield as much water as the younger deposits. Cementation of the sand and gravel strata is a common feature and many wells are left uncased in the older alluvium; the cemented silt, sand, and gravel strata being sufficiently consolidated to stand without support.

Throughout the Sutter-Yuba Area, enough water can be obtained from the old alluvial deposits to supply domestic and stock wells. It is doubtful, however, that large-capacity irrigation wells could be developed in these deposits. Few wells tap only the old alluvium for sure and yields of these are not known. In the area between the Bear and Yuba Rivers, several irrigation wells produce between 1,000 and 2,000 gallons a minute, but these wells are several hundred feet deep and penetrate the intermediate alluvium, the old alluvium, and presumably the volcanic deposits from the Sierra Nevada. It is believed that the bulk of their yield comes from the volcanic deposits below and the intermediate alluvium above.

Intermediate Alluvial Deposits (Pleistocene)

Location and Extent. The intermediate alluvial deposits which rest on the old alluvium and in places are overlain by the young alluvium of Recent age crop out along a broad belt between the old alluvium on the east and the basin deposits on the west. A few small outliers of intermediate alluvium occur in the American Basin east of the Feather-Sacramento junction.

Physical Character. Topographically these deposits underlie moderately to slightly dissected low plains with a gentle westerly to southwesterly slope. Soils are quite variable but all have some hardpan development. The soils adjacent to the flood basins are fine-grained and dark in color. Soils farther east are coarser, frequently reddish, but almost never gravelly. (See soil surveys, U. S. Dept. Agriculture, in references.)

The intermediate alluvium consists of sand, silt, and gravel, in part well-sorted and well-stratified, deposited by the Feather River and its tributaries in building the low alluvial planes. These deposits are heterogeneous and lenticular in character because of their extremely varied mode of formation. In the eastern part of the area they are largely of alluvial-fan origin; the coarse sand and gravel beds extending 3 to 5 miles west from the present course of the Feather River are probably Pleistocene (Feather) river-channel deposits; and the predominantly fine-grained deposits farther west are chiefly of flood basin or lacustrine origin. Well logs indicate that the material penetrated in the top 100 feet becomes progressively finer toward the Sutter and Butte Basins. Sand and gravel give way to sandy clays and clays, and dark colors predominate. The proportion of sand and gravel to fine sediments in the upper 50 feet decreases from maxima of 80 to 90 percent to 5 to 10 percent. The proportion of blue and dark-gray fine-grained materials—indicative of a non-oxidizing environment—possibly flood-basin or lacustrine deposition—becomes greater as the proportion of fine sediments increases.

In general, the intermediate alluvium is not appreciably consolidated. The beds that are indurated have a high proportion of clay and silt which act as a binder. Hardpan layers, representing buried soil zones, are encountered at various depths. These hard layers usually are cemented with hydrous iron and aluminum silicates, although calcareous cementation is common in areas of high water table adjacent to the flood basins.

The intermediate alluvial deposits are inferred to be correlative with the Victor formation of Pleistocene age in the Mokelumne area described by Gale and Piper (Piper and others, 1939).

Thickness. From drillers' logs, it is inferred that the intermediate alluvial deposits do not exceed 110 feet in thickness in the Sutter-Yuba Area. West of the Feather River, these deposits consist of 50 to 110 feet of sandy clay, sand, and gravel. (See Plate B-2, Section B-B1.) North of Yuba City they overlie brown cemented sands and hard brown clays of the old alluvium. South of Yuba City and in the Marysville area the underlying old alluvium usually is blue clay.

In the area east of the Feather River and north of the Yuba River the intermediate alluvium reaches thicknesses of 70 to 100 feet and rests upon cemented sand, gravel, and clay of the old alluvium that crop out in the dissected uplands to the east.

Few wells penetrate the intermediate alluvium south of the Yuba River but the thickness does not appear to exceed 50 feet.

Water-bearing Character. The intermediate alluvium is moderately permeable throughout, but the tongues and layers of well-sorted sand and gravel are highly permeable and yield large quantities of water to wells. Nearly all the domestic and many small irrigation wells located on the low plains are completed in these deposits. Large wells for irrigation and municipal supply obtain much of their water from this material, but also obtain water from the older deposits at greater depths.

Deposits of this age are coarsest and most permeable near the Yuba and Feather Rivers, and less permeable close to the flood basins where dark colored silt and clay predominate.

Young Alluvial Deposits (Recent)

The Recent deposits of the Sacramento Valley may be defined as those sediments that are still accumulating, or would be accumulating under natural conditions. These deposits would include: silt, sand, and gravel laid down in stream channels during times of decreasing flood flow; silt and sand deposited on natural levees at times of overflow; silt and clay deposited in the flood basins; detritus of the alluvial fans surrounding the Sutter Buttes. In this report, the natural levee sediments are grouped with the stream-channel

deposits. The other two types of sediments are called "basin deposits" and "alluvial-fan deposits," respectively. Each of these subdivisions of the Recent sediments has certain unique physiographic, lithologic, and hydrologic characteristics which are discussed below.

Alluvial-fan Deposits of the Sutter Buttes. Alluvial fans of Pleistocene and Recent age form a ring surrounding the Sutter Buttes and extending toward their center in narrow valleys cut into andesite tuff-breccia. Small isolated patches of alluvium occupy valleys high in the Buttes. This alluvium is probably thin and is not continuous with the deposits farther down the flanks.

The fan material consists of volcanic and sedimentary detritus eroded from the Buttes and deposited around their perimeter. The deposits are usually poorly sorted and contain many volcanic fragments as large as boulder size. An average of several logs of wells near Pennington and Sutter City indicates the following proportion of materials: "clay," 70 percent; clay and gravel (including clay and volcanics), 20 percent; sand and gravel, 10 percent. The "clay" is usually yellow and is probably largely silt and fine sand.

Most of the alluvial-fan deposits are poorly sorted and ground-water yields are low. Moderately permeable sand strata yield water of good quality to wells near Pennington and Sutter City, but chances for developing large irrigation wells are generally poor.

Basin Deposits. The basins are nearly flat, poorly drained lands subject to natural overflow of the Sacramento and Feather Rivers during floods. The deposits have formed from the accumulation of silt and clay that were carried in suspension by the flood waters and settled slowly when the current slackened.

Dark-gray clays and clay adobes, often with more than 50 percent clay-size particles, are the chief basin soils. Depth of the soils is usually from three to six feet, and the underlying material is stratified and of lighter color.

Few water wells have been drilled in the basins, so it is difficult to work out the pattern of the subsurface geology from the meager data. Only eight water-well logs were available in Sutter Basin and four logs in the American Basin.

In Sutter Basin soil and yellow clay as much as 48 feet thick are reported above blue clay, blue sand, gray clay, or gravel. The change in color from yellow to blue indicates that the deeper sediments have been in a non-oxidizing environment since deposition. If the blue clay and coarse-grained deposits are Pleistocene in age the basin deposits of Recent age attain a thickness of at least 48 feet in the Sutter Basin and 100 feet in the American Basin.

The Recent basin deposits nearly all consist of relatively impermeable clay and silt. The older sediments, usually at least 50 to 100 feet below land surface, frequently include thin sand and gravel strata which yield moderate amounts of water. Generally, yields from the Sutter Basin deposits are too small to permit economic use of the ground-water for irrigation; and even in the deep wells penetrating permeable strata, poor quality (high chloride content) precludes use of the water. Locally, however, satisfactory deep wells might be developed by casing off strata containing the high-chloride water. Wells in the northern part of the American Basin get fair yields from deep permeable strata (probably in the intermediate alluvial deposits) and apparently do not encounter the chloride contamination present in the Sutter Basin.

Stream-channel Deposits. The stream-channel deposits comprise those sediments which under natural conditions of stream flow would still be in the process of accumulation. They include the sand and gravel deposited in the river channels during times of decreasing flow and the fine sediments deposited on the flood plains and natural levees during floods. The stream-channel deposits range in width from less than one mile to as much as six miles and extend as narrow bands along the major streams of the area.

The river channels are floored with sand and gravel, the flood plains by sand and silt. During stages of moderate flow the rivers occupy only their channels and roll sand and gravel along their beds. During floods muddy water spreads over the flood plain and deposits fine sediments. Flood channels, abandoned river channels, and lakes characterize the flood-plain surface. Natural levees bordering the Sacramento and lower Feather Rivers were deposited during flood stages along the boundary between high velocity flows in the river channels and still waters occupying the flood basins.

The Yuba and Bear Rivers offer a special case. The natural channel deposits of both streams have been completely buried by 15 to 20 feet of hydraulic mining debris deposited since 1870. Levees now confine this debris, which stands as raised channelways subdivided into braided gravelly channels. (See Pl. B-3.) Large quantities of debris choke the lower Feather below the Yuba junction, although the flood plain has not been altered to the same extent as those of the Yuba and Bear Rivers.

Well defined channels of coarse gravel, deposited in trenches excavated in the intermediate alluvial deposits and older sediments, underlie the flood plains of the Feather, Yuba, and Bear Rivers. Coarse gravel deposits from one to two miles in width can be traced beneath the Feather River flood plain from Oroville south 10 miles to the highway bridge east of Gridley. The depth of the base of the gravel is about 30 feet near Oroville, increasing to 105 feet at the Gridley bridge. No subsurface information is available on the river channel deposits between the Gridley bridge and the Feather-Yuba junction. Wells on the Feather River flood plain south of the Yuba-Feather junction en-

counter gravel between depths of 35 and 90 feet that may correspond to the Recent gravel deposits upstream.

Records of wells drilled on the Yuba River flood plain two miles east of Marysville show coarse gravel deposits to a depth of 110 to 130 feet. (See Pl. B-3.)

Sand and gravel underlies the Bear River flood plain for eight miles downstream from the canyon mouth. This gravel deposit which occurs between 25 and 65 feet beneath the surface near Wheatland is terminated rather abruptly about three miles southeast of Wheatland.

Little is known of the subsurface extent of the Recent deposits of the Sacramento River. Wells drilled on the natural levees pass through varicolored sand, gravel, silt, and clay. Well logs show no systematic changes either laterally or vertically. Lateral discontinuity of beds is a marked feature—even closely spaced wells penetrate completely different sections.

Clean, well-sorted sand and gravel of the stream-channel deposits yield water in large quantity and of good chemical quality to irrigation wells on the flood plains of the Feather, Yuba, and Bear Rivers. A few irrigation wells are bottomed in the Recent deposits but wells of large capacity commonly penetrate older sediments as well.

Wells drilled in the natural-levee deposits of the Feather and Sacramento Rivers obtain large supplies of water from thin, discontinuous tongues of gravel and sand which are buried stream-channel deposits. The fine sand and silt of these deposits supply some small stock and domestic wells.

Yields of Wells

Data on yields of wells in the Sutter-Yuba Area for the period 1933 to 1949 have been furnished by the Pacific Gas and Electric Company. The results of tests are summarized in the following table, which shows averages of discharge and specific capacity for 595 wells in five areas within the area. Specific capacity is obtained by dividing the yield in gallons per minute by the drawdown from static to pumping level in feet. It is a measure of the productivity of the well per foot of drawdown.

Area	*Average discharge (gpm)*	*Average specific capacity (gpm/ft. dd)*	*Number of wells*
1. Eastern Sutter County	728	47	261
2. Northwestern Sutter County	878	54	82
3. Southeastern Sutter County	960	47	121
4. Southern Yuba County	846	48	108
5. Northern Yuba County	838	60	23

The table shows that the wells having the highest specific capacities are in areas two and five. A hasty conclusion (based on this relation) might be drawn that the best irrigation wells are to be obtained in the areas of highest average specific capacity. However, a study of well depths in relation to specific capacity changes the picture somewhat. Drillers' logs of 528 irrigation wells were used to obtain a yield factor that would give a reasonable idea of production per foot of well. The yield factor was computed by the following formula:

$$\text{Yield factor} = \frac{\text{Average specific capacity} \times 100.}{\text{Average well depth}}$$

The results are summarized in the following table.

Area	*Number of irrigation wells*	*Total footage drilled*	*Average depth (feet)*	*Yield factor*
1	249	45,270	182	25.7
2	48	15,341	320	16.8
3	104	33,709	324	14.7
4	109	31,828	292	16.7
5	28	5,623	201	29.8

It can be seen from comparison of yield factors that the ratio of well production to depth of wells is higher in areas 1 and 5 than in areas 2, 3, and 4. Plate B-4, showing ground-water storage units, and well-yield areas indicates that areas 1 and 5 lie largely in group A (river flood-plain and channel deposits). Area 2 comprises the Sutter Buttes, the alluvial fans surrounding the Buttes (storage group B) and a large area of basin deposits (storage group D). Only a small part of this area is within storage group A. Most of the wells in area 2 are in the Pennington-Live Oak district, where many wells are 500 feet or more deep.

The other two areas with low yield factors are areas 3 and 4 east of the Feather River in southeastern Sutter and southern Yuba Counties; they embrace extensive areas of low alluvial-plain deposits (storage group B), and smaller areas of basin deposits (storage group D) and dissected alluvial deposits (storage group C). Although area 4 includes large areas of river flood-plain deposits (storage group A) the yield factor approximates that of the poor-yield areas rather than that of high-yield areas as might be expected.

In conclusion, generally speaking, areas of high-yield factor generally correspond to areas of high specific yield as determined from statistical analysis of drillers' logs.

GROUND-WATER STORAGE CAPACITY

Most of the information on ground-water storage capacity of the Sutter-Yuba Area was derived from well logs obtained from water well drillers. In connection with their Sutter-Yuba investigation the Division of Water Resources located in the field about 700 water wells for which drillers' logs were available. The Geological Survey located about 50 wells in western and northwestern Sutter County.

Clay, gravel, sand, and volcanic rocks are usually recognized in the drillers' logs, and the more complete logs mention color, hardness, degree of cementation, and other readily identified lithologic features.

A peg model based on drillers' logs was used to subdivide the shallow sediments of the area into hydro-

logic units. In constructing the model only the deeper well records were used where wells were located within 1,500 feet of each other. In this way 576 well logs were selected. In order to smooth out the effect of close well spacing in residential districts supplied by domestic wells, only the wells selected for the peg model were used in computing storage capacity.

Selection of Depth Zones

The storage capacity of the Sutter-Yuba Area has been estimated for three depth zones: 20 to 50 feet, 50 to 100 feet, and 100 to 200 feet below the land surface. The only exception to this three-zone treatment was in the area south of Yuba City between the natural levee deposits of the Sacramento River and the channel of the Feather River (storage units A 5 and D 2). Water of poor quality underlies that area at relatively shallow depths, and the California Division of Water Resources believes that it would be impractical in general to draw down the water level below 100 feet without causing saline intrusion. Accordingly, in that area the storage capacity was calculated only for the deposits between depths of 20 and 100 feet.

It is believed that for the Sutter-Yuba Area it would be inefficient to store water in the deposits less than 20 feet below land surface, even where permeable. Also, for economic reasons, it is unlikely that water levels will be lowered below 200 feet. In the near future, drawdown of the water table in the Sutter-Yuba Area probably will not extend below the 100-foot depth.

Classification of Materials in Drillers' Logs

In order to estimate the ground-water storage capacity of the water-bearing deposits it was necessary to classify the drillers' logs into a few general categories to which specific-yield values could be assigned. Although many logs reported only gravel, sand, and clay or gradations between these units, some logs reported as many as 10 to 20 different types of materials. It was decided to group the sediments logged into five general classes, namely: (1) gravel; (2) sand, including gravelly sand and gravel and sand; (3) tight sand, hard sand, sandstone and other materials of similar hydrologic character; (4) cemented gravel, clay and gravel, etc.; and (5) "clay," which included silt, clay, shale, and related materials of low permeability including "lava."

Assignment of Specific-yield Values

The specific yield of a rock is the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume. This ratio is customarily expressed in percent. The procedure followed in assigning specific-yield values to the various types of material classified in the well logs of the Sacramento Valley is discussed in detail in the valley-wide report now in preparation and has been summarized in an appendix to Bulletin 1 of the State Water Resources Board (Poland and others, 1950). The table below indicates the values assigned:

Material	*Specific yield (percent)*
Gravel	25
Sand, including sand and gravel, and gravel and sand	20
Fine sand, hard sand, tight sand, sandstone, and related deposits	10
Clay and gravel, gravel and clay, cemented gravel, and related deposits	5
"Clay," silt, sandy clay, lava rock, and related fine-grained deposits	3

Subdivision of Sutter-Yuba Area Into Storage Units

For the purpose of estimating underground storage capacity, the Sutter-Yuba Area was divided into four storage groups, and these in turn were subdivided into 14 storage units. (See Pl. B-4). Boundaries of the storage units were first drawn on significant soil and physiographic changes, then were modified on the basis of the subsurface character of the deposits above a depth of 200 feet below land surface. Special emphasis was placed on the hydrologic character of the sediments in the top 100 feet. There are three reasons for this. First, it is believed that the storage units should be representative for the depth range most widely subject to unwatering or resaturation under present conditions. Second, for nearly all the storage units in the valley except the basin deposits, the specific yield is greater above the 100-foot depth than below it. Lastly, with reference to natural or artificial recharge at or near the land surface, the distribution of water-bearing beds in the near-surface deposits is of primary importance. In this respect, the coarse sand and gravel tongues or blankets that are so well defined at shallow depths beneath or near the channels of the Feather, Yuba, and Bear Rivers are noteworthy.

In the table summarizing the ground-water storage capacity of the Sutter-Yuba Area, the 14 storage units have been assembled within the four groups. Briefly summarized, the groups are:

A. River Flood-plain and Channel Deposits. These deposits contain a high proportion of sand and gravel deposited by streams mostly during the Pleistocene and Recent epochs, although some of the sands and gravels in the 100- to 200-foot depth zone may be of Pliocene age. In general, the river flood-plain and channel deposits have the highest specific yield of the four groups in all three depth zones. The specific yield decreases markedly in the 100- to 200-foot depth zone, but still is higher than in the other three storage groups.

B. Low Alluvial-plain and Alluvial-fan Deposits. These deposits are variable in physical character but are generally much less permeable than the river flood-plain and channel deposits, particularly in the top two depth zones. The near-surface sediments in this group include the alluvial fans of the Sutter Buttes, intermediate alluvial deposits (Pleistocene), old alluvial deposits (Pliocene and Pleistocene) and smaller areas of

Recent stream-channel deposits. Most of the low alluvial-plain deposits above the 200-foot depth are old and intermediate alluvial deposits, however.

C. Dissected Alluvial Deposits. This group is represented in Sutter and Yuba Counties by two widely separated small areas—the northern between Honcut Creek and the Yuba River on the east margin of the valley, and the southern in Sutter County east of the American Basin. The specific yield and physical character of the dissected alluvial deposits and the low alluvial-plain and alluvial-fan deposits are similar, and the geologic units contained are essentially the same, although the dissected alluvial deposits contain a somewhat greater percentage of old alluvium.

D. Basin Deposits. These sediments to a depth of 200 feet include the Recent basin deposits, the intermediate alluvial deposits of Pleistocene age and probably some old alluvium. Silt and clay predominate and permeability and specific yield are correspondingly low. The 100- to 200-foot depth zone in the northern part of the American Basin (D1) contains a rather high proportion of sand which may represent buried Sacramento River channels, but the deep zone in the Butte Basin (D3) has fine-grained material of low permeability. The specific yield of the deep zone in the Sutter Basin (D2) was not calculated because of salt-water contamination, but the well logs record mostly fine-grained material.

Summary of Results

The following table summarizes the estimated ground-water storage capacity of the Sutter-Yuba Area for the four storage groups. This summary is followed by a tabulation of storage capacity for each of the 14 storage units, listed by groups.

The summary for the Sutter-Yuba Area by storage groups first gives total storage capacities for all deposits, including those beneath the basin lands. The totals are then given with the storage capacity of the basin deposits eliminated. There are several reasons for omitting the storage capacity of these deposits from consideration. The deposits in the Sutter and Butte Basins are relatively impermeable in all three depth zones, and those in the American Basin in the top two depth zones. Therefore, well yields would be low and it would be difficult to draw down the water level extensively within the basins unless many closely spaced wells were drilled. Although the basin water levels are close to the surface, the altitude of land surface in the basins is lower than that in all the surrounding lands. Because of the low altitude and the low permeability of the basin deposits, it is believed there would not be appreciable dewatering by lateral drainage to adjacent pumped areas. For the same reasons, recharging the basin deposits would be slow and costly. Because of low well yields and the availability of surface water, it is ordinarily more economical to use surface water than ground water for irrigation of the basin lands.

Excluding the basin storage, the estimated ground-water storage capacity for the Sutter-Yuba Area between limits of 20 and 200 feet below the land surface is about 3,900,000 acre-feet. More than half this storage is in the deposits 20 to 100 feet below the surface. As discussed previously, how much of this ground-water storage capacity is economically usable is not known.

ESTIMATED TOTAL GROUND-WATER STORAGE CAPACITY OF SUTTER-YUBA AREA IN ACRE-FEET

Storage unit	Area[1] (acres)	Depth zone: 20-50 feet		50-100 feet		100-200 feet		All zones 20-200 feet	
		Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)
A. River flood-plain and channel deposits	204,590 (164,430)	10.4	640,000	9.4	960,000	7.0	1,140,000	8.4	2,740,000
B. Low alluvial-plain and alluvial-fan deposits	101,590	5.4	160,000	4.9	250,000	4.7	470,000	4.9	880,000
C. Dissected alluvial deposits	30,600	4.5	40,000	5.5	80,000	4.7	150,000	4.9	270,000
D. Basin deposits	143,590 (29,080)	5.4	230,000	5.1	370,000	6.4	180,000	5.4	780,000
TOTALS	480,370 (325,700)	7.4	1,070,000	6.9	1,660,000	6.0	1,940,000	6.6	4,670,000
Percent of total			22.9		35.5		41.6		

ESTIMATED GROUND-WATER STORAGE CAPACITY, EXCLUDING BASIN DEPOSITS

Total (A+B+C)	336,780 (296,620)	840,000	1,290,000	1,760,000	3,890,000
Percent of total		21.6	33.2	45.2	

[1] Figures in parentheses indicate acreage utilized for computing storage in zone 100 to 200 feet below land surface.

SUTTER AND YUBA COUNTIES
ESTIMATED GROUND-WATER STORAGE CAPACITY OF RIVER FLOOD-PLAIN AND CHANNEL DEPOSITS (A)

Storage unit	Area[1] (acres)	Depth zone: 20-50 feet		50-100 feet		100-200 feet		All zones 20-200 feet	
		Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)
1. Sacramento River	35,680	9.0	96,000	9.8	176,000	8.6	308,000	9.0	580,000
2. East of Feather River north of Yuba River	39,240	10.3	121,000	8.7	170,000	6.0	235,000	7.5	526,000
3. West side Feather River north of Yuba City	35,920	9.8	105,000	8.4	151,000	5.9	214,000	7.3	470,000
4. East side Feather River south of Yuba River and Bear River	53,590	11.8	189,000	10.8	289,000	7.2	384,000	8.9	862,000
5. West of Feather River south of Yuba City	(40,160)	10.4	126,000	8.9	179,000			9.5	305,000
TOTALS	204,590 (164,430)	10.4	637,000	9.4	965,000	7.0	1,143,000	8.4	2,744,000

[1] Figures in parentheses indicate acreage utilized for computing storage in zone 100 to 200 feet below land surface.

SUTTER AND YUBA COUNTIES
ESTIMATED GROUND-WATER STORAGE CAPACITY OF LOW ALLUVIAL-PLAIN AND ALLUVIAL-FAN DEPOSITS (B)

Storage unit	Area (acres)	Depth zone: 20-50 feet		50-100 feet		100-200 feet		All zones 20-200 feet	
		Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)
1. Low plains south of Bear River	36,030	6.5	70,000	5.2	93,000	4.2	151,000	4.8	314,000
2. Low plains north of Bear River	47,070	4.7	67,000	4.5	105,000	5.4	253,000	5.0	425,000
3. Low plains west of Feather River	2,560	5.2	4,000	5.6	7,000	4.0	10,000	4.6	21,000
4. Alluvial plains enclosing Sutter Buttes	15,930	4.8	23,000	5.8	46,000	3.7	59,000	4.5	128,000
TOTALS	101,590	5.4	164,000	4.9	251,000	4.7	473,000	4.9	888,000

SUTTER AND YUBA COUNTIES
ESTIMATED GROUND-WATER STORAGE CAPACITY OF DISSECTED ALLUVIAL DEPOSITS (C)

Storage unit	Area (acres)	Depth zone: 20-50 feet		50-100 feet		100-200 feet		All zones 20-200 feet	
		Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)
1. Deposits between American and Bear Rivers	20,070	4.8	29,000	4.8	48,000	5.2	105,000	5.0	182,000
2. Deposits south of Oroville	10,530	3.9	12,000	7.0	37,000	3.8	40,000	4.7	89,000
TOTALS	30,600	4.5	41,000	5.6	85,000	4.7	145,000	4.9	271,000

SUTTER AND YUBA COUNTIES
ESTIMATED GROUND-WATER STORAGE CAPACITY OF BASIN DEPOSITS (D)

Storage unit	Area[1] (acres)	Depth zone						All zones 20-200 feet	
		20-50 feet		50-100 feet		100-200 feet			
		Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)
1. American Basin	17,860	4.6	25,000	5.0	45,000	7.7	137,000	6.4	207,000
2. Sutter Basin	114,510 (0)	5.5	189,000	5.2	295,000			5.3	484,000
3. Butte Basin	11,220	5.1	17,000	4.6	26,000	4.3	48,000	4.8	91,000
TOTALS	143,590 (29,080)	5.4	231,000	5.1	366,000	6.4	185,000	5.4	782,000

[1] Figures in parentheses indicate acreage utilized for computing storage in zone 100 to 200 feet below land surface.

Best Areas for Ground-water Storage

As can be seen from the ground-water storage table, the best areas for storing water underground are the five river flood-plain and channel deposits units. Excluding basin deposits, about 70 percent of the total storage capacity is in these five areas which include about 40 percent of the Sutter-Yuba Area, and most of the soils and near-surface sediments are sufficiently permeable to permit recharge from the surface. Sand and gravel beds are most continuous in the river-channel deposits of the Feather River, and the deposits west of the river from Yuba City south to the vicinity of Nicolaus seem to be especially favorable for storing ground-water (See Pl. B-2). Unfortunately, however, this area is contaminated with salt water in the lower depth zone, and storage in this zone may not be practicable.

The low alluvial-plain and alluvial-fan deposits and the dissected alluvial deposits are both rather unfavorable for ground-water storage. Soils are generally tight and impervious hardpan is prevalent, and recharge from land surface would be difficult.

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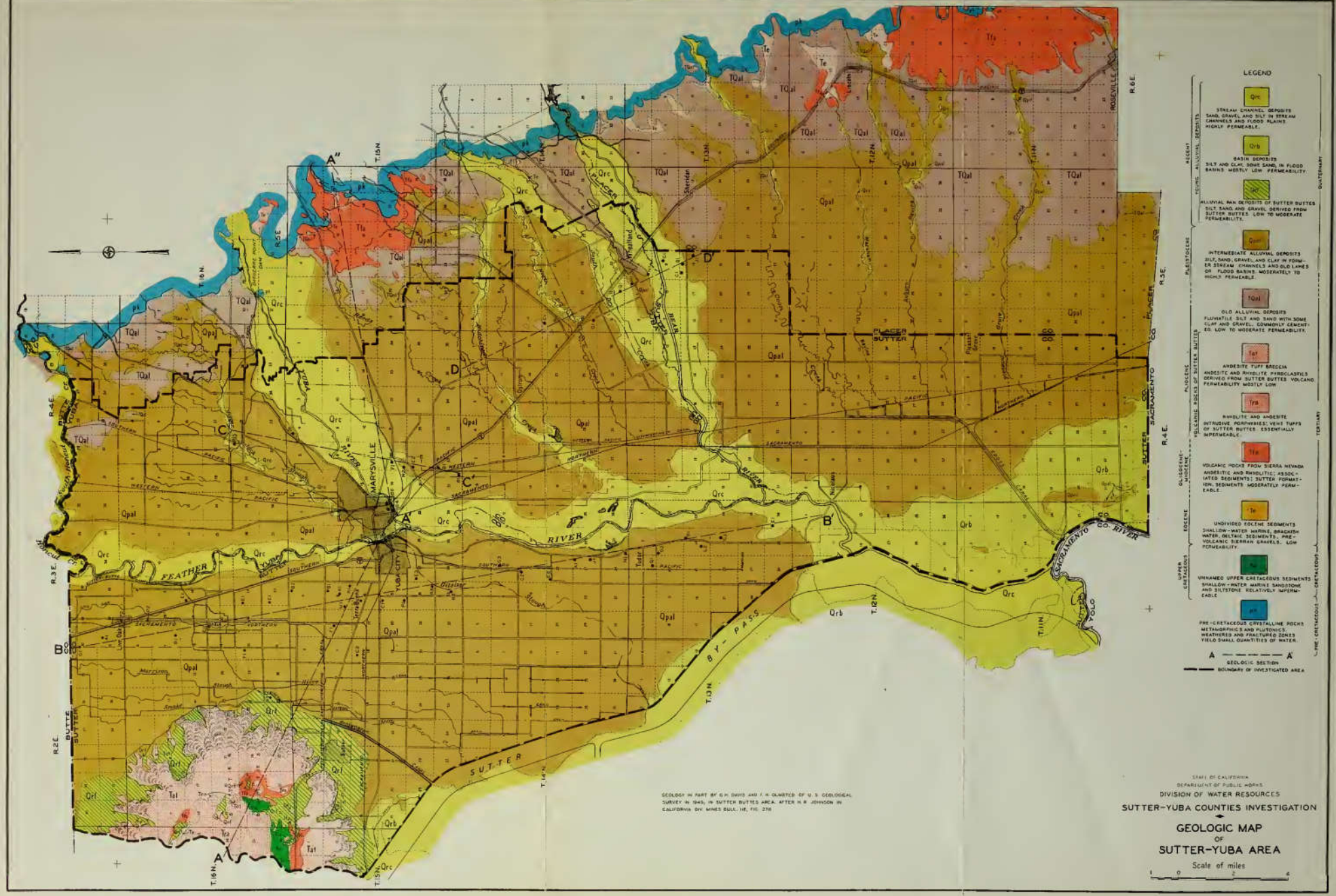
PLATE B-1



GEOLOGY IN PART BY G.H. DAVIS AND J.H. OLMSTED OF U.S. GEOLOGICAL SURVEY IN 1949, IN SUTTER BUTTES AREA. AFTER H.R. JOHNSON IN CALIFORNIA DIV. MINES BULL. 118, FIG. 270

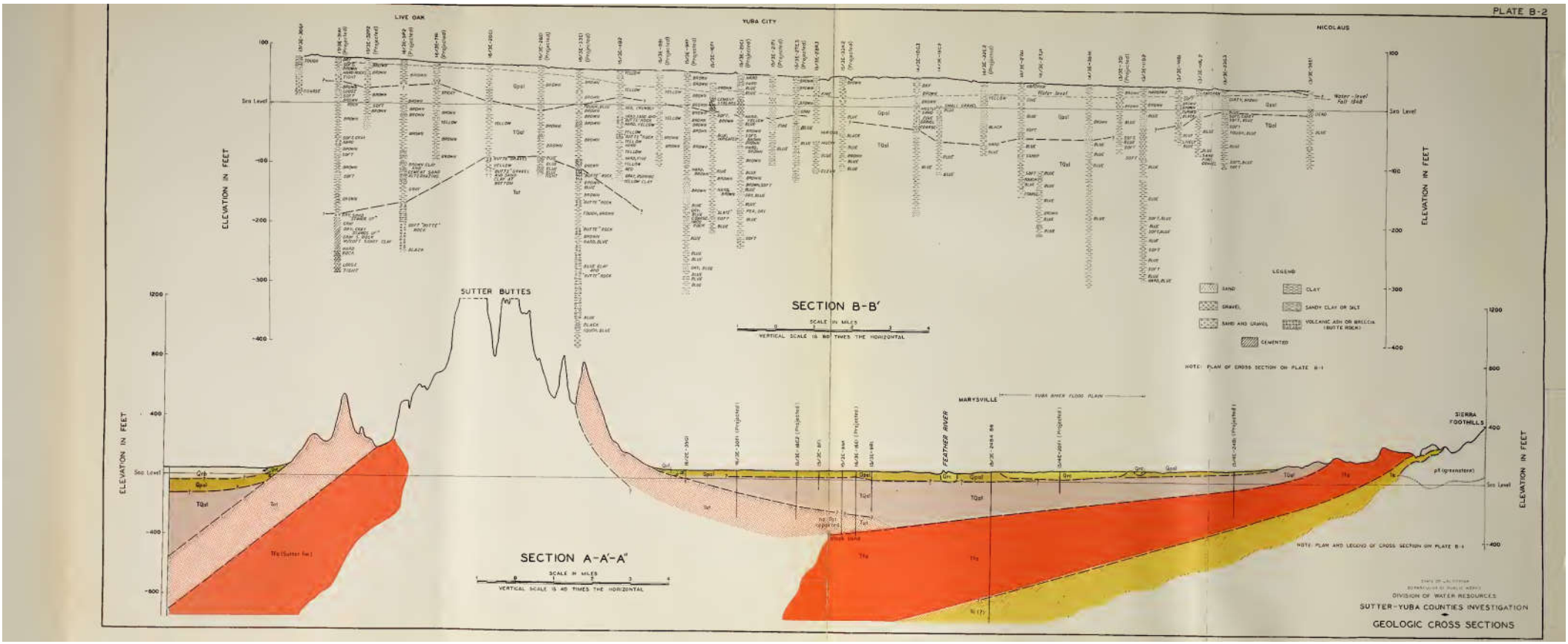
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION

GEOLOGIC MAP OF SUTTER-YUBA AREA

Scale of miles

1 0 2 4

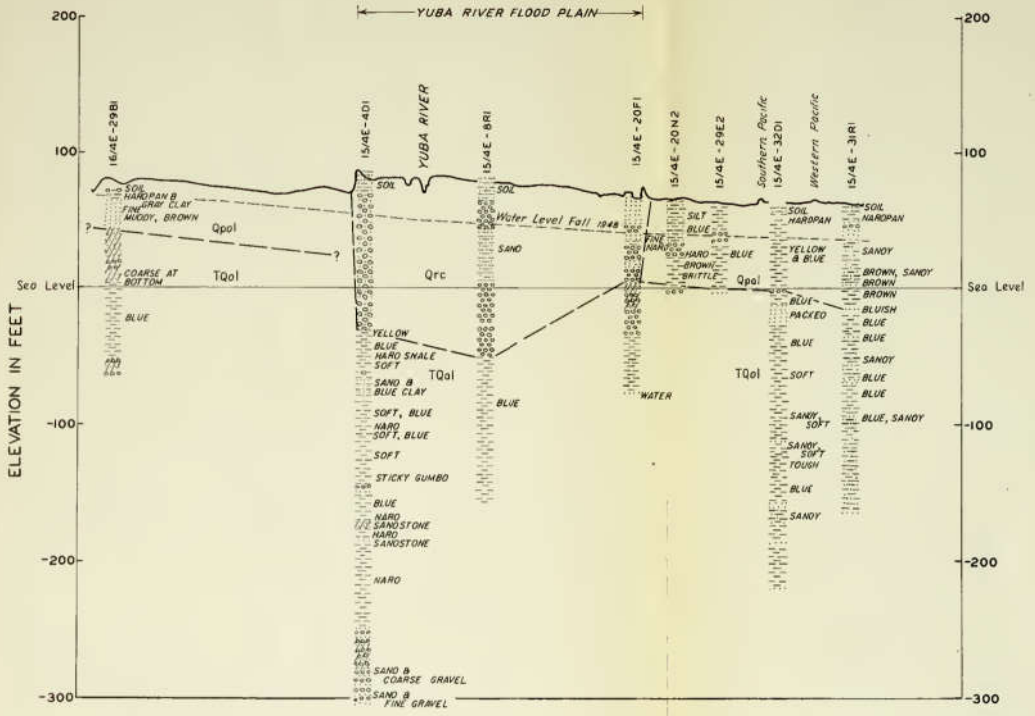
PLATE B-2



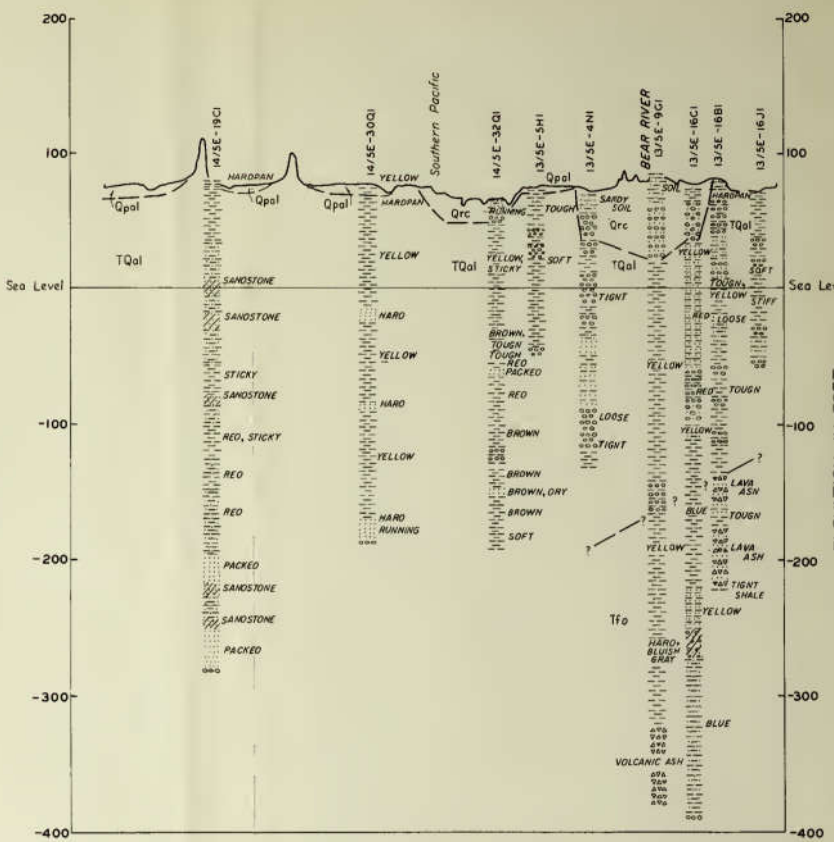
DIVISION OF WATER RESOURCES

SUTTER-YUBA COUNTIES INVESTIGATION

GEOLOGIC CROSS SECTIONS



SECTION C-C'



SECTION D-D'

LEGEND

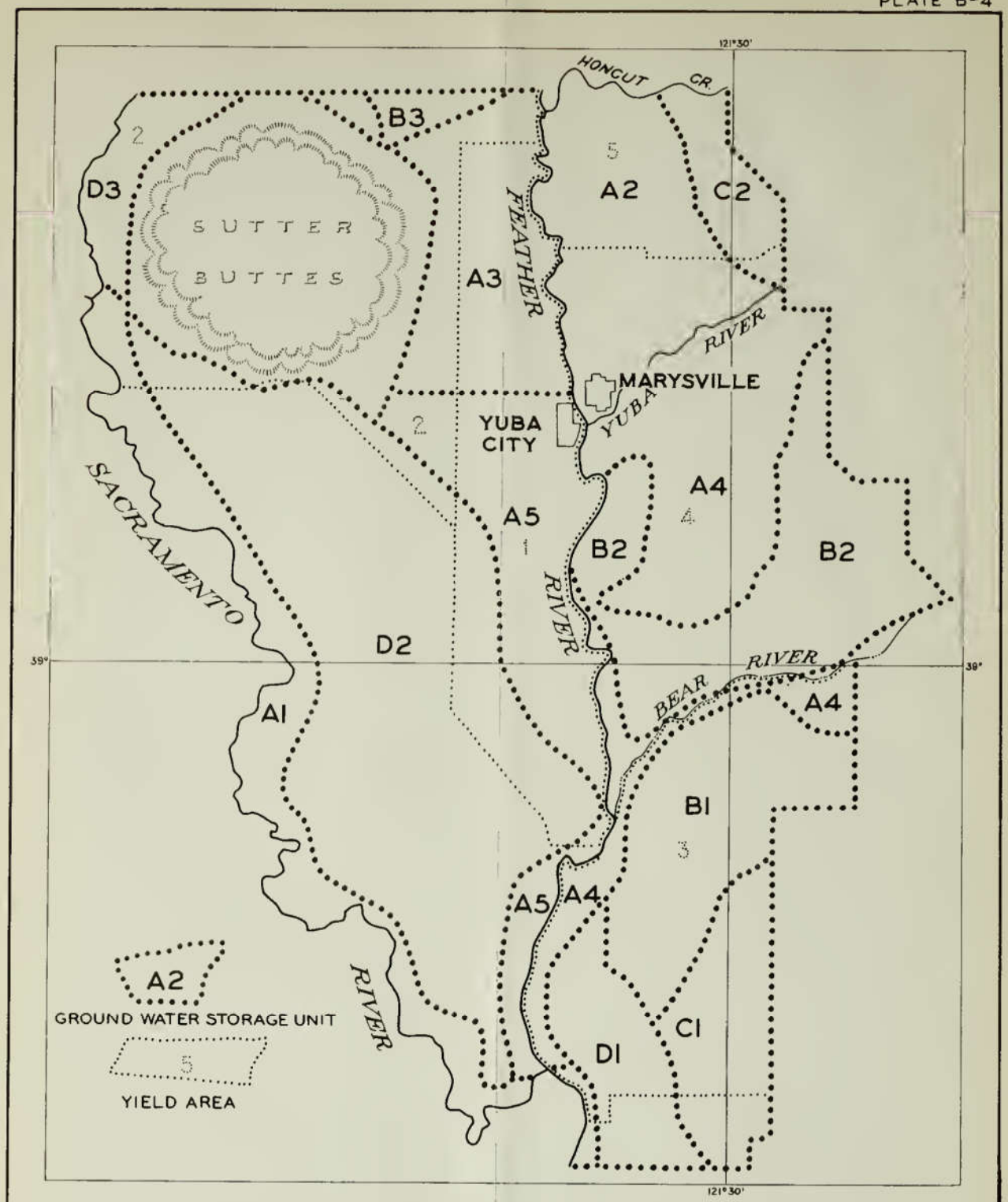
SAND
CLAY
GRAVEL
SANDY CLAY OR SILT
SAND AND GRAVEL
VOLCANIC ASH OR BRECCIA (BUTTE ROCK)
CEMENTED

NOTE: PLAN OF CROSS SECTIONS ON PLATE B-1

SCALE OF MILES
1 0 1 2 3 4
VERTICAL SCALE IS 80 TIMES THE HORIZONTAL

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION

GEOLOGIC CROSS SECTIONS



GROUND WATER STORAGE UNITS IN SUTTER AND YUBA COUNTIES

APPENDIX C

RECORD OF MONTHLY PRECIPITATION AT ROBBINS, CALIFORNIA

RECORD OF MONTHLY PRECIPITATION AT ROBBINS, CALIFORNIA

County: Sutter
Date established: 1926
Type of gage: Not recording
Elevation: 20 feet, U.S.G.S. datum

Latitude: 38° 52'
Longitude: 121° 43'
Record obtained from: Reclamation District 1500, Kirkville

(In inches)

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Total
1925-26											0.55		
1926-27		0.05	Tr.	1.58	7.43	0.81	2.43	5.39	1.69	0.96	0.34	0.45	21.13
1927-28		Tr.	Tr.	1.81	2.05	0.68	1.72	1.61	3.68	0.64	0.03	0.05	12.27
1928-29				0.26	2.51	2.61	0.73	2.01	1.20	0.55	Tr.	1.51	11.38
1929-30				0.10	0.00	4.53	4.12	1.43	2.64	1.07	0.52		14.41
1930-31			0.19	0.42	1.21	1.50	2.65	1.25	0.97	0.20	1.04	0.87	10.30
1931-32		0.02		0.26	2.69	7.65	1.72	1.52	0.49	0.88	0.70		15.93
1932-33	0.05			Tr.	0.27	2.59	3.13	0.65	1.69	0.10	0.48		8.96
1933-34			Tr.	0.76	0.00	5.90	0.24	2.73	0.33	0.54	0.16	0.22	10.88
1934-35			Tr.	1.06	2.62	2.29	5.46	1.56	2.77	3.95	Tr.		19.71
1935-36	Tr.			0.89	1.05	1.71	2.95	5.90	1.01	1.24	0.42	0.43	15.60
1936-37				0.30	0.06	2.50	2.78	5.96	5.39	0.48	0.00	0.14	17.61
1937-38				0.56	2.58	2.97	3.76	7.27	3.77	1.89	0.14	0.05	22.99
1938-39			0.59	1.19	0.58	1.25	2.69	0.63	2.14	0.16	0.44		9.67
1939-40	Tr.		0.27	0.67	0.04	1.71	6.24	7.06	4.11	0.86	0.81		21.77
1940-41			0.06	0.92	1.41	7.76	6.04	6.49	3.31	3.90	2.04	Tr.	31.93
1941-42	Tr.		0.02	1.54	1.77	6.25	4.00	3.75	3.28	5.12	0.59		26.32
1942-43				0.38	2.08	2.87	5.72	2.36	2.73	1.94	0.06	0.05	18.19
1943-44				0.24	0.80	2.42	2.22	7.29	0.55	1.53	1.00	0.01	16.06
1944-45				0.94	4.13	2.31	2.02	1.86	2.97	0.08	0.88	0.16	15.35
1945-46				3.29	2.19	4.75	0.91	0.95	1.64	0.08	0.36		14.17
1946-47	0.09		0.20	0.28	2.27	3.03	0.36	2.24	2.35	0.30	0.29	0.51	11.92
1947-48				2.06	1.06	1.01	0.90	1.41	3.32	3.92	1.82	0.57	16.07
1948-49		0.03	0.30	1.11	0.49	3.97	1.26	1.19	4.67		1.17		14.16
1949-50				0.01	0.70	1.18	3.51	3.28	0.86	1.00	0.15	0.11	10.83
1950-51			0.22	2.48	3.49	4.58	2.24	2.04	0.53	0.76	0.76		17.10
1951-52				0.11	3.01	3.96	3.03	6.57	1.35	2.36	1.05	Tr.	0.43	21.87

APPENDIX D

RECORDS OF DAILY RUNOFF IN SUTTER-YUBA AREA NOT PREVIOUSLY PUBLISHED

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RECORDS OF DAILY RUNOFF IN SUTTER-YUBA AREA NOT PREVIOUSLY PUBLISHED

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COON CREEK AT HIGHWAY 99E
1947 AND 1948

(Daily mean flow, in second-feet)

Date	1947		1948										
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1		14	12	15	21	34	76	64	6	6	9	24	21	26
2		14	16	15	18	33	54	40	6	6	10	24	42	18
3		13	39	17	15	77	47	31	7	6	10	22	58	30
4		13	32	18	16	80	38	33	8	5	10	22	65	44
5	26	14	30	21	15	113	34	35	10	5	10	22	52	34
6	22	15	29	49	12	125	30	34	15	4	10	26	50	57
7	21	15	46	56	12	49	22	32	12	4	10	21	46	38
8	20	14	178	34	12	55	28	31	17	5	9	21	43	44
9	18	13	54	72	15	101	28	34	21	7	8	21	44	39
10	17	13	42	87	18	490	36	31	27	10	9	24	43	31
11	16	12	34	44	12	157	29	25	25	7	8	24	40	26
12	15	13	29	34	12	96	19	23	22	13	9	31	37	23
13	14	13	25	29	34	71	20	22	20	10	9	31	34	68
14	14	13	22	25	89	65	37	21	13	10	8	30	34	95
15	18	14	21	25	81	58	42	19	7	10	7	32	37	67
16	23	15	20	25	64	61	38	18	7	9	10	33	44	47
17	22	18	18	24	89	156	31	16	7	8	12	30	44	138
18	19	20	13	23	57	81	38	14	8	7	12	21	45	92
19	17	20	18	23	86	55	46	13	9	9	19	17	45	53
20	16	18	17	21	63	44	96	11	7	10	18	14	41	43
21	15	19	16	21	48	42	160	10	6	10	18	15	38	38
22	14	18	16	19	39	96	115	9	4	10	20	15	34	33
23	14	17	15	17	54	57	86	8	3	13	23	15	31	30
24	15	15	18	16	719	43	71	7	4	12	23	15	19	28
25	18	11	17	15	299	36	61	8	6	10	24	11	18	29
26	17	11	15	15	108	32	43	10	7	10	24	11	18	46
27	15	12	15	16	74	30	32	9	6	10	22	11	17	240
28	14	15	15	21	55	31	32	10	5	10	22	12	17	123
29	13	14	15	25	50	57	33	9	5	16	26	12	18	67
30	13	13	15		43	107	31	7	4	18	24	13	26	50
31		13	15		38		46		5	9		17		47
Mean		14.6	28.2	28.4	73.2	84.4	48.4	21.1	10.0	9.0	14.4	10.6	36.8	56.3
Runoff, in acre-feet		897	1,730	1,630	4,499	5,022	2,973	1,258	613	553	859	1,263	2,184	3,459

AUBURN RAVINE AT HIGHWAY 99E
1947 AND 1948

(Daily mean flow, in second-feet)

Date	1947		1948											
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1		7	36	54	57	81	37	85	69	69	62	11	12	12
2		7	49	52	62	85	15	70	76	76	62	12	17	25
3		7	56	52	56	117	9	54	71	67	62	9	21	39
4		9	42	57	51	118	16	55	66	67	62	7	13	39
5		11	42	66	55	98	15	51	65	67	62	8	10	31
6		11	43	96	50	80	10	52	61	67	72	6	11	47
7		11	75	74	45	62	9	48	60	67	62	3	10	31
8		12	133	64	49	51	14	48	62	69	62	2	10	44
9		14	81	98	54	66	12	52	57	68	63	2	9	31
10		11	78	81	50	64	11	60	60	67	63	2	9	29
11		11	72	68	48	61	7	63	65	68	63	4	8	27
12		11	68	66	48	54	16	56	70	69	62	6	9	28
13	7	9	62	64	68	56	52	47	82	68	61	5	9	70
14	9	8	62	62	86	54	61	49	80	66	61	5	6	32
15	22	8	58	61	89	63	70	57	79	67	63	5	11	71
16	22	8	58	61	86	46	68	58	78	67	62	4	9	52
17	14	44	56	61	82	66	67	62	77	67	50	4	16	108
18	12	42	54	61	70	44	80	62	79	66	51	3	11	70
19	11	37	53	59	102	38	107	66	78	63	52	8	11	51
20	11	44	54	56	77	35	115	62	75	59	45	16	11	47
21	10	44	55	53	61	32	53	58	71	58	24	17	11	43
22	11	40	56	54	55	62	44	55	70	60	22	15	10	41
23	11	38	55	51	56	38	58	63	70	50	23	6	13	40
24	11	35	52	52	289	29	57	55	69	59	22	5	25	40
25	9	32	51	55	192	26	54	59	70	58	15	8	23	38
26	7	33	48	54	117	23	50	71	70	58	16	8	22	52
27	8	33	51	54	83	20	48	67	69	58	15	7	26	108
28	6	33	51	68	53	20	50	67	70	58	12	11	27	70
29	6	34	51	58	82	55	56	66	70	60	11	9	23	54
30	6	35	50		104	56	61	63	69	62	13	9	13	54
31		35	52		92		89		69	62		11		51
Mean	10.7	23.0	58.3	62.5	79.8	56.9	45.5	59.3	70.2	64.3	45.5	7.4	13.4	47.6
Runoff, in acre-feet	386	1,416	3,578	3,594	4,897	3,382	2,799	3,531	4,318	3,947	2,707	452	825	2,926

DRY CREEK NEAR WALDO
1947 AND 1948

(Daily mean flow, in second-feet)

Date	1947		1948										
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1		2	2	5	16	37	95	36				e 1	14	8
2		2	33	5	10	32	67	30				e 2	26	8
3		2	62	5	9	28	58	28				e 3	24	9
4		2	20	6	9	27	51	28				e 4	28	16
5		2	43	6	9	44	43	28				e 5	14	13
6		2	20	26	9	156	38	25				e 6	12	35
7		2	388	28	9	105	34	20				e 7	9	24
8		2	312	11	9	80	37	19				e 7	8	22
9		2	78	66	9	130	38	16				e 8	7	37
10	5	2	37	84	9	556	36	16				e 8	7	23
11	5	3	26	37	9	292	30	16				e 9	7	18
12	5	4	20	24	9	146	27	16				e 9	7	14
13	5	5	18	19	107	100	23	e16				e10	7	73
14	5	6	15	16	189	90	20	e15				e10	7	106
15	5	7	14	14	146	89	20	e14				e11	7	57
16	5	9	13	14	136	101	19	e13	NO FLOW	NO FLOW	NO FLOW	e11	7	42
17	4	9	12	13	159	407	18	e12				e12	7	79
18	4	8	11	13	88	156	33	e11				e12	7	115
19	3	7	10	13	136	100	64	e10				12	7	42
20	3	6	10	12	86	84	103	e10				12	7	23
21	2	5	9	12	56	67	73	e 9				12	7	17
22	2	4	9	11	39	222	44	e 8				12	6	14
23	2	3	8	10	131	174	38	e 7				12	6	12
24	2	2	7	10	727	95	30	e 6				12	6	10
25	2	2	6	9	316	74	28	e 5				12	7	10
26	2	2	6	9	142	67	28	e 4				12	7	10
27	2	2	6	9	92	58	26	e 3				12	7	138
28	2	2	5	9	71	59	26	e 2				12	7	132
29	2	2	5	12	58	112	28	e 1				12	8	48
30	2	2	5		44	130	67	e 1				12	8	30
31		2	5		41		49					12		24
Mean		13.6	39.2	18.1	93.0	127.0	41.7	14.2				9.4	9.6	38.9
Runoff, in acre-feet		222	2,410	1,008	5,712	7,575	2,561	843				577	571	2,398

e—Estimated.

DRY CREEK NEAR WALDO—1949

(Daily mean flow, in second-feet)

Date	January	February	March	April	May	Date	January	February	March	April	May
1	57	15	34	51	16	16	11	36	162	8	NO RECORD
2	80	15	187	38	12	17	10	33	120	7	
3	40	17	580	32	16	18	10	32	86	4	
4	28	26	475	18		19	11	28	171	4	
5	23	130	390	14		20	18	28	137	4	
6	19	112	335	35		21	17	38	103	5	
7	18	147	220	37		22	53	32	122	5	
8	16	132	154	16		23	63	57	148	5	
9	14	78	171	15		24	37	67	187	5	
10	13	71	780	12		25	29	59	137	4	
11	12	306	780	8		26	26	44	122	3	
12	12	130	278	5		27	24	57	119	4	
13	12	73	187	5		28	22	48	114	4	
14	12	52	137	5		29	20		103	5	
15	11	42	120	6		30	17		68	9	
						31	15		51		
						Mean	24.2	69.9	222.9	12.6	
						Runoff, in acre-feet	1,488	3,878	13,756	728	

SOUTH HONCUT CREEK AT LA PORTE ROAD

1947 AND 1948

(Daily mean flow, in second-feet)

Date	1947		1948										
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1		5	6	5	16	46	118	47	NO FLOW	NO FLOW	NO FLOW		25	5
2		5	122	9	17	38	90	38					54	5
3		6	104	10	14	95	78	34					66	13
4		11	114	11	11	122	70	37					32	34
5		15	132	24	10	147	65	44					15	31
6		11	61	50	9	132	61	38					9	90
7		8	472	46	7	80	52	34					8	48
8	6	7	224	28	4	73	48	28					6	67
9	7	7	77	48	12	430	43	25					5	46
10	6	8	130	70	9	580	40	23					5	27
11	5	8	38	44	3	271	35	22					5	19
12	5	8	34	33	2	158	32	21				8	4	15
13	5	7	30	28	50	118	27	20				5	4	78
14	6	8	27	24	252	115	27	19				3	3	89
15	9	9	25	23	122	132	26	18				4	12	61
16	11	10	24	22	168	127	26	17				5	27	49
17	13	20	22	21	342	406	26	16				6	27	66
18	10	27	21	20	171	158	40	15				7	24	82
19	6	18	20	18	171	115	69	14				6	17	47
20	5	12	19	17	93	95	104	13				6	15	34
21	5	15	19	16	69	85	81	12				5	12	28
22	5	17	25	15	51	250	52	11				5	9	24
23	5	16	21	11	120	143	40	10				5	8	22
24	5	13	21	10	619	101	34	9				5	7	20
25	5	12	21	10	283	81	34	8				5	7	17
26	1	10	13	10	136	70	32	7				6	6	25
27	1	10	12	10	95	64	27	6				5	6	216
28	5	10	11	15	73	73	35	5				3	6	113
29	1	10	10	28	64	132	34	3				5	7	61
30	1	8	7		54	184	63	1				9	7	46
31		7	5		16		69					10		38
Mean	6.2	10.9	60.2	24.1	94.5	154.2	51.0	19.9				5.7	14.6	49.0
Runoff, in acre-feet	284	670	3,703	1,341	5,796	9,166	3,130	1,180				226	869	3,007

APPENDIX E

RECORDS OF DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

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RECORDS OF DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

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2	Depths to Ground Water at Measurement Wells in Sutter-Yuba Area, Measurements Made by S. T. Harding	151
3	Depths to Ground Water at Measurement Wells in Sutter-Yuba Area, Measurements Made by Sutter County Farm Advisor	155

The wells are numbered in accordance with a system adopted by the United States Geological Survey. The numbering system indicates the well locations according to the rectangular land surveys. An explanation of the numbering system is given on page 93 of Appendix B.

Reference point elevations given to the nearest foot have been estimated from United States Geological Survey topographic maps. Reference point elevations given to the nearest 0.1 foot have been established by field surveys.

TABLE 1

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Made by Division of Water Resources
(Depths to woter in feet meosured from reference point)

10N/3E-1A1—Reference point—top of 12-inch casing, elevation 23 feet. West side of Garden Highway at toe of levee, 0.75 mile southwest of Riego Road. 12/7/48, 15.1; 4/6/49, 10.7; 11/30/49, 15.7; 3/30/50, 6.4; 11/9/50, 15.6; 4/5/51, 10.2; 12/4/51, 14.0; 4/4/52, 0.0.

10N/4E-6K1—Reference point—top of 14-inch casing under pump, elevation 20 feet, 0.06 mile south of Riego Road, 0.47 mile west of Power Line Road. 12/23/47, 10.9; 3/4/48, 11.0; 12/7/48, 10.0; 4/6/49, 5.0; 12/1/49, 8.2; 3/30/50, 6.9; 1/9/50, 8.0; 12/4/51, 7.7; 4/4/52, 6.3.

10N/4E-12A1—Reference point—top of casing, elevation 43.1 feet, 0.10 mile west of Pleasant Grove Road, 0.70 mile south of Riego Road. 12/23/47, 22.0; 3/3/48, 20.6; 12/7/48, 28.1; 4/6/49, 23.2; 11/23/49, 36.1; 12/1/49, 27.2; 3/15/50, 29.5; 3/30/50, 28.7; 11/9/50, 35.0; 4/5/51, 25.9; 12/5/51, 26.7; 4/4/52, 24.4.

10N/5E-6J1—Reference point—top of wooden shoring for pit, 12.5 feet above casing, elevation 46 feet, 0.12 mile south of Riego Road, 0.82 mile east of Pleasant Grove Road. 12/24/47, 27.1; 3/3/48, 27.0; 12/7/48, 33.9 (operating); 4/6/49, 29.6; 12/1/49, 33.6; 3/30/50, 34.9; 11/9/50, 40.3; 4/5/51, 38.2; 12/5/51, 33.1; 4/8/52, 42.4 (operating).

10N/5E-8N1—Reference point—top of casing, elevation 37 feet, 1.5 miles south of Riego Road, 1.06 miles east of Pleasant Grove Road. 12/24/47, 25.3.

11N/3E-1D1—Reference point—hole in side of pump base, elevation 25.6 feet. South side of West Catlett Road, 0.18 mile east of Garwood Road. 12/19/47, 12.0; 3/4/48, 11.6; 12/15/48, 11.0; 3/30/49, 6.5; 5/26/49, 20.1; 6/29/49, 23.4; 7/28/49, 23.1; 8/26/49, 23.4; 12/5/49, 14.5; 3/24/50, 8.3; 11/16/51, 12.5; 4/7/52, 5.9.

11N/3E-2B1—Reference point—top of concrete base, elevation 23.8 feet. South side of West Catlett Road, 0.37 mile west of Garwood Road. 12/19/47, 11.0; 3/4/48, 10.8; 12/15/48, 12.3; 3/3/49, 5.9; 12/5/49, 14.1; 3/24/50, 7.4; 11/6/50, 12.4; 4/2/51, 5.1; 11/16/51, 11.7; 4/8/52, 6.1.

11N/3E-2Q1—Reference point—top of casing, elevation 20 feet, 0.50 mile east of Vernon Road, 0.89 mile south of West Catlett Road. 12/9/48, 11.9; 4/6/49, 5.7; 11/28/49, 14.0; 3/30/50, 7.1; 11/8/50, 11.2; 4/3/51, 5.1; 12/5/51, 11.0.

11N/3E-3C2—Reference point—west side of pump base, elevation 26.1 feet. South side of West Catlett Road, 1.57 miles north of Garwood Road. 12/19/48, 13.4; 3/4/48, 11.4; 12/15/48, 13.1; 3/30/49, 7.5; 12/5/49, 15.2; 3/34/50, 7.6; 11/6/50, 13.0; 4/2/51, 5.0; 4/8/52, 1.7.

11N/3E-3N1—Reference point—hole in pump base, elevation 25 feet, 0.85 mile west of Vernon Road, 0.93 mile south of West Catlett Road. 12/9/48, 13.1; 3/31/49, 6.2; 11/28/49, 14.9; 3/30/50, 5.9; 11/18/50, 13.1; 4/1/52, 0.0.

11N/3E-3P1—Reference point—hole in pump base, elevation 22 feet, 0.74 mile west of Vernon Road, 0.82 mile south of West Catlett Road. 12/9/48, 12.4; 11/8/50, 13.1; 4/3/51, 6.2, 12/5/51, 11.9; 4/1/52, 5.3.

11N/3E-10N1—Reference point—pipe in pump base, elevation 26 feet, 0.80 mile west of Vernon Road, 1.75 miles south of West Catlett Road. 3/31/49, 11.3; 11/28/49, 19.1.

11N/3E-11D1—Reference point—top of casing, elevation 21 feet, 0.14 mile east of Vernon Road, 1.08 miles south of West Catlett Road. 12/9/48, 8.3; 4/6/49, 4.5; 11/28/49, 12.2; 3/30/50, 4.9; 11/8/50, 7.7; 4/3/51, 2.7; 4/2/52, 1.9.

11N/3E-13A1—Reference point—top of casing, elevation 20 feet, 0.70 mile north of north levee of Natomas Cross Canal, 1.15 miles northeast of Garden Highway. 12/9/48, 7.6; 4/6/49, 3.3; 11/29/49, 9.4; 3/30/50, 3.6; 11/8/50, 10.0; 4/2/51, 3.0; 12/5/51, 9.5.

11N/3E-13D1—Reference point—hole in pump base, elevation 20 feet, 1.10 miles north of north levee of Natomas Cross Canal, 0.86 mile northeast of Garden Highway. 12/9/48, 11.9; 4/6/49, 7.4; 11/29/49, 13.0; 3/30/50, 8.5; 11/8/50, 13.5; 4/2/51, 7.5; 12/5/51, 13.0.

11N/3E-13F1—Reference point—hole in pump base, elevation 20 feet, 0.75 mile north of north levee of Natomas Cross Canal, 1.13 miles northeast of Garden Highway. 12/9/48, 12.5; 4/6/49, 8.3; 14/29/49, 14.2.

11N/3E-13P1—Reference point—hole in pump base, elevation 20 feet. At toe of north levee of Natomas Cross Canal, 1.37 miles northeast of Garden Highway. 4/6/49, 7.7; 11/29/49, 11.8.

11N/3E-14N1—Reference point—hole in pump base, elevation 25 feet, 0.14 mile east of Vernon Road, 0.60 mile north of Garden Highway. 12/9/48, 12.7.

11N/3E-15C1—Reference point—hole in pump base, elevation 25 feet, 1.50 miles north of Garden Highway, 0.78 miles west of Vernon Road. 12/24/47, 16.9; 3/4/48, 16.2; 12/9/48, 16.1; 3/31/49, 9.9; 11/28/49, 17.9; 3/30/50, 7.9; 11/8/50, 16.1; 4/3/51, 10.3; 12/4/51, 15.0; 4/1/52, 1.1.

11N/3E-22H1—Reference point—top of casing, elevation 27 feet. North side of Garden Highway, 0.23 mile northwest of Verona. 12/24/47, 18.8; 3/4/48, 18.2; 12/9/48, 18.0; 3/31/49, 11.6; 11/28/49, 18.2; 3/30/50, 9.9; 11/8/50, 16.2; 4/3/51, 11.4; 12/5/51, 15.7; 4/1/52, 3.3.

11N/3E-22H2—Reference point—top of casing, elevation 29 feet. Northeast side of Garden Highway, east side of Vernon Road. 11/7/29, 24.3; 9/27/30, 24.3; 12/15/31, 24.3; 11/23/32, 25.2; 12/21/33, 21.6; 10/27/34, 27.3; 11/28/34, 20.3; 11/25/36, 24.8; 11/6/37, 23.8; 1/10/39, 20.8.

11N/3E-22H3—Reference point—top of casing, elevation 29 feet, 300 feet north of Garden Highway, west side of Vernon Road. 12/20/40, 19.9.

11N/3E-23E2—Reference point—top of casing, elevation 27 feet, 100 feet north of Garden Highway, 0.07 mile east of Vernon Road. 11/11/47, 19.7; 12/16/48, 19.0; 12/9/49, 19.0; 11/13/50, 19.3; 12/6/51, 5.9.

11N/3E-23L1—Reference point—top of casing, elevation 29 feet, 0.12 mile north of Garden Highway, 0.47 mile southeast of Vernon Road. 12/23/47, 12.3; 3/4/48, 11.9; 12/9/48, 10.9; 3/31/49, 3.9; 11/28/49, 12.9.

11N/3E-23R1—Reference point—top of casing, elevation 20 feet. At toe of south levee of Natomas Cross Canal, 0.11 mile north of Garden Highway. 12/23/47, 12.1; 3/4/48, 16.0; 12/8/48, 15.2; 3/31/49, 6.9; 11/28/49, 16.1.

11N/3E-25C1—Reference point—top of casing, elevation 23 feet, 0.24 mile south of Sankey Road, 0.44 mile east of Garden Highway. 12/9/48, 11.3; 4/6/49, 7.3; 3/30/50, 7.6; 11/9/50, 10.9; 4/5/51, 5.6; 12/5/51, 11.3; 4/4/52, 4.4.

11N/3E-25P1—Reference point—top of casing, elevation 25 feet, 265 feet northwest of Garden Highway, 1.27 miles north of Riego Road. 11/7/29, 19.0; 9/27/30, 19.3; 12/15/31, 19.5; 11/23/32, 20.2; 12/21/33, 16.6; 10/27/34, 18.1; 11/28/34, 15.6; 11/25/36, 19.2; 11/6/37, 14.7; 1/10/39, 15.6; 12/20/40, 15.0; 11/11/47, 15.5; 12/23/47, 16.6; 3/4/48, 16.0; 12/1/49, 15.6; 4/6/49, 11.9; 11/13/50, 13.5; 12/6/51, 8.3.

11N/4E-1F1—Reference point—top of casing, elevation 49.3 feet, 0.80 mile south of Catlett Road, 0.25 mile east of Pleasant Grove Road. 12/22/47, 21.5; 3/22/48, 19.3; 12/18/48, 23.3; 3/29/49, 19.5; 12/2/49, 25.9; 3/27/50, 22.8; 11/8/50, 27.0; 11/16/51, 27.0; 4/8/52, 17.5.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

11N/4E-1M1—Reference point—concrete floor of pump house, elevation 45 feet, 0.55 mile north of Howsley Road, 0.12 mile east of Pleasant Grove Road. 11/8/29, 13.8; 9/26/30, 13.3; 12/10/31, 14.9; 11/23/32, 14.3; 12/20/33, 15.9; 10/27/34, 16.2; 11/23/36, 13.9; 11/1/37, 12.3; 1/10/39, 11.3; 1/4/41, 11.4; 11/11/47, 22.9; 12/16/48, 22.1; 12/9/49, 24.4; 11/13/50, 24.2; 12/6/51, 27.8.

11N/4E-1R1—Reference point—joint in cover plate around casing, elevation 50 feet. North side of Howsley Road, 1.0 mile east of Pleasant Grove Road. 12/23/47, 24.7; 3/3/48, 22.6; 12/8/48, 25.1; 3/31/49, 22.8; 11/30/49, 25.9; 11/14/50, 28.7.

11N/4E-2M1—Reference point—top of casing, elevation 40 feet, West side of Western Pacific Railroad, 0.29 mile north of Howsley Road. 3/15/48, 11.9; 12/8/48, 15.5; 3/29/49, 9.5; 12/2/49, 16.4.

11N/4E-3P1—Reference point—hole in base of pump, elevation 33 feet, 0.15 mile north of Howsley Road, 0.47 mile east of Pacific Avenue. 12/22/47, 19.8; 3/15/48, 18.1; 12/18/48, 21.1; 3/29/49, 14.4; 12/2/49, 21.3; 3/24/50, 16.3; 11/8/50, 21.6; 4/2/51, 12.3; 11/19/51, 20.8; 4/8/52, 13.2.

11N/4E-4R1—Reference point—top of casing, elevation 30 feet, 0.03 mile north of Howsley Road, 0.16 mile west of Pacific Avenue. 12/23/47, 14.7; 3/15/48, 13.1; 12/15/48, 10.2; 2/30/49, 3.9; 12/2/49, 15.9; 3/24/50, 9.8; 11/8/50, 16.0; 4/2/51, 8.0; 11/19/51, 14.7; 4/6/52, 6.1.

11N/4E-5A1—Reference point—top of casing, elevation 27 feet, 1.10 miles north of Natomas Cross Canal. 12/18/47, 9.9; 12/15/48, 9.9; 3/30/49, 3.8; 5/26/49, 18.1; 7/29/49, 20.1.

11N/4E-6B1—Reference point—hole in pump base, elevation 30 feet. South side of West Catlett Road, 1.50 miles west of Electric Avenue. 12/18/47, 11.5; 12/15/48, 15.1; 3/24/50, 7.9; 11/19/51, 14.0.

11N/4E-7H1—Reference point—edge of pump base, elevation 23 feet, 0.47 mile north of Natomas Cross Canal, 3 miles northeast of Garden Highway. 4/6/49, 10.1; 11/30/49, 12.3; 3/30/50, 10.6; 11/8/50, 14.5; 4/2/51, 9.3.

11N/4E-9C1—Reference point—top of casing, elevation 27 feet, 0.56 mile west of Sacramento Northern Railroad, 0.21 mile south of Howsley Road. 5/5/48, 37.0 (operating); 5/31/48, 10.8; 7/2/48, 49.0 (operating); 7/23/48, 50.5 (operating); 4/6/49, 7.7; 11/30/49, 14.0.

11N/4E-9L1—Reference point—top of casing, elevation 26 feet, 0.45 mile west of Sacramento Northern Railroad crossing on Howsley Road, 0.57 mile south of Howsley Road. 5/5/48, 48.2 (operating) 5/31/48, 12.7; 7/23/48, 50.5 (operating); 4/6/49, 8.8; 11/30/49, 14.2.

11N/4E-11C1—Reference point—top of casing, elevation 41 feet, 0.35 mile east of Western Pacific Railroad, 0.16 mile south of Howsley Road. 3/3/48, 19.9; 3/31/49, 18.8.

11N/4E-11C2—Reference point—top of casing, elevation 45 feet, 0.18 mile south of Howsley Road, 0.40 mile east of Western Pacific Railroad. 12/22/47, 23.1; 12/8/48, 25.1; 3/31/49, 21.0; 11/30/49, 25.8; 3/30/50, 21.2; 11/9/50, 28.1; 4/5/51, 19.2; 12/4/51, 27.1; 1/4/52, 17.6.

11N/4E-11N1—Reference point—top of casing, elevation 38 feet. North side of Fifield Road, west side of Western Pacific Railroad. 12/23/47, 21.2; 3/3/48, 18.6; 12/8/48, 25.5; 4/6/49, 18.0; 11/30/49, 25.1.

11N/4E-12C1—Reference point—top of casing, elevation 46 feet, 0.03 mile east of Pleasant Grove Road, 0.03 mile south of Howsley Road. 11/26/48, 27.2.

11N/4E-12C2—Reference point—top of casing, elevation 50.0 feet, 0.12 mile east of Pleasant Grove Road, 0.02 mile south of Howsley Road. 12/22/47, 23.4; 3/3/48, 20.9; 12/8/48, 23.6; 3/31/49, 22.1; 11/30/49, 23.9.

11N/4E-12H1—Reference point—top of casing, elevation 56.8 feet, 0.76 mile east of Pleasant Grove Road, 0.57 mile south of Howsley Road. 12/7/48, 27.8.

11N/4E-12J2—Reference point—top of casing, elevation 56.8 feet, 0.58 mile south of Howsley Road, 0.78 mile east of Pleasant Grove Road. 12/23/47, 27.3; 3/3/48, 25.2; 12/8/48, 28.2; 3/31/49, 24.7; 11/17/49, 30.8; 11/30/49, 28.9; 3/30/50, 28.0; 4/11/50, 26.9; 11/8/50, 32.5; 11/14/50, 32.4; 4/5/51, 28.9; 11/15/51, 34.0; 4/3/52, 29.2; 4/4/52, 29.6.

11N/4E-12M1—Reference point—slot in base, elevation 44.7 feet, 0.62 mile south of Howsley Road, 0.07 mile west of Pleasant Grove Road. 12/23/47, 22.8; 3/3/48, 19.8; 12/8/48, 24.6; 3/31/49, 20.4; 5/26/49, 26.2; 6/29/49, 25.1; 7/28/49, 32.8; 11/30/49, 27.2; 3/30/50, 23.1; 11/6/50, 28.2; 4/10/51, 23.5; 11/14/51, 35.0; 4/4/52, 23.2.

11N/4E-13D1—Reference point—top of casing, elevation 47.6 feet. West side of Pleasant Grove Road, 0.09 mile south of Fifield Road. 12/8/48, 28.5; 4/6/49, 18.0; 11/30/49, 27.0; 3/15/50, 23.3; 3/30/50, 24.1; 11/8/50, 30.1; 4/5/51, 25.0; 11/14/51, 32.6; 4/4/52, 29.5; 4/10/52, 25.2.

11N/4E-13M1—Reference point—top of casing in pit, elevation 46 feet, 0.12 mile west of Pleasant Grove Road, 0.37 mile north of Keys Road. 12/23/47, 15.9; 12/8/48, 19.1; 3/31/49, 14.0; 11/30/49, 21.7.

11N/4E-14B1—Reference point—top of casing, elevation 40 feet, 0.10 mile south of Howsley Road, 0.52 mile west of Pleasant Grove Road. 12/23/47, 25.8; 3/3/48, 21.8; 12/8/48, 27.8; 3/31/49, 21.1; 11/30/49, 29.6.

11N/4E-14D1—Reference point—top of casing, elevation 36.5 feet, 0.21 mile west of Western Pacific Railroad, 0.26 mile south of Fifield Road. 12/23/47, 21.2; 3/3/48, 18.6; 12/8/48, 25.5; 4/6/49, 18.0; 11/30/49, 25.1.

11N/4E-15C1—Reference point—top of casing, elevation 31.2 feet. South side of Fifield Road, 0.11 mile west of Sacramento Northern Railroad. 12/23/47, 16.9; 3/3/48, 14.9; 12/8/48, 20.0; 4/6/49, 12.9; 11/30/49, 18.8; 3/30/50, 14.4; 11/8/50, 19.5; 4/3/51, 11.0; 12/4/51, 19.1; 4/4/52, 7.2.

11N/4E-15Q1—Reference point—hole in pump base, elevation 33.6 feet, 0.80 mile west of Sacramento Northern Railroad, 0.22 mile north of Keys Road. 12/23/47, 18.5; 3/3/48, 16.8; 12/8/48, 23.5; 4/6/49, 16.0; 11/30/49, 22.2; 3/30/50, 17.9; 11/8/50, 23.5; 4/3/51, 14.7; 12/5/51, 23.0; 4/4/52, 12.6.

11N/4E-21R1—Reference point—top of casing, elevation 24.9 feet, 1.06 miles east of Burns Road, 0.22 mile north of Sankey Road. 12/23/47, 9.9; 3/3/48, 9.6; 12/8/48, 12.3; 4/6/49, 8.0.

11N/4E-22A1—Reference point—top of casing, elevation 32.7 feet, 0.18 mile west of Sacramento Northern Railroad crossing. 12/8/48, 23.5; 4/6/49, 15.2; 11/30/49, 22.6.

11N/4E-23C1—Reference point—top of casing, elevation 37 feet, 0.09 mile south of Keys Road, 0.09 mile east of Western Pacific Railroad. 12/23/47, 21.0; 3/3/48, 18.6; 11/30/49, 26.6; 3/30/50, 22.1; 11/8/50, 28.7; 4/3/51, 20.3; 12/4/51, 28.0; 4/4/52, 20.1.

11N/4E-23H1—Reference point—top of casing, elevation 53.1 feet, 0.02 mile west of Pleasant Grove Road, 0.46 mile south of Keys Road. 12/23/47, 19.5; 3/3/48, 18.0; 12/8/48, 24.1; 4/6/49, 19.8; 11/30/49, 32.2; 3/30/50, 24.6; 11/8/50, 30.7; 4/5/51, 21.6; 12/4/51, 29.2.

11N/4E-23N1—Reference point—top of concrete pit wall, elevation 33 feet, 0.06 mile west of Sacramento Northern Railroad, 0.11 mile north of Sankey Road. 12/23/47, 21.3.

11N/4E-25M1—Reference point—hole in base, elevation 37 feet, 0.58 mile south of Sankey Road, 0.06 mile east of Pleasant Grove Road. 12/23/47, 19.0; 3/3/48, 20.2; 12/8/48, 24.9; 4/6/49, 21.0; 12/1/49, 34.6; 3/30/50, 29.9; 4/4/50, 34.9.

11N/4E-26F1—Reference point—hole in base of pump, elevation 37 feet, 0.40 mile south of Sankey Road, 0.05 mile west of Sacramento Northern Railroad. 12/8/48, 28.0; 4/6/49, 23.0; 12/8/48, 119; 3/30/50, 29.9; 11/9/50, 29.1; 12/6/51, 37.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

11N/4E-28J1—Reference point—top of casing, elevation 34.3 feet, 0.70 mile south of Sankey Road, 0.40 mile west of Pacific Avenue. 3/4/48, 20.4; 12/8/48, 23.6; 4/6/49, 19.2; 12/1/49, 25.3; 3/30/50, 22.5; 11/9/50, 29.1; 4/5/51, 21.4; 12/6/51, 30.5; 4/4/52, 22.8.

11N/4E-33J1—Reference point—top of casing, elevation 25.6 feet, 0.03 mile west of Pacific Avenue, 0.28 mile north of Riego Road. 3/4/48, 13.4; 12/7/48, 15.7; 4/6/49, 12.2; 5/26/40, 11.0; 12/1/49, 17.4; 3/30/50, 14.0; 11/9/50, 14.6; 4/5/51, 12.7; 12/6/51, 14.1; 4/4/52, 14.9.

11N/4E-36E1—Reference point—top of concrete pit wall, elevation 39 feet, 0.07 mile east of Pleasant Grove Road, 0.70 mile north of Riego Road. 12/24/47, 22.3; 3/3/48, 23.0; 12/7/48, 28.9; 4/6/49, 24.9; 12/1/49, 38.7; 3/30/50, 23.2; 11/9/50, 44.4; 4/4/52, 19.0.

11N/5E-6N1—Reference point— top of casing, elevation 59 feet. North side Howsley Road, 0.80 mile east of Pleasant Grove Road. 12/23/47, 24.7; 3/3/48, 22.6; 12/8/48, 25.1; 3/31/49, 22.8; 11/30/49, 25.9; 11/14/50, 28.7; 3/22/51, 26.2.

11N/5E-18N1—Reference point— top of casing, elevation 50 feet. North side of Keys Road, 0.85 mile east of Pleasant Grove Road. 12/24/47, 27.3; 3/3/48, 26.5; 12/8/48, 30.1; 11/30/49, 31.8; 11/14/50, 33.1; 3/22/51, 31.2.

11N/5E-30M1—Reference point—top of casing, elevation 47 feet, 1.05 miles east of Pleasant Grove Road, 0.59 mile south of Sankey Road. 12/24/47, 18.8; 3/3/48, 18.7; 12/8/48, 22.4; 12/1/49, 23.4; 3/30/50, 24.4; 11/9/50, 23.4; 12/5/51, 23.4; 4/4/52, 32.5.

12N/3E-1E1—Reference point—top of casing, elevation 33 feet, 0.10 mile northeast of Garden Highway, 0.20 mile northwest of Sutter Avenue. 12/4/47, 13.6; 3/10/48, 10.0; 12/11/48, 13.2; 3/16/49, 8.3; 12/6/49, 12.6; 3/29/50, 7.5; 11/15/51, 11.1; 4/4/52, 5.9.

12N/3E-1L1—Reference point—top of casing, elevation 31 feet, 150 feet northwest of Sutter Avenue, 0.12 mile northeast of Garden Highway. 12/4/47, 12.6; 3/10/48, 12.1; 12/11/48, 12.9; 3/16/49, 8.0; 12/6/49, 12.5; 11/3/50, 13.2; 4/2/51, 5.3; 11/3/51, 13.2; 4/4/52, 3.3.

12N/3E-2B1—Reference point—top of casing, elevation 31 feet, 0.08 mile east of Garden Highway, 0.49 mile north of Chandler Road. 12/4/47, 9.1; 3/10/48, 9.4; 12/11/48, 9.7; 3/16/49, 6.5; 12/6/49, 8.6.

12N/3E-2E1—Reference point—top of casing, elevation 29 feet, North side of Chandler Road, 0.48 mile west of Garden Highway. 12/4/47, 9.9; 3/10/48, 5.8; 5/11/48, 4.7; 12/11/48, 8.8; 3/16/49, 4.1; 5/26/49, 3.1; 6/29/49, 3.2; 7/27/49, 2.6; 8/25/49, 3.3. Well destroyed.

12N/3E-2J1—Reference point—top of casing, elevation 30 feet, South side of Garden Highway, 0.30 mile northwest of Sutter Avenue. 12/4/47, 12.2; 3/10/48, 8.9; 12/11/48, 12.8; 3/16/49, 8.3; 12/6/49, 11.7.

12N/3E-2K1—Reference point—top of casing, elevation 30 feet, South side of Garden Highway, 0.54 mile west of Sutter Avenue. 12/4/47, 12.2; 3/10/48, 4.9; 5/11/48, 6.7; 3/16/49, 4.8; 12/6/49, 7.5.

12N/3E-3K1—Reference point—top of casing, elevation 25 feet, 0.89 mile west of Garden Highway, 0.08 mile south of Chandler Road. 11/7/29, 8.0; 9/27/30, 6.4; 12/12/31, 6.5; 11/25/32, 10.1; 12/20/33, 8.3; 11/10/34, 9.1; 11/25/36, 10.8; 11/24/37, 5.9; 1/25/39, 9.6; 1/13/41, 4.6; 11/7/47, 8.5; 12/15/48, 8.3; 12/6/49, 9.2.

12N/3E-3K2—Reference point—top of casing, elevation 25 feet, 0.20 mile south of Chandler Road, 0.89 mile west of Garden Highway. 11/13/50, 24.7; 12/6/51, 3.9.

12N/3E-3Q1—Reference point—hole in base of pump, elevation 32 feet, 0.32 mile south of Chandler Road, 0.89 mile west of Garden Highway. 11/6/50, 27.4; 4-2-51, 4.8.

12N/3E-12C1—Reference point—top of casing, elevation 30 feet, 0.15 mile southwest of west end of Nicolaus bridge. 12/9/47, 14.9; 3/11/48, 11.9; 12/11/48, 15.0; 12/6/49, 14.7.

12N/3E-13G1—Reference point—top of casing, elevation 30 feet, 0.68 mile north of Lee Road, 0.38 mile southeast of Garden Highway. 12/5/47, 14.3; 3/15/48, 12.4; 12/14/48, 13.8; well destroyed.

12N/3E-13M1—Reference point—top of pit wall, elevation 29 feet, 0.45 mile southwest of Garden Highway, 0.37 mile northwest of Lee Road. 12/5/47, 14.4; 3/11/48, 13.8; 3/25/49, 12.5; well destroyed.

12N/3E-14H1—Reference point—top of pit wall, elevation 30 feet. East side of Garden Highway, 0.99 mile northeast of Lee Road. 12/5/47, 14.7; 3/15/48, 14.2; 12/11/48, 15.0; 3/25/49, 10.1; 12/6/49, 16.1.

12N/3E-14Q1—Reference point—top of casing, elevation 26 feet, South side of Lee Road, 0.12 mile southeast of Garden Highway. 12/5/47, 14.2; 3/11/48, 13.1; 12/11/48, 14.1; 3/25/49, 9.3; 12/6/49, 14.7; 3/29/50, 9.8.

12N/3E-22R1—Reference point—top of casing, elevation 26 feet, East side of Garden Highway, 1.30 miles south of Lee Road. 11/7/29, 12.0; 9/27/30, 12.7; 12/15/31, 13.0; 11/25/32, 14.9; 12/21/33, 11.3; 10/27/34, 14.5; 11/25/36, 14.1; 11/6/37, 13.5; 1/10/39, 11.1; 12/20/40, 8.4; 11/10/47, 14.1.

12N/3E-22R2—Reference point—top of casing, elevation 26 feet, East side of Garden Highway, 1.30 miles south of Lee Road. 12/16/48, 12.3; 12/9/49, 14.0.

12N/3E-22R3—Reference point—top of casing, elevation 26 feet, 0.15 mile southeast of Garden Highway, 1.30 miles south of Lee Road. 11/13/50, 12.8; 12/6/51, 5.5.

12N/3E-23N1—Reference point—top of casing, elevation 25 feet, 0.09 mile east of Garden Highway, 1.10 miles south of Lee Road. 12/19/47, 12.6; 3/4/48, 11.2; 12/15/48, 12.3; 3/30/49, 6.6; 12/5/49, 15.9; 3/24/50, 5.8; 11/6/50, 12.6; 4/2/51, 6.6; 11/16/51, 11.4.

12N/3E-24A1—Reference point—top of casing, elevation 25 feet, South side of Lee Road, 0.58 mile west of Power Line Road. 12/5/47, 12.4; 3/11/48, 11.2; 12/11/48, 12.6; 3/25/49, 9.4; 12/6/49, 13.3.

12N/3E-24Q1—Reference point—top of casing, elevation 25 feet, 0.10 mile north of Striplin Road, 0.30 mile east of Garwood Road. 12/18/47, 11.6; 3/4/48, 10.8; 12/15/48, 12.9; 3/30/49, 7.9; 12/5/49, 14.1; 3/24/50, 9.1; 11/8/50, 12.1; 4/2/51, 4.3; 11/16/51, 12.8; 4/7/52, 3.5.

12N/3E-26N1—Reference point—lower end of flange around discharge pipe, elevation 22 feet, 0.08 mile southwest of Worth Road, 0.90 mile west of Garwood Road. 12/19/47, 11.1; 3/4/48, 9.9; 12/15/48, 14.1; 3/30/49, 7.9; well destroyed.

12N/3E-27Q1—Reference point—hole in base of pump, elevation 22 feet, 0.10 mile east of Garden Highway, 1.30 miles north of Catlett Road. 11/6/50, 12.5; 4/2/51, 7.0.

12N/4E-1B1—Reference point—top of casing, elevation 58 feet, South side of Cornelius Avenue, 0.54 mile east of Pleasant Grove Road. 12/22/47, 21.7; 3/11/48, 20.0; 12/15/48, 21.4; 3/18/49, 20.3; 12/7/49, 26.2.

12N/4E-2B1—Reference point—hole in base of pump, elevation 53 feet, 0.05 mile south of Cornelius Avenue, 0.50 mile north of Pleasant Grove Road. 12/22/47, 19.8; 3/11/48, 21.8; 12/13/48, 27.2; 3/29/49, 20.8; 12/7/49, 26.2; 3/27/50, 22.1; 11/6/50, 30.9; 4/5/51, 24.0; 4/4/52, 24.0.

12N/4E-2Q1—Reference point—hole in base of pump, elevation 51 feet, 0.46 mile north of Trowbridge Road, 0.34 mile west of Pleasant Grove Road. 3/11/48, 15.7; 5/5/48, 13.3; 5/31/48, 14.7; 6/17/48, 35.2; 6/23/48, 38.0; 7/2/48, 20.3; 12/15/48, 17.9; 3/28/49, 11.6; 5/26/49, 19.5; 6/29/49, 20.9; 7/28/49, 21.7; 8/26/49, 21.2; 12/7/49, 19.0; 3/27/50, 15.4; 11/6/50, 23.9; 4/5/51, 15.5; 4/4/52, 13.2.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Mode by Division of Woter Resources
(Depths to woter in feet meosured from reference point)

12N/4E-3A1—Reference point—top of casing, elevation 52.4 feet. Southwest corner of intersection of Cornelius Avenue and Pleasant Grove Road. 3/11/48, 19.9; 12/14/48, 22.5; 3/29/49, 19.8; 12/7/49, 24.5.

12N/4E-3B1—Reference point—top of casing, elevation 49 feet. South side of Cornelius Avenue, 0.55 mile east of Pacific Avenue. 12/22/47, 21.4; 12/14/48, 23.7; 3/29/49, 19.9; 12/7/49, 24.2.

12N/4E-4A1—Reference point—top of casing, elevation 47 feet. Southwest corner of intersection of Cornelius Avenue and Pacific Avenue. 12/21/40, 19.1; 12/4/47, 24.5; 12/16/48, 26.0; 12/8/51, 31.4.

12N/4E-4A2—Reference point—top of casing, elevation 47 feet. 70.0 feet south of southwest corner of Cornelius Avenue and Pacific Avenue. 11/7/47, 23.7; 12/16/48, 24.8; 12/9/49, 26.0; 11/10/50, 30.0; 12/8/51, 29.8.

12N/4E-4D1—Reference point—top of casing, elevation 42 feet. 0.06 mile south of Cornelius Avenue, 0.12 mile east of Electric Avenue. 12/9/47, 24.1; 3/11/48, 24.2; 5/11/48, 22.4; 12/14/48, 24.9; 3/28/49, 23.4; 12/6/49, 25.8.

12N/4E-4M1—Reference point—top of casing, elevation 40 feet. 0.24 mile east of Electric Avenue, 0.25 mile north of Watts Avenue. 3/11/48, 21.9; 12/14/48, 24.6; 3/28/49, 21.8; 12/7/49, 24.8.

12N/4E-5B1—Reference point—top of wooden pit, elevation 38 feet. South side of Cornelius Avenue, 0.36 mile west of Electric Avenue. 12/9/47, 20.9; 3/11/48, 20.8; 12/14/48, 22.1; 3/28/49, 19.4; 12/6/49, 22.5.

12N/4E-6B1—Reference point—top of wooden pit, elevation 32 feet, 0.29 mile west, 0.14 mile south of west end of Cornelius Avenue. 12/8/47, 14.2; 3/25/48, 12.0; 12/18/48, 13.9; 3/28/49, 8.4; 12/7/49, 15.2.

12N/4E-6Q1—Reference point—top of casing, elevation 30 feet, 1.50 miles west of Electric Avenue, 0.18 mile north of Nicolaus Avenue. 12/8/47, 15.7; 3/25/48, 14.1; 3/16/49, 12.9; 12/6/49, 16.8.

12N/4E-6R1—Reference point—top of casing, elevation 36 feet, 0.22 mile north of Nicolaus Avenue, 1.16 miles west of Electric Avenue. 12/8/47, 6.8; 12/14/48, 7.5; 3/16/49, 4.7; 12/6/49, 8.7.

12N/4E-7B1—Reference point—hole in base of pump, elevation 30 feet. South side of Nicolaus Avenue, 1.41 miles west of Electric Avenue. 12/8/47, 14.8; 5/11/48, 9.8; 12/13/48, 14.5; 3/16/49, 11.4; 6/30/49, 15.0; 7/27/49, 17.1; 12/6/49, 15.8; 3/25/50, 11.1; 11/6/50, 16.5; 4/2/51, 6.6; 11/16/51, 15.7; 4/4/52, 5.5.

12N/4E-7N2—Reference point—bottom of 6" x 14" plank bridge over pit, elevation 30 feet, 0.41 mile southeast of Garden Highway, 0.19 mile southwest of Markham Road. 12/5/47, 14.6; 3/15/48, 12.8; 12/11/48, 14.3; 3/25/49, 10.8; 12/6/49, 15.0.

12N/4E-7P2—Reference point—top of wooden pit, elevation 28 feet, 0.67 mile southeast of Garden Highway, 0.06 mile southwest of Markham Road. 12/5/47, 11.1; 3/11/48, 13.0; 5/11/48, 11.1; 12/11/48, 14.2; 3/25/49, 11.0; 12/6/49, 15.0.

12N/4E-8A1—Reference point—top of casing, elevation 37 feet. South side of Nicolaus Avenue, 0.07 mile west of Electric Avenue. 12/8/47, 19.2; 3/11/48, 17.4; 12/14/48, 19.6; 3/16/49, 17.4; 12/6/49, 20.4.

12N/4E-8C1—Reference point—top of casing, elevation 36 feet, 0.05 mile south of Nicolaus Avenue, 0.50 mile west of Electric Avenue. 12/8/47, 18.6; 3/11/48, 17.3; 5/11/48, 16.0; 12/14/48, 19.0; 3/16/49, 17.1; 12/6/49, 20.2; 3/29/50, 17.0; 11/6/50, 23.1; 1/2/51, 13.8; 11/16/51, 22.2; 1/1/52, 13.1.

12N/4E-8D1—Reference point—hole in base of pump, elevation 32 feet, 0.16 mile south of Nicolaus Avenue, 0.80 mile west of Electric Avenue. 12/8/47, 20.8; 3/25/48, 18.2; 12/11/48, 22.0.

12N/4E-9A1—Reference point—top of casing, elevation 44 feet. West side of Pacific Avenue, 0.24 mile south of Nicolaus Avenue. 12/23/47, 19.4; 3/11/48, 18.1; 12/14/48, 20.9; 3/28/49, 16.6; 12/7/49, 20.3; 3/27/50, 17.5; 11/6/50, 27.6; 4/2/51, 16.7; 11/16/51, 26.0; 4/4/52, 16.6.

12N/4E-9D1—Reference point—hole in pump base, elevation 40 feet. South side of Nicolaus Avenue, 0.13 mile east of Electric Avenue. 3/11/48, 17.9; 12/14/48, 20.0; 3/28/49, 17.3; 5/25/49, 21.0; 6/29/49, 22.7; 7/27/49, 23.9; 8/31/49, 25.1; 12/7/49, 20.6; 3/27/50, 18.2; 11/6/50, 24.8; 4/2/51, 16.1; 11/16/51, 24.0; 4/4/52, 15.8.

12N/4E-9J1—Reference point—top of casing, elevation 42 feet, 0.11 mile west of Pacific Avenue, 0.53 mile south of Nicolaus Avenue. 3/11/48, 18.7; 12/14/48, 21.1; 3/28/49, 16.7; 12/7/49, 20.5.

12N/4E-9J2—Reference point—top of casing, elevation 42 feet, 0.13 mile west of Pacific Avenue, 0.53 mile south of Nicolaus Avenue. 3/11/48, 19.1; 12/14/48, 21.4; 3/28/49, 16.9; 12/7/49, 20.8.

12N/4E-10A1—Reference point—hole in base of pump, elevation 50 feet, 0.09 mile south of Nicolaus Avenue, 0.90 mile east of Pacific Avenue. 3/11/48, 17.4; 4/2/48, 15.8; 5/5/48, 15.6; 5/31/48, 17.0; 6/17/48, 42.5; 7/2/48, 23.2; 12/15/48, 20.0; 3/28/49, 14.1; 7/1/49, 46.7 (operating); 8/1/49, 47.0 (operating); 8/31/49, 46.8 (operating); 12/7/49, 20.6; 3/27/50, 15.3; 11/6/50, 26.1; 4/5/51, 17.5; 4/4/52, 17.5.

12N/4E-10C1—Reference point—top of casing, elevation 47 feet. South side of Nicolaus Avenue, 0.51 mile east of Pacific Avenue. 3/11/48, 18.6; 12/14/48, 21.3; 3/28/49, 16.6; 12/7/49, 21.1.

12N/4E-11H1—Reference point—hole in base of pump, elevation 46 feet, 0.04 mile south of Trowbridge Road, 0.20 mile west of Pleasant Grove Road. 11/19/51, 22.9.

12N/4E-12D1—Reference point—top of casing, elevation 52 feet. West side of Pleasant Grove Road, 0.24 mile north of Trowbridge Road. 12/22/47, 13.4; 3/11/48, 12.5; 12/14/48, 14.0; 3/28/49, 6.9; 12/7/49, 15.8.

12N/4E-13C1—Reference point—hole in base of pump, elevation 51 feet, 0.11 mile south of Marcum Road, 0.53 mile east of Pleasant Grove Road. 3/11/48, 13.4; 12/14/48, 14.3; 12/22/48, 12.6; 3/29/49, 9.3; 11/10/49, 18.0; 3/15/50, 13.9; 3/27/50, 13.8; 4/10/50, 13.4; 11/6/50, 19.6; 11/14/50, 19.9; 3/23/51, 12.3; 11/19/51, 23.5; 4/4/52, 14.6; 4/10/52, 14.6.

12N/4E-13D1—Reference point—top of casing, elevation 50 feet. Southeast of intersection of Pleasant Grove Road and Marcum Road. 12/22/47, 12.1; 3/11/48, 12.3; 12/14/48, 12.2; 3/29/49, 6.6; 2/7/49, 13.9.

12N/4E-14P1—Reference point—top of casing, elevation 43 feet, 1.72 miles south of Trowbridge Road, 0.53 mile west of Pleasant Grove Road. 3/11/48, 9.1; 12/18/48, 8.8; 3/29/49, 3.3; 12/7/49, 10.8; 3/27/50, 7.1; 11/6/50, 4.3; 4/5/51, 5.3; 4/4/52, 4.3.

12N/4E-16A2—Reference point—top of casing, elevation 40 feet, 0.07 mile west of Pacific Avenue, 1.30 miles south of Nicolaus Avenue. 12/23/47, 16.1; 3/11/48, 15.2; 5/11/48, 17.7; 12/14/48, 16.5; 3/28/49, 12.0; 3/27/50, 13.8; 11/6/50, 22.6; 4/2/51, 11.8; 11/16/51, 26.6; 4/4/52, 11.6.

12N/4E-16L1—Reference point—top of 16-inch casing, elevation 34 feet, 0.50 mile east of Electric Avenue, 0.60 mile south of Markham Road. 3/11/48, 13.1; 12/14/48, 12.9; 3/28/49, 8.7; 12/7/49, 16.1; 11/6/50, 19.9; 4/2/51, 8.4.

12N/4E-16L2—Reference point—top of casing, elevation 34 feet, 0.25 mile east of Electric Avenue, 0.50 mile south of Markham Road. 3/11/48, 11.0; 12/13/48, 21.6; 3/28/49, 7.2; 12/7/49, 13.9.

12N/4E-17C1—Reference point—top of 16-inch casing under pump, elevation 35 feet, 0.25 mile south of Markham Road, 0.50 mile west of Electric Avenue. 12/8/47, 16.5; 3/25/48, 15.0; 12/11/48, 16.1; 3/28/49, 13.1; 12/7/49, 17.5.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Divisian of Water Resaurces
(Depths to water in feet measured from reference paint)

12N/4E-17J1—Reference point—top of 16-inch casing, elevation 32 feet. 300 feet west of Electric Avenue, 0.52 mile south of Markham Road. 12/8/47, 13.0; 3/11/48, 12.6; 5/11/48, 12.6; 12/11/48, 13.2; 3/28/49, 9.1; 5/26/49, 14.2; 6/29/49, 15.7; 7/27/49, 16.4; 8/26/49, 17.2; 12/7/49, 15.3; 11/16/51, 18.2; 4/4/52, 6.1.

12N/4E-18A1—Reference point—top of 12-inch casing under pump, elevation 30 feet. 600 feet south of Markham Road, 0.50 mile east of Power Line Road. 12/5/47, 14.3; 3/11/48, 14.9; 12/11/48, 14.7; 3/28/49, 12.4; 12/7/49, 15.6; 3/29/50, 13.3; 11/6/50, 17.1; 4/2/51, 6.4; 11/16/51, 16.4; 4/4/52, —3.0.

12N/4E-18D1—Reference point—top of concrete pit wall, south side, elevation 30 feet, 0.56 mile southeast of Garden Highway, 300 feet southwest of road. 12/5/47, 16.2; 12/11/48, 15.9; 3/25/49, 13.1; 12/6/49, 16.5; 11/6/50, 18.1; 4/2/51, 6.4.

12N/4E-18P1—Reference point—bottom of 4" x 12" plank across wooden pit, elevation 25 feet, 0.27 mile west of Power Line Road, 460 feet north of Lee Road. 12/5/47, 13.4; 3/11/48, 12.2; 12/11/48, 15.2; 3/25/49, 10.8; 12/6/49, 13.9.

12N/4E-19A1—Reference point—top of 14-inch casing, elevation 28 feet, 0.44 mile east of junction of Power Line and Lee Roads. 12/5/47, 12.9; 3/15/48, 12.1; 12/11/48, 13.1; 3/28/49, 10.0; 12/6/49, 14.2; 3/29/50, 11.9; 11/6/50, 13.1; 4/2/51, 4.5; 11/16/51, 15.5.

12N/4E-19C1—Reference point—hole in pump base, elevation 25 feet, 100 feet south of Lee Road, 200 feet west of Power Line Road. 12/5/47, 15.6; 3/11/48, 14.3; 3/25/49, 11.8; 12/6/49, 14.8.

12N/4E-19F1—Reference point—top of casing, elevation 27 feet, 300 feet west of Power Line Road, 0.40 mile south of Lee Road. 12/20/47, 14.6; 3/4/48, 14.0; 12/15/48, 14.8; 3/31/49, 11.3; 12/5/49, 15.9.

12N/4E-20A1—Reference point—top of casing, elevation 30 feet, 150 feet east of Electric Avenue, 0.76 mile north of Striplin Road. 12/20/47, 12.6; 3/4/48, 12.5; 12/15/48, 13.8; 3/30/49, 8.1; 12/2/49, 19.3.

12N/4E-20J1—Reference point—slot in concrete base, elevation 30 feet, 100 feet west of Electric Avenue, 0.42 mile north of Striplin Road. 5/5/48, 11.9; 5/31/48, 63.0 (operating); 7/2/48, 62.0 (operating); 12/15/48, 12.8; 4/13/49, 8.5; 6/30/49, 31.4; 8/1/49, 57.0 (operating); 8/31/49, 56.0 (operating); 12/7/49, 16.6; 3/24/50, 12.3; 11/8/50, 19.6; 4/2/51, 8.2; 11/19/51, 19.0; 4/7/52, 5.7.

12N/4E-20Q1—Reference point—top of 14-inch casing, elevation 30 feet, 0.35 mile west of Electric Avenue on Striplin Road. 5/5/48, 9.9; 5/31/48, 16.2; 12/15/48, 10.8; 4/13/49, 7.0; 6/2/49, 20.6; 8/1/49, 47.6 (operating); 8/31/49, 62.0 (operating); 12/7/49, 14.9.

12N/4E-20R1—Reference point—slot in concrete base, elevation 30 feet, 100 feet west of Electric Avenue, 0.21 mile west of Striplin Road. 5/5/48, 12.4; 5/31/48, 42.0 (operating); 7/2/48, 43.0 (operating); 12/15/48, 13.3; 4/13/49, 9.6; 6/2/49, 28.9; 6/30/49, 33.3; 8/1/49, 52.0 (operating); 8/31/49, 66.0 (operating); 12/7/49, 18.6.

12N/4E-21M1—Reference point—top of 16-inch casing outside of pump house, elevation 32 feet, 0.25 mile east of Electric Avenue, 0.80 mile north of Striplin Road. 12/23/47, 12.4; 3/15/48, 12.4; 12/15/48, 12.8; 3/30/49, 6.7; 12/2/49, 17.9.

12N/4E-24A1—Reference point—top of 14-inch casing, elevation 56 feet, South side of Lee Road, 0.5 mile west of Power Line Road. 12/20/48, 16.5; 4/1/49, 13.4; 11/10/49, 21.8; 3/15/50, 18.0; 4/10/50, 17.8; 10/2/50, 29.5; 11/13/50, 23.8; 3/21/51, 17.8; 5/9/51, 26.6; 11/14/51, 27.9; 3/13/52, 21.1.

12N/4E-24F1—Reference point—top of 14-inch casing, elevation 49 feet, 0.50 mile east of Pleasant Grove Road, 0.75 mile north of Striplin Road. 5/31/48, 11.3; 12/18/48, 13.1; 3/29/49, 8.7; 12/2/49, 16.2; 4/10/50, 13.2; 11/13/50, 18.2; 3/21/51, 11.7; 11/16/51, 21.4.

12N/4E-24M1—Reference point—top of 14-inch casing, elevation 50.9 feet, 75 feet east of Pleasant Grove Road, 0.25 mile north of Striplin Road. 12/22/47, 12.9; 3/22/48, 13.1; 12/18/48, 14.2; 3/29/49, 9.2; 5/26/49, 14.0; 6/29/49, 19.4; 7/28/49, 17.6; 8/26/49, 18.0; 12/2/49, 17.2; 3/15/50, 14.4; 3/27/50, 14.6, 11/6/50, 18.8; 4/5/51, 12.1; 11/16/51, 20.9; 11/19/51, 20.9; 4/8/52, 12.5; 4/10/52, 12.2.

12N/4E-25F1—Reference point—top of 16-inch casing, elevation 50 feet, 0.50 mile east of Pleasant Grove Road, 0.44 mile south of Striplin Road. 11/16/51, 27.1.

12N/4E-25M1—Reference point—hole in pump base, elevation 51.3 feet, 250 feet east of Pleasant Grove Road, 0.70 mile south of Striplin Road. 12/22/47, 15.7, 3/22/48, 15.1; 12/18/48, 17.4; 3/29/49, 13.3; 12/2/49, 20.6; 3/27/50, 17.5; 11/8/50, 22.8; 4/5/51, 15.7; 11/19/51, 29.0; 4/8/52, 19.8.

12N/4E-26M1—Reference point—hole in pump base, elevation 41 feet, 0.75 mile west of Pleasant Grove Road, 1.0 mile north of Catlett Road. 3/22/48, 12.9; 12/18/48, 14.8; 3/29/49, 10.6; 12/2/49, 18.5; 11/8/50, 19.4; 4/5/51, 12.7; 4/8/52, 11.3.

12N/4E-28F1—Reference point—hole in pump base, elevation 32 feet, 0.50 mile west of Pacific Avenue, 0.36 mile south of Striplin Road. 3/15/48, 11.0; 12/18/48, 12.5.

12N/4E-28H1—Reference point—hole in top of discharge pipe, elevation 36 feet. West of Pacific Avenue, 0.36 mile south of Striplin Road. 12/22/47, 11.1; 3/15/48, 11.0; 12/18/48, 11.2; 3/24/50, 11.1; 11/8/50, 15.7; 4/2/51, 8.1; 11/19/51, 11.9; 4/7/52, 8.0.

12N/4E-29A1—Reference point—north side base of pump, elevation 31 feet, 200 feet south of Striplin Avenue, 450 feet west of Electric Avenue. 12/18/47, 12.3; 3/14/48, 12.7; 12/15/48, 11.7; 3/30/49, 6.2; 12/2/49, 17.6; 3/24/50, 12.4; 11/8/50, 18.2; 4/2/51, 9.4; 11/19/51, 19.9; 4/7/52, 4.9.

12N/4E-29R1—Reference point—pump base at hole in concrete, elevation 30 feet, 300 feet west of Electric Avenue, 0.75 mile north of Catlett Road. 12/18/47, 10.2; 3/4/48, 10.8; 12/5/49, 20.8; 3/24/50, 8.0; 11/8/50, 13.5; 4/2/51, 5.6; 11/19/51, 14.0; 4/7/52, 3.9.

12N/4E-30F1—Reference point—pump base, elevation 25 feet, 100 feet east of Power Line Road, 0.50 mile south of Striplin Road. 12/20/47, 11.1; 3/4/48, 10.4; 12/15/48, 11.8; 3/30/49, 4.9; 12/5/49, 12.2; 3/27/50, 8.1; 11/8/50, 10.6; 4/2/51, 3.7; 11/16/51, 10.9; 4/8/52, 4.8.

12N/4E-32K1—Reference point—top of 16-inch casiug, elevation 28 feet, 1,500 feet west of Electric Avenue, 0.52 mile north of West Catlett Road. 3/30/49, 3.2.

12N/4E-33E1—Reference point—top of 18-inch casing, elevation 30 feet, 150 feet north of Catlett Road, 1,000 feet east of Electric Avenue. 3/15/48, 10.6; 12/18/48, 10.4.

12N/4E-33L3—Reference point—top of casing, elevation 31 feet. At dwelling south side of road, 300 feet east of Catlett Station, Sacramento Northern Railroad. 11/8/29, 15.4; 9/28/30, 16.0; 12/10/31, 16.4; 12/5/32, 12.2; 12/20/33, 15.6; 9/27/34, 16.3; 11/23/36, 12.5; 11/24/37, 9.4; 1/10/39, 8.9; 1/13/41, 3.4; 11/10/47, 11.5; 12/16/48, 11.0; 12/9/49, 13.4; 11/10/50, 13.0; 12/6/51, 12.0.

12N/4E-33R1—Reference point—top of 8-inch casing, elevation 31 feet, 100 feet west of Pacific Avenue, 0.32 mile south of Catlett Road. 12/22/47, 11.2; 3/18/48, 10.9; 12/18/48, 11.9; 3/30/49, 6.0; 12/2/49, 13.2; 3/24/50, 9.3; 11/8/50, 12.7; 4/2/51, 7.9; 11/19/51, 13.9; 4/8/52, 5.1.

12N/4E-34J1—Reference point—top of 4-inch casing, elevation 36 feet. Windmill 100 feet south of Catlett Road, 1.0 mile east of Pacific Avenue. 12/22/47, 14.8; 3/22/48, 13.7; 12/18/48, 15.9; 3/29/49, 9.8; 12/2/49, 17.9; 3/27/50, 13.8; 11/8/50, 16.7; 4/5/51, 10.2; 11/19/51, 22.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Mode by Division of Woter Resources
(Depths to woter in feet meosured from reference point)

12N 4E-35H1—Reference point—top of 16-inch casing, elevation 48.8 feet, 0.1 mile west of Pleasant Grove Road, 0.2 mile north of Catlett Road. 12/22/47, 13.3; 3/22/48, 12.0; 12/18/48, 15.2; 3/29/49, 12.0; 12/2/49, 18.3; 3/27/50, 16.4; 11/8/50, 20.1; 4/5/51, 13.3; 5/10/51, 16.7; 7/11/51, 25.1; 8/22/51, 28.2; 9/26/51, 27.3; 11/16/51, 22.2; 11/19/51, 24.7; 4/8/52, 15.2; 4/10/52, 13.6.

12N 4E-36Q1—Reference point—top of casing in bottom of pit, elevation 48 feet, ground surface, 0.47 mile south of Catlett Road, 0.63 mile east of Pleasant Grove Road. 4/11/51, 22.0; 11/16/51, 28.9.

12N 5E-18P1—Reference point—top of 14-inch casing, elevation 61 feet, 0.50 mile west of Brewer Road, 1.0 mile south of Mareum Road. 3/22/48, 15.4.

13N 3E-2C1—Reference point—top of air gage hole, elevation 42.7 feet, 50 feet west of Garden Highway, 0.25 mile north of Tudor Road. 11/13/47, 25.6; 3/24/48, 21.0; 3/29/48, 19.7; 11/10/48, 20.4; 1/24/49, 19.2; 3/23/49, 16.9; 6/30/49, 30.3; 7/27/49, 29.0; 8/25/49, 25.2; 12/6/49, 21.2; 3/29/50, 17.5; 11/7/50, 23.1; 3/25/51, 12.2; 11/15/51, 22.6; 4/3/52, 9.1.

13N 3E-2H1—Reference point—hole in pump base, elevation 43.4 feet, 150 feet south of Shannon Road, 0.5 mile east of Garden Highway. 11/13/47, 21.4; 3/8/48, 19.4; 11/10/48, 18.0; 3/23/49, 14.5; 12/6/49, 19.5; 3/29/50, 13.4; 11/7/50, 19.0; 3/29/51, 12.2; 11/15/51, 18.3; 4/3/52, 6.2.

13N 3E-2L1—Reference point—top of 10-inch casing, elevation 41.2 feet, 0.5 mile west of Garden Highway, 0.1 mile south of Tudor Road. 1/19/48, 18.3; 5/6/48, 15.9; 6/1/48, 15.1; 6/3/48, 25.8; 8/2/48, 16.1; 9/1-48, 21.8; 3/23/49, 16.9.

13N 3E-2P1—Reference point—hole in pump base, elevation 39.9 feet, 200 feet west of Garden Highway, 0.3 mile south of Tudor Road. 11/13/47, 19.9; 3/8/48, 26.0; 11/10/48, 18.0; 3/23/48, 15.9; 12/6/49, 19.8.

13N 3E-3D1—Reference point—hole in pump base, elevation 38.9 feet, 50 feet east of State Highway 24, 0.3 mile north of Tudor Road. 11/14/47, 20.9; 3/8/48, 20.8; 3/29/48, 19.5; 11/10/48, 21.1; 1/24/49, 19.7; 3/25/49, 18.1; 6/1/49, 28.6; 6/28/49, 25.4; 7/29/49, 32.3; 8/30/49, 26.1; 12/6/49, 23.3.

13N 3E-3F1—Reference point—hole in pump base, elevation 38.9 feet, 0.15 mile north of Tudor Road, 0.4 mile east of State Highway 24. 11/14/47, 20.8; 3/18/48, 22.9; 11/10/48, 21.3; 3/25/49, 19.2; 12/6/49, 23.4; 3/29/50, 20.6; 11/7/50, 24.6; 3/29/51, 19.0; 11/15/51, 22.9; 4/3/52, 9.0.

13N 3E-4B1—Reference point—top of wood pit east edge, elevation 36 feet, 0.45 mile west of State Highway 24, 0.4 mile north of Tudor Road. 11/14/47, 18.1; 3/8/48, 14.8; 11/10/48, 20.7; 3/25/49, 17.5; 12/6/49, 23.1.

13N 3E-4P1—Reference point—top of 12-inch casing, elevation 34.7 feet, 0.05 mile west of Hobbs Road, 0.3 mile south of Tudor Road. 12/12/47, 14.6; 3/10/48, 14.7; 3/12/48, 14.6; 11/18/48, 16.5; 3/24/49, 13.8; 3/29/50, 15.9.

13N 3E-4P2—Reference point—top of casing, elevation 34 feet, 100 feet west of Hobbs Road, 0.4 mile south of Tudor Road. 11/7/50, 22.9; 3/29/51, 15.8.

13N 3E-5B1—Reference point—top of 4" x 12" plank bridge over earth pit, elevation 39.1 feet, 50 feet east of Bailey Road, 750 feet south of Tudor Road. 12/12/47, 14.3; 3/10/48, 16.9; 3/12/48, 17.1; 3/29/48, 16.7; 11/8/48, 18.3; 3/24/49, 15.4; 12/5/49, 18.6.

13N 3E-5E1—Reference point—top of 2" x 6" sill, north wall of wooden pit, elevation 38.1 feet, 300 feet east of George Washington Boulevard, 1,000 feet north of Tudor Road. 12/12/47, 14.2; 3/10/48, 11.8; 11/8/48, 13.0; 3/24/49, 12.5; 3/29/50, 12.5; 11/7/50, 17.8; 3/29/51, 13.1; 11/15/51, 15.8; 4/3/52, 10.1.

13N 3E-5J1—Reference point—top of 16-inch casing, elevation 27 feet, 0.1 mile south of Tudor Road, 0.5 mile west of Hobbs Road. 12/12/47, 13.7; 3/10/48, 12.8; 3/12/48, 12.8; 12/5/49, 17.0.

13N 3E-5L1—Reference point—top of 12-inch casing, elevation 37.4 feet, 50 feet south of State Highway 24, 650 feet west of Bailey Road. 12/12/47, 15.6; 3/10/48, 15.6; 3/12/48, 15.6; 5/12/48, 15.1; 11/8/48, 16.3; 1/19/49, 14.8; 3/24/49, 14.9; 6/1/49, 16.7; 6/28/49, 21.2; 7/27/49, 22.0; 8/25/49, 20.4; 12/2/49, 17.3.

13N 3E-6K1—Reference point—top of 16-inch casing, elevation 34 feet, South side of Tudor Road, 0.5 mile west of George Washington Boulevard. 12/15/48, 9.0; 12/9/49, 9.7; 11/10/50, 12.7; 12/6/51, 13.3.

13N 3E-6M1—Reference point—top of 12-inch casing, elevation 34 feet, 400 feet south of Tudor Road, 0.34 mile east of Roberts Road. 12/11/47, 9.9; 3/10/48, 8.2; 3/12/48, 8.3; 11/8/48, 6.2; 3/24/49, 6.6; 12/2/49, 9.0.

13N 3E-7A1—Reference point—top of casing, 20 feet north of pump house, elevation 35.2 feet, 250 feet south of Thompson Road, 300 feet west of State Highway 24. 12/12/47, 10.8; 3/10/48, 11.1; 3/12/48, 11.2; 11/8/48, 11.7; 3/24/49, 10.5; 12/2/49, 12.3.

13N 3E-7J1—Reference point—top of 8-inch casing, elevation 35.1 feet, 0.45 mile north of Everglade Road, 0.15 mile west of George Washington Boulevard, 250 feet south to well. 12/11/47, 9.7; 3/10/48, 10.5; 3/12/48, 10.7; 11/3/48, 12.0; 1/24/49, 11.7; 3/24/49, 10.3; 12/2/49, 12.8.

13N 3E-8B1—Reference point—top of 16-inch casing, elevation 35 feet, 0.05 mile south of Thompson Road, 0.8 mile west of Hobbs Road. 12/12/47, 10.8; 3/10/48, 13.9; 3/12/48, 14.0; 11/18/48, 15.1; 3/25/49, 13.0; 12/5/49, 17.1.

13N 3E-8M1—Reference point—top of wood floor under pump, elevation 35.9 feet, 0.2 mile east of George Washington Boulevard, 0.7 mile south of Thompson Road. 12/11/47, 10.3; 3/10/48, 10.8; 3/12/48, 10.8; 11/8/48, 13.1; 3/24/49, 11.0; 12/2/49, 13.8.

13N 3E-9C1—Reference point—hole in pump base, elevation 36.2 feet, 150 feet west of Hobbs Road, 0.60 mile south of State Highway 24. 12/12/47, 15.4; 3/10/48, 15.8; 3/12/48, 15.7; 11/8/48, 17.7; 1/24/49, 16.3; 3/24/49, 14.8; 6/1/49, 19.1; 6/28/49, 20.9; 7/27/49, 21.8; 8/30/49, 22.4; 12/5/49, 19.8.

13N 3E-9H1—Reference point—top of east wall of concrete pit, elevation 35 feet, 200 feet west of Sawtelle Avenue, 0.57 mile south of Tudor Road. 12/12/47, 16.8; 3/10/48, 17.9; 3/17/48, 18.0; 11/8/48, 19.2; 3/24/49, 16.3.

13N 3E-11A1—Reference point—hole in pump base, elevation 40 feet, 350 feet north of O'Conner Road, 0.55 mile east of Garden Highway. 11/13/47, 20.1; 3/8/48, 20.8; 11/10/48, 19.0; 1/24/49, 18.6; 3/23/49, 15.5; 12/5/49, 20.7.

13N 3E-11L1—Reference point—top of casing, elevation 38 feet, 0.05 mile west of Garden Highway, 1.1 miles south of Tudor Road. 11/14/47, 16.4.

13N 3E-11M1—Reference point—top of casing, elevation 36 feet, 0.4 mile west of Garden Highway, 0.2 mile north of Wilkie Avenue. 1/20/48, 17.5.

13N 3E-11Q2—Reference point—hole in pump base, elevation 39.3 feet, 50 feet west of Garden Highway, 0.15 mile south of Wilkie Avenue. 11/19/47, 16.5; 3/9/48, 19.8; 5/11/48, 13.4; 11/4/48, 16.1; 1/19/49, 15.3; 3/8/49, 14.8; 6/1/49, 17.2; 6/29/49, 23.9; 8/3/49, 23.7; 8/25/49, 19.1; 12/8/49, 17.2.

13N 3E-12L1—Reference point—hole in pump base, elevation 41 feet, 300 feet north of Wilkie Avenue, 0.7 mile east of Garden Highway. 11/14/47, 18.2; 3/8/48, 19.0; 11/10/48, 16.7; 3/23/49, 12.1; 12/5/49, 17.9; 11/7/50, 17.1; 3/29/51, 11.3; 11/15/51, 16.3; 4/3/52, 6.9.

13N 3E-12N1—Reference point—top of casing, elevation 39.5 feet, 0.2 mile south of Wilkie Avenue, 0.45 mile east of Garden Highway. 11/19/47, 15.4; 3/9/48, 18.2; 5/12/48, 10.3; 11/4/48, 16.3; 3/8/49, 13.7; 12/8/49, 16.2.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

13N/3E-13C1—Reference point—hole in pump base, elevation 42.3 feet, 0.7 mile east of Garden Highway, 0.25 mile south of Wilkie Avenue. 11/19/47, 16.9; 3/9/48, 20.3; 11/4/48, 17.0; 3/8/49, 13.8; 12/8/49, 17.9; 3/29/50, 10.8; 11/7/50, 17.1; 3/29/51, 16.7; 11/15/51, 16.7; 4/2/52, 7.3.

13N/3E-13D1—Reference point— edge of pump base, elevation 39 feet, 0.55 mile east of Garden Highway, 0.25 mile south of Wilkie Avenue. 5/5/48, 9.4; 6/1/48, 9.3; 2/6/52, 6.0.

13N/3E-13E1—Reference point—hole in pump base, elevation 37 feet, 0.5 mile east of Garden Highway, 0.75 mile south of Wilkie Avenue. 11/19/47, 15.4; 3/25/48, 14.7; 11/4/48, 15.1; 3/8/49, 13.3; 12/8/49, 15.9.

13N/3E-13L1—Reference point—top of casing, elevation 38 feet, 0.75 mile east of Garden Highway, 0.95 mile south of Wilkie Avenue. 11/19/47, 15.5; 3/9/48, 19.0; 11/4/48, 14.1; 3/8/49, 13.3; 12/7/49, 16.0.

13N/3E-14C1—Reference point—hole in pump base, elevation 35 feet, 0.25 mile west of Garden Highway, 0.35 mile south of Wilkie Avenue. 11/26/29, 15.4; 9/27/30, 15.6; 12/12/31, 15.4; 12/2/32, 15.2; 12/20/33, 16.3; 11/10/34, 16.7; 11/25/36, 13.4; 11/24/37, 11.8; 1/25/39, 10.8; 1/13/41, 8.2; 11/6/47, 15.3; 11/19/47, 15.9; 5/12/48, 13.9; 11/4/48, 15.7; 12/16/48, 14.7; 3/8/49, 14.9; 12/8/49, 16.6; 12/9/49, 16.0; 11/10/50, 16.0; 12/6/51, 13.4.

13N/3E-14G1—Reference point—hole in pump base, elevation 30.8 feet, 50 feet west of Garden Highway, 0.65 mile south of Wilkie Avenue. 3/25/48, 8.8; 11/4/48, 8.9; 3/8/49, 7.9; 12/8/49, 9.9; 3/29/50, 7.5; 11/7/50, 10.3; 3/39/51, 6.7; 11/15/51, 8.9; 4/2/52, 0.2.

13N/3E-14L3—Reference point—hole in pump base, elevation 34.9 feet, 50 feet south of Wilson Road, 0.1 mile west of Garden Highway. 11/19/47, 12.1; 3/25/48, 12.2; 11/4/48, 10.2; 3/8/49, 10.9; 12/7/49, 13.0; 4/2/52, 3.8.

13N/3E-14M2—Reference point—hole in pump base, elevation 35.7 feet, 0.1 mile south of Wilson Road, 0.4 mile west of Garden Highway. 11/19/47, 16.9; 3/9/48, 16.2; 11/5/48, 14.1; 3/8/49, 12.9; 12/7/49, 14.8.

13N/3E-14P1—Reference point—top of casing, elevation 35.6 feet, 0.25 mile west of Garden Highway, 0.4 mile south of Wilson Road. 11/19/47, 11.1; 3/9/48, 14.1; 11/4/48, 12.9; 3/8/49, 11.7; 12/7/49, 13.8.

13N/3E-14Q1—Reference point—top of casing, elevation 35.1 feet, 350 feet west of Garden Highway, 0.45 mile south of Wilson Road. 11/19/47, 14.9; 3/8/49, 11.0; 12/7/49, 12.8.

13N/3E-14R1—Reference point—hole in pump base, elevation 38.4 feet, 0.4 mile east of Garden Highway, 1.0 mile south of Wilkie Avenue. 11/19/47, 15.9; 3/9/48, 17.8; 11/4/48, 14.2; 3/8/49, 12.5; 12/7/49, 14.8.

13N/3E-15C2—Reference point—top of casing, elevation 36.1 feet, 0.3 mile north of Wilson Road, 100 feet west of Southern Pacific Railroad tracks. 12/18/47, 15.1; 3/11/48, 15.6; 11/4/48, 18.2; 3/16/49, 15.0.

13N/3E-15H1—Reference point—top of wooden pit, north side, elevation 37.8 feet, 0.2 mile north of Wilson Road, 0.6 mile west of Garden Highway. 12/18/47, 16.2; 3/11/48, 17.8; 11/4/48, 17.0; 3/8/49, 15.5.

13N/3E-15P1—Reference point—bottom of 2" x 12" over pit, elevation 34.0 feet, 0.25 mile east of Sawtelle Avenue, 100 feet southeast of most southerly corner of Wilson Road. 12/18/47, 13.2; 3/11/48, 13.0; 11/4/48, 6.7; 3/8/49, 12.9; 12/7/49, 14.7; 3/29/50, 12.8. Well destroyed.

13N/3E-15Q1—Reference point—top of casing, elevation 37 feet, 0.15 mile east of Southern Pacific Railroad tracks, 0.5 mile south of Wilson Road. 3/11/48, 13.2; 11/4/48, 13.6; 3/16/49, 11.7; 12/7/49, 13.1.

13N/3E-15R1—Reference point—top of plug in "T" discharge pipe, elevation 36 feet, 0.65 mile west of Garden Highway, 0.5 mile south of Wilson Road. 3/11/48, 14.5; 11/4/48, 13.6; 3/16/49, 13.2; 12/7/49, 14.3.

13N/3E-16A1—Reference point—top of casing, elevation 35 feet. South of Everglade Road, west of Sawtelle Avenue at intersection. 12/12/47, 15.7; 3/10/48, 14.7; 3/12/48, 14.7; 11/8/48, 17.1; 3/25/49, 14.6; 12/5/49, 16.3; 3/29/50, 15.1; 11/7/50, 17.0; 3/29/51, 11.7; 11/15/51, 15.4; 4/3/52, 9.5.

13N/3E-16H1—Reference point—hole in pump base, elevation 36.8 feet, 0.25 mile south of Everglade Road on west side of Sawtelle Ave. 12/18/47, 16.6; 3/4/48, 17.8; 11/4/48, 18.7; 1/24/49, 16.5; 3/8/49, 15.7; 12/7/49, 18.2.

13N/3E-16R1—Reference point—hole in pump base, elevation 38.1 feet, 60 feet west of Sawtelle Avenue, 0.9 mile south of Everglade Road. 12/18/47, 16.4; 3/11/48, 17.3; 11/4/48, 16.3; 3/16/49, 15.2; 12/7/49, 17.7; 3/29/50, 14.7; 11/7/50, 15.2; 3/29/51, 10.8; 11/15/51, 14.0; 4/2/52, 8.0.

13N/3E-17A1—Reference point—top of casing, elevation 31 feet, 0.1 mile south of Everglade Road, 0.9 mile east of George Washington Boulevard. 12/18/47, 9.4; 3/11/48, 9.8; 11/4/48, 8.3; 3/16/49, 6.6; 12/7/49, 10.3.

13N/3E-17B1—Reference point—top of casing, elevation 34.1 feet, 260 feet south of Everglade Road, 0.7 mile east of George Washington Boulevard. 12/12/47, 6.7; 3/10/48, 8.1; 3/12/48, 8.1; 11/8/48, 12.2; 12/5/49, 12.0.

13N/3E-17D1—Reference point—top of casing, elevation 30 feet. South side of Everglade Road, 0.2 mile east of George Washington Boulevard. 12/18/47, 7.9; 3/11/48, 8.7. Well destroyed.

13N/3E-18A1—Reference point—top of casing, elevation 30 feet, 0.25 mile south of Everglade Road, 0.2 mile west of George Washington Boulevard. 12/18/47, 10.2; 3/11/48, 10.7; 11/4/48, 10.7. Well destroyed.

13N/3E-23B1—Reference point—top of concrete pit, elevation 34 feet, 0.1 mile east of Garden Highway, 0.15 mile north of Central Avenue. 11/19/47, 12.3; 3/25/48, 12.3; 11/4/48, 11.9; 3/8/49, 11.2; 12/7/49, 12.7.

13N/3E-23D1—Reference point—top of concrete, elevation 38.3 feet, 0.4 mile west of Garden Highway, 0.25 mile north of Central Avenue. 11/19/47, 14.8; 3/9/48, 16.7; 5/11/48, 13.0; 11/4/48, 16.0; 3/8/49, 14.6.

13N/3E-23F1—Reference point—hole in pump base, elevation 34 feet, 0.15 mile west of Garden Highway, 0.1 mile south of Central Avenue. 11/20/47, 12.8; 3/10/48, 15.1; 11/4/48, 13.7; 3/8/49, 11.3; 12/7/49, 13.1.

13N/3E-23L1—Reference point—hole in pump base, elevation 35 feet, 0.15 mile west of Garden Highway, 0.4 mile south of Central Avenue. 11/20/47, 13.3; 3/10/48, 16.0; 5/11/48, 11.0; 11/4/48, 13.7; 1/24/49, 13.6; 3/8/49, 12.7; 6/7/49, 16.3; 6/29/49, 17.2; 7/27/49, 16.9; 8/25/49, 17.8; 12/7/49, 14.6; 3/29/50, 12.2; 11/7/50, 14.1; 3/29/51, 9.4; 11/15/51, 11.6; 4/2/52, 6.0.

13N/3E-24C2—Reference point—bottom of pump base, elevation 39.6 feet, 0.25 mile north of Central Avenue, 0.8 mile east of Garden Highway. 11/20/47, 15.4; 3/9/48, 16.0; 11/4/48, 14.7; 3/8/49, 13.1; 3/29/50, 11.5; 11/7/50, 15.3; 3/29/51, 7.6; 11/16/51, 14.6; 4/2/52, 7.6.

13N/3E-24D1—Reference point—hole in concrete base, elevation 36.5 feet, 0.45 mile east of Garden Highway, 0.45 mile south of Wilson Road. 11/19/49, 12.2; 3/25/48, 11.9; 5/11/48, 9.1; 11/4/48, 11.9; 3/8/49, 10.6; 6/1/49, 12.0; 8/25/49, 15.4; 12/7/49, 13.1

13N/3E-24E1—Reference point—top of casing, elevation 35 feet, 0.2 mile south of Central Avenue, 0.6 mile east of Garden Highway. 11/20/47, 10.8; 3/9/48, 11.4; 11/5/48, 11.4.

13N/3E-24G1—Reference point—top of casing, elevation 39 feet, 100 feet south of Central Avenue, 1.05 miles east of Garden Highway. 11/20/47, 24.2; 3/9/48, 18.9; 11/4/48, 20.7; 1/24/49, 18.8; 3/8/49, 17.1; 12/7/49, 19.9.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

13N/3E-25N1—Reference point—top of casing, elevation 35 feet, 200 feet north of Oak Avenue, 0.7 mile east of Garden Highway. 11/20/47, 10.9; 3/10/48, 11.9; 11/4/48, 9.3; 1/24/49, 9.3; 3/8/49, 7.6; 12/7/49, 11.0.

13N/3E-26J1—Reference point—top of casing, elevation 35 feet, 300 feet south of Cypress Avenue, 0.4 mile east of Garden Highway. 11/20/47, 9.2; 3/10/48, 9.9.

13N/3E-35H1—Reference point—hole in casing, elevation 32 feet, 0.1 mile north of Laurel Avenue, 0.45 mile east of Garden Highway. 11/20/47, 9.7; 3/10/48, 8.0; 11/4/48, 8.8; 1/24/49, 9.0; 3/8/49, 7.0; 12/7/49, 10.4.

13N/3E-36N1—Reference point—top of 2" x 4" at top of west side of pit, elevation 33 feet, 0.3 mile south of Laurel Avenue, 0.55 mile east of Garden Highway. 12/5/47, 11.9; 3/10/48, 12.2; 5/11/48, 7.0; 12/11/48, 11.6; 3/16/49, 8.2; 12/6/49, 12.8; 3/29/50, 7.7; 11/3/50, 12.0; 4/3/51, 5.2; 11/16/51, 10.2; 4/4/52, 3.6.

13N/4E-1P1—Reference point—top of 14-inch casing, elevation 62 feet, 100 feet west of farm road, 1.1 miles south of Dairy Road. 11/28/47, 18.8.

13N/4E-1Q1—Reference point—bottom of slot inside of casing by air line, elevation 63.2 feet, 800 feet east of farm road, 1.1 miles south of Dairy Road. 11/28/47, 19.4; 2/11/48, 17.5; 2/21/48, 18.1; 3/29/48, 17.4; 5/5/48, 15.2; 6/3/48, 17.9; 7/2/48, 66.0 (operating); 11/12/48, 21.0; 3/24/49, 17.0; 11/28/49, 24.2.

13N/4E-2A1—Reference point—top of 12-inch casing, bottom of pit, elevation 52 feet, Ground elevation 66 feet, 300 feet south of Dairy Road, 2.2 miles southwest of U. S. Highway 99E. 11/28/47, 13.4; 3/2/48, 11.0; 11/12/48, 14.8; 3/25/49, 11.3; 11/23/49, 17.3; 3/28/50, 14.3; 11/8/50, 19.1; 4/4/51, 12.8; 11/30/51, 29.4.

13N/4E-2C1—Reference point—top of 14-inch casing, elevation 64 feet, West of Pleasant Grove Road (Forty Mile Road) about 1.5 miles southeast of Plumas School. 11/28/47, 28.0; 3/1/48, 26.2; 3/22/48, 28.3; 3/29/48, 26.4; 5/5/48, 24.5; 8/13/48, 78.8 (operating); 11/8/48, 29.4; 1/25/49, 27.7; 3/25/49, 26.1; 11/23/49, 31.8.

13N/4E-2K1—Reference point—lower left hole in pump base, elevation 66 feet, 100 feet southeast of Leach Road, 200 feet west of Pleasant Grove Road (Forty Mile Road). 11/29/47, 29.0; 3/1/48, 26.6; 4/8/48, 29.9; 3/25/49, 26.7; 11/23/49, 26.7; 3/28/50, 32.3; 11/6/50, 34.0; 4/3/51, 26.9; 11/30/51, 33.1; 4/1/52, 30.9.

13N/4E-3F1—Reference point—top of concrete pit, elevation 57 feet, West of Hoffman Road, 1.4 miles south of Plumas School. 11/8/48, 30.1.

13N/4E-3G1—Reference point—slot in side of casing, elevation 58 feet, East of Hoffman Road, 1.4 miles south of Plumas School. 11/28/47, 25.6; 11/8/48, 27.0; 11/25/49, 28.7; 3/28/50, 26.0; 11/6/50, 30.4; 4/4/51, 26.0; 12/5/51, 32.8; 4/1/52, 25.9.

13N/4E-4J1—Reference point—top of casing, bottom of pit, elevation 47 feet, ground elevation 52.0 feet, 250 feet west of farm road, 0.75 mile north of Leach Road. 11/29/47, 18.3; 3/1/48, 16.8; 11/8/48, 20.5; 3/25/49, 15.9; 11/26/49, 21.1.

13N/4E-4J2—Reference point—hole in side of casing, elevation 52 feet, 100 feet west of farm road, 0.75 mile north of Leach Road. 11/8/48, 26.1; 3/25/49, 21.1; 11/26/49, 26.0.

13N/4E-7E1—Reference point—hole in pump base, elevation 39 feet, 0.05 mile west of Feather River Boulevard, 2.9 miles south of Country Club Avenue. 11/17/47, 14.3; 3/9/48, 13.1; 5/5/48, 9.1; 5/31/48, 9.1; 7/2/48, 42.0 (operating); 8/1/48, 49.1 (operating); 9/2/48, 44.0 (operating); 9/30/48, 13.5; 11/10/48, 13.9; 1/21/49, 13.8; 3/22/49, 10.8; 6/1/49, 10.8; 6/29/49, 12.8; 7/28/49, 14.2; 8/26/49, 15.8; 12/2/49, 15.3; 3/29/50, 9.7; 11/6/50, 11.7; 3/30/51, 7.8; 11/16/51, 13.7; 4/1/52, 5.5.

13N/4E-9A1—Reference point—top of 14-inch casing, elevation 52 feet, West of farm road, 0.45 mile north of Leach Road. 11/29/47, 19.8; 3/1/48, 17.9; 11/8/48, 20.5; 3/25/49, 17.0; 11/26/49, 22.1; 3/28/50, 19.0; 11/6/50, 23.0; 4/3/51, 16.4; 12/6/51, 22.4; 4/1/52, 18.0.

13N/4E-9R1—Reference point—top of casing, elevation 50 feet, 0.30 mile south of Leach Road. 11/8/48, 21.4; 3/25/49, 17.2; 11/26/49, 24.1; 3/28/50, 18.7; 11/6/50; 25.4; 4/4/51, 14.8; 12/5/51, 23.0; 4/1/52, 14.9.

13N/4E-10D1—Reference point—top of 14-inch casing, elevation 54 feet, 0.25 mile east of farm road, 0.50 mile north of Leach Road. 11/29/47, 25.0; 3/1/48, 23.0; 11/8/48, 26.5; 3/25/49, 22.4; 11/26/49, 27.4; 4/1/52, 24.6.

13N/4E-10J1—Reference point—slot in side of casing, elevation 55 feet, 200 feet south of Leach Road. 11/8/48, 25.6; 3/25/49, 23.0; 11/26/49, 27.6; 3/28/50, 23.5; 11/6/50, 29.6; 4/3/51, 21.5; 4/1/52, 21.0.

13N/4E-11J1—Reference point—bottom of slot in top of casing, elevation 61.3 feet, 200 feet west of Pleasant Grove Road, 0.75 mile north of Four Corners. 12/2/47, 19.6; 2/11/48, 17.8; 2/21/48, 17.7; 3/8/48, 26.5; 3/22/48, 26.4; 3/29/48, 17.8; 5/5/48, 16.0; 6/3/48, 17.8; 9/30/48, 27.2; 11/15/48, 21.2; 1/26/49, 19.5; 3/31/49, 18.3; 12/2/49, 23.6; 3/29/50, 19.6; 11/8/50, 25.5; 4/3/51, 18.6; 11/20/51, 24.4; 4/4/52, 15.7.

13N/4E-12C2—Reference point—top of flange in bottom of pit, elevation 44 feet, Ground elevation 55 feet, 1,000 feet north of Wheatland-Rio Oso Road, 0.45 mile east of Pleasant Grove Road (Forty Mile Road). 11/25/47, 9.2; 2/11/48, 6.9; 2/21/48, 6.0; 3/29/48, 4.8; 11/12/48, 10.5; 3/24/49, 5.5; 6/6/49, 14.0; 7/1/49, 17.4; 8/1/49, 21.6; 8/31/49, 45.0 (operating); 11-26-49, 13.4.

13N/4E-12E1—Reference point—top of 14-inch casing, elevation 60 feet, 150 feet west of Wheatland-Rio Oso Road, 300 feet east of Pleasant Grove Road (Forty Mile Road). 11/29/47, 18.9.

13N/4E-12E2—Reference point—bottom of slot in top of 14-inch casing, elevation 60.8 feet, 100 feet west of Wheatland-Rio Oso Road, 400 feet east of Pleasant Grove Road (Forty Mile Road). 11/29/47, 18.5; 2/11/48, 16.2; 2/21/48, 16.0; 3/2/48, 16.6; 3/11/48, 16.6; 3/29/48, 14.9; 5/18/48, 13.2; 11/12/48, 19.7; 3/24/49, 15.2; 11/23/49, 24.5; 3/29/50, 16.6; 11/8/50, 23.0; 4/3/51, 14.0; 12/3/51, 24.2; 4/2/52, 10.8.

13N/4E-12G1—Reference point—hole in pump base, elevation 65 feet, North of Wheatland-Rio Oso Road, 0.85 mile east of Pleasant Grove Road (Forty Mile Road). 11/28/47, 22.1.

13N/4E-12H1—Reference point—hole in pump base, elevation 67.3 feet, 100 feet north of Wheatland-Rio Oso Road, 1.0 mile east of Pleasant Grove Road (Forty Mile Road). 11/28/47, 22.6; 2/11/48, 20.5; 2/21/48, 21.0; 3/29/48, 21.0; 11/12/48, 23.8; 3/24/49, 19.4; 11/26/49, 26.8.

13N/4E-12H2—Reference point—top of slot in pump base, elevation 67.2 feet, 100 feet north of Wheatland-Rio Oso Road, 0.90 mile east of Pleasant Grove Road (Forty Mile Road). 11/28/47, 22.2; 3/29/48, 19.8; 11/12/48, 23.4; 3/24/49, 19.0; 11/26/49, 26.6.

13N/4E-12H3—Reference point—top of 8-inch casing, elevation 68 feet, 200 feet south of Wheatland-Rio Oso Road, 1.0 mile east of Pleasant Grove Road (Forty Mile Road). 12/2/47, 24.2; 3/8/48, 25.4.

13N/4E-12K1—Reference point—groove in base plate, elevation 69.4 feet, 0.30 mile south of Wheatland-Rio Oso Road, 0.50 mile east of Pleasant Grove Road (Forty Mile Road). 12/2/47, 24.6; 3/8/48, 28.2; 3/29/48, 22.4; 11/15/48, 25.7; 3/31/49, 21.9; 12/2/49, 28.4.

13N/4E-12K2—Reference point—top ridge on base plate, elevation 70 feet, 1,000 feet south of Wheatland-Rio Oso Road, 0.75 mile east of Pleasant Grove Road (Forty Mile Road). 12/2/47, 24.4; 3/8/48, 29.6.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet meosured from reference point)

13N/4E-12L1—Reference point—pipe in base, elevation 65.6 feet, 1,100 feet south of Wheatland-Rio Oso Road, 0.25 mile east of Pleasant Grove Road (Forty Mile Road). 12/2/47, 23.2; 3/8/48, 30.9; 3/22/48, 32.7; 3/29/48, 21.6; 5/5/48, 19.2; 6/3/48, 21.2; 9/30/48, 30.7; 11/15/48, 24.8; 1/26/49, 23.0; 12/2/49, 27.6.

13N/4E-12L2—Reference point—slot in top of casing, elevation 65.1 feet, 800 feet south of Wheatland-Rio Oso Road, 0.30 mile east of Pleasant Grove Road (Forty Mile Road). 12/2/47, 21.6; 3/8/48, 28.3; 3/22/48, 29.0; 3/29/48, 19.9; 9/30/48, 29.3; 11/15/48, 23.4; 3/31/49, 22.8.

13N/4E-12Q1—Reference point—pipe in concrete base, elevation 70.5 feet, 0.30 mile north of Bear River Drive, 0.70 mile east of Pleasant Grove Road. 12/3/47, 26.0; 3/30/48, 24.4; 11/4/48, 27.9; 3/31/49, 23.5; 12/2/49, 30.2.

13N/4E-12R1—Reference point—hole in pump base, elevation 72.4 feet, 0.30 mile north of Bear River Drive, 0.90 mile east of Pleasant Grove Road. 12/3/47, 45.5; 3/30/48, 24.9; 11/4/48, 28.9; 1/26/49, 26.6; 3/31/49, 24.4; 12/2/49, 31.3.

13N/4E-13A1—Reference point—hole in pump base, elevation 71.6 feet, 1,200 feet north of Bear River Drive, 0.75 mile east of Pleasant Grove Road. 12/3/47, 26.5; 3/8/48, 31.6; 3/30/48, 24.9; 11/4/48, 28.3; 3/31/49, 24.0; 12/2/49, 30.8.

13N/4E-13B1—Reference point—hole in pump base, elevation 70 feet, 850 feet north of Bear River Drive, 0.60 mile east of Pleasant Grove Road. 11/4/48, 28.3.

13N/4E-13C1—Reference point—top of 14-inch casing, elevation 69.2 feet, 900 feet north of Bear River Drive, 0.40 mile east of Pleasant Grove Road. 12/3/47, 25.7; 11/4/48, 27.7; 3/31/49, 23.3; 12/2/49, 30.0.

13N/4E-13E1—Reference point—top of 14-inch casing, elevation 60.7 feet, 150 feet south of Bear River Drive, 700 feet east of Four Corners. 12/3/47, 19.5; 3/8/48, 24.2; 3/30/48, 18.1; 11/4/48, 21.6; 3/31/49, 17.0; 12/2/49, 23.6; 3/30/50, 19.8; 11/8/50, 25.4; 11/20/51, 23.1; 4/4/52, 16.7.

13N/4E-13F1—Reference point—bottom of pump base, elevation 62.9 feet, 150 feet south of Bear River Drive, 0.25 mile east of Four Corners. 12/2/47, 21.2; 3/10/48, 31.2; 11/4/48, 23.5; 3/31/49, 19.0; 12/2/49, 25.6.

13N/4E-13F2—Reference point—top of casing, elevation 65.5 feet, North side Bear River Drive, 0.30 mile east of Four Corners. 12/2/47, 23.2; 3/30/48, 21.8; 5/14/48, 19.5; 11/4/48, 25.5; 1/26/49, 23.0; 3/31/49, 21.0.

13N/4E-13F3—Reference point—top of 12-inch casing, elevation 66.9 feet, South side Bear River Drive, 0.50 mile east of Four Corners. 12/2/47, 23.6; 3/8/48, 28.2; 11/4/48, 25.5; 3/31/49, 21.2; 12/2/49, 27.9.

13N/4E-13G1—Reference point—top of 12-inch casing, elevation 67.8 feet, 200 feet south of Bear River Drive, 0.50 mile east of Four Corners. 12/2/47, 24.2; 3/8/48, 27.3; 11/4/48, 25.7; 3/31/49, 21.6; 12/2/49, 28.2.

13N/4E-13G2—Reference point—top of 14-inch casing, elevation 69.1 feet, South side Bear River Drive, 0.70 mile east of Four Corners. 12/2/47, 24.6; 3/10/48, 28.1; 3/30/48, 23.2; 11/4/48, 25.9; 3/31/49, 22.0; 12/2/49, 28.5; 3/30/50, 24.8; 11/8/50, 30.9; 4/3/51, 20.7; 11/20/51, 24.4; 4/4/52, 16.7.

13N/4E-13H1—Reference point—slot in concrete base, elevation 66 feet, 150 feet south of Bear River Drive, 0.95 mile east of Four Corners. 12/3/47, 22.4; 11/4/48, 24.4; 3/31/49, 21.7; 12/2/49, 27.1.

13N/4E-13K1—Reference point—top of twin holes in pump base, elevation 63 feet, 0.40 mile north of Gallagher Road, 0.50 mile east of Pleasant Grove Road. 12/5/47, 18.7.

13N/4E-13M1—Reference point—top of concrete foundation, elevation 60.8 feet, 700 feet east of Pleasant Grove Road, 0.30 mile north of Gallagher Road. 12/5/47, 19.6; 3/8/48, 25.7; 11/15/48, 21.6; 3/31/49, 17.7; 11/30/49, 25.1.

13N/4E-13M2—Reference point—top of casing, elevation 62.2 feet, 0.25 mile east of Pleasant Grove Road, 0.30 mile north of Gallagher Road. 12/5/47, 21.9; 3/8/48, 22.5; 3/31/48, 20.1; 11/15/48, 22.9; 4/1/49, 17.5; 11/30/49, 25.5.

13N/4E-13P1—Reference point—top of 14-inch casing, elevation 20.2 feet, 900 feet north of Gallagher Road, 0.40 mile east of Pleasant Grove Road. 12/5/47, 18.2; 3/8/48, 23.4; 11/5/48, 20.8; 4/1/49, 17.2; 11/30/49, 23.2.

13N/4E-13R1—Reference point—top of 14-inch casing, elevation 69.3 feet, 0.50 mile east of end of Gallagher Road, 1.00 mile east of Pleasant Grove Road. 12/8/47, 25.6; 3/10/48, 27.8; 3/31/48, 24.3; 11/5/48, 28.4; 4/1/49, 24.0; 11/30/49, 31.3; 3/30/50, 27.1; 11/9/50, 34.0; 4/4/51, 25.0; 11/21/51, 33.7.

13N/4E-14A1—Reference point—bottom of cutout in top of casing, elevation 59.28 feet, 900 feet north of Bear River Drive, 1,000 feet west of Pleasant Grove Road. 12/3/47, 19.1; 11/15/48, 20.4; 3/31/49, 16.7; 12/1/49, 22.9.

13N/4E-14D1—Reference point—bottom edge of pump base, elevation 55.0 feet, 900 feet east of Warren Road, 0.25 mile north of Bear River Drive. 12/3/47, 14.8; 2/10/48, 14.6; 3/31/48, 12.4; 11/15/48, 15.3; 3/31/49, 10.5; 12/1/49, 17.2.

13N/4E-14F1—Reference point—top of 12-inch casing, elevation 55.0 feet, 350 feet north of Bear River Drive, 0.30 mile east of Warren Road. 12/3/47, 17.7; 3/8/48, 20.0; 11/15/48, 18.6; 3/31/49, 14.2; 12/1/49, 20.8; 3/30/50, 15.9; 11/9/50, 22.2; 4/3/51, 13.0; 11/20/51, 19.2; 4/4/52, 6.0.

13N/4E-14F3—Reference point—top of casing, elevation 55.2 feet, 250 feet south of Bear River Drive, 0.40 mile east of Warren Road. 12/4/47, 17.4; 11/15/48, 18.9; 3/31/49, 14.8; 12/1/49, 21.3.

13N/4E-14J1—Reference point—hole in pump base, elevation 54 feet, 1,000 feet west of Pleasant Grove Road, 0.30 mile south of Bear River Drive. 12/4/47, 17.4; 11/15/48, 19.4; 3/31/49, 15.4; 12/1/49, 22.3.

13N/4E-14N1—Reference point—top of 14-inch casing in bottom of pit, elevation 48.5 feet, 400 feet east of Warren Road, 0.40 mile south of Bear River Drive. 12/4/47, 14.5; 3/31/48, 12.9; 11/15/48, 15.2; 3/31/49, 10.7; 12/1/49, 17.1.

13N/4E-14N2—Reference point—top of 14-inch casing, elevation 54.4 feet, 1,200 feet east of Warren Road, 0.35 mile south of Bear River Drive. 12/4/47, 21.0; 3/31/48, 19.5; 11/15/48, 21.8; 3/31/49, 17.2; 12/1/49, 23.9.

13N/4E-14Q1—Reference point—top of 14-inch casing, elevation 56 feet, 0.45 mile west of Pleasant Grove Road, 0.50 mile south of Bear River Drive. 12/4/47, 22.5; 11/15/48, 23.9; 3/31/49, 18.7; 12/1/49, 26.3.

13N/4E-14Q2—Reference point—top of 12-inch casing, elevation 59.1 feet, 0.25 mile west of Pleasant Grove Road, 0.25 mile north of Betz Road. 12/5/47, 23.2; 3/10/48, 33.3; 11/15/48, 24.6.

13N/4E-14R1—Reference point—hole in pump base, elevation 60.4 feet, West side Pleasant Grove Road, 1,000 ft. north of Gallagher Road. 12/5/47, 21.2; 3/8/48, 25.1; 3/31/48, 19.5; 5/8/48, 17.3; 11/5/48, 23.6; 11/15/48, 22.4; 1/26/49, 20.3; 3/31/49, 18.1; 11/30/49, 25.4.

13N/4E-14R2—Reference point—top of concrete pit, elevation 60.1 feet, West side Pleasant Grove Road, 1,100 feet north of Gallagher Road. 12/5/47, 21.8; 3/8/48, 21.5; 11/5/48, 23.6.

13N/4E-15A1—Reference point—top of pump base, elevation 54.7 feet, 350 feet west of Warren Road, 0.30 mile north of Bear River Drive. 12/3/47, 17.9; 3/8/48, 19.5; 3/31/48, 16.2; 11/15/48, 19.1; 3/31/49, 14.2; 12/1/49, 21.1.

13N/4E-15J2—Reference point—bottom edge of pump base, elevation 53.2 feet, South side Bear River Drive, 100 feet west of Warren Road. 12/4/47, 19.2; 3/10/48, 19.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Mode by Division of Water Resources
(Depths to woter in feet meosured from reference point)

13N 4E-15K1—Reference point—hole in pump base, elevation 51.8 feet, North side Bear River Drive, 1,200 feet northeast of Swanson Road. 12/4/47, 16.4; 3/30/48, 14.2; 5/5/48, 12.2; 6/3/48, 13.8; 7/2/48, 56.2; 11/15/48, 17.2; 1/26/49, 15.3; 3/31/49, 12.0; 5/25/49, 18.1; 6/29/49, 25.9; 8/26/49, 24.7; 12/1/49, 19.4.

13N 4E-15N1—Reference point—bottom of pump base, elevation 50.8 feet, North side Bear River Drive, 0.40 mile southwest of Swanson Road. 12/4/47, 19.2; 3/10/48, 18.2; 11/15/48, 19.0; 3/31/49, 12.5; 12/1/49, 21.3.

13N 4E-15N2—Reference point—hole in pump base, elevation 52.9 feet, 350 feet south of Bear River Drive, 0.30 mile southwest of Swanson Road. 12/4/47, 21.2; 3/10/48, 20.9; 11/15/48, 21.0; 3/31/49, 14.4; 12/1/49, 23.2.

13N 4E-15P1—Reference point—bottom of pump base, elevation 54.3 feet, 350 feet west of Swanson Road, 1,000 feet south of Bear River Drive. 12/4/47, 22.3; 3/10/48, 21.4; 11/15/48, 22.2; 3/31/49, 15.9; 12/1/49, 24.4.

13N 4E-15P2—Reference point—hole in pump base, elevation 51 feet, 200 feet north of junction of Swanson Road and Bear River Drive. 12/4/47, 17.0; 3/31/48, 14.2; 11/15/48, 17.0; 3/31/49, 11.1; 12/1/49, 18.8; 3/30/50, 11.6; 11/20/50, 19.1; 4/4/52, 5.9.

13N 4E-15R1—Reference point—bottom of slot in concrete base, elevation 54 feet, 100 feet west of Warren Road, 0.45 mile south of Bear River Drive. 12/4/47, 21.4; 3/8/48, 24.0; 11/15/48, 21.7; 3/31/49, 17.0; 12/1/49, 24.0.

13N 4E-16N1—Reference point—hole in pump base, elevation 43.7 feet, 600 feet west of Fourth Avenue, 0.75 mile north of Rio Oso Road. 12/6/47, 14.4; 3/30/48, 9.8; 5/5/48, 7.3; 5/31/48, 7.4; 11/16/48, 12.7; 4/1/49, 6.0; 5/25/49, 11.3; 6/2/49, 9.3; 7/1/49, 11.6; 8/1/49, 17.0; 8/31/49, 16.7; 11/30/49, 16.0; 3/30/50, 7.0; 11/9/50, 15.8; 4/3/51, 4.9; 11/20/51, 13.7; 4/4/52, 3.4.

13N 4E-17A1—Reference point—hole in base of pump, elevation 41 feet, 250 feet west of farm road, 1.25 miles north of Feather River Boulevard at Bear River Bridge. 11/21/47, 11.9; 3/10/48, 10.5; 12/8/49, 14.4.

13N 4E-17G2—Reference point—hole in base of pump, elevation 40 feet, 0.35 mile northeast of Feather River Boulevard at a point 0.60 mile northwest of Bear River Bridge. 11/21/47, 14.1; 3/10/48, 14.9; 11/5/48, 13.6; 3/15/49, 8.3; 12/7/49, 15.8.

13N 4E-17P1—Reference point—bottom of pump base, elevation 39 feet, 300 feet south of Feather River Boulevard, 0.60 mile northwest of Bear River Bridge. 11/20/47, 13.9; 3/10/48, 11.9; 5/8/48, 6.9; 11/5/48, 11.2; 1/24/49, 10.4; 3/15/49, 7.9; 6/1/49, 7.9; 7/29/49, 15.0; 8/26/49, 15.2; 12/8/49, 13.8; 3/29/50, 6.9; 11/6/50, 13.7; 3/30/51, 11.9; 11/16/51, 11.9.

13N 4E-17Q1—Reference point—top of floor board, elevation 42 feet, 800 feet east of Feather River Boulevard at a point 0.45 mile northwest of Bear River Bridge. 11/21/47, 13.1; 3/10/48, 11.9; 3/15/49, 7.2; 12/8/49, 14.9.

13N 4E-18F1—Reference point—hole in base of pump, elevation 35 feet, South side of curve in Feather River Boulevard, approximately 2.0 miles northwest of Bear River Bridge. 3/9/48, 13.0; 5/5/48, 9.0; 5/31/48, 9.0; 11/5/48, 11.5; 1/24/49, 13.0; 3/15/49, 11.3; 12/8/49, 15.9; 3/29/50, 10.6; 11/6/50, 15.1; 3/30/51, 7.5; 11/16/51, 13.8.

13N 4E-18L1—Reference point—top of tin casing, elevation 35 feet, 100 feet south of farm road, 1,200 feet southwest of Feather River Boulevard. 11/20/47, 11.8; 3/9/48, 13.3; 11/5/48, 14.7; 3/15/49, 11.1; 12/8/49, 15.8.

13N 4E-19Q1—Reference point—top of concrete under pump, elevation 35 feet, 0.25 mile northwest of Levee Road, 1.1 miles southwest of Feather River Boulevard at Bear River Bridge. 11/21/47, 13.7; 11/5/48, 15.7; 3/15/49, 9.9; 12/7/49, 17.0; 3/29/50, 10.1; 11/8/50, 15.6; 3/30/51, 10.2.

13N 4E-20B1—Reference point—top of casing, elevation 42 feet, Northeast of Feather River Boulevard just across Bear River Bridge. 11/21/47, 16.4; 3/10/48, 15.8; 11/5/48, 15.0.

13N 4E-20F1—Reference point—top of concrete under pump, elevation 39 feet, 900 feet west of Levee Road, 0.30 mile southwest of Feather River Boulevard at Bear River Bridge. 11/21/47, 12.3; 11/5/48, 12.2; 3/15/49, 7.0; 12/7/49, 13.7.

13N 4E-20G1—Reference point—base of pump, elevation 41 feet, 300 feet west of Levee Road, 700 feet southwest of Feather River Boulevard at Bear River Bridge. 11/21/47, 13.6; 11/5/48, 15.1; 3/15/49, 8.2; 12/7/49, 15.7.

13N 4E-20J1—Reference point—top of casing, elevation 41 feet, 400 feet south of Feather River Boulevard, 500 feet west of Sacramento Northern Railroad. 11/21/47, 12.9; 3/10/48, 11.9; 11/5/48, 11.8; 1/24/49, 10.4; 3/15/49, 6.6; 12/8/49, 14.3; 3/29/50, 6.9; 11/8/50, 14.4; 3/30/51, 3.8; 11/16/51, 12.2.

13N 4E-20N1—Reference point—top of casing, elevation 37 feet, North side of the west levee of Bear River, 0.99 mile south of Feather River Boulevard at Bear River Bridge. 11/21/47, 14.8; 11/5/48, 14.3; 3/15/49, 8.6; 12/7/49, 16.0.

13N 4E-20R2—Reference point—hole in pump base, elevation 41 feet, West of Sacramento Northern Railroad, 0.35 mile south of Rio Oso Road. 11/21/47, 15.9; 3/10/48, 14.9; 5/11/48, 11.4; 3/15/49, 11.0; 12/8/49, 16.3.

13N 4E-21A1—Reference point—bottom edge of pump base, elevation 50 feet, 560 feet south of west end of Bear River Drive. 12/4/47, 19.2; 3/10/48, 18.3; 3/31/48, 15.9; 11/15/48, 19.0; 1/26/49, 17.6; 3/31/49, 11.8; 12/1/49, 21.4; 3/30/50, 12.0; 11/9/50, 21.0; 4/3/51, 9.2; 11/20/51, 18.7; 4/4/52, 6.6.

13N 4E-21B1—Reference point—pipe elbow in casing, elevation 47.8 feet, 0.25 mile west of west end of Bear River Drive. 12/4/47, 16.7; 3/10/48, 19.0; 11/15/48, 16.6; 3/31/49, 9.8; 12/1/49, 18.8; 11/20/51, 16.3; 4/4/52, 5.9.

13N 4E-21C1—Reference point—bottom of flanged coupling, elevation 45.1 feet, 630 feet east of Fourth Avenue, 0.25 mile north of Rio Oso Road. 12/6/47, 17.0; 3/9/48, 15.3; 11/16/48, 15.9; 4/1/49, 8.9; 11/30/49, 18.4.

13N 4E-21D1—Reference point—top of flanged coupling, elevation 43 feet, West side of Fourth Avenue, 0.25 mile north of Rio Oso Road. 12/6/47, 15.0; 3/9/48, 12.8; 3/31/48, 11.7; 11/16/48, 13.5; 4/1/49, 7.9; 11/30/49, 16.4.

13N 4E-21E1—Reference point—top of 12-inch casing, elevation 42 feet, 250 feet north of Rio Oso Road, 800 feet west of Fourth Avenue. 12/6/47, 17.1; 3/11/48, 16.3.

13N 4E-21F1—Reference point—top of 14-inch casing, elevation 43 feet, 600 feet north of Rio Oso Road, 0.2 mile east of Fourth Avenue. 12/6/47, 17.4.

13N 4E-21H1—Reference point—hole in pump base, elevation 46.2 feet, 250 feet north of Rio Oso Road, 800 feet west of Pacific Avenue. 12/5/47, 17.1; 3/9/48, 15.4; 3/31/48, 14.6; 5/8/48, 11.5; 11/16/48, 16.9; 4/1/49, 10.0; 11/29/49, 18.8.

13N 4E-21L1—Reference point—top of 12-inch casing, elevation 42.5 feet, East side of Fourth Avenue, 250 feet south of Rio Oso Road. 12/8/47, 15.6; 3/9/48, 13.8; 11/15/48, 14.7; 4/1/49, 9.6; 11/30/49, 17.0.

13N 4E-21P1—Reference point—bottom of flanged coupling, elevation 36.1 feet, 250 feet east of Fourth Avenue, 300 feet north of Kempton Road. 12/8/47, 9.6; 3/9/48, 8.6.

13N 4E-21P2—Reference point—edge of pump base, elevation 41.7 feet, 600 feet north of Kempton Road, 0.25 mile east of Fourth Avenue. 12/8/47, 17.4; 3/9/48, 16.5; 3/31/48, 15.3; 11/16/48, 17.2; 4/1/49, 12.1; 11/30/49, 19.2; 3/30/50, 13.4; 11/9/50, 20.1; 1/3/51, 9.1; 11/21/51, 18.1; 4/4/52, 8.3.

13N 4E-21R1—Reference point—top of 8-inch casing, elevation 45 feet, 350 feet north of Kempton Road, 650 feet west of Pacific Avenue. 12/16/47, 20.7; 3/10/48, 19.9; 11/16/48, 21.2; 4/1/49, 17.0; 11/29/49, 23.2.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Divisian of Water Resaurces
(Depths to water in feet measured from reference paint)

13N/4E-22A1—Reference point—top of 16-inch casing, elevation 51 feet, 350 feet west of Warren Road, 700 feet north of Betz Road. 12/5/47, 22.6; 3/31/48, 21.1.

13N/4E-22E1—Reference point—top of 12-inch casing, bottom of pit, elevation 40.4 feet, 1,000 feet north of Rio Oso Road, 0.35 mile west of Swanson Road. 12/5/47, 10.4; 3/9/48, 8.8.

13N/4E-22F1—Reference point—hole in pump base, elevation 53.1 feet, 300 feet west of Swanson Road, 500 feet north of Rio Oso Road. 12/5/47, 22.2; 3/10/48, 21.6; 11/16/48, 22.1; 4/1/49, 16.9; 11/30/49, 24.4.

13N/4E-22G1—Reference point—top of 12-inch casing, elevation 55.1 feet, North side of Rio Oso Road, 700 feet east of Swanson Road. 12/5/47, 23.9; 3/9/48, 23.6; 11/16/48, 23.8; 4/1/49, 19.8; 11/30/49, 26.5; 3/30/50, 21.5; 11/9/50, 27.5; 4/4/51, 18.7; 11/20/51, 25.7; 4/3/52, 16.9.

13N/4E-23B1—Reference point—bottom of pump base, elevation 58.6 feet, South side of Gallagher Road, 0.30 mile west of Pleasant Grove Road. 12/5/47, 21.3; 3/10/48, 27.8; 3/31/48, 20.8; 11/15/48, 23.0; 3/31/49, 19.0; 11/30/49, 25.7.

13N/4E-23C1—Reference point—hole in pump base, elevation 55 feet, 0.25 mile north of Betz Road, 0.30 mile east of Warren Road. 12/5/47, 22.7; 3/8/48, 26.9; 3/31/48, 21.9; 11/15/48, 23.6; 3/31/49, 19.6; 11/30/49, 26.2.

13N/4E-23D1—Reference point—bottom of pump base, elevation 51 feet. East side of Warren Road, 1,000 feet north of Betz Road. 12/5/47, 23.4; 3/10/48, 27.6; 11/15/48, 23.8; 3/31/49, 19.5; 11/30/49, 26.4.

13N/4E-23Q1—Reference point—top of 14-inch casing, elevation 62.7 feet, 500 feet north of Kempton Road, 0.25 mile west of Pleasant Grove Road. 12/16/47, 26.2; 3/9/48, 26.2; 5/8/48, 22.9; 11/5/48, 27.3; 1/26/49, 25.4; 4/1/49, 24.0; 11/30/49, 30.0; 3/30/50, 26.9; 11/9/50, 33.1; 4/3/51, 26.5; 11/20/51, 31.4; 4/3/52, 26.8.

13N/4E-24D1—Reference point—top of 14-inch casing, elevation 61.8 feet, 800 feet south of Gallagher Road, 1,000 feet east of Pleasant Grove Road. 12/5/47, 21.0; 3/10/48, 25.2; 3/31/48, 19.8; 11/5/48, 23.8; 3/31/49, 19.4; 11/30/49, 26.1; 3/30/50, 22.4; 11/9/50, 28.5; 4/4/51, 20.6; 11/21/51, 26.4; 4/4/52, 18.0.

13N/4E-24Q1—Reference point—top of 12-inch casing, bottom of pit, elevation 53.8 feet, 100 feet north of Kempton Road, 0.75 mile east of Pleasant Grove Road. 12/8/47, 11.8.

13N/4E-26B1—Reference point—top of 14-inch casing, elevation 58 feet, 200 feet south of Kempton Road, 0.45 mile west of Pleasant Grove Road. 3/9/48, 25.3; 11/5/48, 25.6; 4/1/49, 21.3; 11/30/49, 27.4.

13N/4E-26H1—Reference point—hole in pump base, elevation 57 feet, 350 feet west of Pleasant Grove Road, 0.45 mile south of Kempton Road. 11/8/47, 24.2; 3/9/48, 24.6; 11/16/48, 26.4; 4/4/49, 22.0; 11/30/49, 28.5.

13N/4E-26R1—Reference point—top of 14-inch casing, elevation 59 feet, West side of Pleasant Grove Road, 0.85 mile south of Kempton Road. 12/8/47, 25.5; 3/8/48, 24.9; 3/31/48, 24.2; 11/16/48, 28.1; 1/26/49, 26.5; 4/4/49, 23.7; 5/25/49, 34.0; 6/29/49, 42.4; 7/29/49, 48.8; 8/26/49, 49.0; 11/30/49, 29.6; 3/30/50, 26.4; 11/9/50, 33.9; 11/21/51, 33.7; 4/3/52, 26.9.

13N/4E-27C1—Reference point—bottom of flanged coupling, bottom of pit, elevation 46 feet, 400 feet south of Kempton Road, 0.40 mile east of Pacific Avenue. 12/16/47, 18.0.

13N/4E-27N1—Reference point—hole in pump base, elevation 51 feet, 250 feet east of Pacific Avenue, 0.90 mile south of Kempton Road. 12/16/47, 24.0; 3/11/48, 25.2.

13N/4E-28D1—Reference point—top of 12-inch casing, bottom of pit, elevation 27.7 feet, 600 feet south of Kempton Road, 700 feet west of Fourth Avenue. 12/8/47, 2.7; 3/11/48, 1.3; 3/31/48, 0.4; 11/16/48, 2.4; 4/1/49, —2.8; 11/30/49, 3.3.

13N/4E-28F1—Reference point—access hole to casing in bottom of pit, elevation 32.7 feet, 100 feet east of Fourth Avenue, 0.25 mile south of Kempton Road. 12/8/47, 6.8; 4/1/49, 2.6.

13N/4E-28R1—Reference point—hole in base, elevation 46 feet, 250 feet west of Pacific Avenue, 0.80 mile south of Kempton Road. 12/16/47, 23.2; 3/10/48, 22.4; 11/16/48, 25.1; 4/5/49, 21.5; 11/29/49, 26.1; 11/21/51, 27.9; 4/3/52, 22.5.

13N/4E-29F1—Reference point—top of east concrete wall, elevation 36 feet, 400 feet west of junction of Mark Hopkins Avenue and Berry Road. 11/21/47, 14.7; 3/10/48, 13.1; 11/5/48, 14.3; 1/24/49, 12.5; 3/15/49, 9.5; 5/25/49, 10.5; 6/29/49, 14.5; 7/28/49, 18.3; 8/26/49, 18.4; 12/7/49, 15.7; 3/29/50, 9.5; 11/8/50, 16.4; 3/30/51, 6.2; 11/16/51, 14.8.

13N/4E-29G1—Reference point—top of casing, elevation 37 feet, 0.10 mile southeast of Berry Road, 0.20 mile northeast of Mark Hopkins Avenue. 11/21/47, 13.2; 3/10/48, 11.8; 5/11/48, 8.9; 11/5/48, 13.1; 3/15/49, 8.4; 12/8/49, 14.4.

13N/4E-29M2—Reference point—bottom 2" x 6" floor, elevation 34 feet, 150 feet northwest of Berry Road, 0.25 mile southwest of Mark Hopkins Avenue. 11/21/47, 15.4; 3/10/48, 13.1; 11/5/48, 14.5; 12/7/49, 16.0.

13N/4E-30R2—Reference point—top of casing, elevation 33 feet, 400 feet south of southwest end of Berry Road. 11/21/47, 15.1; 3/11/48, 13.8; 11/5/48, 15.1; 3/16/49, 13.6; 12/8/49, 16.0.

13N/4E-31J1—Reference point—top of casing, elevation 52 feet, 0.25 mile north of Cornelius Avenue, 0.70 mile west of Mark Hopkins Avenue. 12/8/47, 14.8; 3/11/48, 13.1; 5/11/48, 9.2; 12/14/48, 15.6; 3/28/49, 10.2; 12/7/49, 15.8.

13N/4E-32B1—Reference point—top of south concrete wall, elevation 34 feet, 100 feet north of Cramer Road, 150 feet west of Mark Hopkins Avenue. 12/9/47, 14.9; 3/11/48, 13.2; 12/15/48, 16.9; 3/16/49, 12.9; 12/7/49, 16.1.

13N/4E-32D1—Reference point—top of east concrete wall, elevation 34 feet, 200 feet north of Cramer Road, 0.50 mile west of Mark Hopkins Avenue. 12/9/47, 15.1; 3/11/48, 13.2; 12/15/48, 16.9; 3/16/49, 12.3; 12/7/49, 16.1.

13N/4E-32H1—Reference point—top of north concrete wall, elevation 40 feet, East side of Mark Hopkins Avenue, 0.55 mile north of Cornelius Avenue. 12/8/47, 13.6; 3/11/48, 12.8; 5/11/48, 11.1; 12/13/48, 13.9; 3/16/49, 20.3; 12/6/49, 18.0; 3/29/50, 14.6; 11/6/50, 21.0; 3/30/51, 13.5; 11/16/51, 20.8; 4/4/52, 13.4.

13N/4E-32L1—Reference point—top of south concrete wall, elevation 35 feet, 0.25 mile west of Mark Hopkins Avenue, 0.40 mile north of Cornelius Avenue. 12/8/47, 20.6; 3/11/48, 19.4; 12/14/48, 21.9; 3/28/49, 18.4; 12/7/49, 22.3.

13N/4E-33A2—Reference point—pipe in base, elevation 50 feet, 200 feet west of Pacific Avenue, 0.9 mile north of Cornelius Avenue. 12/16/47, 25.6; 3/10/48, 24.6; 3/31/48, 25.7; 11/16/48, 27.9; 1/26/49, 26.0; 4/5/49, 24.4; 11/29/49, 28.7; 3/30/50, 25.7; 11/9/50, 31.6; 4/3/51, 24.0; 11/21/51, 31.8; 4/3/52, 24.1.

13N/4E-33G1—Reference point—bottom of pump base, elevation 47 feet, 0.4 mile west of Pacific Avenue, 0.5 mile north of Cornelius Avenue. 12/16/47, 28.6; 3/10/48, 27.5; 3/31/48, 27.3; 5/11/48, 26.7; 11/16/48, 30.9; 4/5/49, 27.5; 11/29/49, 31.3.

13N/4E-33L1—Reference point—top of casing, elevation 45 feet, 0.3 mile north of Cornelius Avenue, 0.5 mile east of Electric Avenue. 3/29/49, 24.1.

13N/4E-33P1—Reference point—hole in pump base, elevation 45 feet, 0.5 mile east of Electric Avenue, 0.2 mile north of Cornelius Avenue. 3/11/48, 22.1; 12/14/48, 24.7; 3/29/49, 22.3; 12/7/49, 22.6; 3/27/50, 25.7; 11/6/50, 32.0; 4/2/51, 25.0; 11/16/51, 30.6; 4/3/52, 24.6.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

13N 4E-33R1—Reference point—top of concrete pit, elevation 46 feet, 200 feet west of Pacific Avenue, 600 feet north of Cornelius Avenue. 11 8 29, 21.5; 9 8 30, 20.6; 12 30 30, 20.9; 12 10 31, 21.6; 12 11 32, 20.9; 12 20 33, 21.3; 10 27 34, 21.3; 11 23 36, 23.5; 11 24 37, 25.6; 1 30 39, 19.8; 12 22 47, 24.2; 3 11 48, 22.5; 3 31 48, 22.6; 12 14 48, 26.1; 3 29 49, 23.6; 12 7 49, 26.1; 3 27 50, 24.2; 11 6 50, 29.7; 4 2 51, 23.5; 11 16 51, 23.3; 12 6 51, 31.1; 1 4 52, 24.3.

13N 4E-34L1—Reference point—top of casing, elevation 48 feet, 0.2 mile east of Pacific Avenue, 0.4 mile north of Cornelius Avenue. 12 16 47, 23.6; 3 10 48, 22.8; 3 31 48, 22.7; 10 16 48, 26.1; 4 5 49, 23.2; 11 29 49, 27.1; 3 30 50, 24.5; 11 9 50, 30.6; 4 3 51, 24.1; 11 21 51, 30.5; 4 3 52, 24.5.

13N 4E-35J1—Reference point—top of floor of pit, elevation 42 feet, 0.4 mile north of Cornelius Avenue, 0.02 mile west of Pleasant Grove Road. 12 8 47, 8.8; 3 31 48, 7.2; 11 16 48, 11.6; 4 4 49, 8.4; 11 30 49, 13.8; 3 30 50, 11.3; 11 9 50, 19.0.

13N 4E-35Q1—Reference point—top of casing, elevation 56.6 feet, 0.4 mile west of Pleasant Grove Road, 132 feet north of Cornelius Avenue. 3 11 48, 19.9; 12 13 48, 25.1; 3 29 49, 21.1; 12 7 49, 26.0; 11 19 51, 30.4.

13N 4E-36G1—Reference point—top of casing, elevation 58 feet, 528 feet north of Hicks Road, 0.6 mile east of Pleasant Grove Road. 12 16 47, 23.8; 3 9 48, 22.6; 11 16 48, 26.7; 4 4 49, 24.2; 11 30 49, 29.1.

13N 5E-3Q1—Reference point—top of casing at bottom of 10.6-foot pit, elevation 84 feet, 0.25 mile northeast of U. S. Highway 99E, 0.20 mile southeast of Bear River. 11 25 47, 4.4; 3 5 48, 5.5; 11 7 49, 6.0; 4 4 50, 4.9; 11 14 50, 5.7; 3 27 51, 2.6; 11 19 51, 6.3.

13N 5E-4J1—Reference point—top of pump base, elevation 83 feet, 0.2 mile southwest of U. S. Highway 99E at a point 0.45 mile northwest of Bear River bridge. 11 24 47, 14.8; 3 29 48, 12.7; 5 14 48, 11.9; 11 12 48, 15.6; 3 23 49, 12.9; 11 26 49, 17.3; 3 29 50, 14.1; 11 8 50, 17.5; 4 4 51, 12.5; 12 3 51, 16.6; 4 2 52, 11.3.

13N 5E-4J2—Reference point—top of casing, elevation 80 feet, 0.25 mile southwest of U. S. Highway 99E at a point 0.3 mile northwest of Yuba-Placer county line. 4 1 48, 9.2; 5 5 48, 7.9; 6 3 48, 8.5; 7 2 48, 64.0 (operating); 7 1 49, 60.7 (operating); 8 1 49, 65.8 (operating); 8 31 49, 28.8.

13N 5E-4L1—Reference point—hole in pump base, elevation 82.6 feet, 0.3 mile southwest of U. S. Highway 99E in Wheatland on south side of T. H. Richards' farm road. 11 24 47, 19.9; 3 4 48, 21.1; 11 12 48, 21.0; 3 24 49, 27.0; 11 26 49, 22.7.

13N 5E-4N1—Reference point—top of concrete base, elevation 79.9 feet, At T. H. Richards' ranch house, 0.8 mile southwest of Wheatland. 11 25 47, 17.7; 3 5 48, 21.6; 3 29 48, 15.4; 11 12 48, 18.7; 3 24 49, 14.9; 11 26 49, 20.4.

13N 5E-4R1—Reference point top of concrete crib, south of pump, elevation 84 feet, 0.35 mile southwest of U. S. Highway 99E at a point 0.2 mile northwest of Yuba-Placer county line. 11 24 47, 13.7; 5 14 48, 10.2; 11 12 48, 14.1; 1 26 49, 13.4; 3 23 49, 10.8; 11 26 49, 15.3.

13N 5E-5B1—Reference point—top of casing, elevation 69.9 feet, 0.4 mile northeast of Oakley Avenue, 0.45 mile northwest of Wheatland Avenue. 11 24 47, 15.2; 3 5 48, 14.1.

13N 5E-5C1—Reference point—hole in pump base, elevation 68.1 feet, 0.25 mile northeast of Oakley Avenue, 0.45 mile northwest of Wheatland Road. 11 22 47, 14.5; 3 5 48, 13.1; 3 29 48, 12.2; 5 14 48, 11.6; 11 11 48, 16.0; 1 26 49, 14.2; 3 23 49, 12.1; 11 28 49, 18.5; 3 29 50, 14.9; 11 8 50, 20.7; 4 1 51, 11.5; 11 29 51, 19.3; 1 2 52, 8.2.

13N 5E-5C2—Reference point—top of pump base, elevation 72.2 feet, 0.15 mile northeast of Oakley Avenue, 0.35 mile northwest of Wheatland Road. 11 20 47, 18.5; 3 5 48, 17.1.

13N 5E-5D1—Reference point—top of concrete pit, elevation 66.5 feet, 0.1 mile southwest of Oakley Avenue, 0.6 mile northwest of Wheatland Road. 11 20 47, 15.7; 3 5 48, 15.1.

13N 5E-5L1—Reference point—top of casing, elevation 80.6 feet, Southeast side of Wheatland Road, 0.15 mile southwest of Oakley Avenue. 11 20 47, 27.5; 3 8 48, 27.5; 11 11 48, 30.6; 3 24 49, 24.1; 11 26 49, 31.1.

13N 5E-5L2—Reference point—top of concrete curb around casing, elevation 68.1 feet, Southeast side of Wheatland Road, 0.15 mile southwest of Oakley Avenue. 11 20 47, 15.6; 3 8 48, 14.3; 11 11 48, 17.3; 3 24 49, 11.7.

13N 5E-5L3—Reference point—top of casing, elevation 78.1 feet, 300 feet southwest of Oakley Avenue, 0.1 mile northwest of Wheatland Road. 11 20 47, 24.3; 3 5 48, 23.2; 11 11 48, 25.9; 3 25 49, 21.0; 11 28 49, 28.6.

13N 5E-5N1—Reference point—top of concrete crib nearest pump, elevation 70.4 feet, 0.2 mile southeast of Wheatland Road, 0.45 mile southwest of Oakley Avenue. 11 21 47, 19.2; 3 29 48, 16.0; 11 12 48, 21.9; 3 24 49, 15.2; 11 26 49, 23.5.

13N 5E-5P1—Reference point—top of pump base, elevation 71.1 feet, 0.2 mile southwest of Oakley Avenue, 0.25 mile southeast of Wheatland Road. 11 20 47, 17.6; 3 8 48, 18.3; 3 24 49, 14.2; 11 26 49, 21.2.

13N 5E-5Q1—Reference point—top of casing, elevation 75 feet, Southwest side of Oakley Avenue, 0.3 mile southeast of Wheatland Road. 11 20 47, 23.4; 3 8 48, 21.1; 3 24 49, 18.0.

13N 5E-6E1—Reference point—hole in west side pump base, elevation 63.0 feet, 0.7 mile northwest of Wheatland Road, 1.05 miles southwest of Oakley Avenue. 11 21 47, 17.8; 2 21 48, 15.6; 11 12 48, 19.5; 1 26 49, 17.0; 3 24 49, 15.1; 11 23 49, 22.9; 3 20 50, 18.4; 11 8 50, 25.2; 4 3 51, 14.8; 11 30 51, 24.3; 4 2 52, 23.1.

13N 5E-6E2—Reference point—hole in pump base, elevation 63.3 feet, 0.9 mile northwest of Wheatland Road, 1.0 mile southwest of Oakley Avenue. 11 21 47, 19.4; 2 21 48, 16.7; 5 5 48, 13.7; 6 3 48, 15.1; 7 2 48, 21.4; 11 12 48, 21.0; 3 24 49, 16.5; 5 3 49, 21.2; 6 2 49, 22.0; 7 1 49, 51.6 (operating); 8 1 49, 30.1; 8 31 49, 28.8; 11 28 49, 24.3.

13N 5E-6J1—Reference point—top of casing, elevation 67.6 feet, 0.15 mile northwest of Wheatland Road, 0.55 mile southwest of Oakley Avenue. 11 21 47, 19.1; 11 12 48, 21.0; 3 24 49, 15.4; 11 26 49, 23.5.

13N 5E-6L1—Reference point—top of casing, elevation 61.9 feet, 0.5 mile northwest of Wheatland Road, 0.8 mile southwest of Oakley Avenue. 11 21 47, 20.1; 3 5 48, 20.1; 11 12 48, 21.7; 3 24 49, 16.6; 11 26 49, 24.8.

13N 5E-7B1—Reference point—notch in concrete casing, elevation 72.2 feet, Northwest side of Wheatland Road, 0.9 mile southwest of Oakley Avenue. 11 21 47, 24.5; 3 5 48, 26.1; 11 12 48, 25.7; 3 24 49, 20.5; 11 26 49, 28.8; 3 9 50, 23.4; 11 18 50, 30.0; 1 3 51, 19.3; 12 3 51, 29.3; 4 2 52, 16.5.

13N 5E-7C1—Reference point—top of casing, elevation 71.4 feet, Northwest side of Wheatland Road, 1.3 mile southwest of Oakley Avenue. 11 28 47, 24.3; 3 2 48, 25.9; 11 12 48, 25.4; 3 24 49, 20.9.

13N 5E-7C2—Reference point—hole in top of pump base, elevation 68.3 feet, Northwest side of Wheatland Road, 1.2 miles southwest of Oakley Avenue. 11 21 47, 21.5; 3 8 48, 25.1; 3 29 48, 18.6; 5 5 48, 16.3; 6 3 48, 17.5; 7 2 48, 33.0; 11 12 48, 22.7; 3 24 49, 18.1; 6 2 49, 29.8; 8 1 49, 48.1; 8 31 49, 36.3; 11 26 49, 25.7.

13N 5E-7E1—Reference point—slot in casing, elevation 69 feet, Northwest side of Wheatland Road, 1.5 miles southwest of Oakley Avenue. 11 28 47, 23.6; 3 2 48, 26.9; 11 12 48, 24.8; 3 24 49, 20.2; 11 23 49, 28.9.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Mode by Division of Water Resources
(Depths to water in feet measured from reference point)

13N/5E-7G1—Reference point—top of casing, elevation 80.5 feet. At Bear River north levee, 0.35 mile southeast of Wheatland Road, 1.1 miles southwest of Oakley Avenue. 11/21/47, 31.7; 3/5/48, 37.6; 3/29/48, 28.4; 5/14/48, 25.5; 11/12/48, 31.5; 1/26/49, 29.5; 3/24/49, 27.2; 11/23/49, 34.4.

13N/5E-7F1—Reference point—top of concrete base, elevation 77.3 feet. At Bear River north levee, 0.35 mile southeast of Wheatland Road, 1.3 miles southwest of Oakley Avenue. 11/21/47, 29.3; 3/8/48, 33.7; 11/12/48, 30.3; 3/24/49, 26.1; 11/23/49, 34.9; 3/29/50, 28.6; 11/6/50, 35.9; 4/3/51, 25.0; 12/3/51, 33.7; 4/2/52, 22.7.

13N/5E-7H1—Reference point—bottom of pump base, elevation 80.4 feet, 0.3 mile southeast of Wheatland Road, 0.9 mile southwest of Oakley Avenue. 11/21/47, 31.1; 3/5/48, 35.7; 11/12/48, 31.8; 3/24/49, 27.3; 11/23/49, 34.0

13N/5E-7K1—Reference point—hole in pump base, elevation 74.9 feet. West side of Huffaker Road, 0.55 mile north of Bear River Drive. 12/3/47, 26.4; 3/8/48, 29.4; 11/8/48, 27.9; 3/31/49, 23.2; 12/6/49, 30.3; 3/30/50, 26.0; 11/8/50, 33.0; 4/3/51, 21.7; 4/3/52, 18.7.

13N/5E-7L1—Reference point—edge of pump base, elevation 74.8 feet, 0.5 mile north of Bear River Drive on west side of Hudson Road extended. 12/3/47, 27.5; 3/30/48, 25.2; 11/4/48, 29.5; 3/30/49, 25.0; 12/2/49, 33.9.

13N/5E-7M1—Reference point—top of casing, elevation 73.4 feet. At Bear River north levee, 0.25 mile south of Wheatland Road, 1.1 miles east of Pleasant Grove Road. 12/24/47, 28.1; 3/8/48, 33.7; 3/29/48, 25.9; 11/15/48, 29.1; 3/31/49, 25.1; 12/2/49, 31.9.

13N/5E-8B1—Reference point—hole in pump base, elevation 76.7 feet, 0.1 mile southwest of Oakley Avenue, 0.5 mile southeast of Wheatland Road. 11/21/47, 20.6; 3/5/48, 21.3; 11/11/48, 23.3; 3/24/49, 17.3; 11/26/49, 24.2; 3/29/50, 20.1; 11/8/50, 24.5; 4/3/51, 16.6; 12/3/51, 22.2; 4/2/52, 13.2.

13N/5E-8G1—Reference point—hole in pump base, elevation 81.3 feet. At Bear River north levee, 0.1 mile southwest of Oakley Avenue, 11/21/37, 20.1; 3/5/48, 19.3; 11/11/48, 20.1; 3/24/49, 16.3. Well filled.

13N/5E-8H1—Reference point—hole in pump base, elevation 83.7 feet. At Bear River north levee, 0.1 mile northeast of Oakley Avenue. 11/25/47, 21.5; 3/5/48, 21.4; 3/29/48, 19.4; 11/12/48, 22.3; 3/24/49, 18.2; 11/26/49, 23.8.

13N/5E-8J1—Reference point—hole in pump base, elevation 84.4 feet, 0.7 mile north of Bear River Drive, 0.85 mile east of Brewer Road. 11/26/47, 26.6; 3/22/48, 25.5; 11/4/48, 28.5; 3/30/49, 24.0; 12/6/49, 30.3; 3/30/50, 17.9; 11/9/50, 31.0; 4/3/51, 24.0; 11/20/51, 29.8; 4/3/52, 14.6.

13N/5E-8L1—Reference point—hole in pump base, elevation 75 feet, 0.25 mile east of Brewer Road, 0.75 mile north of Bear River Drive. 11/26/47, 26.7; 3/22/48, 23.9; 11/4/48, 26.8; 3/30/49, 22.3; 12/6/49, 29.2.

13N/5E-8N1—Reference point—bottom of pump base by air line, elevation 76.4 feet, 0.15 mile east of Brewer Road, 0.5 mile north of Bear River Drive. 11/26/47, 25.0; 3/22/48, 23.0; 11/4/48, 25.8; 3/30/49, 21.8; 12/6/49, 28.0.

13N/5E-8P1—Reference point—top of casing, elevation 76.6 feet, 0.4 mile north of Bear River Drive, 0.5 mile east of Brewer Road. 11/26/47, 20.6; 3/22/48, 19.0; 3/30/48, 18.2; 11/4/48, 22.1; 3/30/49, 17.7; 12/6/49, 24.6.

13N/5E-8R1—Reference point—pipe in concrete base, elevation 75 feet, 0.5 mile north of Bear River Drive, 0.75 mile east of Brewer Road. 11/4/48, 25.1; 3/30/49, 20.4; 12/6/49, 27.1.

13N/5E-9C1—Reference point—slot in concrete base, elevation 76.8 feet, 0.1 mile north of Bear River north levee, 0.3 mile southeast of T. H. Richards' ranch house, 0.8 mile southwest of Wheatland. 11/25/47, 11.9; 3/5/48, 12.1; 3/29/48, 9.7; 11/12/48, 12.5; 3/24/49, 9.4; 11/26/49, 14.0.

13N/5E-9D1—Reference point—top of base under air line, elevation 82.3 feet. At Bear River north levee, 0.4 mile southeast of T. H. Richards' ranch house, 0.8 mile southwest of Wheatland. 11/25/47, 13.9; 3/5/48, 13.4; 3/29/48, 12.3; 11/12/48, 14.0; 3/24/49, 11.5; 11/26/49, 14.6; 3/29/50, 11.2; 11/8/50, 14.0; 4/3/51, 9.9; 12/3/51, 13.7; 4/2/52, 8.6.

13N/5E-9E1—Reference point—inside edge of tapered base, elevation 83.5 feet. At Bear River north levee, 0.45 mile south of T. H. Richards' ranch house, 0.8 mile southwest of Wheatland. 11/25/47, 18.1; 3/5/48, 17.6; 11/12/48, 18.2; 3/24/49, 15.2. Well destroyed.

13N/5E-9G1—Reference point—hole in pump base, elevation 85.1 feet, 0.3 mile west of Placer Road, 0.75 mile north of Bear River Drive. 11/26/47, 15.9; 11/4/48, 17.2; 3/30/49, 14.2; 12/6/49, 20.4.

13N/5E-9H1—Reference point—top of casing, elevation 86.4 feet, 1.0 mile north of Bear River Drive, 500 feet west of Placer Road extended. 11/26/47, 15.3; 11/4/48, 15.8; 3/30/49, 14.4; 11/7/49, 18.8; 12/6/49, 18.4; 11/9/50, 19.8. Well destroyed.

13N/5E-9H2—Reference point—hole in pump base, elevation 86.4 feet, 1.0 mile north of Bear River Drive, 600 feet west of Placer Road extended. 11/20/51, 20.1; 4/3/52, 13.5.

13N/5E-9P1—Reference point—hole in pump base, elevation 80.4 feet, 0.5 mile north of Bear River Drive, 0.7 mile west of Placer Road. 12/26/47, 17.6; 11/4/47, 19.5; 3/30/49, 15.6; 12/6/49, 21.0.

13N/5E-9R1—Reference point—hole in pump base, elevation 83.6 feet. West side of Placer Road, 0.5 mile north of Bear River Drive. 11/26/47, 15.7; 3/22/48, 14.5; 3/30/48, 13.8; 5/8/48, 12.9; 11/4/48, 17.2; 1/26/49, 16.7; 2/18/49, 16.3; 3/16/49, 15.7; 3/30/49, 14.8; 7/29/49, 50.5 (operating); 11/7/49, 19.9; 12/6/49, 19.6; 2/15/50, 17.6; 3/15/50, 17.2; 4/4/50, 16.7; 5/9/50, 18.1; 6/7/50, 20.0; 8/3/50, 21.9; 10/3/50, 22.2; 11/14/50, 20.3; 12/14/50, 16.5; 1/4/51, 15.2; 2/7/51, 13.2; 3/7/51, 12.8; 3/27/51, 12.6; 7/16/51, 23.7; 8/22/51, 24.9; 9/26/51, 19.5; 11/19/51, 19.6; 2/28/52, 13.5; 4/4/52, 12.0.

13N/5E-16D1—Reference point—hole in casing, elevation 78 feet. North side of Bear River Drive, 0.8 mile west of Placer Road. 11/26/47, 18.1; 3/22/48, 17.8; 3/30/48, 16.2; 5/8/48, 15.0; 11/4/48, 21.2; 1/26/49, 18.3; 3/30/49, 16.0; 6/29/49, 26.3; 7/27/49, 28.4; 8/26/49, 27.8; 12/6/49, 22.9; 3/30/50, 18.7; 11/9/50, 24.6; 4/3/51, 15.9; 11/20/51, 22.2; 4/3/52, 12.9.

13N/5E-16E1—Reference point—hole in pump base, elevation 75.9 feet, 0.1 mile south of Bear River Drive, 0.85 mile west of Placer Road. 11/26/47, 16.5; 3/22/48, 18.2; 11/4/48, 19.9; 3/30/49, 14.3; 12/6/49, 21.4.

13N/5E-17D1—Reference point—top of concrete base, elevation 71.2 feet, 0.15 mile east of Brewer Road, 0.2 mile north of Bear River Drive. 11/26/47, 18.3; 3/22/48, 19.7; 11/4/48, 22.3; 3/30/49, 18.9; 12/6/49, 25.1; 3/30/50, 22.2; 11/9/50, 27.2; 4/3/51, 18.9; 11/20/51, 25.6; 4/3/52, 15.6.

13N/5E-17J2—Reference point—hole in pump base, elevation 70 feet, 0.4 mile south of Bear River Drive, 1.0 mile west of Placer Road. 11/4/48, 19.3; 3/30/49, 13.4; 12/6/49, 21.1.

13N/5E-17R1—Reference point—hole in pump base, elevation 70 feet, 0.7 mile south of Bear River Drive, 0.8 mile east of Brewer Road. 11/4/48, 24.9; 3/30/49, 19.2; 12/6/49, 27.6; 3/30/50, 22.9; 11/9/50, 30.4; 4/4/51, 20.8; 11/20/51, 27.0; 4/3/52, 22.3.

13N/5E-18B1—Reference point—top of casing, elevation 70.8 feet, 1.5 miles east of Pleasant Grove Road, 0.25 mile north of Bear River Drive. 12/3/47, 23.3; 3/8/48, 27.4; 3/30/48, 21.1; 11/4/48, 25.1; 3/30/49, 20.6; 12/6/49, 28.0.

13N/5E-18B2—Reference point—hole in top of pump base, elevation 69.3 feet. North side of Bear River Drive, 0.3 mile west of Brewer Road. 12/17/47, 21.3; 3/22/48, 20.3; 3/30/48, 19.5; 5/14/48, 17.1; 11/4/48, 23.3; 1/26/49, 21.0; 3/30/49, 19.0; 11/30/49, 26.4.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Mode by Division of Water Resources
(Depths to water in feet measured from reference point)

13N 5E-18C1—Reference point—top of casing, elevation 69.6 feet, 0.25 mile north of Bear River Drive, 0.7 mile west of Brewer Road. 12/3/47, 22.5; 3/30/48, 20.3; 11/4/48, 24.0; 3/31/49, 19.8.

13N 5E-18F1—Reference point—top of casing, elevation 60.8 feet, South side of Bear River Drive, 0.6 mile west of Brewer Road. 12/3/47, 14.3; 3/8/48, 15.2; 3/30/48, 12.1; 5/14/48, 14.0; 11/4/48, 20.3; 3/31/49, 15.9; 5/25/49, 21.3; 8/3/49, 31.1; 12/6/49, 23.4.

13N 5E-18R1—Reference point—hole in casing, elevation 69 feet, West side of Brewer Road, 0.75 mile south of Bear River Drive. 12/17/47, 24.2; 3/22/48, 23.7; 3/30/48, 23.0; 5/8/48, 21.4; 11/5/48, 28.4; 3/30/49, 23.5; 11/30/49, 32.8; 3/30/50, 28.0; 11/20/51, 31.4; 4/3/52, 25.7.

13N 5E-19C1—Reference point—bottom of pump base, elevation 71.6 feet, 0.75 mile south of Bear River Drive, 1.2 miles east of Pleasant Grove Road. 12/8/47, 27.7; 3/10/48, 27.0; 3/31/48, 26.0; 5/8/48, 24.5; 11/5/48, 30.0; 1/26/49, 27.4; 4/1/49, 25.2.

13N 5E-19N1—Reference point—top of casing, elevation 68.3 feet, North side of Kempton Road, 1.1 miles east of Pleasant Grove Road. 12/8/47, 24.8; 3/9/48, 25.9; 3/31/48, 23.6; 5/8/48, 22.2; 11/5/48, 28.6; 1/26/49, 25.9; 4/1/49, 24.0; 5/25/49, 42.0; 6/29/49, 54.2; 7/27/49, 45.0; 8/26/49, 58.0; 11/30/49, 31.1; 3/30/50, 27.3; 11/9/50, 34.3; 4/3/51, 26.8; 4/3/52, 22.4.

13N 5E-19P1—Reference point—top of casing, elevation 70.0 feet, North side of Kempton Road, 1.4 miles east of Pleasant Grove Road. 12/8/47, 25.5; 3/9/48, 25.5; 3/31/48, 24.1; 5/8/48, 23.7; 11/5/48, 29.6; 1/26/49, 27.0; 4/1/49, 25.1; 11/30/49, 32.3.

13N 5E-19R1—Reference point—top of casing, elevation 72.5 feet, 100 feet north of Kempton Road, 0.05 mile west of Brewer Road. 12/17/47, 26.6; 3/9/48, 26.8; 11/5/48, 30.5; 4/1/49, 25.9; 11/30/49, 33.3; 3/30/50, 29.7; 11/9/50, 37.1; 4/3/51, 28.5; 11/20/51, 35.7; 4/3/52, 28.5.

13N 5E-28A1—Reference point—slot in concrete base, elevation 80 feet, South side of Kempton Road, 1.8 miles east of Brewer Road. 11/5/48, 28.2; 4/4/49, 22.4; 5/12/49, 25.1; 7/1/49, 29.5; 7/29/49, 31.4; 8/25/49, 32.8; 9/29/49, 31.1; 11/10/49, 29.4; 11/30/49, 28.7; 2/15/50, 26.3; 3/14/50, 25.9; 3/30/50, 25.3; 4/5/50, 25.2; 5/8/50, 27.5; 6/7/50, 31.5; 7/7/50, 34.2; 8/1/50, 36.5; 9/6/50, 38.0; 10/3/50, 34.0; 11/9/50, 31.5; 11/14/50, 31.2; 1/4/51, 25.8; 2/7/51, 26.0; 3/27/51, 24.3; 5/9/51, 24.8; 11/15/51, 31.3; 11/20/51, 31.1; 2/28/52, 25.4; 3/31/52, 24.0; 4/3/52, 24.0.

13N 5E-28C1—Reference point—top of casing, elevation 76 feet, South side of Kempton Road, 1.3 miles east of Brewer Road. 12/17/47, 22.0; 3/9/48, 21.4; 11/5/48, 29.5; 4/4/49, 24.4; 11/10/49, 32.7; 11/30/49, 31.7; 3/30/50, 27.7; 11/9/50, 34.9; 3/27/51, 27.2; 11/20/51, 33.8; 4/3/52, 26.4.

13N 5E-23N1—Reference point—top of casing, elevation 80.7 feet, North side of Waltz Road, 1.25 miles east of Brewer Road. 11/5/48, 29.8; 1/26/49, 26.6; 4/1/49, 25.0; 11/10/49, 33.8; 3/15/50, 28.7; 3/30/50, 28.2; 4/5/50, 28.1; 9/5/50, 43.9; 10/3/50, 39.0; 11/10/50, 35.7; 11/14/50, 35.3; 12/14/50, 32.6; 1/4/51, 32.2; 3/23/51, 28.7; 11/15/51, 36.8; 11/21/51, 36.3; 3/31/52, 29.7; 4/3/52, 29.1.

13N 5E-23R1—Reference point—top of casing, elevation 84.7 feet, 0.1 mile north of Waltz Road, 2.0 miles east of Brewer Road. 11/5/48, 27.1; 4/4/49, 22.0; 9/29/49, 30.3; 11/9/49, 28.1; 2/15/50, 25.2; 3/15/50, 24.7; 4/5/50, 24.1; 5/9/50, 25.1; 6/7/50, 28.0; 7/7/50, 30.2; 8/1/50, 32.2; 9/5/50, 35.4; 10/3/50, 31.2; 11/14/50, 30.0; 12/14/50, 27.7; 1/4/51, 27.2; 3/23/51, 24.8; 5/9/51, 25.7; 6/5/51, 33.1; 7/16/51, 38.0; 8/22/51, 40.6; 9/26/51, 36.8; 11/15/51, 32.9; 2/28/52, 27.3; 3/31/52, 26.3.

13N 5E-29Q1—Reference point—top of casing, elevation 75.8 feet, North side of Waltz Road, 0.6 mile east of Brewer Road. 4/5/50, 28.5.

13N 5E-30A1—Reference point—top of casing, elevation 68 feet, Southwest of corner of Kempton and Brewer Roads. 4/1/49, 27.2.

13N 5E-30C1—Reference point—top of casing, elevation 70.3 feet, South side of Kempton Road, 0.6 mile west of Brewer Road. 12/8/47, 25.9; 3/9/48, 26.3; 3/31/48, 24.5; 11/5/48, 29.9; 4/1/49, 25.3; 11/30/49, 32.6.

13N 5E-30J1—Reference point—hole in pump base, elevation 69 feet, West side of Brewer Road, 0.3 mile north of Waltz Road. 3/22/49, 25.8.

13N 5E-30R1—Reference point—top of casing, elevation 70 feet, Northwest corner of Brewer and Waltz Roads. 11/5/48, 29.5; 4/4/49, 24.8; 11/9/49, 33.2; 11/30/49, 33.4; 2/15/50, 29.5; 3/14/50, 29.0; 3/30/50, 28.3; 4/5/50, 28.2; 11/10/50, 36.1; 11/15/51, 34.7; 11/21/51, 34.7; 3/31/52, 28.7; 4/3/52, 28.5.

13N 5E-31G1—Reference point—top of casing, elevation 69 feet, North side of Hicks Road, 0.35 mile west of Brewer Road. 12/16/47, 22.6; 3/9/48, 21.7; 3/31/48, 21.1; 11/5/48, 27.3; 1/26/49, 24.3; 4/4/49, 22.3; 11/10/49, 30.9; 11/30/49, 30.4; 2/16/50, 27.5; 3/14/50, 26.8; 3/30/50, 26.1; 11/3/50, 33.5; 11/10/50, 33.5; 4/3/52, 26.6.

13N 5E-32C1—Reference point—top of casing, elevation 74 feet, South side of Waltz Road, 0.35 mile east of Brewer Road. 2/25/49, 29.6; 4/1/49, 25.6; 5/12/49, 30.1; 6/27/49, 36.2; 7/29/49, 39.8; 8/25/49, 41.4; 9/29/49, 37.1; 11/9/49, 33.8; 2/15/50, 30.2; 3/15/50, 29.5; 4/5/50, 29.0; 5/9/50, 30.5; 6/7/50, 35.7; 7/7/50, 40.3; 8/1/50, 43.2; 9/5/50, 45.3; 10/3/50, 40.6; 11/14/50, 37.1; 12/14/50, 34.8; 1/4/51, 34.4; 3/23/51, 27.9; 5/9/51, 33.1; 6/5/51, 36.7; 7/11/51, 39.5; 8/22/51, 42.2; 9/26/51, 38.9; 11/15/51, 35.8; 2/28/52, 31.1; 3/31/52, 29.9.

13N 5E-33L1—Reference point—top of casing, elevation 80.1 feet, 0.35 mile north of Cornelius Avenue, 1.3 miles east of Brewer Road. 12/22/48, 27.5; 3/18/49, 25.3; 11/10/49, 34.3; 4/6/50, 28.2; 5/8/50, 28.9; 11/13/50, 35.0; 3/27/51, 29.1; 11/15/51, 37.8; 4/7/52, 30.6.

13N 5E-33P1—Reference point—top of casing, elevation 79.3 feet, 100 feet north of Cornelius Avenue, 1.3 miles east of Brewer Road. 12/22/48, 26.0; 3/18/49, 24.2; 11/10/49, 32.2; 4/6/50, 27.3; 11/13/50, 34.5; 3/27/51, 28.9; 11/15/51, 37.0; 4/7/52, 30.3.

14N 2E-2D2—Reference point—top of casing, elevation 39 feet, 0.15 mile south of Bogue Road, 0.6 mile east of Schlag Road. 12/15/47, 5.3; 3/8/48, 6.4; 11/12/48, 5.2; 3/21/49, 1.8; 11/29/49, 5.4; 3/24/50, 4.3; 11/2/50, 3.9; 3/28/51, 3.5; 11/16/51, 4.2; 4/1/52, 4.0.

14N 2E-10F1—Reference point—top of casing, elevation 35 feet, West side of Schlag Road, 0.55 mile north of Oswald Road. 11/27/29, 9.8; 10/6/30, 9.0; 12/12/31, 9.0; 11/30/32, 9.6; 11/10/34, 9.6; 11/28/36, 9.6; 1/25/39, 10.1; 1/13/41, 5.0.

14N 2E-10L1—Reference point—top of casing, elevation 37 feet, West side of Schlag Road, 0.5 mile north of Oswald Road. 12/20/33, 12.2; 11/10/34, 12.7; 11/11/36, 12.6; 11/24/37, 12.8.

14N 2E-10R1—Reference point—top of casing, elevation 30 feet, North side of Oswald Road, 0.45 mile east of Schlag Road. 11/6/47, 8.9; 12/15/48, 10.5; 12/9/49, 10.6; 11/10/50, 9.4; 12/8/51, 3.4.

14N 2E-12H1—Reference point—top of pipe in base, elevation 41 feet, 150 feet west of Township Road, 0.6 mile north of Oswald Road. 12/15/47, 9.5; 3/9/48, 10.6; 11/12/48, 9.7; 3/21/49, 8.2; 11/29/49, 10.6.

14N 2E-13A1—Reference point—top of casing, elevation 42.1 feet, 0.05 mile south of Oswald Road, 0.1 mile west of Township Road. 12/15/47, 8.9; 3/8/48, 10.3; 11/12/48, 6.1; 3/21/49, 7.0; 11/29/49, 8.4.

14N 2E-13C1—Reference point—top of casing, elevation 39 feet, 100 feet south of Oswald Road, 0.7 mile west of Township Road. 12/15/47, 5.5; 3/8/48, 6.6; 11/12/48, 4.7; 3/21/49, 3.1; 11/29/49, 6.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet meosured from reference point)

14N/2E-13R1—Reference point—top of casing, elevation 37 feet, 0.1 mile west of Township Road, 0.4 mile south of Pierce Road. 12/15/47, 10.9; 3/8/48, 11.7; 10/8/48, 8.0; 11/12/48, 9.5; 1/18/49, 11.0; 3/21/49, 8.5; 6/6/49, 10.4; 6/30/49, 6.7; 7/27/49, 5.4; 8/25/49, 5.5; 11/29/49, 11.1; 3/24/50, 10.9; 11/2/50, 10.2; 3/28/51, 9.0; 11/16/51, 11.2; 4/1/52, 6.5.

14N/2E-14E1—Reference point—top of casing, elevation 34 feet, 0.4 mile south of Oswald Road, 0.4 mile west of Boulton Road. 12/15/47, 5.5; 3/8/48, 6.6; 11/12/48, 4.7; 3/21/49, 3.1; 11/29/49, 6.0.

14N/2E-14J1—Reference point—top of stone casing, elevation 36 feet, 0.1 mile south of Pierce Road, 0.3 mile east of Boulton Road. 12/15/47, 4.7; 3/8/48, 6.0; 10/8/48, 2.2; 11/12/48, 3.9.

14N/2E-26R1—Reference point—top of casing, elevation 33 feet, 0.2 mile north of O'Banion Road, 1.1 miles west of Township Road. 12/11/47, 7.4; 3/10/48, 7.6; 11/8/48, 6.4; 3/24/49, 3.9; 12/2/49, 7.7.

14N/3E-1H1—Reference point—top of casing, elevation 54 feet, 0.20 mile west of Feather River Boulevard, 1.70 miles north of Ella Avenue. 11/12/47, 21.2; 3/5/48, 20.0; 5/8/48, 15.8; 10/7/48, 23.8; 11/11/48, 22.3; 1/27/49, 20.9; 3/22/49, 17.6; 6/1/49, 25.2; 7/3/49, 25.5; 8/26/49, 25.5; 12/1/49, 23.5; 3/28/50, 17.2; 11/21/51, 22.7; 4/5/52, 10.8.

14N/3E-1R1—Reference point—top of casing, elevation 53 feet, 0.20 mile west of Feather River Boulevard, 1.20 miles north of Ella Avenue. 11/12/47, 20.5; 3/5/48, 20.2; 11/11/48, 20.1; 3/22/49, 17.9; 12/1/49, 23.5.

14N/3E-2G1—Reference point—hole in base of pump, elevation 49 feet, 0.36 mile north of Stewart Road, 0.45 mile east of Garden Highway. 11/11/47, 32.3; 3/24/48, 24.0; 10/6/48, 27.7; 11/15/48, 24.4; 3/17/49, 21.4; 11/30/49, 29.8.

14N/3E-2Q1—Reference point—hole in base of pump, elevation 53.9 feet, 0.07 mile south of Stewart Road, 0.10 mile east of Garden Highway. 11/10/47, 26.8; 3/4/48, 33.9; 11/15/48, 28.8; 3/17/49, 21.7; 11/30/49, 23.2; 3/27/50, 21.4; 11/3/50, 26.7; 3/29/51, 17.9; 11/20/51, 27.2.

14N/3E-3A1—Reference point—hole in side of pump, elevation 50 feet, 0.19 mile south of Bogue Road, 0.25 mile east of Highway 24. 11/10/47, 36.1; 3/23/48, 35.5; 10/6/48, 36.3; 11/15/48, 31.0; 3/7/49, 29.3; 11/30/49, 35.0; 3/27/50, 30.5; 11/3/50, 33.5; 3/28/51, 27.2; 11/16/51, 32.2.

14N/3E-3C2—Reference point—hole in base of pump, elevation 53.1 feet, 0.05 mile south of Bogue Road, 0.11 mile west of State Highway 24. 3/12/48, 43.8; 10/6/48, 35.6; 11/11/48, 33.9; 1/18/49, 32.8; 3/7/49, 32.1; 6/1/49, 37.6; 6/28/49, 45.0; 7/27/49, 47.5; 8/25/49, 42.3; 12/1/49, 35.4.

14N/3E-3C3—Reference point—bottom of pump base, elevation 53.1 feet, 0.27 mile south of Bogue Road, 0.06 mile west of State Highway 24. 3/29/48, 36.4; 11/15/48, 33.9; 3/7/49, 32.7; 11/30/49, 35.0.

14N/3E-3F1—Reference point—top of casing, elevation 51.3 feet, 0.2 mile west of State Highway 24, 0.45 mile south of Bogue Road. 11/18/47, 31.6; 3/23/48, 39.2; 10/6/48, 34.0; 11/11/48, 32.8; 3/17/49, 30.9; 11/30/49, 34.4.

14N/3E-3G1—Reference point—hole in pump base, elevation 52 feet, 0.17 mile east of State Highway 24, 0.54 mile south of Bogue Road. 3/4/48, 37.5; 11/16/48, 32.8; 3/17/49, 29.7; 11/30/49, 32.9.

14N/3E-3N1—Reference point—top of casing, elevation 55.4 feet, 0.09 mile south of Stewart Road, 0.40 mile west of State Highway 24. 11/10/47, 38.7; 3/4/48, 41.5; 11/15/48, 39.7; 3/17/49, 37.1; 11/30/49, 43.7.

14N/3E-3N2—Reference point—hole in base of pump, elevation 48 feet, South side of Stewart Road, 0.30 mile west of State Highway 24. 3/12/48, 40.4; 11/15/48, 34.7.

14N/3E-3P1—Reference point—top of pit, elevation 50 feet, 0.10 mile north of Reed Road, 0.17 mile west of State Highway 24. 11/26/29, 28.3; 9/27/30, 32.4; 12/12/31, 33.8; 12/1/32, 32.4; 12/15/33, 33.4; 11/10/34, 34.1; 11/25/36, 28.4; 11/24/37, 26.2; 1/26/39, 20.4; 1/13/41, 24.0; 11/6/47, 33.8; 12/15/48, 34.2; 12/9/49, 36.0; 11/10/50, 39.1.

14N/3E-3R2—Reference point—slot in base, elevation 51.3 feet, 0.19 mile south of Stewart Road, 0.35 mile east of Garden Highway. 11/10/47, 31.1; 11/15/48, 28.4; 3/17/49, 25.2; 11/30/49, 30.7.

14N/3E-4E3—Reference point—top of casing, elevation 47 feet, 0.05 mile south of Star Road, 0.20 mile east of Grove Avenue. 12/16/47, 30.6; 3/24/48, 31.7; 11/12/48, 33.3; 3/18/49, 30.0; 11/29/49, 35.8.

14N/3E-4G1—Reference point—hole in pump base, elevation 50.1 feet, 0.20 mile east of Walton Avenue, 0.48 mile south of Bogue Road. 11/18/47, 33.8; 3/12/48, 35.4; 10/6/48, 37.0; 11/11/48, 35.1; 3/18/49, 33.1; 11/30/49, 37.1.

14N/3E-4Q1—Reference point—hole in base of pump, elevation 47 feet, 0.10 mile north of Reed Road, 0.04 mile east of Walton Avenue. 11/10/47, 32.9; 3/4/48, 34.0; 3/12/48, 36.7; 3/29/48, 32.3; 11/15/48, 33.9; 3/18/49, 31.2; 11/29/49, 35.6; 3/27/50, 33.2; 11/3/50, 38.5; 3/28/51, 32.9; 11/16/51, 36.2.

14N/3E-5A2—Reference point—top of concrete pit, elevation 49 feet, West side of Grove Avenue, 0.15 mile south of Bogue Road. 12/16/47, 29.9; 3/9/48, 32.7; 10/7/48, 34.8; 11/12/48, 32.5; 3/18/49, 29.0; 11/29/49, 34.0.

14N/3E-5C1—Reference point—hole in base of pump, elevation 50 feet, 0.07 mile south of Bogue Road, 0.50 mile east of George Washington Boulevard. 12/16/48, 30.4; 3/9/48, 28.8; 10/7/48, 31.2; 11/12/48, 29.0; 3/18/49, 26.1; 6/1/49, 32.8; 7/27/49, 41.8; 8/25/49, 39.0; 11/29/49, 30.2; 3/27/50, 27.1; 11/3/50, 33.5; 3/28/51, 23.6; 4/1/52, 23.8.

14N/3E-5D1—Reference point—invert of pipe in base, elevation 48.1 feet, South side of Bogue Road, 0.15 mile east of George Washington Boulevard. 12/20/47, 23.4; 3/5/48, 25.3; 10/4/48, 26.6; 11/18/48, 24.8; 3/29/49, 22.0.

14N/3E-5K1—Reference point—hole in base of pump, elevation 46 feet, 0.14 mile north of Stewart Road, 0.47 mile west of Grove Avenue. 3/9/48, 27.3; 3/30/48, 28.4; 11/12/48, 31.0; 12/9/49, 31.7.

14N/3E-6G1—Reference point—slot in concrete base, elevation 45 feet, 0.45 mile west of George Washington Boulevard, 0.38 mile south of Bogue Road. 12/16/47, 13.9; 3/9/48, 14.7; 11/12/48, 14.6; 12/9/49, 15.0.

14N/3E-6M1—Reference point—hole in base of pump, elevation 40 feet, 0.50 mile north of Reed Road, 0.06 mile east of Township Road. 12/15/47, 10.8; 3/24/48, 13.2; 10/8/48, 7.3; 11/12/48, 9.3; 1/18/49, 10.9; 3/21/49, 9.2; 6/6/49, 6.1; 6/28/49, 6.7; 7/27/49, 6.6; 8/25/49, 6.0; 11/29/49, 10.1; 3/24/50, 9.9; 11/2/50, 10.0; 3/28/51, 8.7; 11/16/51, 9.2; 4/1/52, 7.9.

14N/3E-7A1—Reference point—hole in base of pump, elevation 45 feet, 0.12 mile south of Reed Road, 0.25 mile west of George Washington Boulevard. 12/17/47, 19.5; 3/9/48, 20.2; 11/12/48, 20.6; 3/21/49, 18.6; 11/29/49, 21.3.

14N/3E-7M1—Reference point—top of casing under pump, elevation 42 feet, 0.10 mile east of Township Road, 0.52 mile north of Oswald Avenue. 12/15/47, 11.2; 3/9/48, 12.3; 11/12/48, 11.8; 3/21/49, 10.2; 11/29/49, 11.2; 3/24/50, 10.8; 11/2/50, 11.8; 3/28/51, 9.0; 11/16/51, 11.1; 4/2/52, 10.1.

14N/3E-8B1—Reference point—hole in base of pump, elevation 45 feet, South side of Reed Road, 0.52 mile west of Walton Avenue. 12/17/47, 26.3; 3/9/48, 25.6; 11/12/48, 30.2; 3/21/49, 25.0; 11/29/49, 31.1; 3/27/50, 26.1; 11/3/50, 35.3; 3/28/51, 24.3; 11/16/51, 31.6; 4/2/52, 27.7.

14N/3E-8D1—Reference point—hole in base of pump, elevation 46.6 feet, South side of Reed Road, 0.15 mile east of George Washington Boulevard. 12/17/47, 23.2; 3/9/48, 23.5; 3/21/49, 21.6.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

14N 3E-8J1—Reference point—hole in base of pump, elevation 45 feet, 0.03 mile west of Grove Avenue, 0.45 mile north of Oswald Avenue, 12/16/47, 27.8; 3/4/48, 29.0; 11/12/48, 30.8; 3/18/49, 27.3; 11/29/49, 33.1; 3/27/50, 29.4; 11/3/50, 36.2; 3/28/51, 29.1; 11/19/51, 33.8; 4/2/52, 23.8.

14N 3E-8K1—Reference point—hole in base of pump, elevation 45 feet, 0.40 mile west of Grove Avenue, 0.35 mile north of Oswald Road, 12/16/47, 26.9; 3/24/48, 28.3; 11/12/48, 30.9; 3/18/49, 26.8; 11/29/49, 32.1.

14N 3E-8M3—Reference point—top of casing, elevation 45 feet, 0.20 mile east of George Washington Boulevard, 0.50 mile north of Oswald Road, 12/17/47, 22.7; 3/9/48, 21.1; 10/7/48, 28.0; 11/12/48, 25.6; 1/18/49, 23.1; 3/21/49, 21.8; 6/1/49, 25.0; 6/30/49, 26.3; 7/27/49, 34.5; 8/25/49, 31.5; 11/29/49, 26.7.

14N 3E-8N1—Reference point—top of casing, elevation 44.8 feet, North side of Oswald Avenue, 0.15 mile east of George Washington Boulevard, 12/16/47, 21.5; 3/9/48, 16.4; 3/12/48, 21.8; 11/12/48, 23.8; 3/21/49, 20.7; 11/29/49, 21.9; 3/24/50, 21.4; 11/2/50, 29.3; 3/28/51, 18.9; 11/19/51, 25.5; 4/2/52, 13.5.

14N 3E-9A2—Reference point—top of concrete pit, south edge, elevation 40 feet, 0.1 mile south of Reed Road, 0.35 mile east of Walton Avenue, 11/19/47, 32.0; 3/4/48, 32.3; 5/12/48, 31.1; 11/15/48, 32.1; 11/18/49, 32.1; 3/18/49, 31.0; 11/30/49, 35.2.

14N 3E-9D1—Reference point—hole in base of pump, elevation 46 feet, 0.10 mile south of Reed Road, 0.45 mile west of Walton Road, 12/16/47, 31.4; 3/9/48, 33.8.

14N 3E-9K1—Reference point—top of casing, elevation 45 feet, South side of Barry Road, 0.25 mile east of Walton Avenue, 11/8/47, 33.2; 3/4/48, 34.9; 3/12/48, 34.1; 3/29/48, 32.5; 10/6/48, 35.6; 11/15/48, 34.3; 3/17/49, 32.0; 11/30/49, 35.8.

14N 3E-9Q1—Reference point—hole in base of pump, elevation 42 feet, North side of Oswald Road, 0.25 mile east of Walton Avenue, 3/12/48, 29.0; 11/15/48, 23.4; 3/17/49, 21.3.

14N 3E-10B1—Reference point—top of casing, elevation 50 feet, 0.17 mile east of State Highway 24, 0.33 mile north of Barry Road, 11/19/47, 29.4; 10/6/48, 31.3; 11/30/49, 31.2; 11/3/50, 33.5; 11/20/51, 31.7.

14N 3E-10B2—Reference point—top of casing, elevation 49 feet, 0.32 mile south of Stewart Road, 0.18 mile east of State Highway 24, 11/19/47, 29.4; 3/4/48, 32.0; 10/6/48, 31.3; 11/15/48, 31.5; 3/7/49, 26.3; 11/30/49, 31.2; 3/27/50, 28.4; 11/3/50, 33.5; 3/29/51, 24.8; 11/20/51, 31.7.

14N 3E-10F1—Reference point—top of casing at bottom of pit, elevation 27 feet, 0.70 mile west of State Highway 24, 0.80 mile north of Barry Road, 11/18/47, 35.1; 3/4/48, 34.1; 3/12/48, 33.9; 11/15/48, 34.8; 3/17/49, 31.7; 11/29/49, 36.6.

14N 3E-10N1—Reference point—top of concrete base, elevation 18.6 feet, 0.08 mile north of Oswald Avenue, 0.36 mile west of State Highway 24, 11/8/47, 30.1; 3/12/48, 32.1; 3/29/48, 29.1; 5/12/48, 27.0; 10/6/48, 32.2; 11/15/48, 31.3; 1/18/49, 29.4; 3/17/49, 28.5; 11/30/49, 32.2; 3/29/50, 30.0; 11/3/50, 33.9; 3/29/51, 28.6; 11/20/51, 32.3.

14N 3E-11D2—Reference point—top of casing, elevation 49 feet, 0.10 mile north of Barry Road, 0.63 mile east of State Highway 24, 11/19/47, 27.3; 3/4/48, 30.6; 3/29/48, 31.3; 5/12/48, 23.4; 10/6/48, 34.1; 11/16/48, 27.7; 11/18/49, 25.8; 3/17/49, 24.4; 6/1/49, 31.6; 6/28/49, 39.2; 8/3/49, 38.9; 8/25/49, 31.8; 11/30/49, 29.1.

14N 3E-11F2—Reference point—hole in base of pump, elevation 51.7 feet, 0.17 mile north of Barry Road, 0.95 mile east of State Highway 24, 11/10/47, 27.1; 3/23/48, 27.8; 11/16/48, 21.2; 3/17/49, 20.7; 11/30/49, 26.1; 3/27/50, 19.6; 11/3/50, 26.1; 3/29/51, 16.0; 11/20/51, 25.0.

14N 3E-12F1—Reference point—top of casing, elevation 52 feet, 0.65 mile north of Ella Road, 0.50 mile east of Feather River Boulevard, 3/28/50, 17.0; 11/6/50, 23.6; 3/30/51, 18.4; 4/5/52, 20.6.

14N 3E-12M1—Reference point—hole in base of pump, elevation 50 feet, 0.22 mile north of Ella Avenue, 0.84 mile west of Feather River Boulevard, 11/12/47, 20.4; 3/6/48, 20.5; 11/15/48, 20.2; 3/22/49, 16.8; 12/1/49, 22.1; 3/28/50, 17.6; 11/6/50, 72.1; 11/21/51, 20.8; 4/5/52, 9.5.

14N 3E-12Q1—Reference point—hole in base of pump, elevation 53.6 feet, 0.23 mile north of Ella Avenue, 0.29 mile west of Feather River Boulevard, 11/11/49, 21.7; 3/5/48, 23.0; 5/8/48, 19.5.

14N 3E-13B1—Reference point—top of casing, elevation 50.9 feet, 0.17 mile south of Ella Avenue, 0.44 mile west of Feather River Boulevard, 11/12/47, 20.7; 3/5/48, 22.8; 11/11/48, 20.2; 3/2/49, 18.0; 12/1/49, 22.1; 3/28/50, 21.7; 11/6/50, 21.8; 3/30/51, 13.0; 11/20/51, 21.8; 4/5/52, 12.1.

14N 3E-13N1—Reference point—hole in base of pump, elevation 48.3 feet, 0.11 mile north of Plumas Road, 0.81 mile west of Feather River Boulevard, 3/6/48, 24.1; 5/8/48, 16.0; 11/11/48, 19.8; 1/27/49, 18.4; 3/21/49, 16.9; 12/1/49, 21.1; 3/29/50, 17.4; 11/6/50, 20.9; 4/5/52, 10.0.

14N 3E-14E1—Reference point—hole in base of pump, elevation 47 feet, 0.20 mile west of Garden Highway, 0.75 mile north of Messick Road, 11/18/47, 25.3; 3/23/48, 22.1; 11/15/48, 22.2; 3/17/49, 19.6; 11/29/49, 22.4.

14N 3E-14E2—Reference point—top of casing, elevation 47 feet, 0.11 mile west of Garden Highway, 0.75 mile north of Messick Road, 11/10/47, 20.6; 3/5/48, 23.7; 5/12/48, 13.9; 10/6/48, 21.6; 11/15/48, 20.2; 1/27/49, 19.2; 3/17/49, 17.1; 6/1/49, 19.5; 6/30/49, 26.7; 7/27/49, 28.0; 8/25/49, 25.7; 11/29/49, 23.3; 3/29/50, 16.4; 11/3/50, 23.3; 3/29/51, 12.7; 11/20/51, 20.8.

14N 3E-14N1—Reference point—hole in base of pump, elevation 46 feet, 0.27 mile north of Messick Road, 0.13 mile east of Garden Highway, 11/18/47, 19.1; 3/5/48, 27.7; 11/15/48, 19.4; 3/17/49, 16.6; 11/29/49, 21.6.

14N 3E-14R1—Reference point—hole in base of pump, elevation 49.4 feet, 1.07 miles west of Feather River Boulevard, 0.67 mile north of Broadway, 11/11/47, 24.3; 3/6/48, 25.8; 11/11/48, 20.9; 3/21/49, 17.9; 12/1/49, 22.1; 3/29/50, 17.9; 11/6/50, 22.3; 3/30/51, 13.4; 11/20/51, 21.1; 4/5/52, 10.9.

14N 3E-15A2—Reference point—slot in base of pump, elevation 47 feet, 0.57 mile south of Barry Road, 0.41 mile east of State Highway 24, 11/19/47, 27.6; 3/23/48, 27.8; 11/15/48, 29.7; 3/17/49, 24.8; 11/29/49, 28.8.

14N 3E-15B1—Reference point—top of casing, elevation 47 feet, 0.18 mile south of Oswald Avenue, 0.04 mile east of State Highway 24, 11/8/47, 39.0; 3/5/48, 33.8; 3/12/48, 32.5; 11/15/48, 28.5; 3/17/49, 35.1; 11/29/49, 33.2.

14N 3E-15B2—Reference point—top of casing, elevation 48 feet, 1.0 mile north of Messick Road, 0.17 mile east of State Highway 24, 11/18/47, 26.9.

14N 3E-15E1—Reference point—hole in base of pump, elevation 17.2 feet, 0.48 mile south of Oswald Road, 0.43 mile west of State Highway 24, 3/23/48, 27.9; 10/6/48, 29.0; 11/15/48, 27.0; 3/17/49, 25.9; 11/30/49, 29.4.

14N 3E-15P1—Reference point—top of casing, elevation 45 feet, 0.38 mile north of Messick Road, 0.02 mile west of State Highway 24, 3/23/48, 29.2; 11/15/48, 17.2; 3/17/49, 25.9; 11/29/49, 28.5.

14N 3E-16C1—Reference point—hole in base of pump, elevation 48.9 feet, 0.10 mile west of Walton Avenue, 0.22 mile south of Oswald Road, 12/16/47, 32.3; 3/20/48, 30.6; 3/26/48, 29.9; 3/30/48, 29.9; 5/12/48, 28.1; 11/15/48, 31.8; 3/18/49, 29.6; 11/29/49, 34.7.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

14N/3E-16E1—Reference point—top of casing, elevation 47.7 feet, 0.25 mile east of Carlson Road, 0.40 mile south of Oswald Road. 12/16/47, 27.1; 3/20/48, 29.0; 10/7/48, 30.2; 11/15/48, 28.9; 3/18/49, 26.8; 11/29/49; 35.8; 3/27/50, 28.6; 11/3/50, 32.6; 3/29/51, 30.2; 11/19/51, 30.6; 4/2/52, 22.2.

14N/3E-16J1—Reference point—top of casing, elevation 46.4 feet, 0.77 mile west of State Highway 24, 0.64 mile south of Oswald Avenue. 11/7/47, 28.4; 3/5/48, 25.2; 3/12/48, 25.3; 10/6/48, 28.2; 11/15/48, 26.8; 1/27/49, 26.1; 3/17/49, 25.4; 3/29/50, 26.6; 11/3/50, 24.2; 3/29/51, 25.1.

14N/3E-17B1—Reference point—top of "I" beam pump support, elevation 44 feet, 0.35 mile west of Carlson Road, 0.06 mile south of Oswald Road. 12/16/47, 31.9; 3/9/48, 24.2; 3/12/48, 24.7; 11/12/48, 26.9; 3/18/49, 24.0; 11/29/49, 29.0.

14N/3E-17Q1—Reference point—top of casing under pump, elevation 42.5 feet, 0.30 mile west of Carlson Road, 0.25 mile north of Best Road. 12/16/47, 22.7; 3/8/48, 23.5; 3/12/48, 23.2; 10/7/48, 26.3; 11/15/48, 24.9; 1/27/49, 23.9; 3/18/49, 23.1; 11/29/49, 29.7.

14N/3E-17R1—Reference point—top of casing, elevation 45.9 feet, West side of Carlson Road, 0.23 mile north of Best Road. 3/30/48, 24.5; 11/15/48, 27.3; 3/18/49, 25.8.

14N/3E-18D1—Reference point—top of casing, elevation 43 feet, Southeast corner of Oswald Avenue and Township Road. 11/26/29, 9.3; 10/6/30, 7.2; 12/12/31, 11.0; 11/30/32, 10.3; 12/20/33, 12.5; 11/10/34, 10.1; 11/28/36, 8.7; 11/24/37, 8.6; 1/25/39, 8.5; 1/13/41, 1.3; 11/6/47, 6.9; 12/15/48, 7.9; 12/9/49, 7.9; 11/10/50, 7.7; 12/8/51, 5.8.

14N/3E-18F1—Reference point—top of casing, elevation 40 feet, 0.41 mile south of Oswald Avenue, 0.23 mile east of Township Road. 12/15/47, 11.3; 3/8/48, 6.1; 10/8/48, 5.1; 11/12/48, 5.1; 3/2/49, 5.0; 11/29/49, 5.8; 3/27/50, 5.2; 11/2/50, 6.7; 3/28/51, 4.8; 11/16/51, 6.7; 4/2/52, 5.0.

14N/3E-18H3—Reference point—top of concrete pit, elevation 41 feet, West side George Washington Boulevard, 0.44 mile south of Oswald Avenue. 12/16/47, 19.6; 3/8/48, 18.2; 10/7/48, 20.9; 11/12/48, 20.1; 3/21/49, 18.0; 11/29/49, 20.6.

14N/3E-18R1—Reference point—top of casing, elevation 40 feet, 0.10 mile north of Best Road, 0.26 mile west of George Washington Boulevard. 12/15/47, 16.9; 3/8/48, 17.1; 11/12/48, 18.5; 3/21/49, 16.8; 11/29/49, 19.6.

14N/3E-19L1—Reference point—hole in pump base, elevation 37 feet, 0.50 mile west of George Washington Boulevard, 0.69 mile south of Best Boad. 12/5/47, 10.9; 3/8/48, 11.6; 10/8/48, 15.8; 11/12/48, 13.8; 3/18/49, 12.7; 11/29/49, 14.9; 3/27/50, 13.1; 11/2/50, 15.8; 3/28/51, 10.6; 11/16/51, 14.5; 4/2/52, 6.0.

14N/3E-19P1—Reference point—top of pipe in base, elevation 38 feet, 0.50 mile west of George Washington Boulevard, 0.83 mile north of Best Road. 12/11/47, 13.2; 3/24/48, 14.0; 11/8/48, 13.7; 3/24/49, 12.2; 12/2/49, 14.6.

14N/3E-20A2—Reference point—hole in casing, elevation 44.5 feet, 0.10 mile south of Best Road, east side of George Washington Boulevard. 12/16/47, 22.7; 3/8/48, 21.6; 11/15/48, 25.3; 3/18/49, 24.0; 11/29/49, 26.9; 3/27/50, 25.4; 11/3/50, 32.6; 3/28/51, 25.2; 11/19/51, 26.4; 4/2/52, 18.4.

14N/3E-20E1—Reference point—top of casing, elevation 40 feet, 0.27 mile south of Best Road, 0.20 mile east of George Washington Boulevard. 12/16/47, 17.9; 3/8/48, 20.0; 3/29/48, 18.0; 11/12/48, 20.1; 3/18/49, 18.3; 11/29/49, 21.7.

14N/3E-20F1—Reference point—top of casing, elevation 40 feet, 0.49 mile east of George Washington Boulevard, 0.51 mile north of Hutchinson Road. 12/16/47, 20.8; 3/8/48, 23.7; 3/12/48, 23.6; 10/7/48, 24.0; 11/15/48, 23.1; 3/18/49, 21.4; 11/29/49, 24.8; 3/27/50, 22.6; 11/2/50, 26.4; 3/28/51, 20.6; 11/19/51, 24.2; 4/2/52, 15.7.

14N/3E-20Q1—Reference point—top of concrete pit, elevation 42 feet, 0.54 mile west of George Washington Boulevard, 0.14 mile north of Hutchinson Road. 12/13/47, 20.1; 3/10/48, 21.3; 3/12/48, 21.5; 11/8/48, 24.9; 3/23/49, 20.5; 12/5/49, 24.0; 3/24/50, 21.5; 11/7/50, 26.7; 3/28/51, 21.8; 11/15/51, 22.7; 4/3/52, 14.8.

14N/3E-21M1—Reference point—top of casing, elevation 44.3 feet, 0.46 mile north of Hutchinson Road, west side of Carlson Road. 12/16/47, 21.8; 3/8/48, 23.0; 3/20/48, 23.4; 3/26/48, 22.2; 3/30/48, 21.7; 10/7/48, 24.2; 11/15/48, 24.0; 3/18/49, 23.2; 11/29/49, 25.7.

14N/3E-21Q1—Reference point—hole in pump base, elevation 42 feet, North side of Hutchinson Road, 0.48 mile west of State Highway 24. 11/15/47, 21.9; 3/8/48, 23.9; 3/12/48, 27.4; 3/26/48, 22.0; 3/29/48, 21.9; 5/12/48, 21.2; 11/9/48, 25.0; 1/18/49, 24.0; 3/23/49, 22.8; 6/1/49, 21.8; 6/28/49, 30.4; 8/3/49, 20.1; 8/25/49, 28.6; 12/6/49, 26.0.

14N/3E-22B2—Reference point—bottom of pump base, elevation 48.3 feet, North side of Messick Road, 0.50 mile west of Garden Highway. 11/7/47, 25.9; 3/5/48, 26.1; 3/12/48, 26.6; 3/29/48, 25.2; 10/6/48, 28.5; 11/15/48, 25.8; 3/17/49, 24.4; 11/30/49, 27.6; 3/29/50, 25.2; 11/3/50, 28.0; 3/29/51, 22.3; 11/20/51, 26.3.

14N/3E-22E2—Reference point—bottom of pump base, elevation 47.8 feet, South of Messick Road, 0.1 mile east of State Highway 24. 11/7/47, 26.6; 3/5/48, 26.2; 3/12/48, 27.8; 11/15/48, 25.3; 3/17/49, 23.8; 11/29/49, 27.5.

14N/3E-22H1—Reference point—top of casing, elevation 47.2 feet, 0.03 mile west of Garden Highway, 0.16 mile south of Messick Road. 3/5/48, 22.1; 10/6/48, 19.8; 11/15/48, 20.7.

14N/3E-22R1—Reference point—hole in concrete base, elevation 45.2 feet, West side Garden Highway, 0.15 mile north of Hutchinson Road. 11/15/47, 20.9; 3/8/48, 26.4; 3/29/48, 19.0; 5/12/48, 16.5; 11/10/48, 20.7; 1/24/49, 19.9; 3/23/49, 17.9; 12/6/49, 22.4.

14N/3E-23D2—Reference point—top of concrete base, elevation 48.1 feet, 0.2 mile east of Garden Highway, 0.03 mile south of Messick Road. 11/7/47, 20.6; 3/23/48, 21.1; 10/6/48, 23.3; 11/15/48, 22.2; 3/17/49, 20.9; 11/29/49, 23.0; 3/29/50, 18.8; 11/3/50, 22.9; 3/29/51, 16.3; 11/20/51, 22.3.

14N/3E-24B1—Reference point—hole in pump base, elevation 50.8 feet, 0.01 mile south of Plumas Road, 0.26 mile west of Feather River Boulevard. 11/11/47, 23.1; 3/6/48, 22.6; 5/8/48, 20.7; 10/7/48, 24.2; 11/11/48, 22.0; 3/21/49, 19.9; 6/1/49, 24.6; 7/3/49, 31.0; 7/28/49, 28.8; 8/26/49, 30.0; 12/1/49, 23.4; 3/29/50, 22.2; 11/6/50, 24.5; 3/30/51, 14.4; 11/20/51, 23.9; 4/5/52, 14.6.

14N/3E-24G1—Reference point—top of casing at pit bottom, elevation 39.4 feet, 0.10 mile north of Broadway, 0.31 mile east of Feather River Boulevard. 11/11/47, 14.2; 3/6/48, 12.1, 11/11/48, 12.0; 3/21/49, 9.4; 12/1/49, 13.4.

14N/3E-25B2—Reference point—hole in side of pump, elevation 47 feet, South of Anderson Road, 0.31 mile west of Feather River Boulevard. 11/17/47, 22.5; 3/8/48, 19.7; 5/8/48, 17.3; 11/10/48, 20.1; 1/24/49, 18.9; 3/23/49, 17.6; 12/2/49, 21.3.

14N/3E-25C1—Reference point—top of casing, elevation 49.5 feet, 0.15 mile south of Anderson Road, 0.71 mile west of Feather River Boulevard. 11/17/47, 22.3; 3/8/48, 19.8; 11/10/48, 22.0; 3/23/49, 19.8; 12/2/49, 22.7; 3/29/50, 18.6; 11/6/50, 22.6; 3/30/51, 15.9; 11/6/51, 21.5; 4/1/52, 15.4.

14N/3E-25K2—Reference point—top of casing, elevation 46.1 feet, 0.01 mile south of Country Club Road, 0.26 mile west of Feather River Boulevard. 11/17/47, 17.8; 3/8/48, 18.5; 3/23/49, 15.6; 12/2/49, 19.1.

14N/3E-26M2—Reference point—hole in base of pump, elevation 44 feet, 0.32 mile north of O'Banion Road, 0.22 mile east of Garden Highway. 11/14/47, 21.0; 3/8/48, 23.4; 5/6/48, 14.4; 6/1/48, 14.7; 7/3/48, 52.4 (operating); 11/10/48, 20.9; 3/23/49, 16.8; 12/6/49, 22.4.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

14N/3E-27D1—Reference point—top of casing, elevation 42 feet. East side of State Highway 24, 0.10 mile south of Hutchinson Road. 11/15/47, 21.7; 3/8/48, 22.0; 3/12/48, 28.4; 5/12/48, 20.8; 11/9/48, 24.2; 3/23/49, 21.8; 12/6/49, 25.4; 3/29/50, 23.2; 11/7/50, 26.1; 3/29/51, 19.9; 11/15/51, 26.4; 4/3/52, 13.5.

14N/3E-27J1—Reference point—hole in base of pump, elevation 43 feet. West side of Garden Highway, 0.36 mile north of O'Banion Road. 11/14/47, 21.4; 3/8/48, 30.7; 5/5/48, 15.0; 11/10/48, 20.6; 3/23/49, 17.1; 6/1/49, 21.5; 8/30/49, 26.6; 12/6/49, 22.1; 3/29/50, 17.6; 11/7/50, 22.3; 3/29/51, 13.8; 11/15/51, 21.1; 4/3/52, 9.0.

14N/3E-27M2—Reference point—hole in base of pump, elevation 41 feet, 0.06 mile east of State Highway 24, 0.33 mile north of O'Banion Road. 11/15/47, 22.3; 3/8/48, 24.1; 11/9/48, 23.1; 3/23/49, 20.6; 12/6/49, 24.8.

14N/3E-28G2—Reference point—top of casing, elevation 41 feet, 0.28 mile west of State Highway 24, 0.45 mile south of Hutchinson Road. 1/16/48, 21.4.

14N/3E-28M1—Reference point—top of wooden platform under pump, elevation 43.6 feet, 0.31 mile north of O'Banion Road, 0.15 mile east of Carlson Road. 12/13/47, 21.6; 3/9/48, 25.4; 3/12/48, 25.6; 11/8/48, 25.6; 3/24/49, 22.3; 12/5/49, 26.6.

14N/3E-28R1—Reference point—top of casing, elevation 40 feet, 0.16 mile west of State Highway 24, 0.16 mile north of O'Banion Road. 11/14/47, 21.3; 3/24/48, 21.9; 11/9/48, 23.8; 3/23/49, 20.4; 12/6/49, 30.3; 3/29/50, 22.5; 11/2/50, 26.7; 3/29/51, 19.5.

14N/3E-29A1—Reference point—hole in base of pump, elevation 43.5 feet, 0.16 mile west of Carlson Road, 0.24 mile south of Hutchinson Road. 12/13/47, 22.6; 3/10/48, 24.0; 3/12/48, 24.6; 11/8/48, 25.1; 3/24/49, 22.2; 12/5/49, 26.3.

14N/3E-29L1—Reference point—top of casing, elevation 41 feet, 0.48 mile east of George Washington Boulevard, 0.27 mile north of O'Banion Road. 12/13/47, 20.0; 3/9/48, 20.0; 11/8/48, 21.3; 3/24/49, 18.9; 5/31/49, 28.1; 6/30/49, 31.3; 8/1/49, 32.0; 12/5/49, 22.4.

14N/3E-29R1—Reference point—hole in pump base, elevation 43.5 feet. West side of Carlson Road, 0.19 mile north of O'Banion Road. 5/21/48, 22.1; 11/8/48, 25.6; 3/24/49, 22.5; 12/5/49, 26.4; 3/29/50, 23.5; 11/7/50, 28.0; 3/29/51, 21.6; 11/15/51, 26.9; 4/3/52, 16.0.

14N/3E-30E1—Reference point—top of casing, elevation 36 feet, 0.22 mile east of Township Road, 0.40 mile south of Hutchinson Road. 12/11/47, 12.1; 3/10/48, 8.6; 3/12/48, 8.5; 11/8/48, 8.3; 3/24/49, 6.4; 12/2/49, 9.1.

14N/3E-30H1—Reference point—top of casing, elevation 38 feet, 0.28 mile south of Hutchinson Road, 0.03 mile west of George Washington Boulevard. 12/11/47, 14.9; 3/10/48, 14.6; 3/12/48, 14.5; 11/8/48, 16.1; 3/24/49, 14.0; 12/2/49, 17.5.

14N/3E-30M1—Reference point—top of concrete pit (west wall), elevation 37 feet, 0.38 mile north of O'Banion Road, 0.03 mile east of Township Road. 12/11/47, 8.5; 3/10/48, 9.6; 3/12/48, 9.6; 11/8/48, 9.3; 3/24/49, 6.0; 12/2/49, 9.0.

14N/3E-31B1—Reference point—top of casing, elevation 38 feet, 0.06 mile south of O'Banion Road, 0.36 mile west of George Washington Boulevard. 12/11/47, 12.6; 3/10/48, 13.1; 3/12/48, 13.1; 3/29/48, 12.9; 11/8/48, 12.2; 1/24/49, 13.1; 3/24/49, 11.4; 12/2/49, 13.4; 3/29/50, 12.0; 11/7/50, 15.3; 3/29/51, 10.7; 11/15/51, 14.3; 4/3/52, 7.7.

14N/3E-31L1—Reference point—top of casing, elevation 35 feet, 0.24 mile east of Township Road, 0.66 mile south of O'Banion Road. 12/11/47, 12.3; 3/10/48, 7.9; 3/12/48, 7.9; 11/8/48, 9.5; 3/25/49, 8.7.

14N/3E-31R1—Reference point—top of casing, elevation 36 feet, 0.12 mile west of George Washington Boulevard, 0.78 mile south of O'Banion Road. 12/12/47, 15.9; 3/10/48, 16.3; 3/12/48, 16.1; 11/8/48, 14.2; 3/24/49, 13.5; 12/5/49, 16.3.

14N/3E-32D1—Reference point—hole in base of pump, elevation 40 feet, 0.11 mile south of O'Banion Road, 0.09 mile east of George Washington Boulevard. 12/2/47, 16.7; 3/10/48, 17.5; 3/12/48, 17.4; 5/12/48, 16.2; 11/8/48, 16.7; 3/24/49, 14.8; 6/30/49, 20.8; 8/25/49, 19.2; 12/5/49, 17.9.

14N/3E-33D3—Reference point—hole in base of pump, elevation 40 feet, 0.18 mile south of O'Banion Road, 0.03 mile west of Burch Road. 12/12/47, 26.1; 3/9/48, 21.2; 3/12/48, 20.8; 3/29/48, 19.7; 5/29/48, 18.2; 11/8/48, 12.7; 1/19/49, 20.6; 3/24/49, 19.0; 6/1/49, 21.7; 6/28/49, 44.2; 7/27/49, 28.4; 8/25/49, 23.6.

14N/3E-33M2—Reference point—top of 2" x 4" plank over earth pit, elevation 27.8, 0.67 mile south of O'Banion Road, 0.15 mile west of Burch Road. 12/12/47, 15.8; 3/24/48, 16.9.

14N/3E-34C1—Reference point—top of casing, elevation 39 feet, 0.21 mile east of State Highway 24, south side of O'Banion Road. 11/14/47, 20.4; 3/8/48, 24.2; 3/29/48, 21.4; 5/12/48, 19.4; 11/9/48, 23.5; 1/19/49, 21.7; 3/23/49, 20.6; 12/6/49, 25.3.

14N/3E-34L1—Reference point—hole in side of pump, elevation 40 feet, 0.43 mile east of State Highway 24, 0.51 mile south of O'Banion Road. 11/14/47, 26.9; 3/8/48, 24.5; 11/10/48, 28.4; 3/25/49, 22.7; 12/6/49, 21.7.

14N/3E-35Q1—Reference point—hole in side of pump, elevation 43 feet, 0.35 mile east of Garden Highway, 0.57 mile north of Tudor Road. 11/14/47, 21.2; 3/8/48, 17.2; 11/10/48, 17.3; 3/23/49, 11.4; 12/6/49, 18.9.

14N/3E-36C1—Reference point—top of casing, elevation 50 feet, 0.51 mile south of Country Club Road, 0.72 mile east of Feather River Boulevard. 11/17/47, 17.7; 3/9/48, 16.7; 5/8/48, 9.2; 11/10/48, 18.2; 1/24/49, 17.6; 3/23/49, 11.8; 12/2/49, 18.6; 3/29/50, 10.7; 11/6/50, 18.0; 3/30/51, 11.0; 11/16/51, 16.2; 4/1/52, 6.4.

14N/4E-2F1—Reference point—top of casing outside shed, elevation 67.8 feet, 0.1 mile west of Virginia Road, 0.3 mile south of junction of Earle and Spenceville Roads. 12/4/47, 20.8; 3/18/48, 19.6; 11/22/48, 23.4; 3/21/49, 22.3.

14N/4E-2K1—Reference point—top of casing under pump, elevation 65.9 feet, 200 feet east of Virginia Road, 0.7 mile south of Spenceville Road. 12/4/47, 17.2; 5/18/48, 16.7; 11/22/48, 21.0; 11/23/49, 26.8.

14N/4E-2R1—Reference point—top of casing under pump, elevation 68.9 feet, 250 feet north of Earle Road, 0.2 mile east of junction of Virginia Road and Spenceville Roads. 12/3/47, 21.5; 3/18/48, 21.3; 11/19/48, 25.9; 3/21/49, 24.2; 11/23/49, 32.3.

14N/4E-4A1—Reference point—hole in side of pump, elevation 65 feet, 0.9 mile north of Hale Road, 1.0 mile east of U. S. Highway 99E. 12/1/47, 29.1; 3/18/48, 27.4; 11/19/48, 31.3; 3/23/49, 29.2; 11/23/49, 35.0; 3/27/50, 32.3; 11/3/50, 36.2; 4/5/51, 30.8; 11/21/51, 37.2; 4/4/52, 32.1.

14N/4E-4C1—Reference point—vertical hole in side of pump, elevation 63 feet, 0.6 mile east of U. S. Highway 99E, 0.9 mile north of Hale Road. 11/19/48, 28.4; 3/23/49, 26.1; 11/23/49, 31.6.

14N/4E-4M1—Reference point—top of hole in pump base, elevation 60 feet, 0.2 mile west of U. S. Highway 99E, 0.7 mile north of McGowan Road. 12/1/47, 21.3; 3/17/48, 19.9; 11/19/48, 23.9; 3/21/49, 21.7; 12/7/49, 26.7; 3/27/50, 24.5; 11/3/50, 28.5; 4/5/51, 24.6; 11/21/51, 33.7; 4/2/52, 26.2.

14N/4E-5A1—Reference point—top of casing under pump, elevation 60 feet, 0.05 mile west of U. S. Highway 99E, 1.3 miles north of McGowan Road. 12/1/47, 23.2; 3/17/48, 21.4.

14N/4E-5C1—Reference point—top tin, casing under pump, elevation 58 feet, 1.3 miles north of McGowan Road, 0.5 mile west of U. S. Highway 99E. 12/1/47, 22.8; 3/15/48, 22.1.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet meosured from reference point)

14N/4E-5J1—Reference point—top of casing under pump, elevation 62 feet, 0.3 mile west of U. S. Highway 99E, 0.8 mile north of McGowan Road. 12/1/47, 20.8; 3/15/48, 19.7.

14N/4E-5L1—Reference point—top of casing, elevation 60 feet, 0.4 mile west of U. S. Highway 99E, 1.9 miles north of McGowan Road. 12/1/47, 22.1; 3/15/48, 21.5; 11/19/48, 24.1; 3/21/49, 23.0; 12/7/49, 26.5; 4/3/52, 23.8.

14N/4E-7A1—Reference point—top of casing, 2.5 feet above ground, elevation 55 feet, 0.15 mile west of Arboga Road, 0.80 mile north of Ella Road. 11/12/47, 22.3; 3/15/48, 20.9; 5/14/48, 22.0; 10/17/48, 27.2; 11/11/48, 23.0; 3/21/49, 21.0; 12/1/49, 24.6; 3/29/50, 22.7; 11/6/50, 26.2; 3/30/51, 20.7; 11/20/51, 25.4; 4/5/52, 20.6.

14N/4E-7A2—Reference point, top of casing, elevation 58 feet, 264 feet west of Arboga Road, 0.81 mile north of Ella Road. 3/5/48, 21.5; 5/14/48, 21.6; 3/21/49, 19.5; 12/1/49, 25.0; 3/29/50, 21.2; 11/6/50, 27.9.

14N/4E-7D1—Reference point—top of casing at bottom of 9-foot pit, elevation 52 feet, 500 feet east of Feather River Boulevard, 0.85 mile north of Ella Road. 11/12/47, 12.3; 3/5/48, 11.0; 10/7/48, 13.8; 11/11/48, 11.5; 3/22/49, 10.5; 12/1/49, 15.2.

14N/4E-7F1—Reference point—top of discharge flange, elevation 53 feet, 0.4 mile east of Feather River Boulevard, 0.7 mile north of Ella Avenue. 11/12/47, 16.1; 3/5/48, 19.0; 11/11/48, 19.7; 3/22/49, 17.4; 12/1/49, 20.5.

14N/4E-8C1—Reference point—top of casing, concrete box, elevation 57 feet, 0.9 mile west of U. S. Highway 99E, 0.4 mile north of McGowan Road. 12/1/47, 28.2.

14N/4E-9B1—Reference point—top of casing, elevation 62 feet, 200 feet west of U. S. Highway 99E, 0.3 mile north of McGowan Road 12/2/47, 28.6; 3/17/48, 27.3; 11/19/48, 30.6; 3/21/49, 28.5; 11/23/49, 33.9.

14N/4E-9F1—Reference point—hole in pump base, elevation 60 feet, 50 feet north of McGowan Road, 0.7 mile west of U. S. Highway 99E. 11/19/48, 28.2; 1/25/49, 27.0; 3/18/49, 25.5; 11/23/49, 31.5; 3/28/50, 28.2; 11/3/50, 33.3; 4/5/51, 28.1.

14N/4E-9L1—Reference point—top of casing under pump, elevation 61 feet, 0.3 mile south of McGowan Road, 0.8 mile west of U. S. Highway 99E. 12/2/47, 23.7; 3/17/48, 21.4.

14N/4E-9Q1—Reference point—top of casing, elevation 52 feet, 0.7 mile west of U. S. Highway 99E, 0.3 mile south of McGowan Road. 12/2/47, 20.9; 3/17/48, 10.4; 11/19/48, 13.5; 3/18/49, 10.0; 11/23/49, 16.9; 4/2/52, 9.5.

14N/4E-10H2—Reference point—top of concrete pit, north edge, elevation 63 feet, 1.1 miles east of U. S. Highway 99E, 0.6 mile north of Ostrom Road. 12/3/47, 23.9; 3/18/48, 23.5; 11/19/48, 27.6; 3/21/49, 25.1; 11/23/49, 32.5; 3/22/50, 28.2; 11/3/50, 33.8; 4/5/51, 28.4; 11/23/51, 24.2; 4/4/52, 17.2.

14N/4E-10L1—Reference point—top of casing under pump, elevation 60 feet, 0.1 mile east of U. S. Highway 99E, 0.4 mile north of Slaughter House Road. 12/3/47, 16.9; 3/17/48, 15.4.

14N/4E-10M1—Reference point—top of casing 2 feet above ground line, elevation 58 feet, 0.2 mile west of U. S. Highway 99E, 0.4 mile north of Slaughter House Road. 11/19/48, 16.4.

14N/4E-10R1—Reference point—top of casing under pump, elevation 62 feet, 50 feet north of Ostrom Road, 0.5 mile east of U. S. Highway 99E. 12/3/47, 23.7; 3/18/48, 22.3; 11/19/48, 27.7; 11/23/49, 31.3.

14N/4E-11C1—Reference point—top of casing, elevation 68.6 feet, 2.0 miles east of U. S. Highway 99E, 0.7 mile south of Virginia Road. 11/18/48, 24.7.

14N/4E-11C2—Reference point—top of casing, elevation 68 feet, 1.9 miles east of U. S. Highway 99E, 0.7 mile south of Virginia Road. 11/18/48, 26.1; 3/21/49, 24.2; 11/23/49, 31.6.

14N/4E-11H1—Reference point—top of casing, elevation 72 feet, 1.0 mile west of Bradshaw Road, 0.6 mile north of Ostrom Road. 11/18/48, 29.4; 3/21/49, 27.7; 11/24/49, 35.9; 3/27/50, 33.2; 11/2/50, 38.6; 4/5/51, 34.6; 11/23/51, 40.6; 4/4/52, 37.2.

14N/4E-11J1—Reference point—top of casing, elevation 69.8 feet, 0.4 mile north of Ostrom Road, 1.1 miles west of Bradshaw Road. 11/18/48, 30.1; 3/21/49, 28.3; 11/23/49, 36.4.

14N/4E-11Q1—Reference point—top of casing, elevation 71 feet, 50 feet north of Ostrom Road, 1.5 miles west of Bradshaw Road. 11/18/48, 30.0; 11/23/49, 34.8.

14N/4E-12A1—Reference point—hole in pump base, elevation 75 feet, 100 feet west of Bradshaw Road, 1.0 mile north of Ostrom Road. 11/18/48, 31.4; 1/18/48, 28.8; 3/29/49, 28.1; 11/23/49, 36.6; 3/30/50, 33.6; 11/2/50, 40.5; 4/5/51, 43.2; 4/4/52, 37.1.

14N/4E-12B1—Reference point—hole in pump base, elevation 72 feet, 0.4 mile west of Bradshaw Road, 1.0 mile north of Ostrom Road. 11/18/48, 29.0; 4/5/51, 34.7.

14N/4E-12E1—Reference point—top of casing, elevation 70 feet, 0.7 mile north of Ostrom Road, 100 feet east of Virginia Road. 10/7/48, 29.55; 11/18/48, 28.9; 1/18/49, 28.0; 3/21/49, 27.15; 11/23/49, 35.4.

14N/4E-12R1—Reference point—top of casing, elevation 78 feet, 100 feet northwest of the intersection of Bradshaw and Ostrom Roads. 10/7/48, 35.0; 11/18/48, 33.0; 3/18/49, 30.8; 11/23/49, 39.8; 3/22/50, 36.7; 11/2/50, 44.2; 4/5/51, 39.0; 11/23/51, 47.4; 4/3/52, 40.8.

14N/4E-13A1—Reference point—top of casing, elevation 79.4 feet, 50 feet west of Bradshaw Road, 0.2 mile south of Ostrom Road. 3/24/48, 29.8; 10/7/48, 37.4; 11/18/48, 35.1; 1/18/48, 33.8; 3/18/49, 32.8; 11/23/49, 41.8; 3/27/50, 38.4.

14N/4E-13B1—Reference point—top of casing, elevation 75.5 feet, 0.3 mile west of Bradshaw Road, 100 feet south of Ostrom Road. 11/18/46, 31.6.

14N/4E-13C1—Reference point—top of casing, elevation 73.5 feet, 100 feet south of Ostrom Road, 0.6 mile west of Bradshaw Road. 10/7/48, 30.6; 11/18/48, 29.0; 1/18/49, 28.0; 3/18/49, 27.0; 11/23/49, 34.9; 3/27/50, 32.0; 11/2/50, 38.4; 4/5/51, 33.4; 11/23/51, 39.8; 4/3/52, 35.1.

14N/4E-13Q1—Reference point—top of casing under pump, elevation 71 feet, 0.9 mile south of Ostrom Road, 0.5 mile east of Virginia Road. 12/3/47, 30.4; 3/18/48, 29.1; 10/7/48, 34.7; 11/18/48, 33.6; 3/18/49, 31.6; 11/23/49, 39.0; 3/27/50, 36.7; 11/3/50, 41.8; 4/5/51, 37.9.

14N/4E-13R1—Reference point—top of casing, elevation 80 feet, 50 feet west of Bradshaw Road, 1 mile south of Ostrom Road. 11/18/48, 39.1; 3/18/49, 36.5; 11/24/49, 57.7.

14N/4E-14C1—Reference point—top of casing, elevation 70 feet, 20 feet south of Ostrom Road, 0.8 mile east of U. S. Highway 99E. 10/7/48, 30.7; 11/18/48, 29.0; 1/18/49, 28.0; 3/18/49, 29.1; 11/24/49, 33.9; 3/27/50, 31.5; 11/2/50, 36.2; 4/5/51, 31.6; 11/23/51, 38.4; 4/4/52, 33.6.

14N/4E-14J1—Reference point—top of casing, elevation 62 feet, 200 feet west of Virginia Road, 0.5 mile south of Ostrom Road. 12/3/47, 23.8; 3/18/48, 22.6; 10/7/48, 27.5; 11/18/48, 27.0; 3/18/49, 25.4.

14N/4E-14R1—Reference point—top of casing, elevation 70 feet, 260 feet west of Virginia Road, 0.4 mile north of U. S. Highway 99E. 3/18/49, 30.4.

14N/4E-15C1—Reference point—hole in pump base, elevation 64.6 feet, 200 feet south of Slaughter House Road, 0.4 mile west of U. S. Highway 99E. 12/2/47, 23.9; 3/17/48, 22.6; 10/7/48, 30.5; 11/19/48, 25.9; 3/18/49, 23.3; 11/23/49, 29.6; 3/28/50, 26.5; 11/3/50, 31.0; 4/5/51, 26.0; 11/21/51, 33.1; 4/2/52, 28.9.

14N/4E-15C2—Reference point—top of casing under pump, elevation 65 feet, 500 feet south of Slaughter House Road, 0.3 mile west of U. S. Highway 99E. 12/2/47, 23.1; 3/17/48, 20.8.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

14N 4E-15C3—Reference point—top of casing, 1 foot below ground, elevation 62.7 feet, 250 feet north of Slaughter House Road, 0.2 mile west of U. S. Highway 99E. 11/22/29, 16.4; 9/18/30, 15.9; 12/11/31, 16.4; 12/10/32, 15.7; 12/21/33, 11.0; 11/23/34, 10.7; 11/22/37, 15.8; 11/27/39, 12.1; 12/21/40, 15.3; 11/7/47, 23.2; 12/16/48, 24.3; 12/7/49, 28.2; 11/10/50, 29.7; 12/5/51, 31.3.

14N 4E-15C4—Reference point—top of 1-inch pipe to jet, elevation 65.2 feet, 0.1 mile north of Slaughter House Road, 0.3 mile west of U. S. Highway 99E. 11/19/48, 26.6; 3/18/49, 24.1; 11/23/49, 30.3.

14N 4E-15D1—Reference point—top of casing, elevation 55.9 feet, 200 feet southwest of Slaughter House Road, 0.7 mile due west of U. S. Highway 99E. 12/2/47, 15.8; 3/17/48, 14.1; 11/19/48, 17.5.

14N 4E-15L1—Reference point—top of casing under pump, elevation 66 feet, 0.8 mile west of U. S. Highway 99E, 0.4 mile south of Slaughter House Road. 12/2/47, 25.6; 3/17/48, 24.4; 10/7/48, 29.5; 11/19/48, 27.6; 1/25/49, 26.6; 3/18/49, 25.2; 5/25/49, 33.1; 6/29/49, 34.5; 7/29/49, 35.5; 11/23/49, 31.4; 3/28/50, 28.4; 11/3/50, 32.8; 4/5/51, 28.2; 11/21/51, 37.0; 4/2/52, 29.0.

14N 4E-16M1—Reference point—top of casing, elevation 55 feet, 1.3 miles south of McGowan Road, 0.4 mile east of Western Pacific Railroad tracks. 12/3/47, 22.5; 3/18/48, 20.3; 11/19/48, 20.9; 3/13/49, 18.4.

14N 4E-17C1—Reference point—top of casing under pump, elevation 55 feet, 0.5 mile south of McGowan Road, 100 feet west of Western Pacific Railroad. 12/2/47, 23.9; 3/18/48, 20.6; 11/19/48, 23.6; 3/18/49, 21.1; 11/22/49, 25.3; 3/28/50, 22.8; 11/3/50, 26.7; 4/5/51, 20.8.

14N 4E-17D1—Reference point—hole in side of casing, elevation 54 feet, 0.5 mile south of McGowan Road, 0.3 mile west of Western Pacific Railroad. 3/18/49, 21.0; 3/28/50, 22.5.

14N 4E-17D2—Reference point—top of casing under pump, elevation 54 feet, 0.5 mile south of McGowan Road, 0.3 mile west of Western Pacific Railroad. 12/1/47, 22.3.

14N 4E-17P1—Reference point—top of casing under pump, elevation 58.7 feet, 500 feet west of Western Pacific Railroad, 1.4 miles south of McGowan Road. 12/3/47, 23.2; 3/18/48, 21.8; 5/14/48, 23.2; 11/19/48, 24.4; 3/18/49, 21.9; 11/23/49, 25.8; 3/28/50, 23.0; 11/31/50, 26.6; 4/5/51, 20.9; 4/3/52, 23.2.

14N 4E-18C1—Reference point—hole in top of casing, elevation 53.1 feet, 200 feet south of Ella Road, 0.4 mile east of Feather River Boulevard. 11/11/47, 20.9; 3/5/48, 19.7; 10/7/48, 27.5; 11/11/48, 19.5; 1/27/49, 18.7; 3/21/49, 17.8; 12/1/49, 20.4; 3/28/50, 19.1; 11/6/50, 23.5; 3/30/51, 15.1; 11/20/51, 23.3; 4/5/52, 15.7.

14N 4E-18H1—Reference point—bottom of pump, elevation 54.1 feet, 400 feet west of Arboga Road, 0.5 mile south of Ella Road. 11/11/47, 21.2; 3/5/48, 19.8; 10/7/48, 24.9; 11/11/48, 21.0; 3/21/49, 19.6; 12/1/49, 21.6.

14N 4E-18J1—Reference point—top of suction flange, elevation 45.6 feet, 400 feet west of Arboga Road, 0.6 mile south of Ella Road. 11/11/47, 17.6; 3/5/48, 14.2; 11/11/48, 16.3; 3/21/49, 14.8; 12/1/49, 22.0.

14N 4E-19E1—Reference point—top of casing, 4 feet below ground in pit, elevation 52 feet, 0.2 mile east of Feather River Boulevard, 0.1 mile north of Broadway. 11/8/29, 8.0; 9/26/30, 8.7; 12/11/31, 8.6; 12/31/32, 8.6; 12/21/33, 8.9; 11/20/34, 9.1; 11/27/36, 9.1; 11/21/37, 11.1; 1/30/39, 6.6; 12/21/40, 8.1.

14N 4E-19L1—Reference point—top of casing, 0.6 foot above ground, elevation 18 feet, 0.1 mile east of Feather River Boulevard, 0.1 mile south of Broadway. 11/7/47, 20.6; 12/16/48, 20.7; 12/9/49, 21.8; 11/10/50, 23.6; 12/5/51, 21.2.

14N 4E-19P1—Reference point—top of casing, top of concrete floor, elevation 50.1 feet, 0.3 mile south of Broadway, 0.5 mile east of Feather River Boulevard. 11/17/47, 33.6; 3/9/48, 18.4; 11/10/48, 19.7; 3/23/49, 17.5; 12/2/49, 21.4; 3/29/50, 18.9; 11/6/50, 22.3; 3/30/51, 18.7; 11/16/51, 22.1; 4/1/52, 9.5.

14N 4E-20D1—Reference point—top of casing under pump, elevation 53 feet, 200 feet north of Broadway, 0.6 mile west of Arboga Road. 12/3/47, 24.9; 3/18/48, 23.3.

14N 4E-20E1—Reference point—pump base hole, elevation 54.3 feet, 150 feet north of Broadway, 1.0 mile east of Feather River Boulevard. 11/11/48, 20.9; 3/21/49, 18.2.

14N 4E-20M1—Reference point—bottom of pump mount, blocked up from concrete, elevation 52.2 feet, 50 feet south of Broadway, 0.95 mile east of Feather River Boulevard. 11/11/47, 22.4; 3/6/48, 20.0; 10/7/48, 22.8; 11/11/48, 21.5; 1/24/29, 20.6; 3/21/49, 19.7; 12/1/49, 23.0; 3/29/50, 20.9; 11/6/50, 23.1; 11/20/51, 23.3; 4/5/52, 17.4.

14N 4E-20M2—Reference point—hole in side of pump, elevation 52.8 feet, 400 feet south of Broadway, 1.0 mile east of Feather River Boulevard. 11/11/47, 18.7; 3/6/48, 20.0; 10/7/48, 21.7; 11/11/48, 19.5; 3/2/49, 16.9; 12/1/49, 21.2; 3/29/50, 18.5; 11/6/50, 22.1; 3/30/51, 18.0; 11/20/51, 21.7; 4/5/52, 16.1.

14N 4E-22F1—Reference point—hole in top of pump base, elevation 60 feet, 100 feet west of Forty Mile Road, 1.35 miles south of Slaughter House Road. 12/1/47, 22.6; 3/1/48, 21.3; 3/31/48, 20.8; 10/7/48, 25.6; 11/8/48, 24.0; 1/25/49, 23.0; 3/18/49, 21.5; 11/23/49, 27.7.

14N 4E-22F2—Reference point—hole in base of pump, elevation 58.4 feet, 200 feet west of Forty Mile Road, 1.2 miles south of Slaughter House Road. 12/2/47, 18.7; 3/17/48, 17.4.

14N 4E-22F3—Reference point—access pipe in concrete base, elevation 61.9 feet, 150 feet west of Forty Mile Road, 1.3 miles south of Slaughter House Road. 12/2/47, 23.6; 3/17/48, 22.2; 11/19/48, 24.9; 3/18/49, 21.9; 11/23/49, 27.0; 3/28/50, 25.6; 11/2/50, 30.1; 4/5/51, 28.9; 11/21/51, 32.4; 4/2/52, 25.5.

14N 4E-22M1—Reference point—top of casing, elevation 61.8 feet, 0.4 mile west of Forty Mile Road, 1.25 miles north of Plumas School. 12/1/47, 21.7; 3/1/48, 20.5; 10/7/48, 25.1; 11/8/48, 23.5; 3/25/49, 20.5; 11/23/49, 26.4; 3/28/50, 23.1; 11/3/50, 28.1; 12/3/51, 28.1; 4/1/52, 23.9.

14N 4E-22P1—Reference point—top of concrete curb around open pit well, elevation 64.9 feet, 50 feet west of Forty Mile Road, 1.2 miles north of Plumas School. 11/21/47, 26.9.

14N 4E-23A1—Reference point—top of casing, elevation 60 feet, 300 feet southwest of U. S. Highway 99E, 1.5 miles southeast of Slaughter House Road. 12/3/47, 31.7; 3/18/48, 30.2; 11/18/48, 33.8; 3/18/49, 32.2; 11/23/49, 38.2; 3/29/50, 36.5; 11/3/50, 40.4; 11/21/51, 43.4; 4/2/52, 41.0.

14N 4E-23B1—Reference point—top of casing, elevation 70 feet, 0.07 mile southwest of U. S. Highway 99E, 0.38 mile northwest of Virginia Road. 12/3/47, 30.7; 3/18/48, 29.5.

14N 4E-23G1—Reference point—top of pump base, elevation 70 feet, 0.70 mile west of U. S. Highway 99E, at a point 2.02 miles southeast of Slaughter House Road. 12/1/47, 30.9; 10/7/48, 33.2; 11/8/48, 32.9; 3/29/49, 30.9; 11/25/49, 37.2.

14N 4E-23Q1—Reference point—top of casing, elevation 72 feet, 1.98 miles south of Slaughter House Road, 1.05 miles east of Forty Mile Road. 11/21/47, 32.6; 3/3/48, 29.2.

14N 4E-23R1—Reference point—top of casing, elevation 67 feet, 1.98 miles south of Slaughter House Road, 1.48 miles east of Forty Mile Road. 11/21/47, 30.5; 3/31/47, 29.7; 11/11/48, 33.0; 3/29/49, 30.6; 11/25/49, 36.1.

14N 4E-24B1—Reference point—top of pump base, elevation 75 feet, 0.80 mile east of Virginia Road, 1 mile south of Ostrom Road. 3/18/49, 28.3.

14N 4E-24H1—Reference point—top of pump base, elevation 85 feet, 1.3 miles south of Ostrom Road, 0.14 mile west of Bradshaw Road. 11/18/48, 36.9; 3/18/49, 34.0; 11/23/49, 42.9; 3/27/50, 39.8; 11/2/50, 45.8; 4/5/51, 41.3; 11/30/51, 51.7; 4/3/52, 43.7.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

14N/4E-24M1—Reference point—top of casing, elevation 70 feet, 0.05 mile southwest of U. S. Highway 99E, 0.38 mile southeast of Virginia Road. 11/21/47, 22.5; 3/2/48, 28.7; 11/11/48, 31.1; 3/23/49, 28.3; 11/25/49, 34.5.

14N/4E-24P1—Reference point—top of pump base, elevation 70 feet. West side of U. S. Highway 99E, 0.68 mile southeast of Virginia Road. 11/21/47, 32.7; 3/2/48, 30.5; 11/9/48, 33.7; 1/25/49, 31.9; 3/23/49, 30.5; 5/25/49, 40.3; 7/1/49, 44.8; 11/25/49, 38.5; 3/28/50, 35.1; 11/3/50, 40.6; 4/4/51, 35.8; 12/6/51, 39.6; 4/2/52, 41.9.

14N/4E-25R1—Reference point—top of casing, elevation 74 feet, 0.53 mile northwest of Dairy Road, 0.67 mile southwest of U. S. Highway 99E. 12/2/47, 29.4; 3/2/48, 27.6; 10/7/48, 32.8; 11/11/48, 31.2; 3/29/49, 28.0; 11/23/49, 34.7.

14N/4E-26A1—Reference point—hole in base of pump, elevation 65 feet, 1.03 miles southeast of Virginia Road, 0.98 mile west of U. S. Highway 99E. 11/11/48, 33.2; 3/29/49, 30.2.

14N/4E-26C1—Reference point—top of casing, elevation 66 feet, 1.45 mile north of Levee Road, 0.95 mile east of Forty Mile Road. 12/1/47, 18.2; 3/3/48, 16.7; 11/11/48, 19.7; 3/29/49, 17.5; 11/25/49, 22.4; 3/29/50, 20.9; 11/8/50, 24.8; 4/4/51, 20.8; 5/5/51, 23.5; 4/2/52, 23.0.

14N/4E-27D1—Reference point—top of casing, elevation 60 feet, 1.20 miles north of Levee Road, 0.40 mile west of Forty Mile Road. 11/21/47, 24.8.

14N/4E-27L1—Reference point—pipe in base, elevation 64.1 feet, 2.60 miles south of Slaughter House Road, west side of Forty Mile Road. 12/1/47, 24.8; 3/1/48, 23.4; 3/29/48, 23.5; 10/7/48, 30.0; 11/8/48, 28.1; 1/25/49, 26.7; 3/25/49, 25.6; 11/23/49, 29.6; 3/28/50, 28.0; 11/3/50, 32.5; 11/30/51, 23.0; 4/1/52, 28.5.

14N/4E-27R1—Reference point—top of casing, elevation 60 feet, 2.85 miles south of Slaughter House Road, 0.52 mile east of Forty Mile Road. 12/2/47, 30.3; 3/1/48, 28.7; 11/8/48, 31.7; 3/25/49, 28.8; 11/23/49, 33.6.

14N/4E-28N1—Reference point—top of casing, elevation 49 feet, 2.05 miles south of Slaughter House Road, 1.50 miles west of Forty Mile Road. 11/8/29, 10.5; 9/26/30, 10.4; 12/11/31, 11.0; 12/5/32, 11.1; 12/21/33, 11.2; 11/20/34, 11.5; 11/27/36, 11.9; 11/24/37, 12.0; 11/30/39, 9.2; 12/21/40, 10.9; 11/7/47, 13.1; 12/16/48, 13.8; 12/9/49, 15.9; 11/10/50, 15.0; 12/5/51, 15.9.

14N/4E-28R1—Reference point—pipe in base of pump, elevation 60.2 feet, 0.55 mile north of Levee Road, 0.68 mile west of Forty Mile Road. 12/2/47, 25.2; 3/1/48, 24.1; 11/8/48, 25.6; 3/25/49, 23.6; 11/23/49, 27.4; 3/28/50, 25.6; 11/3/50, 29.1; 4/4/51, 21.7; 11/30/51, 34.1; 4/1/52, 24.6.

14N/4E-30E1—Reference point—hole in base of pump, elevation 48.6 feet, 0.11 mile east of Feather River Boulevard, 0.25 mile south of Anderson Road. 11/17/47, 23.5; 3/9/48, 19.3; 11/10/48, 20.3; 3/23/49, 18.1; 12/2/49, 21.8.

14N/4E-30F1—Reference point—top of casing, elevation 45 feet, 0.15 mile north of Country Club Road, 0.46 mile east of Feather River Boulevard. 11/17/47, 16.9; 3/9/48, 16.9; 11/10/48, 17.9.

14N/4E-30K1—Reference point—top of casing, elevation 45.0 feet, South side of Country Club Boulevard, 0.51 mile east of Feather River Boulevard. 11/17/47, 14.5; 3/8/48, 14.5; 5/8/48, 12.0; 11/10/48, 15.4; 1/29/49, 14.4; 3/23/49, 12.1; 6/1/49, 22.6; 6/29/49, 24.0; 7/28/49, 25.7; 8/26/49, 30.1; 3/29/50, 13.5; 11/6/50, 17.2; 3/30/51, 12.2; 11/16/51, 16.8; 4/1/52, 12.2.

14N/4E-31E1—Reference point—top of casing, elevation 38.5 feet, 0.06 mile east of Feather River Boulevard, 0.80 mile south of Country Club Road. 11/10/48, 11.9; 3/22/49, 8.9; 12/2/49, 11.8.

14N/4E-32L1—Reference point—top of casing, elevation 45 feet, 1.0 mile south of Country Club Avenue, 1.24 miles east of Feather River Boulevard. 11/17/47, 18.0; 3/9/48, 18.2; 11/10/48, 17.3; 3/29/49, 15.4; 12/2/49, 19.3.

14N/4E-33K1—Reference point—top of casing, elevation 51 feet, 1.50 mile west of Forty Mile Road, 0.55 mile north of Levee Road. 12/1/47, 19.7; 11/8/48, 20.6; 3/25/49, 18.0.

14N/4E-33M1—Reference point—top of casing, elevation 51 feet, 3.73 miles south of Slaughter House Road, 0.21 mile east of Western Pacific Railroad. 11/17/47, 14.3; 3/9/48, 13.1; 5/5/48, 9.1; 5/31/48, 9.1; 11/10/48, 13.9; 1/24/49, 13.8; 3/22/49, 10.8; 6/1/49, 10.8; 6/29/49, 12.8; 7/28/49, 14.2; 8/26/49, 15.8; 12/2/49, 15.3; 3/29/50, 9.7; 11/6/50, 14.7; 11/16/51, 13.7; 4/1/52, 5.5.

14N/4E-34C1—Reference point—top of concrete pit, elevation 63.4 feet, 3.05 miles south of Slaughter House Road, 0.05 mile west of Forty Mile Road. 12/1/47, 27.8; 3/1/48, 26.5; 5/5/48, 25.1; 6/3/48, 26.8; 6/24/48, 32.2 (operating); 7/8/48, 29.2 (operating).

14N/4E-35N1—Reference point—slot in base, elevation 62 feet. West side of Forty Mile Road, 0.60 mile northwest of Dairy Road. 11/28/47, 25.7; 3/1/48, 24.4; 3/21/48, 24.2; 3/29/48, 23.8; 5/5/48, 22.5; 5/13/48, 61.5 (operating); 11/8/48, 27.5; 1/26/49, 25.6; 3/25/49, 24.0; 11/23/49, 30.3; 3/28/50, 27.3; 11/6/50, 32.1; 4/4/51, 26.3; 11/30/51, 33.1; 4/1/52, 27.4.

14N/4E-36G1—Reference point—top of casing, elevation 70 feet, 0.20 mile northwest of U. S. Highway 99E. 12/2/47, 30.5; 3/2/48, 28.5; 3/29/48, 28.0; 10/7/48, 33.6; 11/11/48, 32.4; 1/25/49, 31.8; 3/25/49, 29.0; 11/23/49, 36.7; 3/28/50, 32.6; 11/8/50, 37.6; 4/4/51, 30.8; 12/3/51, 41.0.

14N/5E-5A1—Reference point—top of casing, elevation 90.2 feet, 400 feet south of Spenceville Road, 1.0 mile west of South Beale Road. 12/5/49, 39.1; 11/2/50, 46.9; 4/5/51, 41.9; 4/4/52, 41.5.

14N/5E-6B1—Reference point—top of 12-inch casing, elevation 78.5 feet, 150 feet south of Spenceville Road, 2.25 miles west of South Beale Road. 11/28/48, 26.0; 1/18/49, 25.2; 3/21/49, 24.9; 11/24/49, 32.4; 3/27/40, 30.3; 11/2/50, 37.6; 4/5/51, 32.8; 11/30/51, 37.6; 4/4/52, 34.6.

14N/5E-6D1—Reference point—top of 8-inch casing, elevation 76.4 feet, 600 feet south of Spenceville Road, 1.75 miles east of Virginia Road. 12/24/47, 22.4; 3/24/48, 22.3; 3/21/49, 23.7; 11/24/49, 33.7.

14N/5E-6D2—Reference point—top of 6-inch casing, elevation 73.6 feet, 800 feet south of Spenceville Road, 1.75 miles east of Virginia Road. 11/18/48, 23.9.

14N/5E-8A1—Reference point—top of 16-inch casing, elevation 90 feet, 0.40 mile northwest of South Beale Road at a point 0.70 mile northeast of Ostrom Road. 11/18/48, 24.7.

14N/5E-8D1—Reference point—top of casing, elevation 82 feet, 1.0 mile north of Ostrom Road, 1.0 mile east of Bradshaw Road. 3/18/49, 31.2.

14N/5E-8R1—Reference point—top of 14-inch casing, elevation 89.6 feet, 0.15 mile northeast of intersection of Ostrom Road and South Beale Road. 11/18/48, 30.5; 3/18/49, 30.1; 11/23/49, 39.7; 4/5/52, 39.2.

14N/5E-15D1—Reference point—top of casing, elevation 111 feet, 500 feet east of Ostrom Road, 0.25 mile south of Ostrom Road. 12/9/49, 42.3; 11/2/50, 46.4; 12/8/51, 47.3.

14N/5E-16C1—Reference point—top of brick casing, elevation 99 feet, 100 feet south of Ostrom Road, 100 feet west of Jasper Lane. 11/22/29, 26.3; 9/8/30, 25.5; 12/11/31, 27.5; 12/10/32, 26.7; 12/21/33, 27.6; 11/20/34, 27.8; 11/23/36, 26.4; 11/22/37, 25.6; 1/27/39, 25.5; 1/13/41, 30.0; 11/7/47, 30.0; 12/23/47, 29.7; 3/24/48, 30.0; 10/7/48, 31.2; 11/18/48, 31.2; 12/16/48, 31.9; 1/18/49, 31.7; 3/18/49, 31.2.

14N/5E-16C2—Reference point—top of casing, elevation 100 feet, 40 feet west of Jasper Lane, 40 feet south of Ostrom Road. 12/5/51, 41.9.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

14N 5E-17B1—Reference point—top of 12-inch casing, elevation 85.7 feet, 100 feet south of Ostrom Road, 0.30 mile west of South Beale Road. 12/23/47, 28.0; 3/24/48, 24.7; 10/7/48, 31.3; 11/18/48, 30.7; 3/18/49, 29.8; 11/23/49, 40.7; 4/3/52, 40.1.

14N 5E-17B2—Reference point—top of 16-inch casing, elevation 90.4 feet, Northwest side of South Beale Road, 1,000 feet southwest of Ostrom Road intersection. 11/19/48, 34.6; 3/18/49, 33.4; 11/23/49, 42.6.

14N 5E-17D1—Reference point—top of 12 inch casing, elevation 86.8 feet, 600 feet south of Ostrom Road, 0.80 mile west of South Beale Road. 11/18/48, 37.1; 1/18/49, 36.0; 3/18/49, 35.2; 11/23/49, 48.3.

14N 5E-18A1—Reference point—top of casing, elevation 87.0 feet, 750 feet south of Ostrom Road, 0.80 mile west of South Beale Road. 12/23/47, 33.7; 3/24/48, 32.9; 10/7/48, 39.0; 11/18/48, 37.5; 1/18/49, 36.4; 3/18/49, 35.6; 11/23/49, 45.1; 3/27/50, 41.8; 11/2/50, 50.1; 4/5/51, 44.4; 11/23/51, 50.5; 1/3/52, 45.8.

14N 5E-18B1—Reference point—top of 12-inch casing, elevation 78.1 feet, South side of Ostrom Road, 0.35 mile east of Bradshaw Road. 12/23/47, 25.7; 3/2/48, 28.5; 10/7/48, 33.5; 11/18/48, 31.7; 3/18/49, 28.0; 5/25/49, 36.6; 6/29/49, 40.4; 8/1/49, 42.7; 8/30/49, 51.2; 11/23/49, 39.7.

14N 5E-21R1—Reference point—top of casing, elevation 93 feet, 200 feet northeast of Jasper Lane at a point 1.9 miles south of Ostrom Road. 11/25/47, 21.5.

14N 5E-26P1—Reference point—top of concrete crib, elevation 119.7 feet, 0.25 mile southeast of Wheatland-Spenceville Road at a point 0.85 mile northeast of Jasper Lane. 11/25/47, 28.5; 3/6/48, 28.2; 11/9/48, 28.8; 3/23/49, 27.5; 12/9/49, 31.0; 3/29/50, 29.9; 11/8/50, 33.7; 4/5/51, 29.9.

14N 5E-27K1—Reference point—top of concrete crib, elevation 84.7 feet, 0.25 mile northeast of Jasper Lane at a point 0.85 mile northwest of Wheatland-Spenceville Road. 11/25/47, 12.0; 3/6/48, 11.8; 11/9/48, 13.2; 3/23/49, 11.3; 6/29/49, 12.7; 7/28/49, 13.3; 8/30/49, 13.9; 11/28/49, 16.8.

14N 5E-27L1—Reference point—top of 14 inch casing at bottom of pit, elevation 81.2 feet, 900 feet northeast of Jasper Lane at a point 1.1 miles northwest of Wheatland-Spenceville Road. 27L2 replaces 27L1 after 4/4/51. 11/25/47, 6.7; 3/6/48, 6.3; 11/9/48, 7.9; 3/23/49, 6.0; 11/28/49, 9.1; 3/29/50, 7.1; 11/8/50, 12.2; 4/4/51, 5.4.

14N 5E-27L2—Reference point—top of casing, elevation 92 feet, 900 feet northeast of Jasper Lane at a point 1.1 miles northwest of Wheatland-Spenceville Road. 11/21/51, 32.2; 4/2/52, 27.5.

14N 5E-28M1—Reference point—top of casing pit, elevation 86.5 feet, 1.0 mile southwest of Jasper Lane at a point 1.15 miles northwest of Wheatland-Spenceville Road. 11/26/47, 25.7; 3/6/48, 24.6; 11/9/48, 26.9; 3/29/49, 24.5; 11/28/49, 30.4; 3/29/50, 27.7; 11/28/49, 30.4; 3/29/50, 27.7; 11/8/50, 34.0; 1/1/51, 29.0; 11/21/51, 31.2; 4/2/52, 28.2.

14N 5E-30J1—Reference point—top of 11-inch casing, elevation 81.8 feet, 0.30 mile northeast of U. S. Highway 99E at a point 1.8 miles northwest of Wheatland Road. 11/25/47, 38.8; 11/9/48, 32.8; 3/29/49, 29.1; 12/8/49, 36.0.

14N 5E-30Q1—Reference point—top of 16-inch casing, elevation 76.6 feet, 100 feet southwest of Oakley Lane, 0.10 miles northwest of Dairy Road. 11/24/47, 30.4; 3/5/48, 28.6; 3/29/48, 27.9; 5/8/48, 27.0; 11/11/48, 32.5; 1/25/49, 31.0; 3/23/49, 29.5; 11/23/49, 35.9; 3/28/50, 35.7; 11/8/50; 39.5; 4/4/51, 34.5; 12/6/51, 39.0; 1/2/52, 36.1.

14N 5E-31B1—Reference point—hole in casing, elevation 76.8 feet, 150 feet northwest of Dairy Road, 500 feet southwest of Oakley Lane. 11/22/47, 28.1; 3/5/48, 27.1; 11/11/48, 30.2; 3/25/49, 26.8; 11/25/49, 33.6.

14N 5E-31J1—Reference point—top of 8-inch casing at bottom of pit, elevation 59.8 feet, 100 feet southwest of Oakley Lane, 0.45 mile southeast of Dairy Road. 11/22/47, 11.2; 3/5/48, 9.5; 11/11/48, 13.1; 3/25/49, 9.3; 11/28/49, 16.1.

14N 5E-32F1—Reference point—top of 14-inch casing, elevation 71.0 feet, Southwest of U. S. Highway 99E, 0.35 mile southeast of Dairy Road. 11/22/47, 17.1; 3/5/48, 16.6; 3/29/48, 15.6; 11/11/48, 19.4; 1/26/49, 18.0; 3/24/49, 16.0; 11/23/49, 22.5.

14N 5E-32M1—Reference point—top of 12-inch casing, elevation 67.2 feet, 0.25 mile northeast of Oakley Lane, 0.60 mile southeast of Dairy Road. 11/22/47, 14.7; 3/5/48, 13.6; 11/11/48, 16.2; 3/23/49, 12.5; 11/28/49, 19.7.

14N 5E-32N1—Reference point—top of casing at bottom of pit, elevation 63.2 feet, Southwest side of Oakley Lane, 0.70 miles southeast of Dairy Road. 11/20/47, 11.7; 3/5/48, 10.7; 11/11/48, 13.3; 3/25/49, 9.3; 11/23/49, 17.2; 3/29/50, 12.7; 11/8/50, 18.5; 4/4/51, 9.9; 12/3/51, 17.6; 4/2/52, 8.5.

14N 5E-32R1—Reference point—top of concrete base, elevation 73.8 feet, 400 feet southwest of U. S. Highway 99E at a point 0.55 mile northwest of Wheatland Road. 12/24/47, 16.9; 3/5/48, 15.7; 11/11/48, 17.5; 3/30/49, 15.0; 5/3/49, 16.9; 6/2/49, 19.8; 7/2/49, 21.1; 8/31/49, 24.0; 11/28/49, 20.3.

14N 5E-32R2—Reference point—top of 14-inch casing, elevation 74.8 feet, 100 feet southwest of U. S. Highway 99E, 0.55 mile northwest of Wheatland Road. 11/24/47, 17.3; 3/5/48, 16.2; 11/11/48, 18.5; 3/30/49, 15.2; 6/2/49, 24.9; 7/2/49, 27.6; 8/31/49, 28.0; 11/24/49, 21.1; 3/29/50, 18.0; 11/8/50, 23.1; 4/4/51, 15.1; 11/21/51, 23.2; 4/2/52, 13.0.

14N 5E-33K1—Reference point—bottom of slot in casing, elevation 78.3 feet, 0.40 mile northwest of Wheatland-Spenceville Road at a point 0.45 mile northeast of U. S. Highway 99E. 11/25/47, 14.0; 3/6/48, 13.3; 11/9/48, 15.5; 3/23/49, 11.4; 11/28/49, 17.6; 3/29/50, 13.9; 11/8/50, 19.5; 11/21/51, 19.5; 4/2/52, 10.4.

14N 5E-33M1—Reference point—top of casing at bottom of pit, elevation 65.8 feet, 0.15 mile northeast of U. S. Highway 99E at a point 0.55 mile northwest of Wheatland Road. 11/25/47, 6.0; 3/6/48, 5.6; 12/6/48, 6.8.

14N 5E-33Q1—Reference point—top of concrete well curb, elevation 86 feet, Northwest of the northeast corner of town of Wheatland, 1,000 feet north of school house east side. 11/22/29, 22.2; 9/18/30, 23.6; 12/11/31, 23.3; 12/10/32, 22.4; 12/21/33, 22.7; 11/20/34, 23.5; 11/23/36, 23.4; 11/22/37, 22.0; 1/27/39, 20.8; 1/2/40, 20.4; 11/7/47, 27.0; 12/16/48, 26.3; 12/9/49, 29.0; 11/8/50, 31.3; 12/5/51, 28.8.

14N 5E-34F1—Reference point—top of casing, elevation 90.2 feet, 500 feet northwest of Wheatland-Spenceville Road, 0.25 mile southwest of Jasper Lane. 11/25/47, 19.0; 3/6/48, 18.1; 11/9/48, 20.2; 3/23/49, 17.4; 11/28/49, 22.5.

14N 5E-34H1—Reference point—base of pump, elevation 99.7 feet, 600 feet southeast of Wheatland-Spenceville Road, 1,000 feet northeast of Jasper Lane. 11/25/47, 20.6; 3/6/48, 20.4; 11/9/48, 21.2; 3/23/49, 19.8; 11/28/49, 23.4.

15N 1E-12A1—Reference point—hole in pump base, elevation 150 feet, 1.05 miles north of South Butte Road, 2.1 miles west of Irwin Avenue. 12/2/48, 83.0 (operating).

15N 1E-12H1—Reference point—hole in pump base, elevation 80 feet, 0.75 mile north of South Butte Road, 2.1 miles west of Irwin Avenue. 12/2/48, 13.2.

15N 1E-3A1—Reference point—hole in pump base, elevation 57 feet, 0.1 mile north of South Butte Road, 2.1 miles west of Irwin Avenue. 12/22/49, 25.1; 3/4/48, 21.8; 3/29/49, 19.4; 11/15/49, 24.0; 3/23/50, 13.3; 11/2/50, 27.2; 4/3/52, 27.1.

15N 1E-13B1—Reference point—hole in cement pipe base, elevation 55 feet, 0.15 mile north of South Butte Road, 2.3 miles west of Irwin Avenue. 12/2/48, 31.8; 11/2/50, 33.2; 3/26/51, 63.8 (operating).

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Divisian of Water Resources
(Depths to woter in feet meosured from reference point)

15N/1E-14F1—Reference point—bottom of 2" x 4" board under pump, elevation 54 feet. South side of South Butte Road, 0.3 mile east of Sutter Bypass east levee. 12/22/47, 18.5; 3/4/48, 18.3; 5/4/48, 15.5; 6/2/48, 15.8; 7/3/48, 16.6; 8/3/48, 17.7; 9/1/48, 17.9; 12/2/48, 18.9; 12/8/49, 19.0; 3/23/50, 10.9; 11/2/50, 19.6.

15N/1E-14F2—Reference point—top of concrete pit, elevation 47 feet, 0.05 mile south of South Butte Road, 0.2 mile east of Sutter Bypass east levee. 11/27/29, 16.8; 10/6/30, 15.0; 12/16/31, 14.8; 12/8/32, 15.0; 12/15/33, 15.1; 11/2/34, 14.8; 11/23/34, 14.3; 11/27/36, 14.4; 11/15/37, 15.6; 1/25/39, 14.8; 1/11/41, 10.7; 11/4/47, 15.4; 12/13/48, 15.7; 12/8/49, 16.1; 11/10/50, 16.8; 12/7/51, 14.3.

15N/2E-1A1—Reference point—top of concrete pit, elevation 58.0 feet, 100 feet south of Nuestro Road, 0.15 mile west of Township Road. 12/19/47, 11.9; 3/3/48, 12.7; 12/1/48, 12.5; 1/20/49, 12.2; 3/16/49, 12.2; 6/28/49, 10.2; 7/27/49, 9.4; 11/11/49, 13.2; 3/23/50, 13.2; 11/6/50, 13.5; 4/3/51, 9.7; 11/14/51, 12.1; 4/3/52, 6.5.

15N/2E-1C1—Reference point—top of casing, elevation 58.2 feet, 0.1 mile south of Nuestro Road, 0.65 mile west of Township Road. 12/19/47, 10.3; 12/2/48, 11.7; 11/11/49, 11.5.

15N/2E-1H1—Reference point—top of concrete pit, elevation 57.7 feet, 150 feet west of Township Road, 0.35 mile south of Nuestro Road. 12/22/47, 13.3; 3/3/48, 13.6; 12/1/48, 14.0; 3/16/49, 13.7; 11/11/49, 14.6.

15N/2E-2C1—Reference point—top of wooden platform under pump, elevation 60.4 feet, 50 feet west of East Butte Road, 0.15 mile north of Nuestro Road. 12/19/47, 11.8; 3/3/48, 11.8; 12/2/48, 9.5; 3/16/49, 8.0; 11/10/49, 6.5; 3/22/50, 9.4; 11/2/50, 6.8; 4/4/51, 8.6; 11/14/51, 8.1; 4/3/52, 6.3.

15N/2E-2H1—Reference point—top of casing, elevation 57.6 feet, 0.3 mile south of Nuestro Road, 1.1 miles west of Township Road. 12/19/47, 10.4; 3/3/48, 11.3; 12/2/48, 10.0; 3/16/49, 9.0; 11/11/49, 9.2; 3/23/50, 10.1; 11/2/50, 9.1; 4/4/51, 9.7; 11/14/51, 9.0; 4/3/52, 7.9.

15N/2E-3K1—Reference point—top of casing, elevation 57 feet, 0.1 mile east of Mallott Road, 0.8 mile north of Butte House Road. 12/22/47, 10.7; 3/4/48, 11.8; 12/2/48, 10.0; 11/16/49, 9.5.

15N/2E-4Q1—Reference point—top of casing, elevation 86 feet, 0.15 mile east of Acacia Avenue, 0.3 mile north of Butte House Road. 12/22/47, 35.7; 3/4/48, 36.2; 12/2/48, 35.6; 3/29/49, 36.0; 11/16/49, 36.6.

15N/2E-4R1—Reference point—base of pump, elevation 74 feet, 0.3 mile east of Acacia Avenue, 0.35 mile north of Butte House Road. 12/22/47, 34.2; 12/2/48, 35.0; 11/16/49, 37.0; 3/23/50, 36.0; 11/2/50, 38.0; 4/5/51, 34.0; 11/15/51, 37.0; 4/3/52, 31.0.

15N/2E-8J1—Reference point—hole in pump base, elevation 75 feet, 0.2 mile west of Irwin Avenue, 0.45 mile north of South Butte Road. 5/4/48, 33.6; 12/2/48, 34.7; 12/8/49, 34.8; 3/23/50, 34.2; 11/15/51, 35.8; 4/3/52, 34.7.

15N/2E-8Q1—Reference point—hole in pump base, elevation 62 feet, 250 feet north of South Butte Road, 0.25 mile west of Irwin Avenue. 12/22/47, 29.4; 12/2/48, 29.3; 3/29/49, 27.8; 11/15/49, 29.6; 3/23/50, 27.7; 11/2/50, 30.6; 4/5/51, 30.6; 11/15/51, 30.3; 4/3/52, 24.5.

15N/2E-10F1—Reference point—top of casing, elevation 56 feet, 0.1 mile south of Butte House Road, 0.2 mile west of Mallott Road. 12/22/47, 21.2; 3/5/48, 19.1; 3/29/49, 20.0; 11/16/49, 20.5; 3/23/50, 21.4; 11/2/50, 20.5; 3/26/51, 20.1; 11/15/51, 20.1; 4/2/52, 15.5.

15N/2E-11C1—Reference point—top of casing, elevation 53.6 feet, 200 feet north of Butte House Road, 0.15 mile west of East Butte Road. 12/22/47, 9.0; 3/3/48, 10.6; 12/2/48, 7.7; 3/16/49, 9.1; 11/10/49, 7.4; 3/23/50, 8.2; 11/2/50, 7.6; 4/4/51, 9.1; 11/14/51, 6.9; 4/3/52, 7.2.

15N/2E-11N1—Reference point—top of casing, elevation 50 feet, 50 feet west of Humphrey Road, 0.55 mile south of Butte House Road. 12/22/47, 9.9; 3/5/48, 10.8; 9/27/48, 5.1; 11/17/48, 8.9; 3/28/49, 9.1.

15N/2E-12A1—Reference point—top of casing, elevation 55.8 feet, 100 feet southwest of intersection of Township and Pease Roads. 12/21/47, 5.8; 3/3/48, 16.8; 12/1/48, 15.0; 3/16/49, 13.6; 11/11/49, 14.8.

15N/2E-12K1—Reference point—base of pump, elevation 53.8 feet, 100 feet north of Butte House Road, 0.45 mile west of Township Road. 12/22/47, 13.2; 3/3/48, 12.4; 12/2/48, 11.9; 1/20/49, 13.3; 3/17/49, 11.5; 11/10/49, 11.3; 3/23/50, 11.1; 11/1/50, 11.3; 4/4/51, 9.2; 11/14/51, 10.0; 4/3/52, 5.2.

15N/2E-12R1—Reference point—top of casing, elevation 52 feet, 0.1 mile west of Township Road, 0.3 mile south of Butte House Road. 12/19/47, 6.2; 3/24/48, 7.2; 11/18/48, 7.0; 3/28/49, 6.0; 11/23/49, 6.4.

15N/2E-13E1—Reference point—top of wooden planks under pump, elevation 50 feet, 0.3 mile south of Fortuna Road, 0.9 mile west of Township Road. 12/22/47, 7.8; 3/5/48, 9.5; 11/18/48, 11.3; 3/28/49, 7.5; 11/23/49, 9.4.

15N/2E-13J2—Reference point—top of casing at bottom of pit, elevation 46 feet, 250 feet west of Township Road, 0.4 mile north of State Highway 20. 12/19/47, 8.1; 3/5/48, 9.1; 9/27/48, 9.3; 11/18/48, 9.0; 3/28/49, 8.1; 5/26/49, 8.0; 6/28/49, 10.7; 7/27/49, 11.3; 8/26/49, 10.5; 11/23/49, 9.8; 3/23/50, 8.0; 3/27/51, 6.8; 11/14/51, 7.9; 4/1/52, 4.4.

15N/2E-14A1—Reference point—top of brick casing, elevation 51.7 feet, 200 feet south of Fortuna Road, 1 mile west of Township Road. 12/22/47, 10.8; 3/3/48, 10.2; 12/2/48, 10.1; 3/16/49, 9.2; 11/11/49, 9.3; 3/23/50, 9.7; 11/2/50, 9.6; 4/4/51, 7.4; 11/14/51, 7.9; 4/3/52, 5.8.

15N/2E-15C1—Reference point—top of casing at bottom of pit, elevation 39 feet, 200 feet south of South Butte Road, 0.85 mile east of Acacia Road. 12/23/47, 4.0; 3/4/48, 4.5; 12/2/48, 3.3; 12/8/49, 2.4.

15N/2E-15D1—Reference point—top of casing in pit, elevation 44 feet, South side of South Butte Road, 0.5 mile east of Acacia Avenue. 12/23/47, 5.4; 3/4/48, 6.2; 12/2/48, 6.2; 3/29/49, 6.1; 11/16/49, 4.4; 3/23/50, 4.7; 11/2/50, 4.1; 4/1/51, 4.3; 11/15/51, 3.6; 4/2/52, 1.1.

15N/2E-15R1—Reference point—top of casing, elevation 48 feet, 150 feet west of Humphrey Road, 0.1 mile north of State Highway 20. 12/22/47, 9.3; 3/5/48, 10.4; 9/27/48, 3.8; 11/17/48, 5.9; 3/28/49, 4.5; 11/23/49, 5.7; 3/24/50, 5.5; 10/31/50, 4.7; 3/26/51, 3.1; 11/15/51, 4.1; 4/1/52, 2.6.

15N/2E-16E1—Reference point—slot in casing, elevation 56 feet, 200 feet west of Third Avenue, 0.25 mile south of South Butte Road. 12/22/47, 21.4; 3/4/48, 22.2; 12/2/48, 21.15; 3/29/49, 20.7; 11/16/49, 20.0.

15N/2E-17E1—Reference point—slot in casing, elevation 46 feet, 0.3 mile south of South Butte Road, 0.7 mile west of Irwin Avenue. 12/22/47, 14.1; 3/4/48, 14.1; 12/2/48, 14.2; 3/29/49, 12.1; 11/15/49, 14.9; 3/23/50, 12.9; 11/2/50, 15.8; 3/26/51, 35.2 (operating); 11/15/51, 21.0; 4/3/52, 8.9.

15N/2E-21C1—Reference point—top of casing in pit, elevation 38 feet, South west corner of Acacia Road and State Highway 20. 12/22/47, 1.6; 3/4/48, 2.6; 12/2/48, 1.8; 3/29/49, 0.8; 11/16/49, 0.3; 3/24/50, 0.5; 11/2/50, —0.7; 3/26/51, —1.0; 11/15/51, 0.0; 4/2/52, —2.7.

15N/2E-22B1—Reference point—top of casing, elevation 46 feet, 0.2 mile south of State Highway 20, 0.3 mile west of Humphrey Road. 12/23/47, 10.2; 3/4/48, 11.2; 12/2/48, 9.5; 3/24/49, 4.9; 11/16/49, 8.9; 3/23/50, 9.5; 11/2/50, 9.1; 3/26/51, 8.5; 11/15/51, 8.3; 4/2/52, 6.8.

15N/2E-22R1—Reference point—top of casing, elevation 45 feet, 200 feet north of Franklin Road, 0.15 mile west of Humphrey Road. 12/22/47, 8.9; 3/5/48, 9.5; 9/27/48, 6.0; 11/17/48, 8.0; 3/28/49, 4.1.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N 2E-23B1—Reference point—top of casing, elevation 45 feet, 100 feet south of State Highway 20, 0.75 mile east of Humphrey Road. 12/22/47, 6.8; 3/5/48, 7.8; 11/17/48, 6.2; 3/28/49, 5.9; 11/23/49, 6.4; 3/24/50, 6.7; 10/31/50, 7.1; 3/26/51, 5.0; 11/15/51, 5.2; 4/1/52, 2.8.

15N 2E-24B1—Reference point—hole in pump base, elevation 51 feet, 300 feet south of State Highway 20, 0.3 mile west of Township Road. 12/22/47, 13.7; 3/5/48, 14.4; 9/27/48, 12.4; 11/17/48, 13.5; 3/28/49, 13.5; 11/23/49, 8.1; 3/24/50, 13.8; 10/31/50, 14.6; 3/27/51, 11.0; 11/11/51, 12.9; 4/1/52, 7.0.

15N 2E-24N1—Reference point—top of concrete foundation, elevation 47 feet, 0.1 mile north of Franklin Road, 0.8 mile west of Township Road. 11/27/29, 14.0; 10/6/30, 13.0; 12/15/31, 14.0; 11/30/32, 13.0; 12/14/33, 13.9; 11/10/34, 13.6; 11/28/36, 11.2; 11/24/37, 10.9; 1/25/39, 10.3; 1/11/41, 5.6; 11/4/47, 9.4; 12/14/48, 10.9; 12/8/49, 10.4; 11/10/50, 10.4; 12/7/51, 6.6.

15N 2E-25A1—Reference point—top of concrete pit, elevation 48 feet, 0.05 mile south of Franklin Road, 0.2 mile west of Township Road. 12/22/47, 13.4; 3/5/48, 14.6; 11/17/48, 13.5; 3/28/49, 12.2; 11/23/49, 13.5; 3/24/50, 13.1; 10/31/50, 13.4; 3/27/51, 10.7; 11/14/51, 12.0; 4/1/52, 6.9.

15N 2E-25N1—Reference point—top of casing, elevation 49 feet, 0.1 mile north of Lincoln Road, 0.85 mile west of Township Road. 12/22/47, 11.8; 3/5/48, 13.0; 11/17/48, 11.1; 3/28/49, 10.6; 11/23/49, 10.8.

15N 2E-26B1—Reference point—top of concrete pipe casing, elevation 46 feet, 50 feet south of Franklin Road, 0.6 mile east of Humphrey Road. 12/22/47, 7.3; 3/5/48, 8.2; 9/27/48, 3.0; 11/17/48, 6.0; 3/28/49, 5.5; 11/23/49, 6.4; 3/24/50, 6.9; 10/31/50, 5.6; 3/27/51, 5.3; 11/15/51, 5.2; 4/1/52, 4.1.

15N 2E-26E1—Reference point—top of wooden box casing, elevation 42 feet, 250 feet east of Humphrey Road, 0.45 mile south of Franklin Road. 12/22/47, 9.8; 3/5/48, 9.8; 11/17/48, 8.2; 3/28/49, 6.6; 11/23/49, 7.0; 3/24/50, 8.1; well destroyed.

15N 2E-28D1—Reference point—top of casing, elevation 41 feet, 500 feet south of Franklin Road, 0.1 mile west of Wadsworth Canal west levee. 12/22/47, 7.1; 3/4/48, 8.2; 12/2/48, 7.0; 3/29/49, 5.5; 11/16/49, 5.9; 3/23/50, 7.7.

15N 2E-28D2—Reference point—top of casing in pit, elevation 38 feet, 500 feet south of Franklin Road, 0.2 mile west of Wadsworth Canal west levee. 11/2/50, 2.5; 3/26/51, 11.6 (operating); 11/15/51, 2.4; 4/3/52, —0.8.

15N 2E-34D1—Reference point—top of casing, elevation 41 feet, Southeast of intersection of Lincoln and Clements roads. 12/22/47, 7.5; 3/4/48, 8.1; 12/2/48, 7.0; 11/15/49, 5.1.

15N 2E-35B1—Reference point—top of casing in pit, elevation 35 feet, 0.1 mile south of Lincoln Road, 1.4 miles west of Township Road. 12/22/47, 1.6; 3/5/48, 2.6; 10/4/48, 0.5; 11/17/48, 1.5; 3/28/49, —0.6.

15N 2E-35D1—Reference point—hole in pump base, elevation 42 feet, 0.1 mile south of Lincoln Road, 1.8 miles west of Township Road. 12/23/47, 8.7; 3/6/48, 9.5; 11/17/48, 8.1; 3/28/49, 6.2; 11/23/49, 8.3; 3/24/50, 6.8; 11/1/50, 7.2; 3/27/51, 6.8; 11/11/51, 6.2; 4/1/52, 1.7.

15N 2E-35Q1—Reference point—top of casing, elevation 41.6 feet, 0.1 mile north of Bogue Road, 1.3 miles west of Township Road. 12/22/47, 5.0; 3/5/48, 6.1; 10/4/48, 4.7; 11/17/48, 4.4; 3/29/49, 3.0; 11/25/49, 4.1; 3/24/50, 4.1; 11/1/50, 3.3; 3/27/51, 2.9; 11/14/51, 2.5.

15N 2E-36A1—Reference point—top of casing, elevation 46 feet, 100 feet south of Lincoln Road, 0.1 mile west of Township Road. 12/22/47, 12.3; 3/5/48, 13.3; 10/4/48, 10.6; 11/12/48, 11.6; 3/28/49, 11.6; 6/28/49, 6.7; 7/27/49, 7.4; 8/25/49, 7.9; 11/23/49, 11.2; 3/24/50, 11.3; 11/1/50, 10.9; 3/27/51, 9.4; 11/11/51, 10.2; 4/2/52, 6.3.

15N 2E-36H1—Reference point—top of plank in pit, elevation 40 feet, 0.15 mile west of Township Road, 0.45 mile south of Lincoln Road. 12/22/47, 6.3; 3/5/47, 7.5; 11/17/48, 4.1; 3/29/49, 5.0.

15N 2E-36P1—Reference point—top of casing, elevation 43.7 feet, 0.15 mile north of Bogue Road, 0.65 mile west of Township Road. 12/22/47, 7.6; 3/5/48, 8.9; 11/17/48, 6.0; 3/29/49, 3.6; 11/25/49, 5.8; 3/24/50, 6.8.

15N 3E-1C1—Reference point—top of 16-inch casing, elevation 63 feet, 0.3 mile east of State Highway 24, 1.0 mile south of Ellis Road. 11/6/47, 14.5; 3/17/48, 14.0; 11/30/48, 14.9; 1/26/49, 14.2; 3/17/49, 13.0; 11/17/49, 15.7; 3/21/50, 13.1; 11/6/50, 15.9; 3/29/51, 9.9; 11/27/51, 14.6; 4/6/52, 7.5.

15N 3E-1D1—Reference point—hole in pump base, elevation 64 feet, 0.1 mile east of State Highway 24, 0.75 mile south of Ellis Road. 11/6/47, 19.5; 3/20/48, 16.1; 11/30/48, 17.0; 3/17/49, 15.0; 11/16/49, 18.8.

15N 3E-2A1—Reference point—top of 16-inch casing, elevation 64 feet, 0.3 mile west of State Highway 24, 0.85 mile south of Ellis Road. 11/6/47, 25.1; 3/20/48, 18.9; 11/30/48, 21.6; 11/16/49, 22.3; 3/31/50, 16.3; 11/6/50, 22.1.

15N 3E-2A2—Reference point—top of 14-inch casing, elevation 63 feet, 0.25 mile west of State Highway 24, 1.05 miles south of Ellis Road. 11/6/47, 20.4; 11/30/48, 14.7; 3/17/49, 16.9; 11/17/49, 19.0.

15N 3E-2A3—Reference point—hole in base of pump, elevation 65 feet, 0.05 mile west of State Highway 24, 0.5 mile south of Ellis Road. 11/6/47, 18.4; 3/20/48, 18.2; 12/2/48, 17.7; 3/17/49, 15.5; 11/16/49, 19.8.

15N 3E-2B2—Reference point—hole in base of pump, elevation 64 feet, 0.35 mile west of State Highway 24, 0.75 mile south of Ellis Road. 11/6/47, 21.2; 11/30/48, 17.2; 3/17/49, 16.2; 11/16/49, 22.0; 3/29/51, 12.9.

15N 3E-2C1—Reference point—hole in base of pump, elevation 65 feet, 0.85 mile west of State Highway 24, 0.9 mile south of Ellis Road. 11/6/47, 24.5; 3/20/48, 23.5; 11/30/48, 23.3; 3/17/49, 20.4; 11/17/49, 25.3; 3/21/50, 19.2; 11/6/50, 24.3; 3/29/51, 15.1; 11/16/51, 23.5; 4/6/52, 10.2.

15N 3E-2H1—Reference point—bottom of pump base, elevation 63 feet, 0.3 mile west of State Highway 24, 1.25 miles south of Ellis Road. 11/6/47, 20.6; 3/17/48, 19.0; 5/7/48, 17.3; 11/30/48, 19.6; 3/17/49, 17.8; 11/17/49, 21.3.

15N 3E-2J1—Reference point—top of 16-inch casing, elevation 63 feet, 0.1 mile west of State Highway 24, 1.6 miles south of Ellis Road. 11/6/47, 17.8; 3/17/48, 16.8; 5/7/48, 14.8; 11/30/48, 17.4; 1/26/49, 16.7; 3/17/49, 15.5; 11/17/49, 18.4.

15N 3E-3D2—Reference point—top of casing, elevation 63.7 feet, 250 feet south of Eager Road, 0.1 mile west of U.S. Highway 99E. 11/4/47, 25.8.

15N 3E-3G1—Reference point—hole in base of pump, elevation 62 feet, 0.2 mile south of Rednall Road, 0.3 mile east of U.S. Highway 99E. 11/5/47, 28.6; 3/17/48, 28.1; 5/12/48, 23.6; 11/29/48, 28.5; 3/17/49, 25.7; 11/14/49, 30.6; 3/22/50, 24.9; 11/6/50, 29.6; 4/3/51, 21.2; 11/14/51, 27.7; 4/3/52, 19.1.

15N 3E-4C1—Reference point—top of casing, elevation 60.9 feet, 0.20 mile south of Eager Road, 0.65 mile west of Onstott Road. 12/19/47, 23.2; 3/2/48, 27.5; 12/1/48, 22.7; 3/17/49, 21.2; 11/11/49, 25.8; 4/3/51, 18.4.

15N 3E-4C2—Reference point—hole in pump base, elevation 61.5 feet, 0.25 mile south of Eager Road, 0.50 mile west of Onstott Road. 5/4/48, 22.9; 6/3/48, 22.0; 9/1/48, 30.3; 9/30/48, 27.2; 11/29/48, 23.7; 1/20/49, 23.2; 3/17/49, 22.5; 11/11/49, 27.1; 3/22/50, 23.7; 11/1/50, 27.5; 11/14/51, 23.7; 4/3/52, 11.9.

15N 3E-4H1—Reference point—top of concrete base, bottom of pit, elevation 47.2 feet, 0.1 mile west of Onstott Road, 0.6 mile south of Eager Road. 11/4/47, 17.9; 11/20/48, 15.5; 3/17/49, 12.4; 11/14/49, 16.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N/3E-4J1—Reference point—top of casing, bottom of pit, elevation 47.7 feet, 0.15 mile west of Onstott Road, 0.85 mile south of Eager Road. 11/4/47, 17.6; 11/29/48, 16.0; 3/17/49, 13.0; 11/14/49, 18.4; 11/14/50, 23.0.

15N/3E-4N1—Reference point—top of casing, elevation 59.4 feet, 0.1 mile north of Pease Road, 0.5 mile east of Terra Buena Road. 12/21/47, 27.1; 3/24/48, 27.1; 12/1/48, 27.6; 3/16/49, 26.5; 5/26/49, 27.0; 6/30/49, 34.0; 11/11/49, 29.6; 3/23/50, 25.9; 11/6/50, 30.7; 4/4/51, 22.6; 11/14/51, 26.8.

15N/3E-5B2—Reference point—hole in base of pump, elevation 62.5 feet, 0.15 mile south and 150 feet east of a point on Eager Road at intersection of Larkin Road. 12/19/47, 21.8; 3/2/48, 22.1; 12/1/48, 20.7; 1/20/49, 20.2; 3/17/49, 19.5; 11/11/49, 23.0.

15N/3E-5D2—Reference point—hole in base of pump, elevation 59.8 feet, 50 feet south of Nuestro Road, 0.4 mile west of Terra Buena Road. 12/19/47, 18.7; 3/24/48, 20.6; 12/1/48, 18.0; 3/16/49, 17.3; 11/11/49, 19.9; 3/23/50, 15.1; 11/6/50, 22.0; 4/3/51, 12.3; 11/14/51, 18.2; 4/3/52, 7.4.

15N/3E-5G1—Reference point—hole in base of pump, elevation 59.5 feet, 0.25 mile east of Terra Buena Road, 0.5 mile north of Pease Road. 12/19/47, 18.9; 3/3/48, 24.2; 12/1/48, 23.0; 3/16/49, 22.0; 11/11/49, 24.7.

15N/3E-6B1—Reference point—top of 2" x 6" bridge over concrete pit, elevation 59.8 feet, 200 feet east of Broadway, 0.15 mile west of Nuestro Road. 12/19/47, 16.8; 3/24/48, 17.4; 12/1/48, 16.1; 3/16/49, 13.7; 11/11/49, 18.2.

15N/3E-6C1—Reference point—top of 2" x 6" bridge over concrete pit, elevation 58.8 feet, 400 feet north of Nuestro Road, 0.2 mile east of Township Road. 12/19/47, 14.2; 3/3/48, 14.3; 12/1/48, 14.9; 3/16/49, 12.2; 5/26/49, 13.8; 6/28/49, 15.4; 7/27/49, 17.3; 8/25/49, 16.5; 11/11/49, 16.3.

15N/3E-6Q1—Reference point—slot in concrete base, elevation 56.4 feet, 0.2 mile north of Pease Road, 0.4 mile east of Township Road. 12/21/47, 17.8; 3/3/48, 17.6; 12/1/48, 18.2; 3/16/49, 17.0; 11/11/49, 18.7; 3/23/50, 21.9; 11/1/50, 20.8; 4/4/51, 12.9; 11/14/51, 17.4; 4/3/52, 7.5.

15N/3E-7H2—Reference point—top of casing, elevation 57.0 feet, 0.5 mile north of Butte House Road, 0.55 mile west of Terra Buena Road. 12/21/47, 23.9; 3/24/48, 23.6; 12/1/48, 24.8; 3/16/49, 22.5; 11/11/49, 26.1.

15N/3E-7P1—Reference point—hole in base of pump, elevation 55.4 feet, 500 feet south of Butte House Road, 0.35 mile east of Township Road. 12/21/47, 19.8; 3/3/48, 20.8; 12/1/48, 21.0; 3/16/49, 19.5; 11/10/49, 22.1.

15N/3E-7Q1—Reference point—hole in base of pump, elevation 56 feet, 150 feet south of Butte House Road, 0.45 mile east of Township Road. 12/19/47, 20.7; 3/24/48, 20.9; 11/18/48, 22.1; 3/28/49, 19.8; 11/23/49, 22.9; 3/23/50, 19.8; 10/31/50, 24.4; 3/27/51, 17.9; 11/14/51, 21.2; 4/1/52, 9.8.

15N/3E-7R1—Reference point—top of discharge pipe, elevation 55.8 feet, 0.1 mile north of Butte House Road, 0.7 mile west of Terra Buena Road. 12/21/47, 23.8; 3/3/48, 22.5; 12/1/48, 24.8; 3/16/49, 22.5; 11/11/49, 26.2; 3/23/50, 19.6; 11/1/50, 23.3; 4/4/51, 19.4; 11/14/51, 24.1; 4/3/52, 12.2.

15N/3E-8C1—Reference point—bottom of pump base, elevation 57.5 feet, 50 feet south of Pease Road, 0.15 mile west of Terra Buena Road. 12/22/47, 23.9; 3/3/48, 24.7; 12/1/48, 24.2; 1/20/49, 23.0; 3/16/49, 22.2; 11/11/49, 25.0; 3/23/50, 21.5; 11/1/50, 28.0; 4/4/51, 17.4; 11/14/51, 23.6; 4/3/52, 11.2.

15N/3E-8J4—Reference point—top of casing, elevation 56.8 feet, 200 feet west of Elmer Avenue, 0.7 mile north of Butte House Road. 12/22/47, 27.9; 3/3/48, 26.9; 3/16/49, 26.0; 11/11/49, 30.7.

15N/3E-9A1—Reference point—top of concrete floor, elevation 59.8 feet, 300 feet south of Pease Road, 0.1 mile west of Onstott Road. 11/4/47, 37.9; 5/12/48, 27.1; 6/1/48, 26.5; 6/30/48, 48.8 operating; 8/2/48, 45.0; 9/30/48, 33.2; 10/21/48, 31.8; 11/30/48, 29.3; 1/20/49, 27.4; 3/17/49, 26.4; 11/14/49, 31.3; 3/22/50, 22.2; 11/1/50, 31.0; 4/4/51, 24.1; 11/14/51, 27.3; 4/3/52, 19.7.

15N/3E-9C1—Reference point—top of casing, elevation 58.1 feet, 0.1 mile south of Pease Road, 0.55 mile west of Onstott Road. 11/4/47, 40.6; 3/17/48, 27.6; 11/29/48, 27.4; 3/17/49, 25.5; 11/14/49, 29.5.

15N/3E-9G1—Reference point—top of pneumatic gage hole, elevation 61.0 feet, 50 feet east of Stabler Lane, 0.45 mile south of Pease Road. 11/4/47, 32.8; 3/17/48, 34.2; 11/29/48, 32.5; 3/17/49, 29.4; 11/14/49, 34.8.

15N/3E-9N1—Reference point—bottom of pump base, elevation 57.6 feet, 100 feet east of Blevin Road, 0.55 mile north of Butte House Road. 12/22/47, 29.8; 3/3/48, 31.6; 12/1/48, 31.0; 3/16/49, 28.0; 11/11/49, 33.3.

15N/3E-9P3—Reference point—top of 12-inch casing, elevation 55 feet, 0.30 mile east of Blevin Road, 0.60 mile north of Butte House Road. 11/18/47, 27.7; 11/18/48, 28.2; 3/23/49, 26.6.

15N/3E-9R2—Reference point—bottom of pump base, elevation 200 feet, West of Onstott Road, 1.4 miles north of Butte House Road. 11/18/47, 35.0; 3/17/48, 35.5; 11/19/48, 36.4; 3/23/49, 32.0; 11/22/49, 37.9; 3/23/50, 34.0; 11/13/51, 34.4; 4/1/52, 32.6.

15N/3E-10G1—Reference point—hole in pump base, elevation 60 feet, 0.05 mile west of U. S. Highway 99E, 0.50 mile south of Pease Road. 11/19/47, 30.2; 3/17/48, 28.3; 11/19/48, 34.6; 3/23/49, 26.6; 11/22/49, 33.4; 3/23/50, 24.3; 11/30/50, 30.8; 3/27/51, 20.9; 11/14/51, 36.1; 4/1/52, 20.3.

15N/3E-11B1—Reference point—top of concrete base, elevation 60 feet, 0.80 mile west of State Highway 24, 2.50 miles south of Ellis Road. 11/7/49, 21.5; 3/7/48, 21.1; 5/19/48, 18.1; 11/30/48, 21.6; 3/17/49, 19.2; 11/17/49, 23.1; 3/21/50, 19.2; 11/6/50, 23.0; 3/29/51, 16.5; 11/16/51, 22.3; 4/6/52, 12.1.

15N/3E-11H1—Reference point—top of casing, elevation 61 feet, 0.45 mile west of State Highway 24, 2.70 miles south of Ellis Road. 11/6/47, 18.5; 3/17/48, 16.8; 11/30/48, 17.8; 3/17/49, 15.6; 11/17/49, 18.2.

15N/3E-11H2—Reference point—top of casing, elevation 61 feet, 0.40 mile west of State Highway 24, 2.70 miles south of Ellis Road. 11/6/47, 16.9; 3/17/48, 16.4; 11/30/48, 16.7; 3/17/49, 13.5; 11/17/49, 17.7.

15N/3E-14M1—Reference point—top of casing, elevation 57 feet, 0.35 mile east of U. S. Highway 99E at a point 0.70 mile north of State Highway 20. 11/19/47, 24.2; 3/17/48, 22.2. Well destroyed.

15N/3E-15B2—Reference point—hole in pump base, elevation 59 feet, 0.05 mile west of U. S. Highway 99E, 1.0 mile north of State Highway 20. 11/19/47, 31.4; 3/17/48, 30.2; 5/12/48, 26.7; 9/27/48, 31.1; 11/19/48, 33.6; 3/23/49, 28.8; 11/22/49, 32.9; 3/23/50, 28.4; 10/30/50, 32.0; 3/27/51, 30.8; 4/1/52, 24.1.

15N/3E-15E2—Reference point—base of pump, elevation 58.6 feet, 400 feet east of Onstott Road, 0.30 mile north of Butte House Road. 11/18/47, 35.3; 3/4/48, 34.8; 3/15/48, 34.8; 11/19/48, 41.8; 3/23/49, 32.7; 11/22/49, 39.3; 3/23/50, 34.6; 11/30/50, 38.7; 3/27/51, 33.9; 3/13/51, 36.1; 4/1/52, 29.7.

15N/3E-16C1—Reference point—hole in pump base, elevation 56 feet, 0.25 mile east of Blevin Road, 0.50 mile north of Butte House Road. 11/19/47, 33.6; 3/17/48, 33.6; 5/13/48, 30.8; 11/19/48, 39.0; 3/23/49, 32.2; 11/29/49, 36.4; 11/3/50, 36.6.

15N/3E-16L1—Reference point—concrete rim of pit, elevation 56 feet, 300 feet east of Tharp Road, 0.1 mile south of Butte House Road. 11/18/47, 34.8; 3/15/48, 34.8; 11/18/48, 37.9; 3/23/49, 32.0; 11/23/49, 36.1; 3/23/50, 33.6; 10/31/50, 38.2; 3/27/51, 31.4; 11/14/51, 35.2; 4/1/52, 24.5.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N 3E-16R2—Reference point—top of casing, elevation 57.1 feet, 300 feet east of Blevin Road, 0.35 mile north of Butte House Road. 12/19/47, 31.0; 3/24/48, 32.9; 9/27/48, 34.5; 11/18/48, 31.7; 3/28/49, 28.9; 11/23/49, 32.7; 3/23/50, 29.7; 11/23/49, 32.7; 3/23/50, 29.7; 10/30/50, 35.2; 3/27/51, 27.2; 11/11/51, 31.9; 4/1/52, 24.8.

15N 3E-17C1—Reference point—top of casing at bottom of pit, elevation 16.8 feet, 200 feet east of Hooper Road, 0.05 mile north of Butte House Road. 12/19/47, 17.5; 3/6/48, 16.0; 9/27/48, 20.9; 11/18/48, 19.0; 3/28/49, 16.0; 11/23/49, 19.3; 3/23/50, 24.8; 10/30/50, 20.7; 3/27/51, 13.5.

15N 3E-17P2—Reference point—top of flanged coupling at bottom of pit, elevation 41.0 feet, 0.05 mile north of State Highway 20, 0.25 mile east of Hooper Road. 12/19/47, 15.1; 3/6/48, 14.6; 9/27/48, 19.6; 11/18/48, 16.9; 3/28/49, 12.8. Well destroyed.

15N 3E-18R1—Reference point—top of casing, elevation 53 feet, 0.1 mile north of State Highway 20, 0.1 mile west of George Washington Boulevard. 12/19/47, 23.3; 3/6/48, 22.8; 11/18/48, 25.6; 3/28/49, 21.9; 11/23/49, 26.2; 10/31/50, 28.2; 3/27/51, 19.7; 11/11/51, 25.3; 4/1/52, 12.7.

15N 3E-19B1—Reference point—2" x 4" on top of concrete pit, elevation 57.3 feet, 0.21 mile south of State Highway 20, 0.54 mile east of Township Road. 12/21/47, 29.2; 3/3/48, 27.6; 12/1/48, 30.0; 1/20/49, 28.7; 3/16/49, 27.0; 11/11/49, 32.3; 3/23/50, 27.5; 11/1/50, 22.4; 4/4/51, 25.6; 11/14/51, 30.6.

15N 3E-20E1—Reference point—top of casing, elevation 37.5 feet, 0.48 mile west of El Margarita Road, 0.53 mile south of State Highway 20. 12/19/47, 9.6; 3/6/48, 9.5; 9/27/48, 13.8; 11/18/48, 11.7; 3/28/49, 8.4; 11/25/49, 11.3.

15N 3E-20G1—Reference point—hole in base of pump, elevation 52 feet, 0.25 mile east of El Margarita Road, 0.50 mile south of State Highway 20. 12/19/47, 30.8; 3/6/48, 31.0; 3/28/49, 28.7; 11/25/49, 29.1; 10/31/50, 36.6; 11/14/51; 39.4; 4/1/52, 23.6.

15N 3E-20R1—Reference point—top of casing, elevation 53.4 feet, 0.20 mile west of Harding Road, 0.05 mile north of Franklin Road. 12/19/47, 29.9; 3/24/48, 30.8; 11/18/48, 33.2; 3/28/49, 28.0; 5/26/49, 33.5; 6/28/49, 35.4; 7/27/49, 38.4; 8/25/49, 38.7; 11/25/49, 33.4; 3/27/50, 30.1; 10/31/50, 35.3; 3/27/51, 28.9; 11/14/51, 36.6; 1/1/52, 25.3.

15N 3E-21C1—Reference point—hole in concrete base, elevation 54 feet, 0.40 mile east of Harding Road, 0.12 mile south of State Highway 20. 3/17/48, 32.8; 11/18/48, 32.5; 3/23/49, 29.2; 11/25/49, 31.4.

15N 3E-21D1—Reference point—hole in concrete base, elevation 55.6 feet, 0.05 mile south of State Highway 20, 0.24 mile east Harding Road. 12/19/47, 30.8; 3/24/48, 31.2; 5/12/48, 31.1; 9/22/48, 37.1; 11/18/48, 32.8; 3/28/49, 28.8; 5/26/49, 37.8; 6/30/49, 45.0; 8/25/49, 41.8; 11/25/49, 31.1.

15N 3E-21F1—Reference point—hole in concrete base, elevation 55 feet, 0.28 mile east of Harding Road, 0.38 mile south of State Highway 20. 11/17/47, 34.3; 3/17/48, 34.8; 11/18/48, 39.3; 3/23/49, 31.5; 11/25/49, 38.9; 10/31/50, 39.0; 3/27/51, 32.5; 11/11/51, 37.3; 4/1/52, 28.4.

15N 3E-21L2—Reference point—top of casing, elevation 55.0 feet, 0.04 mile west of Walton Road, 0.61 mile south of State Highway 20. 12/19/47, 32.2; 3/24/48, 32.7; 11/18/48, 31.5; 3/28/49, 30.3; 11/25/49, 35.9.

15N 3E-21P2—Reference point—slot in casing, elevation 51.3 feet, 0.18 mile north of Franklin Road, 0.48 mile east of Harding Road. 11/18/47, 33.3; 3/15/48, 34.8; 11/18/48, 34.8; 3/23/49, 31.0; 11/25/49, 35.4.

15N 3E-21Q1—Reference point—top of pit, elevation 53 feet, North side of Franklin Road, 0.25 mile east of Walton Road. 1/4/41, 24.5; 11/4/47, 33.6; 12/15/48, 33.5; 12/8/49, 36.1; 11/17/50, 38.4; 12/7/51, 35.8.

15N 3E-21R1—Reference point—top of casing, elevation 53.3 feet, 0.1 mile west of Onstott Road, 0.13 mile north of Franklin Road. 11/17/47, 31.1; 3/17/48, 31.4; 3/29/48, 30.4; 5/12/48, 30.7; 9/27/48, 35.1; 11/18/48, 32.7; 3/23/49, 29.5; 11/25/49, 35.1; 3/27/50, 31.4; 10/31/50, 36.2; 3/27/51, 30.7; 11/13/51, 34.5; 1/1/52, 26.7.

15N 3E-22D1—Reference point—hole in base of pump, elevation 54.8 feet, 0.05 mile east of Onstott Road, 0.17 mile south of State Highway 20. 11/17/47, 31.2; 3/17/48, 31.5; 9/27/48, 34.2; 11/19/48, 32.2; 3/23/49, 29.2; 11/25/49, 34.7.

15N 3E-24N1—Reference point—top of casing, elevation 48.6 feet, 0.38 mile southwest of Western Pacific Railroad crossing of Yuba River, 0.50 mile west of U. S. Highway 99E. 11/14/47, 10.0; 3/19/48, 8.6; 11/23/48, 11.0; 3/24/49, 6.8; 11/22/49, 13.8; 3/28/50, 24.0; 11/20/51, 31.3; 4/2/52, 12.6.

15N 3E-24N2—Reference point—top of casing, elevation 70.9 feet, 0.35 mile southwest of Western Pacific Railroad crossing of Yuba River, 0.50 mile north of U. S. Highway 99E. 11/14/47, 31.5; 3/19/48, 29.9; 11/23/48, 31.7.

15N 3E-24Q1—Reference point—pipe in base, elevation 64.8 feet, 0.04 mile south of Riverside Boulevard, 0.04 mile west of Western Pacific Railroad. 11/12/47, 27.2; 3/19/48, 27.4; 11/22/48, 31.4; 3/24/49, 24.8; 12/13/49, 31.0.

15N 3E-25C1—Reference point—top of casing, elevation 53.4 feet, 0.15 mile west of Riverside Boulevard, 0.55 mile south of Western Pacific Railroad crossing on Yuba River. 11/14/47, 14.6; 3/19/48, 13.2; 3/30/48, 12.5; 11/23/48, 15.0; 3/24/49, 11.2; 11/22/49, 15.1.

15N 3E-25F1—Reference point—top of casing, elevation 61.0 feet, 0.85 mile south of Western Pacific Railroad crossing on Yuba River, 0.27 mile west of Riverside Boulevard. 11/12/47, 24.4; 3/19/48, 23.3; 11/23/48, 25.1; 3/24/49, 21.6; 11/22/49, 26.5; 3/28/50, 20.8; 11/9/50, 25.6; 3/28/51, 15.1; 11/20/51, 24.0; 4/3/52, 15.3.

15N 3E-25H1—Reference point—base of pump, elevation 59.9 feet, South side of Walnut Avenue, 0.15 mile southwest of Garden Avenue. 11/12/47, 22.3; 3/19/48, 22.5; 10/4/48, 24.2; 11/22/48, 23.2; 3/24/49, 19.5; 11/18/49, 23.8.

15N 3E-25H2—Reference point—hole in base of pump, elevation 57.1 feet, West side of Garden Avenue, 0.15 mile south of Walnut Avenue. 11/14/47, 19.3; 11/22/48, 20.8; 3/24/49, 18.0; 11/18/49, 21.5.

15N 3E-25K1—Reference point—hole in base of pump, elevation 61.5 feet, 0.11 mile east of Riverside Boulevard, 0.86 mile north of Feather River Boulevard. 11/12/47, 24.8; 3/19/48, 23.1; 11/23/48, 24.8.

15N 3E-25K2—Reference point—top of casing, elevation 48.0 feet, 0.15 mile east of Riverside Boulevard, 0.82 mile north of Feather River Boulevard. 11/12/47, 10.9; 3/19/48, 9.3; 3/30/48, 8.7; 10/4/48, 21.2; 11/22/48, 19.5; 3/24/49, 16.7; 11/22/49, 21.0.

15N 3E-26M1—Reference point—top of casing, elevation 52 feet, 0.31 mile north of Lincoln Road, 0.24 mile east of Garden Highway. 11/14/47, 23.8; 3/17/48, 23.6; 3/2/48, 20.8; 10/4/48, 26.8; 11/19/48, 24.7; 3/23/49, 21.8; 6/29/49, 29.8; 7/31/49, 32.8; 8/25/49, 31.4; 11/28/49, 25.9; 3/27/50, 21.1; 11/1/50, 26.1; 3/27/51, 23.2; 11/13/51, 28.0; 4/1/52, 17.0.

15N 3E-27C1—Reference point—hole in base of pump, elevation 53 feet, 0.10 mile west of Clark Avenue, 0.14 mile south of Franklin Road. 11/17/47, 29.7; 3/17/48, 29.9; 11/19/48, 31.6; 3/23/49, 30.5.

15N 3E-28B3—Reference point—top of pit, elevation 53 feet, 0.25 mile east of Walton Road, south side of Franklin Road. 11/27/29, 23.8; 9/27/30, 27.8; 12/15/31, 28.8; 12/1/32, 28.4; 12/14/33, 30.5; 11/10/34, 31.3; 11/25/36, 21.5; 11/24/37, 23.6; 1/26/39, 18.3.

15N 3E-28C1—Reference point—top of casing, elevation 54.2 feet, 0.18 mile west of Walton Road, 0.07 mile south of Franklin Road. 12/19/47, 33.1; 3/24/48, 33.4; 5/12/48, 31.3; 9/27/48, 36.4; 11/18/48, 36.6; 3/28/49, 31.5; 11/25/49, 37.1.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N/3E-28G1—Reference point—top of casing, elevation 54.3 feet. 0.09 mile east of Walton Road, 0.37 mile south of Franklin Road. 11/17/47, 33.7; 3/15/48, 33.5; 11/18/48, 36.4; 3/23/49, 32.0; 11/25/49, 36.6; 3/27/50, 34.3; 10/31/50, 39.6; 3/27/51, 33.2; 11/13/51, 37.4; 4/1/52, 28.5.

15N/3E-28Q1—Reference point—base of pump, elevation 52.9 feet, 0.10 mile north of Lincoln Road, 0.18 mile east of Walton Road. 11/17/47, 32.0; 3/15/48, 32.0; 3/29/48, 31.4; 10/4/48, 35.2; 11/18/48, 34.8; 3/23/49, 31.0; 11/28/49, 36.6.

15N/3E-29D1—Reference point—bottom of flange coupling in pit, elevation 40.2 feet, west side of Butte Avenue, 0.14 mile south of Franklin Road. 12/19/47, 13.3; 3/5/48, 14.2; 11/18/48, 17.9; 3/28/49, 13.0; 12/13/49, 17.3; 3/27/50, 14.9; 11/1/50, 19.7; 3/27/51, 11.1; 11/14/51, 19.0; 4/1/52, 16.7.

15N/3E-29N1—Reference point—top of casing, in pit, elevation 36.9 feet, 0.14 mile north of Lincoln Road, 0.13 mile east of George Washington Boulevard. 12/19/47, 10.4; 3/5/48, 10.6; 11/18/48, 12.0; 3/28/49, 9.1; 11/23/49, 14.3; 3/27/50, 9.6; 11/1/50, 14.9; 3/27/51, 7.6; 11/14/51, 15.3; 4/1/52, 14.0.

15N/3E-29R2—Reference point—top of pump base, elevation 51.9 feet, 0.57 mile west of Walton Avenue, 0.03 mile north of Lincoln Road. 12/19/47, 31.6; 3/24/48, 31.1; 10/4/48, 34.7; 11/18/48, 33.2; 11/25/49, 34.8.

15N/3E-30Q1—Reference point—top of discharge pipe, elevation 47 feet. North side Lincoln Road, 0.40 mile west of George Washington Boulevard. 12/22/47, 20.3; 3/5/48, 20.5; 10/4/48, 21.6; 11/17/48, 20.7; 3/28/49, 18.9; 11/23/49, 21.3.

15N/3E-32N1—Reference point—top of casing, elevation 48.4 feet, 0.05 mile north of Bogue Road, 0.20 mile east of George Washington Boulevard. 12/20/47, 23.7; 3/5/48, 27.9; 11/17/48, 25.4; 3/29/49, 23.5; 11/25/49, 24.3; 3/27/50, 22.9; 11/1/50, 30.5; 3/27/51, 20.4; 11/14/51, 27.6; 4/1/52, 15.8.

15N/3E-33D1—Reference point—hole in base of pump, elevation 51 feet, 0.08 mile south of Lincoln Road, 0.32 mile west of Walton Road. 5/4/48, 30.0; 6/1/48, 29.4; 11/18/48, 34.7; 3/29/49, 29.5; 11/25/49, 35.0; 3/27/50, 32.3; 11/1/50, 37.7; 3/27/51, 31.3; 11/14/51, 35.5; 4/1/52, 29.0.

15N/3E-33F1—Reference point—hole in base of pump, elevation 52.0 feet, 0.10 mile west of Walton Road, 0.27 mile south of Lincoln Road. 12/20/47, 29.7; 3/5/48, 34.5; 5/4/48, 28.3; 5/12/48, 29.2; 6/1/48, 28.2; 11/18/48, 35.0; 3/29/49, 31.8; 11/25/49, 33.7; 3/27/50, 30.5; 11/1/50, 36.0; 3/27/51, 29.9; 11/14/51, 36.3; 4/1/52, 26.0.

15N/3E-33K1—Reference point—hole in base of pump, elevation 52.1 feet. East side of Walton Road, 0.54 mile south of Lincoln Road. 3/12/48, 36.1; 5/6/48, 31.3; 6/1/48, 30.9; 11/11/48, 36.5.

15N/3E-33K2—Reference point—hole in base of pump, elevation 49 feet, 0.20 mile east of Walton Road, 0.73 mile south of Lincoln Road. 11/17/47, 35.6; 3/15/48, 35.6; 11/25/49, 35.9.

15N/3E-33N2—Reference point—hole in base of pump, elevation 48.4 feet, 0.32 mile west of Walton Road, 0.06 mile north of Bogue Road. 12/20/47, 27.9; 3/5/48, 33.8; 11/18/48, 30.0; 3/29/49, 26.7; 11/25/49, 31.4; 3/27/50, 20.6; 11/1/50, 34.4; 11/14/51, 32.9; 4/1/52, 23.8.

16N/3E-33P1—Reference point—top of concrete pit, elevation 50.5 feet. West side of Walton Road, 0.15 mile north of Bogue Road. 11/10/47, 30.3; 3/23/48, 32.7; 11/11/48, 32.1; 1/18/49, 29.8; 3/7/49, 29.0; 11/29/49, 33.2; 3/27/50, 30.6; 11/3/50, 35.7; 11/16/51, 33.3.

15N/3E-33C2—Reference point—hole in base of pump, elevation 48.6 feet, 0.20 mile north of Bogue Road, 0.10 mile east of Walton Avenue. 3/16/48, 34.0; 11/11/48, 31.6; 3/7/49, 29.1; 12/1/49, 33.4.

15N/3E-34L1—Reference point—top of casing, elevation 50 feet, 0.52 mile south of Lincoln Road, 0.96 mile east of Walton Road. 11/14/47, 31.3; 3/15/48, 33.9; 5/5/48, 29.2; 6/1/48, 29.2; 7/3/48, 57.0 (operating); 8/3/48, 48.1; 9/30/48, 37.8; 10/4/48, 41.5; 11/19/48, 37.7; 3/23/49, 31.0; 5/31/49, 33.7; 8/31/49, 38.6; 11/28/49, 36.8; 3/27/50, 31.5; 11/1/50, 35.7; 3/28/51, 30.3; 11/13/51, 33.9; 4/1/52, 32.0.

15N/3E-34N1—Reference point—top of casing, elevation 39.5 feet, 0.05 mile west of Phillips Road, 0.15 mile north of Bogue Road. 3/12/48, 21.2; 11/11/48, 37.0; 3/7/49, 34.2; 12/1/49, 36.5.

15N/3E-35E1—Reference point—top of casing, elevation 50 feet, 0.37 mile east of Garden Highway, 0.44 mile south of Lincoln Road. 11/14/47, 22.1; 3/17/48, 21.2; 11/23/48, 22.5; 3/23/49, 20.5; 11/28/49, 21.1; 3/27/50, 20.8.

15N/4E-3A1—Reference point—top of casing, elevation 95.0 feet 0.31 mile east of Hallwood Road, south side of Walnut Road. 11/25/47, 16.6; 3/3/48, 19.8; 4/1/48, 19.1; 11/29/48, 17.0; 3/22/49, 18.8; 11/18/49, 17.7.

15N/4E-3B1—Reference point—top of casing, elevation 95.4 feet, 0.47 mile south of Walnut Road, 0.03 mile west of Hallwood Road. 11/25/47, 23.5; 3/3/48, 26.2; 11/29/48, 24.0; 1/27/49, 25.2; 3/22/49, 23.9; 11/16/49, 23.7.

15N/4E-3D1—Reference point—top of casing, elevation 93.4 feet, 0.45 mile west of Hallwood Road, 0.01 mile south of Walnut Road. 11/25/47, 18.8; 3/3/48, 21.9; 4/1/48, 21.8; 11/29/48, 20.0; 1/27/49, 22.2; 3/22/49, 20.1; 11/18/49, 19.4.

15N/4E-3D2—Reference point—top of casing, elevation 90 feet, 0.56 mile west of Hallwood Road, southeast of curve in Walnut Road. 11/29/48, 22.2; 3/23/49, 22.0.

15N/4E-4A1—Reference point—top of casing, elevation 90.4 feet, South side of Walnut Road, 0.85 mile along Walnut Road from intersection with State Highway 20. 11/25/47, 19.9; 3/3/48, 20.9; 11/29/48, 19.8; 3/22/49, 19.0; 11/18/49, 19.2.

15N/4E-4C1—Reference point—top of casing, elevation 88.7 feet, 0.05 mile south of Walnut Road, 0.41 mile along Walnut Road from intersection with State Highway 20. 11/25/47, 19.4; 3/3/48, 21.1; 4/1/48, 20.4; 11/29/48, 20.4; 3/22/49, 18.8; 11/18/49, 20.0.

15N/4E-4D1—Reference point—hole in pump base, elevation 85 feet, 0.03 mile southeast of intersection of State Highway 20 and Walnut Road. 11/29/48, 26.1; 1/27/49, 26.0; 3/22/49, 23.2; 12/9/49, 27.1.

15N/4E-4E1—Reference point—top of 10-inch casing inside shed, elevation 87.5 feet, 0.17 mile east of State Highway 20, 0.38 mile south along State Highway 20 from intersection of Walnut Road. 11/25/47, 21.9; 3/2/48, 22.8; 4/1/48, 22.4; 11/26/48, 22.8; 1/27/49, 23.2; 3/22/49, 21.0; 11/18/49, 22.5; 3/23/50, 21.5; 10/31/50, 22.2; 3/30/51, 20.5; 11/14/51, 22.3.

15N/4E-4H1—Reference point—top of tin casing at suction line, elevation 85 feet, 0.9 mile east of State Highway 20, 0.5 mile south of Walnut Road. 11/28/47, 20.2; 3/2/48, 20.8; 4/1/48, 21.7; 3/22/49, 20.5; 11/18/49, 20.8.

15N/4E-4N1—Reference point—top of casing, elevation 85.6 feet, 0.55 mile east of State Highway 20, 0.82 mile south of intersection of State Highway 20 and Walnut Road. 11/25/47, 24.3; 3/2/48, 24.3; 4/1/48, 23.5; 11/26/48, 24.6; 3/22/49, 22.6; 12/9/49, 25.2.

15N/4E-4N2—Reference point—top of casing, elevation 85.3 feet, 0.61 mile east of State Highway 20, 0.91 mile south along State Highway 20 from intersection with Walnut Road. 11/25/47, 23.9; 3/2/48, 23.9; 3/22/49, 22.0.

15N/4E-4P1—Reference point—top of casing, elevation 86.5 feet, 0.72 mile east of State Highway 20, 0.73 mile south along State Highway 20 from intersection with Walnut Road. 11/25/47, 70.4; 3/2/48, 25.6.

15N/4E-4R1—Reference point—hole in side of pump, elevation 85.7 feet, 0.81 mile northwest of Dantoni Packing Shed on Dantoni Road, southeast of Yuba River. 11/24/47, 26.3; 3/4/48, 25.0; 3/31/48, 27.3; 10/4/48, 25.4; 11/24/48, 25.4; 1/17/49, 25.2; 3/16/49, 24.0; 5/24/49, 26.3; 6/29/49, 28.7; 7/28/49, 27.8; 8/26/49, 27.9; 11/21/49, 26.2; 3/23/50, 24.1; 10/31/50, 26.5; 4/2/51, 21.4; 11/21/51, 25.6; 4/5/52, 20.4.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N/4E-5D1—Reference point—top of tin casing, elevation 65 feet, 0.17 mile northwest of Kimball Lane at curve, 1.0 mile along Kimball Lane from intersection with Nigger Jack Slough Road. 11/26/47, 7.2; 3/1/48, 8.8; 11/30/48, 8.2; 3/23/49, 8.5; 12/9/49, 8.5.

15N/4E-6C1—Reference point—top of suction pipe flange, elevation 65 feet, 0.10 mile north of intersection of Kimball Lane and Nigger Jack Slough Road on west side of Nigger Jack Slough Road. 11/7/47, 8.3; 12/2/48, 6.0; 3/18/49, 4.5; 11/17/49, 5.1.

15N/4E-7J1—Reference point—top of casing, elevation 68 feet. North side of State Highway 20, 1.65 miles along State Highway 20 from Yuba Street. 11/19/47, 15.9; 3/19/48, 15.9; 11/21/48, 16.3; 3/28/48, 15.0; 11/17/49, 16.0; 3/28/50, 15.8; 11/2/50, 15.7; 3/28/51, 10.5; 11/16/51, 16.2; 4/2/52, 10.2.

15N/4E-7M1—Reference point—hole in base of pump, elevation 61 feet, 0.80 mile north of 15th Street, west side of Nigger Jack Slough Road. 11/19/47, 19.4; 3/19/48, 18.8; 10/5/48, 19.1; 11/22/48, 19.7; 3/28/49, 17.5; 11/17/49, 19.8; 3/28/50, 16.9.

15N/4E-8D1—Reference point—top of casing outside milk house, elevation 65 feet, 0.46 mile east of Nigger Jack Slough Road, 0.25 mile northwest of State Highway 20. 11/25/47, 15.4; 3/2/48, 16.1; 11/30/48, 15.9; 3/22/49, 14.7; 11/21/49, 15.1; 3/23/50, 14.3; 10/31/50, 15.0; 3/30/51, 14.7; 11/14/51, 15.8; 4/5/52, 12.6.

15N/4E-8M1—Reference point—top of casing, elevation 74 feet, 0.20 mile east of State Highway 20, 1.68 miles from intersection with Yuba Street. 11/25/47, 23.1; 3/2/48, 22.7; 11/26/48, 23.1; 3/22/49, 22.2; 12/9/49, 24.7.

15N/4E-8R1—Reference point—base of pump, elevation 80.3 feet, 1.58 miles north of intersection of Dantoni and Hammond Roads on south bank of Yuba River. 11/19/47, 26.7; 3/2/48, 26.7; 3/31/48, 25.7; 5/5/48, 23.3; 6/1/48, 23.2; 10/4/48, 26.8; 11/21/48, 26.9; 3/16/49, 25.4; 11/21/49, 27.7; 3/23/50, 25.0; 10/31/50, 27.7; 4/2/51, 22.2; 11/21/51, 26.9; 4/5/52, 23.4.

15N/4E-9G1—Reference point—top of casing, elevation 84.6 feet, 0.70 mile northwest of Dantoni Road, 0.10 mile southwest along road from Dantoni Packing Shed. 11/24/47, 29.6; 3/3/48, 24.9; 3/4/48, 25.1; 10/4/48, 25.9; 11/24/48, 25.5; 1/17/49, 24.9; 3/16/49, 23.7; 11/21/49, 26.0; 3/23/50, 23.2; 10/31/50, 25.9; 4/2/51, 21.1; 11/21/51, 25.0; 4/5/52, 20.3.

15N/4E-9R1—Reference point—hole in side of pump, elevation 77.2 feet, 0.23 mile northwest of Dantoni Road, 0.40 mile southwest along road from Dantoni Packing Shed. 11/24/47, 19.2; 3/1/48, 20.9; 3/3/48, 21.0; 11/24/48, 20.1; 3/16/49, 20.2; 11/21/49, 21.1.

15N/4E-10F1—Reference point—hole in base of pump, elevation 80.5 feet, 0.23 mile northwest of Dantoni Road, 0.20 mile northeast along road from Dantoni Packing Shed. 11/24/47, 21.5; 3/1/48, 19.8; 3/31/48, 25.7; 10/4/48, 20.9; 11/24/48, 20.6; 3/16/49, 19.7; 11/21/49, 21.5.

15N/4E-10L2—Reference point—pipe in concrete base, elevation 87.8 feet, 0.12 mile southeast from Dantoni Road, opposite Dantoni Packing Shed. 11/21/47, 26.2; 3/3/48, 31.0; 3/4/48, 26.9; 5/6/48, 25.0; 10/8/48, 27.4; 11/21/48, 27.3; 1/17/49, 26.8; 3/16/49, 26.1; 3/24/49, 31.0; 6/29/49, 29.5; 7/28/49, 30.3; 8/30/49, 30.5; 11/21/49, 28.6.

15N/4E-10N1—Reference point—hole in casing, elevation 84.1 feet, 0.16 mile southeast of Dantoni Road, 0.30 mile southwest along road from Dantoni Packing Shed. 11/24/47, 28.6; 3/1/48, 26.0; 3/31/48, 26.6; 5/6/48, 24.2; 10/4/48, 26.2; 11/24/48, 26.5; 3/16/49, 25.8; 11/21/49, 28.0; 12/7/49, 27.8; 3/23/50, 26.6; 10/31/50, 28.2; 4/2/51, 20.7; 11/21/51, 26.9; 4/5/52, 23.0.

15N/4E-11C1—Reference point—top of casing, elevation 90 feet, 1.60 miles north of Hammonton Road at a point 0.55 mile southwest along Hammonton Road from Brophy Road. 5/13/48, 25.0; 6/1/48, 24.7; 10/1/48, 27.5; 11/23/48, 27.5; 1/17/49, 26.9; 3/16/49, 26.5; 11/21/49, 28.8; 3/23/50, 25.4; 3/30/51, 18.8; 11/1/51, 27.1; 4/4/52, 18.4.

15N/4E-11G1—Reference point—hole in pump base, elevation 85 feet, 1.17 miles north of Hammonton Road at a point 0.35 mile southwest along Hammonton Road from Brophy Road. 5/13/48, 25.3; 6/1/48, 24.9; 9/1/48, 29.5; 10/1/48, 26.2; 11/23/48, 26.1, 1/17/49, 26.1; 3/16/49, 25.4; 4/12/49, 24.1; 5/24/49, 28.5; 6/29/49, 29.4; 7/28/49, 28.5; 8/26/49, 28.4; 11/21/49, 23.6; well destroyed.

15N/4E-11K1—Reference point—hole in top of pump base, elevation 83 feet, 0.29 mile west of Brophy Road, 0.90 mile north of Brophy School. 5/13/48, 18.1; 10/1/48, 20.1; 11/23/48, 19.4; 3/16/49, 18.4.

15N/4E-12P1—Reference point—hole in pump base, elevation 82.3 feet, 0.57 mile north of Brophy School, 0.29 mile east of Brophy Road. 11/24/47, 24.3; 3/1/48, 25.9; 3/31/48, 23.8; 11/23/48, 27.5; 11/21/49, 26.7; 12/5/49, 26.6; 3/24/50, 22.4; 11/2/50, 27.6; 4/4/52, 19.4.

15N/4E-13B1—Reference point—top of casing, elevation 84 feet, South side of Hammonton Road, 0.4 mile northeast from intersection with Brophy Road. 12/24/47, 22.9; 3/23/48, 22.6; 11/23/48, 25.7; 3/21/49, 22.1; 12/5/49, 26.2; 3/23/50, 22.7; 11/2/50, 27.7; 4/2/51, 18.7; 11/21/51, 26.4; 4/4/52, 20.4.

15N/4E-14B1—Reference point—top of casing, elevation 80.5 feet, 0.21 mile north of Hammonton Road, 0.20 mile southwest from intersection with Brophy Road. 11/26/47, 16.1; 3/1/48, 16.4; 3/31/48, 16.4; 11/24/48, 17.8; 3/17/49, 16.3; 11/22/49, 16.4; 3/30/51, 4.6; 11/20/51, 17.0; 4/4/52, 4.7.

15N/4E-14N1—Reference point—hole in pump base, elevation 79 feet, 0.11 mile south of Hammonton Road, 0.85 mile southwest from intersection with Brophy Road. 5/6/48, 24.0; 6/3/48, 26.7; 3/17/49, 25.7; 11/21/49, 30.3.

15N/4E-14N2—Reference point—top of casing, elevation 78.8 feet, North side of Hammonton Road, 0.87 mile southwest from intersection with Brophy Road. 11/26/47, 22.7; 5/6/48, 21.8; 10/1/48, 26.4; 10/8/48, 25.8; 11/24/48, 24.9; 1/17/49, 23.9; 3/16/49, 23.3; 5/24/49, 31.3; 6/29/49, 33.5; 7/28/49, 35.3; 8/26/49, 30.8; 11/22/49, 27.7; 3/23/50, 24.3; 11/10/50, 28.7; 3/30/51, 18.5; 11/20/51, 27.9; 4/4/52, 20.3.

15N/4E-14P1—Reference point—hole in pump base, elevation 82 feet, 0.52 mile west of Brophy Road, 0.23 mile south of Hammonton Road. 5/6/48, 25.2; 6/3/48, 28.7; 3/17/49, 26.9; 8/2/49, 40.6; 11/21/49, 30.7.

15N/4E-15A1—Reference point—pipe in concrete base, elevation 78.5 feet, 1.02 miles west of Brophy Road, 0.86 mile north of Hammonton Road. 11/26/47, 18.3; 3/2/48, 17.1; 3/31/48, 18.5; 10/8/48, 20.2; 11/24/48, 19.6; 1/7/49, 19.0; 3/16/49, 18.4; 11/21/49, 21.0; 3/23/50, 19.1; 11/10/50, 22.0; 4/2/51, 11.1; 11/21/51, 20.3; 4/4/52, 12.2.

15N/4E-15L1—Reference point—top of concrete pit, elevation 81.5 feet, 0.15 mile east of Griffith Avenue, 0.66 mile north of Hammonton Road. 11/26/47, 27.0; 3/2/48, 29.8.

15N/4E-16A1—Reference point—hole in side of pump base, elevation 79.5 feet, North side of Dantoni Road, 0.73 mile along road from Dantoni Packing Shed. 11/7/47, 22.5; 3/2/48, 23.2; 3/31/48, 22.7; 10/4/48, 23.7; 10/8/48, 23.7; 11/24/48, 23.7; 1/17/49, 23.2; 3/16/49, 23.0; 11/21/49, 25.1.

15N/4E-16K1—Reference point—base of pump, elevation 81.0 feet, 0.03 mile west of Dantoni Road, 1.43 miles along road from intersection with Hammonton Road. 11/22/47, 26.8; 3/2/48, 28.2; 3/31/48, 27.9; 10/4/48, 30.0; 10/8/48, 29.9; 11/24/48, 29.2; 3/16/49, 28.4; 11/22/49, 31.2; 11/10/50, 30.5; 4/2/51, 21.5; 11/21/51, 29.5; 4/5/52, 22.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N/4E-16N2—Reference point—hole in pump base, elevation 74.5 feet, 0.28 mile northwest of Dantoni Road, 0.76 mile along road from intersection with Hammonton Road. 11/19/47, 23.9; 3/2/48, 23.3; 3/31/48, 23.1; 5/6/48, 22.3; 6/1/48, 21.8; 10/4/48, 24.5; 11/24/48, 24.2; 3/16/49, 23.6.

15N/4E-16P1—Reference point—base of pump, elevation 76.9 feet, 0.23 mile west of Dantoni Road, 1.31 miles along road from intersection with Hammonton Road. 11/5/47, 24.7; 3/2/48, 24.1; 5/13/48, 24.2; 6/1/48, 22.3; 10/4/48, 25.8; 10/8/48, 25.7; 11/24/48, 24.7; 3/16/49, 24.4; 11/21/49, 28.2.

15N/4E-17M1—Reference point—top of casing, elevation 74.2 feet, 0.76 mile measured perpendicular north of Simpson Lane at a point 0.82 mile from 7th St. Bridge. 11/11/47, 26.4; 3/19/48, 25.8; 3/30/48, 25.5; 11/5/48, 27.0; 11/22/48, 32.8; 3/24/49, 25.2; 11/17/49, 27.3; 3/28/50, 24.7; 11/2/50, 28.2; 3/28/51, 17.9; 11/16/51, 25.8; 4/2/52, 15.9.

15N/4E-17N1—Reference point—top of casing, elevation 74.5 feet, 0.35 mile measured perpendicular north of Simpson Lane at a point 1.27 miles from intersection with Yuba Street. 11/11/47, 26.0; 3/19/48, 25.4; 3/30/48, 25.3; 11/22/48, 26.6; 3/24/49, 25.2; 11/17/49, 27.6.

15N/4E-18G1—Reference point—top of casing, elevation 71 feet, 0.13 mile east of State Highway 20 at a point 0.90 mile from intersection with Yuba Street. 11/19/47, 27.7; 3/19/48, 26.2; 11/21/48, 28.5; 3/28/49, 24.5; 11/17/49, 28.1; 11/2/50, 26.2; 3/28/51, 22.3; 11/16/51, 28.1; 4/2/52, 21.6.

15N/4E-18Q1—Reference point—base of pump at edge, elevation 68.7 feet, 0.36 mile measured perpendicular north of Simpson Lane at a point 0.75 mile from intersection with Yuba Street. 11/12/47, 23.7; 3/18/48, 22.5; 11/22/48, 24.3; 3/24/49, 22.0; 11/17/49, 25.5; 11/16/51, 27.7.

15N/4E-19H1—Reference point—surface of concrete block, elevation 67.0 feet, 0.13 mile measured perpendicular south of Simpson Lane at a point 1.04 miles from intersection with Yuba Street. 11/11/47, 23.5; 3/19/48, 22.6; 10/5/48, 29.0; 11/22/48, 26.5; 3/24/49, 20.7; 11/17/49, 25.0; 11/2/50, 25.3; 3/28/51, 13.7.

15N/4E-19J1—Reference point—hole in pump base, elevation 71.8 feet, 0.43 mile south of Simpson Lane at a point 1.12 miles from intersection with Yuba Street. 11/11/47, 27.4; 3/19/48, 27.3; 3/24/49, 26.8; 11/18/49, 30.0; 3/28/50, 27.5; 11/3/50, 30.3; 3/28/51, 18.5; 11/16/51, 26.5; 4/2/52, 17.6.

15N/4E-19N1—Reference point—top of casing, elevation 59.9 feet. South bank of Levee Road, 0.35 mile east of U. S. Highway 99E bridge over Yuba River. 11/10/47, 20.0; 3/17/48, 19.0; 3/24/49, 17.0; 11/18/49, 21.4.

15N/4E-19P1—Reference point—top of casing, elevation 64.0 feet, 0.04 mile south of levee between Avondale and Southern Pacific Railroad. 11/11/47, 22.7; 3/17/48, 22.6; 3/30/48, 21.1; 11/22/48, 33.7; 3/24/49, 21.0; 12/13/49, 25.2.

15N/4E-20F1—Reference point—hole in pump base, elevation 72.5 feet, 0.20 mile due west from intersection of Hammonton and Dantoni Roads. 11/11/47, 25.7; 3/17/48, 26.0; 5/3/48, 24.7; 6/2/48, 25.4; 11/22/48, 26.2; 3/24/49, 26.5; 11/17/49, 29.6; 3/28/50, 27.3; 11/16/51, 25.1; 4/2/52, 23.6.

15N/4E-20L1—Reference point—top of casing, elevation 66 feet, 0.41 mile north of Hammonton Road at a point 0.55 mile along Hammonton Road from intersection with U. S. Highway 99E. 11/11/47, 14.3; 3/17/48, 15.0; 11/22/48, 13.3; 11/18/49, 22.4; 11/3/50, 22.7; 3/28/51, 12.6.

15N/4E-20N1—Reference point—top of casing, elevation 57.8 feet, 0.40 mile north of Hammonton Road at a point 0.41 mile along Hammonton Road from intersection with U. S. Highway 99E. 11/11/47, 13.6; 3/17/48, 13.9; 10/4/48, 24.4; 11/22/48, 19.3; 3/24/49, 13.5; 11/18/49, 16.1; 3/28/50, 14.3.

15N/4E-20N2—Reference point—top of casing, 8.5 feet below top of concrete pit, elevation 53.4 feet, 0.22 mile north of Hammonton Road at a point 0.45 mile along Hammonton Road from intersection with U. S. Highway 99E. 11/11/47, 12.6; 3/17/48, 12.9; 3/24/49, 6.0; 11/18/49, 8.6.

15N/4E-20N3—Reference point—top of casing, elevation 58.9 feet, 0.31 mile north of Hammonton Road at a point 0.50 mile along Hammonton Road from intersection with U. S. Highway 99E. 4/8/47, 14.7; 3/17/48, 15.3; 3/30/48, 14.5; 11/12/48, 22.2; 3/24/49, 15.9; 11/18/49, 17.3.

15N/4E-20P1—Reference point—top of concrete pit, east wall, elevation 67.5 feet, 0.14 mile due west of intersection of Hammonton and Linda Roads. 12/10/47, 22.5; 3/1/48, 22.5; 11/22/48, 23.3; 3/17/49, 22.9; 11/22/49, 24.6; 3/24/50, 23.2; 11/2/50, 25.7; 11/15/51, 20.7.

15N/4E-20R1—Reference point—top of casing, elevation 67.4 feet. North side of Linda Road, 0.41 mile east of Hammonton Road. 12/12/47, 22.2; 3/1/48, 21.3; 11/22/48, 23.6; 11/22/49, 25.2.

15N/4E-21F1—Reference point—base of wooden block supporting pump, south side, elevation 70.4, 0.10 mile north of Hammonton Road, 0.68 mile west of Griffith Avenue. 11/26/47, 23.6; 3/1/48, 23.6; 10/8/48, 25.7; 11/24/48, 24.8; 3/16/49, 23.5; 6/29/49, 29.2; 8/26/49, 31.0; 11/21/49, 28.8; 3/23/50, 25.3; 11/2/50, 30.0; 3/30/51, 19.1; 11/20/51, 30.8; 4/5/52, 21.9.

15N/4E-21R2—Reference point—hole in pump base, elevation 75.1 feet. West side of Griffith Avenue, 0.05 mile north of North Beale Road. 11/26/47, 27.1; 10/8/48, 29.4; 11/22/48, 29.2; 3/17/49, 27.8; 11/21/49, 32.3; 3/24/50, 29.9; 11/3/50, 34.3; 3/30/51, 26.3; 11/21/51, 33.7; 4/3/52, 26.9.

15N/4E-22B1—Reference point—top of casing, elevation 73.6 feet. North side of Hammonton Road, 0.75 mile along road from intersection with Griffith Avenue. 11/26/47, 20.6; 3/1/48, 20.1; 3/31/48, 20.0; 5/6/48, 19.6; 10/1/48, 23.3; 10/8/48, 23.1; 11/24/48, 22.4; 1/17/49, 21.9; 3/16/49, 21.3; 5/24/49, 24.9; 7/1/49, 31.1; 8/3/49, 28.9; 8/26/49, 28.1; 11/21/49, 25.3; 3/23/50, 22.7; 11/2/50, 27.2; 3/30/51, 15.2; 11/20/51, 24.9; 4/4/52, 27.1.

15N/4E-22K1—Reference point—top of casing, elevation 86.9 feet, 0.40 mile north of North Beale Road, 0.76 mile east of Griffith Road. 12/10/47, 27.7; 3/1/48, 34.7; 10/8/48, 36.6; 11/22/48, 36.9; 3/17/49, 36.5; 11/22/49, 40.0.

15N/4E-22L1—Reference point—top of casing, elevation 74 feet, 0.39 mile east of Griffith Road, 0.26 mile north of North Beale Road. 11/22/29, 25.7; 9/16/30, 25.3; 12/14/31, 27.3; 12/9/32, 27.6.

15N/4E-22P1—Reference point—top of concrete foundation, elevation 72 feet, 0.32 mile east of Griffith Road, 0.15 mile north of North Beale Road. 11/5/47, 23.6; 12/10/48, 26.3; 12/9/49, 29.5; 11/10/50, 31.5; 12/5/51, 30.7.

15N/4E-22P2—Reference point—top of brick lining of well, elevation 73 feet, 0.31 mile east of Griffith Road, 0.15 mile north of North Beale Road. 12/14/33, 29.6; 11/20/34, 30.4; 11/28/36, 27.9; 11/22/37, 27.6; 1/27/39, 25.1; 1/9/41, 22.0.

15N/4E-23A1—Reference point—crack between wood blocks, southeast corner, elevation 84.2 feet. West side of Brophy Road, 0.96 mile north of North Beale Road. 11/26/47, 24.5; 3/1/48, 24.1; 3/31/48, 24.0; 5/6/48, 23.4; 6/3/48, 38.0; 10/1/48, 28.1; 10/8/48, 27.5; 11/23/48, 26.5; 1/17/49, 25.7; 3/16/49, 25.3; 6/1/49, 34.6; 7/3/49, 39.5 (operating); 8/2/49, 39.5 (operating); 11/22/49, 31.0; 3/23/50, 26.7; 11/2/50, 31.2; 3/30/51, 23.8; 11/21/51, 30.8; 4/4/52, 25.1.

15N/4E-23P1—Reference point—top of casing, elevation 77.2 feet, 0.04 mile north of North Beale Road, 0.65 mile east of Brophy Road. 12/10/47, 27.1; 3/1/48, 27.6; 3/31/48, 24.9; 10/8/48, 27.3; 11/22/48, 27.4; 3/17/49, 27.0; 11/22/49, 30.3; 11/2/50, 32.5.

15N/4E-23R1—Reference point—top of wooden platform under pitcher pump, elevation 79.1 feet, 0.05 mile northwest of intersection of North Beale and Brophy Roads. 12/10/47, 24.2; 3/1/48, 24.2.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N 4E-24C1—Reference point—top of casing, elevation 83 feet, 0.19 mile east of Brophy Road, 0.99 mile north of North Beale Road. 5-5-48, 25.1; 6-3-48, 28.6; 11-23-48, 28.1; 1-17-49, 27.4; 3-16-49, 27.0; 7-3-49, 16.0 (operating); 8-2-49, 52.0 (operating); 12-5-49, 30.8; 3-24-50, 29.1; 11-2-50, 33.3; 4-2-51, 28.3; 11-21-51, 38.1; 4-4-52, 35.9.

15N 4E-25L1—Reference point—hole in pump base, elevation 78 feet, 0.49 mile east of Brophy Road, 0.51 mile south of North Beale Road. 10-6-49, 30.0; 11-23-48, 29.5; 3-21-49, 28.6; 12-5-49, 33.7; 3-27-50, 32.1; 11-2-50, 37.2; 4-4-51, 34.5; 11-21-51, 40.0; 4-5-52, 36.7.

15N 4E-26J1—Reference point—hole in base of pump, elevation 76 feet, 0.70 mile south of North Beale Road due south of Brophy Road. 11-23-48, 28.8; 3-17-49, 28.5; 11-23-49, 31.9; 12-5-49, 32.6.

15N 4E-27E2—Reference point—top of concrete north wall, elevation 71.0 feet, 0.23 mile east of Griffith Road, 0.40 mile south of North Beale Road. 12/10-47, 23.1; 3/1/48, 22.3; 3-31-48, 22.4; 10-8-48, 25.5; 11-22-48, 25.4; 3-17-49, 24.5; 11-22-49, 28.5; 4-4-52, 25.3.

15N 4E-28D1—Reference point—hole in pump base, elevation 77.7 feet, 0.04 mile south of North Beale Road, 0.17 mile east of intersection of North Beale and Linda Roads. 11/26/47, 32.3; 3-1-48, 31.5; 11-22-48, 34.1; 3/26-49, 32.5; 11/21-49, 36.9; 3-24-50, 34.3; 11-2/50, 38.9; 3/30/51, 37.5 (operating); 11-21-51, 39.1; 4-3/52, 31.5.

15N 4E-29E1—Reference point—top of casing, elevation 61 feet, 0.23 mile northeast of U. S. Highway 99E, 0.20 mile southeast of Hammonton Road. 12-10-47, 20.9; 3/1/48, 20.6.

15N 4E-29F2—Reference point—top of 4" x 4" bridge over pit, elevation 64 feet, 0.26 mile south of North Beale Road, 0.62 mile west of intersection of North Beale and Linda Roads. 12/10/47, 22.4; 3/1/48, 20.9.

15N 4E-29P1—Reference point—top of 4" x 6" mud sill of shed, elevation 63.6 feet, 0.03 mile north of Earle Road, 0.04 mile east of Southern Pacific Railroad. 12/10/47, 21.5; 3/1/48, 22.7; 10-8-48, 25.0; 11-22-48, 24.2.

15N 4E-30B2—Reference point—hole in base of pump, elevation 62.7 feet, Northeast side of Avondale Avenue, 0.05 mile northwest of North Beale Road. 11/10-47, 21.3; 3/17/48, 20.3; 10-4-48, 23.7; 11-22-48, 22.2; 3-24-49, 19.0; 12/13/49, 23.4; 3-28-50, 20.5; 11-2-50, 24.6.

15N 4E-30D1—Reference point—base of pump, north side, elevation 59.1 feet, 0.03 mile south of U. S. Highway 99E at first turn south of Rancho Motel. 11-10-47, 20.4; 3-17/48, 20.5; 3-30-48, 18.8; 5-5-48, 16.0; 6-2-48, 16.6; 7-1-48, 39.2 (operating); 11-22-48, 21.6; 3-24-49, 18.0; 5-24/49, 20.8; 6-29-49, 24.3; 8-26-49, 25.1; 11-22-49, 24.8; 3-28/50, 17.0; 11-2-50, 22.3; 3-28-51, 10.2; 10-20-51, 21.8.

15N 4E-30E2—Reference point—base of pump, elevation 56.8 feet, Southwest side of Garden Avenue, 0.38 mile southeast of Walnut Avenue. 11-12-47, 18.9; 3-19-48, 17.8; 10-4-48, 22.1; 11-22-48, 21.0; 3-21-49, 16.8; 11-18-49, 21.2.

15N E-30L1—Reference point—top of pump base, elevation 56.0 feet, 0.04 mile southwest of Garden Avenue, 0.25 mile northwest of Feather River Boulevard. 11-11-47, 18.2; 3-19-48, 16.8; 11-22-18, 18.8; 3-21-49, 16.0; 11-18-49, 21.2.

15N 4E-30L2—Reference point—hole in pump base, elevation 56.5 feet, 0.03 mile northwest of Feather River Boulevard, 0.08 mile southwest of Garden Avenue. 11-12-47, 18.2; 3-19-48, 17.3; 3-30-48, 17.0; 3-24-49, 16.7; 12-13-49, 20.7; 3-28-50, 7.0; 11-2-50, 21.7; 3-28-51, 10.2; 11/20-51, 18.2; 4-1-52, 9.8.

15N 4E-31K1—Reference point—hole in pump base, elevation 63.1 feet, 0.56 mile south of Earle Road, 0.33 mile west of Arboga Road. 12-10-47, 21.8; 3-2-48, 21.4; 3-30-48, 20.9; 11-22-48, 23.1; 3-17-49, 21.6; 11-23-49, 22.7.

15N 4E-31Q1—Reference point—hole in side of pump, elevation 57 feet, 0.34 mile west of Arboga Road, 2.20 miles north of Ella Road. 11-12-47, 23.0; 3/5/48, 21.4.

15N 4E-32D1—Reference point—hole in pump base, elevation 61.6 feet, 0.10 mile west of intersection of U. S. Highway 99E and Earle Road, 0.03 mile south of Earle Road. 12-10/47, 31.2; 3/2/48, 22.7; 3/30-48, 22.3; 11/22/48, 24.5; 3/18/49, 23.1; 11/23-49, 26.1; 11-2/50, 28.5.

15N 4E-32D2—Reference point—top of casing, elevation 62 feet, South side Pasado Avenue 0.13 mile west of U. S. Highway 99E. 3/19/48, 22.4; 11/22/48, 27.6; 3/28/50, 27.1.

15N 4E-32F1—Reference point—top of wood frame in concrete floor under pump, elevation 62.2 feet, 0.18 mile west of U. S. Highway 99E at a point 0.53 mile south of intersection with Earle Road. 12/10/47, 21.8; 3/2/48, 22.2; 3/30-48, 20.8; 5-14/48, 20.9; 11/22/48, 23.7; 11/23/49, 25.1.

15N 4E-32L1—Reference point—top of concrete under pump, elevation 64 feet, 0.06 mile east of Olivehurst Avenue at a point 0.03 mile from intersection with U. S. Highway 99E. 12/1/47, 30.7; 3/17/48, 22.8.

15N 4E-32M1—Reference point—top of casing, elevation 60 feet, 0.40 mile due west of intersection of Olivehurst Avenue and U. S. Highway 99E. 12/1/47, 22.1; 3/17/48, 22.3; 11/19/48, 24.4; 3/21-49, 23.5.

15N 4E-33D1—Reference point—top of casing, elevation 70.5 feet, 0.10 mile south of Earle Road, 0.80 mile east of intersection with U. S. Highway 99E. 12/10/47, 28.2; 3/1/48, 26.7; 11/22/49, 33.1.

15N 4E-33D2—Reference point—top of concrete pit, north wall, elevation 70.2 feet, 0.10 mile south of Earle Road, 0.85 mile west of Griffith Avenue. 12/10/47, 28.1; 3/2/48, 26.6; 3/31/48, 26.6; 10-8/48, 31.6; 11/22/48, 30.5; 3/17/49, 28.2; 11-22/49, 33.8; 3/24/50, 30.8; 4-4/52, 31.8.

15N 4E-33H1—Reference point—top of casing, elevation 64.0 feet, 0.05 mile west of Griffith Avenue, 0.46 mile south of Earle Road. 12/4/47, 26.8; 3/18/48, 25.5; 11-19/48, 29.3; 3/23/49, 27.5; 11-23/49, 32.6; 3/27/50, 30.3; 11-2/50, 34.9; 7/5/51, 29.5; 11/30/51, 34.9; 4/4/52, 30.3.

15N 4E-33R1—Reference point—top of casing, elevation 65 feet, 1.51 miles north of McGowan Road, 1 mile due east of U. S. Highway 99E. 12-1/47, 26.8; 3/8/48, 29.6; 11/19/48, 33.9; 3/23-49, 31.6; 11-23/49, 38.0.

15N 4E-34D1—Reference point—top of wooden floor of pump house, elevation 69.4 feet, South side of Earle Road, 0.10 mile east of Griffith Avenue. 12/10/47, 22.7; 10-8/48, 26.5; 11/22/48, 25.6; 3/17/49, 24.8; 11/22-49, 29.0; 3/30/51, 26.8; 11-21-51, 31.2; 4/4/52, 26.1.

15N 4E-35E1—Reference point—top of 6" x 6" sill, south wall, elevation 68.7 feet, 0.15 mile east of curve in Earle Road, 1.32 miles south of North Beale Road. 12/10-47, 23.4; 3/1/48, 13.8; 3-31-48, 13.6; 10-8/48, 26.1; 11-22-48, 26.5; 3/17-49, 26.1; 11/22/49, 30.2; 3-24-50, 29.8; 11-2-50, 32.4; 3/30-51, 30.4; 11-21-51, 35.2; 4-4-52, 32.6.

15N 4E-35Q1—Reference point—top of casing, elevation 72.2 feet, North side of Spenceville Road, 0.26 mile east of intersection with Earle Road. 12-4/47, 21.8; 3/18/48, 21.6; 11-18-48, 25.3; 3/23/49, 23.9.

15N 5E-19C1—Reference point—top of brick curb, elevation 86 feet, 1.20 miles south of Hammonton Road at a point 1.50 miles from intersection of Brophy Road. 11-22-29, 24.3; 9-6-30, 24.1; 12-14-31, 26.2; 12-9/32, 25.7; 12-11/33, 25.9; 11-20/34, 26.6; 11/28-36, 25.4; 1-9-41, 3.0; 11-6-47, 24.6; 12-10-48, 24.6; 12-7-49, 27.3; 11/10/50, 26.9.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Mode by Division of Woter Resources
(Depths to water in feet meosured from reference point)

15N/5E-19L1—Reference point—top of concrete crib, elevation 86 feet, 1.77 miles south of Hammonton Road at a point 1.40 miles from intersection of Brophy Road. 11/22/29, 25.8; 9/26/30, 25.5; 12/14/31, 26.5; 12/9/32, 26.7; 12/14/33, 27.4; 11/20/34, 27.6; 11/28/36, 26.2; 11/23/37, 27.1; 1/9/41, 3.0; 11/6/47, 30.9; 12/10/48, 33.4; 12/7/49, 37.0; 11/10/50, 39.6; 12/5/51, 69.7.

15N/5E-31R1—Reference point—top of casing, elevation 79.2 feet. North side of Spenceville Road, 2.43 miles east of intersection with Virginia Road. 12/24/47, 22.1; 3/24/48, 22.0; 11/18/48, 26.7; 1/18/48, 24.9; 3/21/49, 24.2; 12/5/49, 32.2; 3/27/50, 30.3; 11/2/50, 38.4; 4/2/51, 33.2; 4/4/52, 36.5.

15N/5E-32J1—Reference point—top of casing, elevation 91 feet, 0.26 mile north of Spenceville Road, 3.43 miles east of intersection with Virginia Road. 12/24/47, 33.9; 3/24/48, 33.7; 11/18/48, 36.0; 3/21/49, 36.1; 12/5/49, 43.5; 3/27/50, 42.1; 11/2/50, 50.6; 4/2/51, 45.6; 11/21/51, 48.6.

16N/2E-1B1—Reference point—top of casing, elevation 76.2 feet, 350 feet south of Pennington Road, 0.3 mile west of Township Road. 12/22/47, 10.1; 3/1/48, 10.4; 12/8/48, 9.6; 3/29/49, 8.0; 11/8/49, 9.4; 3/21/50, 8.8; 11/2/50, 9.7 3/27/51, 8.6; 11/13/51, 9.2; 4/2/52, 8.1.

16N/2E-1J1—Reference point—hole in pump flange, elevation 72.1 feet, 0.2 mile west of Township Road, 0.5 mile south of Pennington Road. 12/23/47, 7.2; 3/1/48, 7.4; 12/18/48, 6.9; 1/20/49, 6.5; 3/21/49, 4.0; 11/9/49, 6.6.

16N/2E-2A1—Reference point—top of concrete floor, elevation 74.2 feet, 300 feet south of Pennington Road, 0.15 mile west of Schroeder Road. 12/22/47, 8.1; 3/1/48, 8.6; 12/8/48, 7.7; 3/20/49, 6.1; 11/8/49, 6.1; 3/21/50, 7.3; 11/2/50, 6.9; 3/23/51, 7.2; 11/13/51, 7.3; 4/2/52, 6.6.

16N/2E-2J1—Reference point—top of casing, elevation 73.6 feet, 300 feet west of Schroeder Road, 0.75 mile south of Pennington Road. 12/23/47, 8.8; 3/1/48, 9.2; 12/8/48, 8.7; 3/21/49, 5.7; 11/9/49, 6.1.

16N/2E-3K1—Reference point—top of casing, elevation 71.0 feet, 0.50 mile south of Pennington Road, 0.50 mile west of Krehe Road. 11/26/29, 8.4; 10/21/30, 8.7; 12/16/31, 8.1; 12/9/32, 8.4; 12/13/33, 7.0; 11/21/34, 7.8; 11/27/36, 7.5; 12/1/37, 7.1; 1/25/39, 6.8; 1/10/41, 3.5; 11/4/47, 2.7; 12/14/48, 6.2; 11/8/49, 5.6; 11/10/50, 6.7; 11/26/51, 6.1.

16N/2E-4B1—Reference point—top of casing, elevation 73.7 feet, 0.30 mile south of Pennington Road, 1.27 miles west of Krehe Road. 12/22/47, 9.9; 3/2/48, 10.1; 12/3/48, 10.0; 3/30/49, 8.2; 11/15/49, 8.6.

16N/2E-5B1—Reference point—bottom of flange above discharge pipe, elevation 74.8 feet, 0.15 mile south of Pennington Road, 2.3 miles west of Krehe Road. 12/22/41, 6.8; 3/2/48, 6.7; 12/3/48, 9.2; 3/30/49, 10.0; 11/16/49, 8.0.

16N/2E-5L1—Reference point—top of casing, elevation 87.8 feet, 0.55 mile south-southeast of 90 degree turn in Pennington Road, 2.5 miles west of Krehe Road. 12/22/47, 12.8; 3/2/48, 12.8; 12/3/48, 13.6; 3/30/49, 12.0; 11/15/49, 14.0; 3/24/50, 12.8; 11/2/50, 16.1; 3/27/51, 12.9.

16N/2E-12J1—Reference point—top of casing, elevation 71.8 feet, 0.25 mile west of Township Road, 0.15 mile north of Paseo Avenue. 12/23/47, 8.5; 3/1/48, 8.6; 12/8/48, 8.4; 3/21/49, 4.0; 11/9/49, 8.0; 3/22/50, 7.3; 11/3/50, 8.0; 4/3/51, 7.1; 11/14/51, 7.8; 4/2/52, 7.0.

16N/2E-13G2—Reference point—top of casing, elevation 64.6 feet, 0.3 mile west of Township Road, 0.7 mile north of Clark Road. 12/23/47, 7.0; 3/1/48, 3.6; 12/8/48, 3.2; 3/21/49, —1.5; 11/10/49, 5.8; 3/22/50, 7.4.

16N/2E-24D1—Reference point—top of casing, elevation 66.4 feet, 100 feet south of Clark Road, 0.8 mile west of Township Road. 12/23/47, 8.9; 3/1/48, 8.0; 12/8/48, 7.7; 1/20/49, 8.5; 3/21/49, 6.1; 11/10/49, 4.5; 3/22/50, 8.2; 11/3/50, 8.1; 4/3/51, 36.2 (operating); 11/14/51, 8.2; 4/2/52, 6.6.

16N/2E-25P1—Reference point—top of casing, elevation 62.1 feet, 100 feet north of Sanders Road, 1.0 mile west of Broadway. 12/19/47, 9.7; 3/3/48, 10.5; 12/2/48, 9.2; 1/20/49, 10.0; 3/16/49, 8.8; 11/10/49, 7.7; 3/22/50, 9.2; 11/6/50, 8.2; 4/4/51, 8.6; 11/14/51, 8.3; 4/3/52, 6.9.

16N/2E-26K1—Reference point—top of casing, elevation 66.4 feet, 500 feet east of East Butte Road, 0.25 mile north of Sanders Road. 12/19/47, 14.7; 3/3/48, 14.5; 12/2/48, 13.5; 3/16/49, 13.3; 11/10/49, 10.8; 3/22/50, 11.9; 11/2/50, 12.8; 4/4/51, 11.9; 11/14/51, 12.4; 4/3/52, 9.2.

16N/2E-35B1—Reference point—top of casing, elevation 64 feet, 800 feet east of East Butte Road, 0.25 mile south of Sanders Road. 11/26/29, 12.0; 10/21/30, 11.5; 12/16/31, 13.0; 12/8/32, 12.1; 11/21/34, 12.2; 11/24/36, 12.7; 12/1/37, 11.0; 1/25/39, 12.0; 1/11/41, 6.7; 11/4/47, 1.0; 12/14/48, 12.1; 11/11/49, 10.3; 11/10/50, 11.1; 11/26/51, 11.6.

16N/2E-35C2—Reference point—top of casing (10 feet above ground), elevation 65 feet, 300 feet west of East Butte Road, 0.1 mile south of Sanders Road. 12/13/33, 16.3; 11/21/34, 16.9; 12/1/37, 14.5; 1/25/39, 16.2; 1/11/41, 9.8.

16N/3E-1E1—Reference point—top of casing at bottom of pit, ground elevation 80 feet, 0.1 mile east of State Highway 24, 0.6 mile north of Ramirez Road. 11/3/47, 12.5; 3/23/48, 9.4; 12/6/48, 11.2; 3/21/49, 9.4; 11/15/49, 13.4.

16N/3E-1E2—Reference point—base of pump, elevation 80 feet, 0.20 mile east of State Highway 24, 0.6 mile north of Ramirez Road. 11/3/47, 22.3; 3/23/48, 19.2; 12/6/48, 20.6; 3/21/49, 19.0; 11/15/49, 23.1; 3/21/50, 17.0; 11/7/50, 24.5; 3/29/51, 15.2; 11/15/51, 21.7; 4/6/52, 10.7.

16N/3E-1M1—Reference point—top of casing, elevation 78 feet, 500 feet east of State Highway 24, 0.3 mile north of Ramirez Road. 11/4/47, 21.2; 3/23/48, 18.5.

16N/3E-1P2—Reference point—base of pump, elevation 78 feet, 300 feet north of Ramirez Road, 0.60 mile east of State Highway 24. 11/4/47, 18.4; 3/23/48, 15.1; 12/2/48, 15.8; 3/21/49, 15.0; 11/15/49, 18.2; 3/2/50, 19.7; 3/29/51, 11.6; 11/15/51, 17.7; 4/6/52, 5.6.

16N/3E-2C1—Reference point—top of casing, elevation 80 feet, 0.60 mile west of State Highway 24, 0.70 mile north of Ramirez Road. 11/3/47, 21.6; 3/23/48, 18.0; 12/6/48, 20.5; 3/21/49, 18.5; 11/15/49, 22.6; 3/21/50, 16.2; 11/7/50, 22.4; 3/29/51, 14.0; 11/15/51, 21.0; 4/6/52, 10.3.

16N/3E-2J1—Reference point—top of casing, elevation 79 feet, 0.17 mile west of State Highway 24, 0.32 mile north of Ramirez Road. 6/1/48, 16.5; 6/30/48, 20.0; 7/21/48, 34.9; 9/1/48, 21.2; 9/30/48, 20.6; 12/3/48, 17.9; 3/21/49, 16.1.

16N/3E-4L1—Reference point—top of casing, elevation 75 feet, 30 feet west of Sheldon Road, 0.25 mile south of Archer Road. 11/10/47, 10.4; 3/20/48, 13.4; 12/3/48, 10.9; 3/8/49, 13.0; 11/9/49, 9.2.

16N/3E-4M1—Reference point—top of casing, elevation 79.2 feet, 50 feet east of Sinnard Road, 0.15 mile south of Archer Road. 12/23/47, 11.3; 3/1/48, 11.9; 12/3/48, 10.7; 3/21/49, 9.4; 11/9/49, 9.9.

16N/3E-4N1—Reference point—top of casing, elevation 76.9 feet, 100 feet south of Coleman Avenue, 0.05 mile west of Sinnard Road. 12/23/47, 9.9; 3/1/48, 10.8; 12/3/48, 9.2.

16N/3E-5A1—Reference point—top of casing, elevation 78.6 feet, 400 feet south of Pennington Road, 0.4 mile east of Larkin Road. 12/23/47, 10.7; 3/1/48, 11.0; 12/8/48, 10.5; 3/30/49, 9.0; 11/8/49, 10.1; 3/22/50, 8.1; 11/2/50, 11.1; 3/27/51, 8.3; 11/14/51, 10.6; 4/2/52, 7.5.

16N/3E-5P1—Reference point—hole in pump base, elevation 74.0 feet, 0.15 mile west of Larkin Road, 1.0 mile north of Paseo Road. 5/4/48, 8.9; 6/2/48, 8.7; 6/30/48, 49.9 (operating); 12/4/48, 11.5; 3/21/49, 5.4; 4/3/51, 7.7.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

16N 3E-6A1—Reference point—top of casing, elevation 77.9 feet. South side of Pennington Road, 0.8 mile east of Township Road. 12/22/47, 12.1; 3/1/48, 11.4; 5/13/48, 10.0; 12/8/48, 12.3; 1/21/49, 11.4; 3/30/49, 8.0; 11/8/49, 12.6; 3/22/50, 8.6; 11/2/50, 13.6; 3/27/51, 7.5; 11/13/51, 12.8; 4/2/52, 5.2.

16N 3E-7D2—Reference point—top of casing, elevation 73.5 feet, 0.1 mile east of Township Road, 0.65 mile north of Paseo Avenue. 12/23/47, 10.1; 3/1/48, 9.8; 12/8/48, 9.5; 3/21/49, 3.6; 11/9/49, 9.2; 3/22/50, 8.0; 11/3/50, 10.0; 4/3/51, 7.4; 11/14/51, 8.7; 4/2/52, 7.0.

16N 3E-8C1—Reference point—top of curb, elevation 74.1 feet, 0.2 mile west of Larkin Road, 0.75 mile north of Paseo Avenue. 12/23/47, 8.9; 3/1/48, 9.1; 12/4/48, 9.1; 3/21/49, 5.4; 11/9/49, 6.9; 3/22/50, 5.5; 11/3/50, 9.9; 4/3/51, 6.3; 11/14/51, 8.9; 4/2/52, 2.9.

16N 3E-8P1—Reference point—top of casing, elevation 72.0 feet, 200 feet north of Paseo Avenue, 0.15 mile west of Larkin Road. 12/23/47, 8.8; 3/1/48, 9.0; 12/4/48, 8.7; 3/21/49, 5.5; 11/9/49, 7.3.

16N 3E-8R1—Reference point—top of casing, elevation 71 feet, 160 feet north of Paseo Avenue, 400 feet east of U. S. Highway 99E. 1/10/41, 3.1; 11/5/47, 7.6; 12/5/47, 9.2; 12/13/48, 9.3; 11/9/49, 7.1; 3/22/50, 8.7; 11/10/50, 9.4; 4/2/51, 7.2; 11/26/51, 7.8.

16N 3E-8R2—Reference point—top of casing, elevation 71 feet, 100 feet north of Paseo Avenue, 300 feet east of U. S. Highway 99E. 1/23/29, 8.8; 9/27/30, 8.3; 12/16/31, 9.3; 12/9/32, 9.3; 12/13/33, 8.9; 11/21/34, 7.3; 1/24/36, 8.4; 12/1/37, 7.3; 1/26/39, 10.3.

16N 3E-9A1—Reference point—top of casing, elevation 72 feet, 1,500 feet north of Bishop Road, 100 feet east of Levee. 11/10/47, 14.9; 3/20/48, 17.1; 12/3/48, 16.0; 3/8/49, 17.4; 11/9/49, 13.7; 3/22/50, 10.0; 11/3/50, 13.8; 4/2/51, 11.0; 11/14/51, 14.5; 4/3/52, 11.7.

16N 3E-9M1—Reference point—top of casing, elevation 71 feet, 400 feet east of Simard Road, 0.3 mile north of Paseo Avenue. 3/20/48, 11.5; 12/3/48, 10.8; 3/8/49, 11.3; 11/9/49, 8.7; 3/22/50, 9.1; 11/3/50, 9.0; 4/2/51, 7.3; 11/14/51, 8.8; 4/3/52, 5.9.

16N 3E-9Q1—Reference point—top of casing, elevation 75 feet, 60 feet west of Kent Avenue, 150 feet north of Paseo Avenue. 11/10/47, 16.1; 3/20/48, 19.1; 5/13/48, 13.1; 12/3/48, 18.6; 3/8/49, 18.2; 11/8/49, 17.2.

16N 3E-11C1—Reference point—base of pump, elevation 79 feet, 0.50 mile west of State Highway 24 on Ramirez Road extension. 11/4/47, 21.2; 3/23/48, 18.9; 5/7/48, 16.6; 12/3/48, 19.9; 1/26/49, 19.4; 3/21/49, 19.0; 11/15/49, 22.1; 3/21/50, 18.1; 11/7/50, 22.6; 3/29/51, 14.4; 11/15/51, 20.8; 4/6/52, 10.6.

16N 3E-11E1—Reference point—top of casing, elevation 78 feet, 0.75 mile west of State Highway 24, 0.45 mile south of Ramirez Road. 11/5/47, 21.2; 3/23/48, 18.3; 12/3/48, 20.7; 3/21/49, 17.6; 11/15/49, 21.6.

16N 3E-11F1—Reference point—top of casing, elevation 77 feet, 0.50 mile west of State Highway 24, 0.35 mile south of Ramirez Road. 11/5/47, 20.6; 3/23/48, 18.6; 12/3/48, 19.1; 3/21/49, 17.0; 11/15/49, 21.1.

16N 3E-11F2—Reference point—base of pump, elevation 76 feet, 0.50 mile west of State Highway 24, 0.30 mile south of Ramirez Road. 11/5/47, 19.8; 3/23/48, 17.5; 12/3/48, 19.2; 3/21/49, 15.2; 11/15/49, 20.3.

16N 3E-11K1—Reference point—base of pump, elevation 76 feet, 0.20 mile west of State Highway 24, 0.70 mile south of Ramirez Road. 11/5/47, 19.8; 3/23/48, 20.6; 12/3/48, 18.0; 3/18/49, 16.5; 11/15/49, 19.4.

16N 3E-11L1—Reference point—top of casing, elevation 76 feet, 0.40 mile west of State Highway 24, 0.7 mile south of Ramirez Road. 11/5/47, 18.0; 3/23/48, 16.2; 12/3/48, 16.4; 3/18/49, 14.6; 11/15/49, 17.8.

16N 3E-11Q1—Reference point—top of casing, elevation 75 feet, 750 feet west of State Highway 24, 0.9 mile south of Ramirez Road. 11/5/47, 10.1; 12/3/48, 9.5; 3/18/49, 7.0; 11/15/49, 10.0.

16N 3E-12B1—Reference point—top of casing, elevation 79 feet, 20 feet south of Ramirez Road, 0.70 mile east of State Highway 24. 11/4/47, 16.4; 3/23/48, 14.5; 5/7/48, 13.1; 12/2/48, 14.5; 1/25/49, 14.2; 3/21/49, 13.0; 11/15/49, 16.7.

16N 3E-12B2—Reference point—top of casing, elevation 79 feet, 750 feet south of Ramirez Road, 0.75 mile east of State Highway 24. 11/4/47, 9.4; 3/23/48, 7.4; 12/2/48, 7.2; 3/21/49, 5.6; 11/15/49, 8.6.

16N/3E-12E1—Reference point—top of casing at bottom of pit, elevation 76 feet, 0.3 mile east of State Highway 24, 0.6 mile south of Ramirez Road. 11/5/47, 10.2; 3/23/48, 7.6; 12/6/48, 9.5; 3/18/49, 7.5; 11/15/49, 10.3; 3/21/50, 15.3; 11/7/50, 20.6*; 3/29/51, 11.9; 11/15/51, 18.2*; 4/6/52, 6.4*.

16N/3E-12L2—Reference point—top of casing, elevation 76 feet, 0.6 mile east of State Highway 24, 0.6 mile south of Ramirez Road. 11/7/47, 11.3; 3/23/48, 9.2; 12/6/48, 5.4; 3/18/49, 8.0; 11/15/49, 10.1.

16N/3E-13G1—Reference point—top of casing, elevation 72 feet, 2,600 feet north of Magnon Way, 4,300 feet east of State Highway 24. 11/7/47, 14.6; 3/25/48, 13.8; 12/10/48, 13.7; 11/16/49, 14.7; 3/21/50, 13.6; 11/7/50, 18.1; 3/29/51, 9.1; 4/6/52, 5.5.

16N/3E-14B1—Reference point—top of casing, elevation 75 feet, 500 feet west of State Highway 24, 1.2 miles south of Ramirez Road. 11/5/47, 9.2; 3/23/48, 8.1; 5/7/48, 5.8; 12/3/48, 7.8; 3/18/49, 6.1; 11/15/49, 9.3; 3/21/50, 10.0; 11/7/50, 10.3; 3/29/51, 1.7; 11/15/51, 7.9; 4/6/52, 3.7.

16N/3E-14C1—Reference point—top of casing, elevation 74 feet, 1.2 miles south of Ramirez Road, 0.4 mile west of State Highway 24. 11/5/47, 9.75; 3/25/48, 9.1; 12/3/48, 6.8; 3/18/48, 6.8; 11/15/49, 9.9.

16N/3E-14D1—Reference point—top of casing, elevation 72 feet, 1.2 miles south of Ramirez Road, 0.5 mile west of State Highway 24. 11/5/47, 9.9; 3/23/48, 10.7; 5/7/48, 5.8; 12/3/48, 8.9; 1/26/49, 7.9; 3/18/49, 7.0; 11/15/49, 10.2; 3/21/50, 13.9; 11/7/50, 11.2; 3/29/51, 9.4; 11/15/51, 15.8.

16N/3E-14J1—Reference point—hole in front of base of pump, elevation 71 feet, 600 feet north of Magnolia Way, 950 feet east of State Highway 24. 11/8/47, 16.1; 3/25/48, 14.8; 12/3/48, 15.3; 3/18/49, 13.1; 11/16/49, 16.5.

16N/3E-14L1—Reference point—top of casing at bottom of 12-foot pit, elevation 59 feet, 0.5 mile west of State Highway 24, 1.5 miles south of Ramirez Road. 11/8/47, 6.7; 3/25/48, 5.1; 12/3/48, 5.3; 3/18/49, 5.1; 11/16/49, 7.3; 3/21/50, 3.2; 11/7/50, 7.8; 3/29/51, 12.0*; 11/15/51, 18.8*; 4/6/52, 6.0.

16N/3E-16M1—Reference point—top of concrete block, elevation 70 feet, 900 feet south of Cutting Avenue, 300 feet east of U. S. Highway 99E. 11/10/47, 7.65; 3/20/48, 11.7; 12/3/48, 8.9.

16N/3E-17C1—Reference point—top of flange under pump, elevation 72.4 feet, 400 feet east of Larkin Road, 0.8 mile north of Clark Road. 12/23/47, 8.7; 3/1/48, 8.8; 12/4/48, 7.7, 3/21/49, 6.5; 11/9/49, 7.8; 3/22/50, 7.6; 11/3/50, 8.9; 4/3/51, 7.5; 11/14/51, 8.2; 4/2/52, 6.9.

16N/3E-17Q1—Reference point—top of concrete pit, elevation 70.5 feet, 0.2 mile east of Larkin Road, 500 feet north of Clark Road. 12/23/47, 9.3; 3/2/48, 10.1; 5/4/48, 8.0; 6/1/48, 7.0; 12/1/48, 9.4; 1/20/49, 9.8; 3/21/49, 7.5; 5/26/49, 7.0; 6/30/49, 5.6; 7/31/49, 6.2; 8/31/49, 6.5; 11/10/49, 8.7; 3/22/50, 8.9; 11/3/50, 8.8; 4/3/51, 6.8; 11/14/51, 7.9; 4/3/52, 5.4.

* Top of pit.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

16N/3E-18C1—Reference point—top of casing, elevation 68.3 feet, 100 feet south of Pasco Avenue, 100 feet west of Broadway. 12/23/47, 6.4; 3/1/48, 6.3; 12/4/48, 8.3; 1/20/49, 6.2; 3/21/49, 4.1.

16N/3E-19C1—Reference point—top of casing, elevation 66.8 feet, 250 feet west of Broadway, 0.1 mile south of Clark Road. 12/23/47, 7.1; 3/2/48, 7.2; 12/4/48, 6.8; 3/21/49, 4.7; 11/10/49, 5.5; 3/22/50, 8.6; 11/3/50, 6.3; 4/3/51, 6.4; 11/14/51, 6.7; 4/2/52, 5.7.

16N/3E-20E1—Reference point—slot in concrete base, elevation 69.8 feet, 200 feet west of Marden Avenue, 0.2 mile south of Clark Road. 12/23/47, 10.4; 3/24/48, 11.3; 12/4/48, 10.2; 3/21/49, 8.1; 5/26/49, 7.5; 6/28/49, 7.8; 7/27/49, 9.3; 8/25/49, 8.7; 11/10/49, 9.7; 3/22/50, 10.0; 11/3/50, 9.3; 4/3/51, 9.6; 11/14/51, 10.3; 4/2/52, 9.2.

16N/3E-21D1—Reference point—hole in base of pump, elevation 70 feet, 200 feet south of Clark Road, 0.6 mile east of Larkin Road. 12/23/47, 10.7; 3/2/48, 11.4; 12/3/48, 10.3; 11/8/49, 10.3; 3/22/50, 9.6; 11/3/50, 10.3; 4/3/51, 6.4; 11/4/51, 9.2; 4/3/52, 4.0.

16N/3E-21J1—Reference point—top of casing, elevation 68.0 feet, 0.4 mile east of U. S. Highway 99E, 0.3 mile north of Encinal Road. 11/10/47, 17.9; 3/20/48, 16.4; 5/13/48, 13.3; 12/3/48, 17.5; 1/21/49, 17.0; 3/8/49, 16.8; 11/10/49, 18.6; 3/22/50, 17.2; 4/3/51, 10.5; 11/14/51, 16.5; 4/3/52, 5.2.

16N/3E-21P2—Reference point—top of casing, elevation 65.9 feet, West side of Southern Pacific Railroad Right of Way, 0.1 mile north of Encinal Road. 12/23/47, 14.5; 3/2/48, 15.3; 12/3/48, 14.1; 3/21/49, 13.0; 11/10/49, 15.3.

16N/3E-23C1—Reference point—top of casing, elevation 71 feet, 0.25 mile west of State Highway 24 at a point 0.4 mile south of Magnolia Way intersection. 11/8/47, 17.2; 3/25/48, 15.9; 5/19/48, 13.9; 12/2/48, 15.9; 1/26/49, 15.5; 3/8/49, 13.0.

16N/3E-23J1—Reference point—top of casing, elevation 70 feet, 0.1 mile east of State Highway 24, 0.3 mile north of Woodruff Lane. 11/8/47, 14.3; 3/25/48, 13.1; 5/19/48, 11.9; 12/2/48, 14.6; 3/18/49, 13.0; 11/16/49, 15.1.

16N/3E-23R3—Reference point—center of pump shaft, elevation 70 feet, 200 feet north of Woodruff Lane, 0.3 mile east of State Highway 24. 11/8/47, 14.0; 3/25/48, 13.0; 12/2/48, 13.0; 3/18/49, 11.5; 11/16/49, 13.9.

16N/3E-24A1—Reference point—top of casing, elevation 70 feet, 0.2 mile south of Magnolia Way extended 1.1 miles east of State Highway 24. 11/7/47, 13.8; 3/25/48, 13.5; 12/2/48, 13.7; 1/26/49, 14.4; 3/18/49, 11.1; 11/16/49, 14.5; 3/21/50, 12.1; 11/6/50, 15.8; 3/29/51, 9.4; 11/15/51, 15.1; 4/6/52, 6.0.

16N/3E-24C1—Reference point—top of casing, elevation 70 feet, 0.4 mile south of Magnolia Way, 0.75 mile east of State Highway 24. 11/7/47, 12.3; 3/25/48, 11.7; 12/10/48, 12.1; 3/18/49, 9.8; 11/16/49, 13.2.

16N/3E-24Q1—Reference point—top of casing in pit, elevation 66 feet, North of Woodruff Lane, 1.05 miles east of State Highway 24. 11/7/47, 4.2; 3/25/48, 4.2; 5/19/48, 2.9; 11/30/48, 4.6; 11/16/49, 11.8; 3/21/50, 8.8; 11/6/50, 12.8; 3/29/51, 6.9; 11/15/51, 17.3; 9/6/52, 5.0.

16N/3E-24R2—Reference point—hole in pump base, elevation 69 feet, 0.1 mile north of Woodruff Lane, 0.1 mile east of State Highway 24. 6/2/48, 11.8; 7/1/48, 15.2; 7/21/48, 15.5; 8/1/48, 18.1; 9/2/48, 17.3.

16N/3E-26F1—Reference point—hole in pump base, elevation 69 feet, 0.45 mile west of State Highway 24, at a point 0.3 mile south of Woodruff Lane intersection. 11/15/47, 18.0; 5/3/48, 12.3; 6/1/48, 13.2; 11/30/48, 18.2; 12/13/48, 18.1; 1/26/49, 15.5; 3/18/49, 14.1; 12/9/49, 18.7; 3/21/50, 14.0; 11/6/50, 17.8; 11/10/50, 18.6; 3/29/51, 10.1; 11/15/51, 17.4; 12/7/51, 14.7; 4/6/52, 5.9.

16N/3E-26F2—Reference point—top of concrete pit, elevation 68 feet, 0.5 mile west of State Highway 24, at a point 0.3 mile south of Woodruff Lane intersection. 11/26/29, 15.9; 9/25/30, 15.6; 12/16/31, 16.7; 12/6/32, 16.8; 12/14/33, 16.5; 11/23/34, 16.9; 11/24/36, 15.8; well destroyed.

16N/3E-26G1—Reference point—hole in pump base, elevation 68 feet, 0.25 mile west of State Highway 24 at a point 0.3 mile south of Woodruff Lane intersection. 5/7/48, 12.2; 6/30/48, 52.6 (operating); 11/30/48, 13.6.

16N/3E-26G2—Reference point—top of casing, elevation 68 feet, 0.15 mile west of State Highway 24, at a point 0.3 mile south of Woodruff Lane intersection. 12/1/37, 11.0; 1/27/39, 9.4; 1/10/41, 6.5.

16N/3E-27E1—Reference point—top of casing, elevation 66 feet, 0.1 mile north of Morse Road, 0.4 mile east of U. S. Highway 99E. 3/17/48, 21.9; 11/29/48, 23.7; 3/17/49, 20.0; 5/26/49, 20.5; 6/28/49, 24.5; 7/27/49, 25.1; 8/25/49, 26.2; 11/14/49, 25.2.

16N/3E-28C1—Reference point—top of concrete pit, elevation 65 feet, 0.05 mile south of Encinal Road, 0.1 mile west of U. S. Highway 99E. 3/17/48, 14.2; 11/29/48, 14.6; 3/17/49, 13.7; 11/14/49, 15.5.

16N/3E-28E1—Reference point—top of casing, elevation 65 feet, 0.25 mile south of Encinal Avenue, 0.35 mile west of U. S. Highway 99E. 11/4/47, 17.5.

16N/3E-28N1—Reference point—top of casing, elevation 64.6 feet, 200 feet north of Sanders Road, 0.6 mile east of Larkin Road. 12/19/47, 17.2; 11/29/48, 17.5; 3/17/49, 15.8; 11/10/49, 18.6; 3/22/50, 15.9; 11/3/50, 18.9; 4/3/51, 11.2; 11/14/51, 16.6; 4/3/52, 7.6.

16N/3E-29B1—Reference point—top of concrete pit, elevation 66.8 feet, South side of Encinal Road, 0.2 mile east of Larkin Road. 12/23/47, 12.8; 3/2/48, 13.6; 5/13/48, 11.5; 12/4/48, 13.0; 1/19/49, 13.0.

16N/3E-29N1—Reference point—top of concrete pit, elevation 65.8 feet, 0.25 mile west of Sacramento Northern Railroad tracks, 0.25 mile north of Sanders Road. 12/19/47, 15.3; 3/2/48, 15.2; 12/1/48, 14.3; 3/16/49, 14.0; 1/10/49, 14.7; 3/22/50, 13.2; 11/3/50, 14.5; 4/3/51, 9.6; 11/14/51, 12.4; 4/3/52, 7.3.

16N/3E-29R1—Reference point—hole in pump base, elevation 62 feet, 150 feet north of Sanders Road, 0.4 mile east of Larkin Road. 5/4/48, 17.3; 6/1/48, 16.1; 11/29/48, 19.6.

16N/3E-30A2—Reference point—top of casing, elevation 68.8 feet, 0.1 mile south of Encinal Road, 0.35 mile east of Broadway. 12/23/47, 12.1; 3/2/48, 12.8; 12/4/48, 11.9; 3/21/49, 11.4; 11/10/49, 11.0.

16N/3E-30F1—Reference point—top of pit wall, elevation 64.3 feet, 0.1 mile west of Broadway, 0.45 mile south of Encinal Road. 12/23/47, 11.1; 3/2/48, 11.6; 12/4/48, 10.8; 1/19/49, 10.7; 3/21/49, 9.0; 11/10/49, 10.5; 3/22/50, 10.1; 11/3/50, 10.7; 4/3/51, 9.2; 11/14/51, 10.8; 4/3/52, 6.7.

16N/3E-30L1—Reference point—top of casing next to pump, elevation 62.5 feet, 0.4 mile north of Sanders Road, 400 feet west of Broadway. 12/19/47, 8.9; 3/2/48, 9.5; 12/1/48, 8.7; 3/16/49, 8.8; 11/10/49, 7.8.

16N/3E-30R1—Reference point—top of casing next to pump, elevation 62.5 feet, 500 feet north of Sanders Road, 0.5 mile west of Sacramento Northern Railroad. 12/19/47, 12.9; 3/2/48, 12.6.

16N/3E-31D1—Reference point—top of casing under pump, elevation 60.4 feet, 500 feet south of Sanders Road, 0.2 mile west of Broadway Road. 12/19/47, 9.1; 3/3/48, 9.7; 3/16/49, 9.5.

16N/3E-31K2—Reference point—top of tin cover under pump, elevation 63.2 feet, 0.2 mile east of Broadway Road, 0.5 mile south of Sanders Road. 12/19/47, 13.7; 3/3/48, 14.1; 12/1/48, 17.3; 3/16/49, 16.4; 11/11/49, 18.3; 3/22/50, 15.2; 11/6/50, 19.3; 4/3/51, 12.1; 11/14/51, 16.6; 4/3/52, 17.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

16N 3E-32A2—Reference point—pump base hole, elevation 64.9 feet, 200 feet south of Sanders Road, 0.6 mile east of Sacramento Northern Railroad. 1/6/48, 19.5; 3/2/48, 19.7; 11/29/48, 21.0; 3/17/49, 17.0; 11/10/49, 19.8.

16N 3E-32B2—Reference point—top of 2" x 14" bridge over earth pit, elevation 64.4 feet, 200 feet south of Sanders Road, 0.3 mile east of Sacramento Northern Railroad. 12/19/47, 15.9; 3/2/48, 17.25; 12/1/48, 16.2; 3/17/49, 15.0; 11/10/49, 17.7.

16N 3E-32C2—Reference point—top of casing under pump, elevation 64.4 feet, 0.2 mile south of Sanders Road, 200 feet west of Sacramento Northern Railroad. 12/19/47, 18.1; 3/2/48, 18.7; 12/1/48, 16.9; 3/17/49, 16.1; 11/11/49, 18.5; 3/22/50, 15.9; 11/3/50, 18.2; 4/3/51, 11.3; 11/14/51, 16.1; 4/3/52, 6.4.

16N 3E-32G2—Reference point—hole in pump base, elevation 62.8 feet, 0.5 mile south of Sanders Road, 0.3 mile east of Sacramento Northern Railroad. 12/19/47, 18.9; 3/2/48, 20.2; 12/1/48, 16.9; 3/17/49, 16.8; 11/11/49, 19.8.

16N 3E-33D1—Reference point—top of concrete base, elevation 61.2 feet, 100 feet south of Sanders Road at a point 0.55 mile west of U. S. Highway 99E. 11/4/47, 17.2; 11/29/48, 19.2; 1/20/49, 17.2; 3/17/49, 16.8; 5/26/49, 17.1; 6/28/49, 19.3; 7/27/49, 26.15; 8/25/49, 25.9; 11/14/49, 20.0.

16N 3E-33E1—Reference point—top of concrete base under pump, elevation 64.1 feet, 0.3 mile south of Sanders Road at a point 0.8 mile west of U. S. Highway 99E. 11/4/47, 17.6; 3/17/48, 21.3; 5/13/48, 15.6; 11/29/48, 17.3; 11/14/49, 18.7; 3/22/50, 16.0; 11/6/50, 19.1; 4/3/51, 11.6; 4/3/52, 7.6.

16N 3E-33J2—Reference point—edge of pump base, elevation 66 feet, 150 feet west of U. S. Highway 99E at a point 0.45 mile north of Eager Road. 5/12/48, 20.3; 11/29/48, 27.0; 1/20/49, 23.0; 3/17/49, 22.0; 11/14/49, 27.3; 3/22/50, 22.0; 11/6/50, 25.4; 4/3/51, 17.2.

16N 3E-33P1—Reference point—hole beneath pump base, elevation 61.9 feet, 250 feet north of Eager Road at a point 0.6 mile west of U. S. Highway 99E. 1/9/48, 22.9; 11/22/48, 22.6; 3/17/49, 22.5; 11/14/49, 25.5.

16N 3E-35G1—Reference point—top of volute plug, elevation 67 feet, 400 feet north of Ellis Road at a point 0.5 mile west of State Highway 24. 11/6/47, 17.1; 1/26/49, 14.7; 3/18/49, 18.0; 11/16/49, 22.3.

16N 3E-35J1—Reference point—top of casing, elevation 70 feet, 100 feet south of Ellis Road at a point 0.2 mile west of State Highway 24. 11/6/47, 18.7; 3/29/48, 17.7; 11/30/48, 19.0; 3/17/49, 17.0; 11/16/49, 20.2.

16N 3E-35L1—Reference point—top of air gage hole, elevation 65 feet, 0.2 mile south of Ellis Road at a point 0.7 mile west of State Highway 24. 11/6/47, 20.2; 3/20/48, 20.1; 11/30/48, 20.9; 3/17/49, 20.1; 11/16/49, 22.9; 3/21/50, 17.4; 11/6/50, 22.9; 3/29/51, 19.5; 11/15/51, 23.5; 4/6/52, 10.1.

16N 3E-36G1—Reference point—top of concrete base under pump, elevation 64 feet, 300 feet north of Bills Road at a point 0.5 mile east of State Highway 24. 11/5/47, 11.7; 3/29/48, 11.4; 5/7/48, 10.0; 11/30/48, 12.2; 3/18/49, 9.6; 11/16/49, 12.1; 3/21/50, 11.1; 11/6/50, 12.7; 3/29/51, 6.7; 11/15/51, 11.8; 4/6/52, 4.6.

16N 4E-4L1—Reference point—top of concrete cribbing, elevation 96 feet, 0.15 mile west of La Porte Road, 0.30 mile north of Ramirez Road. 11/19/47, 22.4; 3/15/48, 22.8; 12/1/48, 23.1; 3/23/49, 24.0; 3/22/50, 24.9; 10/31/50, 26.7; 3/28/51, 23.5.

16N 4E-4N1—Reference point—top of casing, elevation 94 feet, 10.0 feet north of Ramirez Road, 0.05 mile east of Loma Rica Road. 3/15/48, 10.8.

16N 4E-5G1—Reference point—top of concrete cribbing, elevation 91 feet, 0.15 mile north of Ramirez Road, 0.5 mile west of Loma Rica Road. 11/19/47, 19.4; 3/15/48, 19.4; 12/1/48, 20.9; 3/23/49, 18.0; 12/9/49, 22.5; 3/22/50, 20.6; 10/31/50, 24.9; 3/28/51, 19.2; 11/14/51, 23.4; 4/6/52, 23.4.

16N 4E-6H1—Reference point—base of pump, elevation 85 feet, 0.50 mile north of Ramirez Road, 1.0 mile west of Loma Rica Road. 11/4/47, 17.8; 11/18/47, 17.2; 3/15/48, 17.6; 3/23/48, 17.4; 12/1/48, 18.1; 12/2/48, 19.0; 1/26/49, 17.1; 3/21/49, 16.2; 11/15/49, 20.7; 3/22/50, 17.6; 3/29/51, 16.7.

16N 4E-6J1—Reference point—top of casing, elevation 86 feet, 0.25 mile north of Ramirez Road, 1.0 mile west of Loma Rica Road. 11/4/47, 19.4; 11/19/47, 19.2; 3/15/48, 19.2; 3/23/48, 19.2; 12/1/48, 19.4; 12/2/48, 20.0; 3/21/49, 18.1; 11/15/49, 22.6; 3/21/50, 20.0; 3/22/50, 20.0; 11/7/50, 23.8; 11/15/51, 22.7; 4/6/52, 16.5.

16N 4E-6N1—Reference point—top of casing, elevation 80 feet, 30 feet north of Ramirez Road, 1.1 miles east of State Highway 24. 11/4/47, 16.9; 3/23/48, 15.5; well destroyed.

16N 4E-7B1—Reference point—top of casing, elevation 82 feet, 200 feet south of Ramirez Road, 1.5 miles west of Loma Rica Road. 11/4/47, 16.6; 3/23/48, 15.5; 12/2/48, 17.0; 3/21/49, 16.1; 11/15/49, 18.6.

16N 4E-8A1—Reference point—hole in pump base, elevation 91 feet, 150 feet south of Ramirez Road, 0.15 mile west of Loma Rica Road. 11/19/47, 18.8; 3/15/48, 20.0; 5/7/48, 17.5; 3/23/49, 17.8; 6/7/49, 40.5; 7/3/49, 37.3; 8/2/49, 37.6; 11/15/49, 22.0; 3/22/50, 19.8; 10/31/51, 18.9; 11/14/51, 23.0; 11/27/51, 22.6; 4/6/52, 18.0.

16N 4E-8A2—Reference point—top of casing, elevation 94 feet. South side of Ramirez Road, 0.15 mile west of Loma Rica Road. 11/26/29, 18.4; 9/25/30, 17.6; 12/14/31, 19.5; 12/6/32, 19.2; 12/14/33, 19.6; 11/23/34, 19.8; 11/24/36, 18.1; 11/23/37, 17.8; 11/27/39, 15.7; 1/9/41, 16.8; 11/5/47, 18.1; 12/13/48, 21.0; 12/9/49, 22.1; 11/10/50, 23.6.

16N 4E-9J1—Reference point—top of casing, elevation 95 feet, 200 feet west of Bangor Road, 0.6 mile south of Ramirez Road. 11/19/47, 23.2; 3/15/48, 23.4; 12/1/48, 24.0; 3/23/49, 21.8; 11/15/49, 26.6.

16N 4E-10E1—Reference point—top of casing at bottom of pit, elevation 80 feet, 400 feet east of Bangor Road, 0.35 mile south of Ramirez Road. 3/15/48, 2.4; 12/1/48, 3.4; 3/23/49, 2.6.

16N 4E-16A1—Reference point—hole in 4" x 4" board support, elevation 90 feet, 0.1 mile east of Bangor Road, 1.1 mile south of Ramirez Road. 11/19/47, 19.8; 3/15/48, 20.5; 5/7/48, 19.6; 12/1/48, 20.0; 3/23/49, 20.0; 11/17/49, 23.6; 3/23/50, 21.9; 10/31/50, 25.3; 3/28/51, 21.4; 11/14/51, 24.7; 4/6/52, 20.6.

16N 4E-16E1—Reference point—hole in pump base, elevation 81 feet, 100 feet east of Loma Rica Road, 1.25 miles south of Ramirez Road. 11/19/47, 13.0; 3/15/48, 9.3; 12/1/48, 13.6; 3/23/49, 11.8; 11/17/49, 16.5; 3/23/50, 14.5; 3/28/51, 13.1; 11/14/51, 14.6; 4/6/52, 10.8.

16N 4E-21M1—Reference point—top of casing, elevation 75 feet, 0.1 mile east of Loma Rica Road, 0.15 mile south of Bangor Road. 11/19/47, 5.6; 3/15/48, 6.5; 12/1/48, 6.2; 3/23/49, 4.0.

16N 4E-25M1—Reference point—top of concrete floor at bottom of pit, elevation 89 feet, 0.1 mile south of State Highway 20, 1.50 miles east of Loma Rica Road. 11/26/47, 2.8; 3/3/48, 5.0.

16N 4E-26F1—Reference point—top of casing, elevation 91 feet, 0.20 mile north of State Highway 20, 0.85 mile east of Loma Rica Road. 11/26/47, 16.5; 3/3/48, 17.4; 11/29/48, 16.9; 3/23/49, 17.2; 11/18/49, 17.8.

16N 4E-27F1—Reference point—bottom of 90° elbow on suction pipe, elevation 93.6 feet, 600 feet north of Woodruff Lane, 0.20 mile west of Loma Rica Road. 11/26/47, 7.3; 11/18/49, 8.4.

16N 4E-27M1—Reference point—top of casing, elevation 89 feet, 150 feet south of Woodruff Lane, 0.2 mile west of State Highway 20. 12/6/32, 6.4; 12/14/33, 6.9; 11/23/34, 6.9; 11/28/36, 5.6; 11/23/37, 11.6 (operating); 1/9/41, 2.7.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

16N/4E-27N1—Reference point—top of casing, elevation 89.9 feet, 500 feet north of State Highway 20, 0.30 mile south of Woodruff Lane. 11/27/29, 10.9; 9/25/30, 8.3; 12/14/31, 11.3; 1/9/41, 4.8; 11/5/47, 7.5; 11/26/47, 4.9; 3/3/48, 13.7; 11/29/48, 11.2; 12/13/48, 12.0; 3/23/49, 11.0; 11/18/49, 10.2; 12/9/49, 11.7; 3/23/50, 12.5; 10/31/50, 8.8; 3/30/51, 10.7; 11/14/51, 10.5; 11/27/51, 11.8; 4/6/52, 8.2.

16N/4E-28B1—Reference point—top of casing, elevation 89.4 feet, 0.25 mile north of Woodruff Lane, 0.60 mile east of Kimball Lane. 11/26/47, 13.3; 3/3/48, 16.1; 11/29/48, 13.7; 3/23/49, 12.2; 11/18/49, 12.8.

16N/4E-28E1—Reference point—top of 90° elbow, elevation 80.9 feet, 0.20 mile north of Woodruff Lane, 0.15 mile east of Kimball Lane. 11/26/47, 9.7; 3/3/48, 10.8; 11/29/48, 10.2; 3/23/49, 7.0; 11/18/49, 9.5; 3/23/50, 10.0; 10/31/50, 8.2; 3/30/51, 9.7; 11/14/51, 9.1; 4/6/52, 7.9.

16N/4E-29B1—Reference point—top of casing, elevation 78.1 feet, 500 feet west of Mathews Lane, 0.35 mile north of Woodruff Lane. 11/26/47, 8.7; 3/3/48, 9.6; 5/7/48, 8.1; 11/29/48, 9.3; 3/23/49, 7.2; 11/17/49, 9.5; 10/31/50, 9.0.

16N/4E-33B1—Reference point—top of casing, elevation 83 feet, 200 feet north of West Hallwood Road, 0.6 mile west of State Highway 20. 11/26/47, 7.7; 3/3/48, 10.6; 11/30/48, 8.5; 3/23/49, 13.0; 11/15/49, 7.9.

16N/4E-33J1—Reference point—top of casing, elevation 88.7 feet, 200 feet east of State Highway 20, 0.45 mile south of West Hallwood Road. 11/26/47, 11.8; 3/3/48, 14.9; 3/23/49, 13.0; 11/18/49, 11.8.

16N/4E-33K1—Reference point—top of casing, elevation 84.0 feet, 200 feet northwest of State Highway 20, 0.70 mile south of West Hallwood Road. 11/26/47, 9.2; 3/8/48, 12.1; 11/30/48, 10.5; 3/23/49, 9.7; 11/18/49, 9.7.

16N/4E-33N1—Reference point—top of casing cap, elevation 80.1 feet, 200 feet northwest of State Highway 20, 1.3 miles south of West Hallwood Road. 11/26/47, 8.3; 3/4/48, 11.5; 11/30/48, 10.6; 3/23/49, 9.2; 11/18/49, 10.0; 3/23/50, 10.2; 10/31/50, 9.3; 3/30/51, 9.1; 11/14/51, 10.0; 4/5/52, 7.4.

16N/4E-34B1—Reference point—top of casing, elevation 96.8 feet, 100 feet north of West Hallwood Road, 200 feet east of levee. 11/25/47, 14.4; 3/3/48, 20.5; 11/29/48, 19.5; 3/22/49, 15.8; 11/18/49, 14.6.

16N/4E-34D1—Reference point—top of casing, elevation 91.9 feet, 600 feet west of State Highway 20, 0.20 mile north of West Hallwood Road. 11/26/47, 12.7; 3/3/48, 16.1; 11/30/48, 13.8; 3/23/49, 13.5; 11/18/49, 13.0.

16N/4E-34L1—Reference point—top of casing 2.5 feet above ground, elevation 98.5 feet, 0.4 mile north of Walnut Road, 200 feet west of Hallwood Road. 10/25/47, 17.5; 3/3/48, 21.7; 11/29/48, 18.7; 3/22/49, 19.9; 11/18/49, 18.3.

16N/4E-34Q1—Reference point—top of casing under pump, elevation 95.3 feet, 400 feet north of Walnut Road, 400 feet east of Hallwood Road. 11/25/47, 16.7; 3/3/48, 21.1; 11/29/48, 17.7; 3/22/49, 19.3; 11/18/49, 16.7; 3/23/50, 19.7; 10/31/50, 16.6; 3/30/51, 17.6; 11/14/51, 17.1; 4/6/52, 15.1.

16N/4E-35M1—Reference point—top of casing under pump, elevation 101.1 feet, 0.6 mile east of Hallwood Road, 0.5 mile north of Walnut Road. 11/25/47, 15.3; 3/3/48, 17.9; 4/1/48, 18.1; 3/23/49, 16.8; 11/18/49, 16.6.

17N/1E-25J1—Reference point—hole in base of pump, elevation 77 feet, 100 feet south of North Butte Road, 0.4 mile west of 90° turn (NW.) in North Butte Road. 3/25/48, 18.9; 12/3/48, 19.7; 3/30/49, 16.7; 11/15/49, 22.0; 3/24/50, 16.6; 11/2/50, 21.6; 3/27/51, 21.2; 11/13/51, 23.8.

17N/2E-22R1—Reference point—top of casing, elevation 79.5 feet, 0.07 mile northwest of intersection of Krehe and Lucerne Roads. 12/22/47, 7.7; 3/2/48, 8.3; 11/15/49, 7.4.

17N/2E-24N1—Reference point—top of casing, elevation 81.1 feet, 100 feet north of Lucerne Road, 0.95 mile west of Township Road. 12/22/47, 7.4; 3/1/48, 8.2; 12/8/48, 8.0; 1/21/49, 7.5; 3/30/49, 4.5; 11/8/49, 6.5.

17N/2E-29M1—Reference point—hole in pump base, elevation 79.6 feet, 0.1 mile east of Crane Road, 0.3 mile north of Bigelow Road. 12/22/47, 14.6; 12/3/48, 16.1; 3/30/49, 12.6; 11/15/49, 16.1; 3/24/50, 13.5; 3/27/51, 12.6.

17N/2E-29Q1—Reference point—top of casing, elevation 77.9 feet, 0.1 mile, east-northeast of 90° turn in Bigelow Road, at a point 0.5 mile east of Crane Road. 12/23/47, 13.9; 3/2/48, 15.1; 12/3/48, 15.5; 3/30/49, 12.0; 11/15/49, 14.3.

17N/2E-30N1—Reference point—top of casing, elevation 83 feet, 0.15 mile south of Pennington Road at a point 0.1 mile west of Pennington School. 3/25/48, 22.9; 12/3/48, 24.1; 3/30/49, 21.3; 11/15/49, 25.2.

17N/2E-31A1—Reference point—top of casing, elevation 85 feet, 100 feet north of Pennington Road at a point 0.1 mile west of Bigelow and Pennington Roads intersection. 3/25/48, 23.5; 12/3/48, 24.7; 3/30/49, 22.8; 11/15/49, 25.5; 3/24/50, 23.0; 11/2/50, 26.7; 3/27/51, 21.8; 11/13/51, 28.3; 4/2/52, 20.2.

17N/2E-33J1—Reference point—top of casing, elevation 71.3 feet, 0.35 mile north of Pennington Road, 1.05 miles west of Krehe Road. 12/23/47, 6.4; 3/2/48, 6.5; 12/13/48, 6.2; 3/30/49, 4.0; 11/15/49, 3.7.

17N/2E-34A1—Reference point—top of casing, elevation 74.6 feet, East side of Krehe Road, 0.9 mile north of Pennington Road. 12/22/47, 6.8; 3/1/48, 7.2; 12/8/48, 6.8; 1/21/49, 6.6; 3/30/49, 5.0; 11/8/49, 4.2; 3/21/50, 6.7; 11/2/50, 4.9; 3/27/51, 12.7 (operating); 11/13/51, 6.2; 4/2/52, 5.8.

17N/2E-34Q1—Reference point—top of outer casing, elevation 71.8 feet, North side of Pennington Road, 0.5 mile west of Krehe Road. 12/22/47, 6.4; 3/2/48, 7.1; 12/3/48, 7.0; 3/30/49, 5.0; 11/15/49, 5.7; 3/24/50, 5.5; 11/2/50, 5.5; 3/27/51, 6.6; 11/13/51, 6.1; 4/2/52, 5.4.

17N/2E-35A1—Reference point—top of casing, elevation 75.2 feet, 50 feet west of Schroeder Road, 0.95 mile north of Pennington Road. 12/22/47, 4.7; 3/1/48, 5.7; 12/8/48, 5.5; 3/30/49, 4.0; 5/26/49, 3.8; 6/28/49, 4.2; 7/27/49, 3.4; 8/25/49, 3.5; 11/8/49, 4.4; 3/21/50, 6.0; 11/2/50, 5.9; 3/27/51, 5.0; 11/13/51, 6.2; 4/2/52, 5.5.

17N/2E-36H1—Reference point—top of casing, elevation 76 feet, 300 feet west of Township Road, 0.6 mile north of Pennington Road. 3/26/48, 7.0; 12/8/48, 7.9.

17N/3E-22R1—Reference point—top of casing, elevation 86 feet, 0.25 mile north of Laurel Road at a point 0.48 mile west of intersection with Thame Road. 10/29/47, 23.3; 3/22/48, 26.0; 12/10/48, 21.9; 3/8/49, 21.2; 11/14/49, 23.3; 3/21/50, 22.2; 11/7/50, 23.4; 3/28/51, 16.8; 11/15/51, 22.1; 4/6/52, 13.6.

17N/3E-23P1—Reference point—hole in concrete base, elevation 87 feet, 0.37 mile north of Laurel Road, due north of intersection with Thame Road. 10/29/47, 22.7; 12/10/48, 20.5; 3/8/49, 20.0; 11/14/49, 22.9.

17N/3E-25G1—Reference point—hole in base of pump, elevation 85 feet, 2.57 miles north of Ramirez Road, 0.53 mile east of State Highway 24. 10/29/47, 22.9; 3/22/48, 19.1; 12/10/48, 19.4; 3/8/49, 18.8; 11/14/49, 21.6; 3/21/50, 18.1; 11/7/50, 21.7; 3/28/51, 46.0 (operating); 11/15/51, 23.4; 4/6/52, 9.3.

17N/3E-25M1—Reference point—hole in base of pump, elevation 80 feet, 2.27 miles north of Ramirez Road, 0.15 mile east of State Highway 24. 10/29/47, 22.6; 3/22/48, 19.8; 12/10/48, 20.8.

17N/3E-25N1—Reference point—hole in base of pump, elevation 84 feet, 1.97 miles north of Ramirez Road, 0.24 mile east of State Highway 24. 3/22/48, 20.7; 12/10/48, 19.3; 3/8/49, 18.0; 11/14/49, 21.8.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

17N/3E-25Q1—Reference point—hole in base of pump, elevation 84 feet, 2.27 miles north of Ramirez Road, 0.75 mile east of State Highway 24. 10/31/47, 18.7; 3/22/48, 18.7; 12/10/48, 17.7; 3/8/49, 15.3; 11/14/49, 20.2.

17N/3E-26A2—Reference point—hole in base of pump, elevation 85 feet, 0.04 mile south of Laurel Road, 0.10 mile west of State Highway 24. 10/28/47, 22.8; 3/28/48, 21.9; 12/10/48, 21.1; 1/26/49, 20.5; 3/8/49, 20.1; 11/14/49, 23.7; 3/21/50, 21.1; 11/7/50, 22.8; 3/28/51, 14.6; 11/15/51, 27.6; 4/6/52, 11.1.

17N/3E-26B1—Reference point—flange of suction line, elevation 87 feet, 0.07 mile north of Laurel Road, 0.28 mile west of State Highway 24. 10/29/47, 15.5; 3/22/48, 11.9; 5/7/48, 9.7; 12/10/48, 13.5; 3/8/49, 12.5; 11/14/49, 15.5.

17N/3E-26H1—Reference point—hole in base of pump, elevation 85 feet, 0.25 mile south of Laurel Road, 0.22 mile west of State Highway 24. 10/29/47, 24.1; 12/10/48, 22.6; 11/14/49, 23.7.

17N/3E-26R1—Reference point—hole in base of pump, elevation 84 feet, 0.10 mile west of State Highway 24, 0.65 mile south of Laurel Road. 10/29/47, 20.0; 3/22/48, 20.8; 12/10/48, 18.8; 3/8/49, 18.0; 11/14/49, 21.0.

17N/3E-28P1—Reference point—top of flange on suction pipe, elevation 82 feet, 0.18 mile east of Cooley Road, 1.10 miles north of intersection of Meteer Road. 10/31/47, 5.8; 3/20/48, 7.4; 5/30/48, 4.7; 12/8/48, 4.9; 3/8/49, 7.0; 11/8/49, 5.5; 3/22/50, 5.1; 11/3/50, 7.0; 3/27/51, 3.1; 11/14/51, 6.5; 4/3/52, 2.2.

17N/3E-29C1—Reference point—top of casing, elevation 82.4 feet, 0.21 mile west of Larkin Road, 0.04 mile north of Riviera Road. 12/22/47, 8.9; 3/1/48, 9.4; 12/8/48, 9.7; 3/30/49, 5.9; 11/8/49, 8.2; 3/21/50, 6.3; 11/2/50, 8.8; 3/27/51, 5.8; 11/13/51, 8.8; 4/2/52, 4.5.

17N/3E-29H1—Reference point—top of casing, elevation 77.7 feet, South side Riviera Road, 0.52 mile east of Larkin Road. 12/23/47, 5.0; 3/1/48, 5.6; 5/12/48, 3.5; 11/8/49, 4.7.

17N/3E-30F1—Reference point—top of casing, elevation 80.6 feet, South side Riviera Road, 0.35 mile east of Township Road. 11/26/29, 4.7; 9/27/30, 3.3; 12/16/31, 6.2; 12/9/32, 5.4; 12/13/33, 5.6; 11/21/34, 5.4; 11/23/37, 3.7; 1/26/39, 6.4; 1/10/49, 3.1; 11/4/47, 7.8; 12/5/47, 8.0; 12/22/47, 8.2; 3/1/48, 8.5; 12/8/48, 8.6; 12/13/48, 9.3; 11/8/49, 7.6; 3/30/49, 5.4; 3/21/50, 3.5.

17N/3E-30G1—Reference point—top of casing, elevation 81 feet, South Side of Riviera Road, 0.23 mile west of U. S. Highway 99E. 11/10/50, 8.6; 11/26/51, 8.7.

17N/3E-30N1—Reference point—top of pumphouse floor, elevation 73.0 feet, 0.08 mile east of Township Road, 1.25 miles north of Pennington Road. 12/22/47, 4.1; 3/1/48, 4.4; 5/13/48, 3.1; 12/8/48, 4.0; 1/21/49, 4.0; 3/30/49, 1.5; 5/26/49, 7.0; 6/28/49, 7.0; 7/27/49, 7.5; 8/25/49, 8.5; 11/8/49, 3.7; 3/21/50, 6.5; 11/2/50, 8.9; 3/27/51, 6.6; 11/13/51, 8.4; 4/2/52, 1.0.

17N/3E-31A2—Reference point—hole in base of pump, elevation 82 feet, 1.01 miles west of Township Road, 0.85 mile north of Pennington Road. 12/8/48, 10.0; 3/30/49, 6.6.

17N/3E-31M1—Reference point—top of casing, elevation 75 feet, 0.24 mile east of Township Road, 0.32 mile north of Pennington Road. 3/26/48, 7.1; 12/8/48, 9.1.

17N/3E-32B1—Reference point—top of casing, elevation 81.5 feet, 0.09 mile east of Larkin Road, 1 mile south of Riviera Road. 12/23/47, 12.2; 3/1/48, 12.4; 12/8/48, 11.7; 3/30/49, 8.1; 1/8/49, 13.3; 3/22/50, 7.8; 3/27/51, 6.5; 11/13/51, 9.8; 4/2/52, 4.7.

17N/3E-33Q1—Reference point—top of casing, elevation 80 feet, North side of Pennington Road, 0.50 mile east of Meteer Road. 11/10/47, 12.2; 3/20/48, 16.7; 12/3/48, 13.1; 3/8/49, 16.6; 11/9/49, 10.7; 3/22/50, 14.0; 11/3/50, 11.4; 4/2/51, 11.3; 11/14/51, 12.4; 4/3/52, 8.8.

17N/3E-35H1—Reference point—top of casing, elevation 82 feet, 0.05 mile west of State Highway 24, 1.57 miles north of Ramirez Road. 10/29/47, 21.5; 3/22/48, 19.0; 10/10/48, 19.7; 3/8/49, 19.0; 11/15/49, 22.2.

17N/3E-35H2—Reference point—hole in base of pump, elevation 82 feet, 1.67 miles north of Ramirez Road, west side of State Highway 24. 10/29/47, 23.4; 3/22/48, 21.0; 5/7/48, 17.2; 12/10/48, 19.9; 3/8/49, 19.0; 11/15/49, 22.3; 3/21/50, 18.2; 11/7/50, 22.9; 3/28/51, 14.2; 11/15/51, 22.3; 4/6/52, 10.1.

17N/3E-36B1—Reference point—top of casing, elevation 84 feet, 0.70 mile east of State Highway 24, 1.87 miles north of Ramirez Road. 10/31/47, 17.9; 3/22/48, 17.6; 12/10/48, 17.0; 3/8/49, 15.5; 11/14/49, 19.6.

17N/3E-36B2—Reference point—hole in base of pump, elevation 84 feet, 0.55 mile east of State Highway 24, 1.9 miles north of Ramirez Road. 10/31/47, 23.7; 3/22/48, 17.3; 5/7/48, 17.0; 12/10/48, 17.6; 1/26/49, 17.1; 3/8/49, 16.3; 11/14/49, 19.9; 3/21/50, 16.6; 11/7/50, 20.2; 3/28/51, 12.3; 11/15/51, 18.6; 4/6/52, 7.4.

17N/3E-36E1—Reference point—slot in base, elevation 83 feet, 0.2 mile east of State Highway 24, 1.55 miles north of Ramirez Road. 10/31/47, 20.3; 3/22/48, 18.4; 3/8/49, 17.7; 11/15/49, 20.8.

17N/4E-22H1—Reference point—top of casing, elevation 116 feet, 0.2 mile east of La Porte Road bridge across Middle Honcut Creek. 2/25/48, 16.1; 3/15/48, 15.3; 11/17/49, 18.3; 3/28/51, 12.1; 11/14/51, 18.6; 4/6/52, 10.2.

17N/4E-27E1—Reference point—top of concrete pit cribbing, elevation 105 feet, 0.30 mile west of La Porte Road bridge across South Honcut Creek. 11/19/47, 29.9; 3/15/48, 33.2; 11/30/48, 30.0; 3/23/49, 24.2.

17N/4E-27F1—Reference point—top of casing, elevation 106 feet, West side La Porte Road, south bank of South Honcut Creek. 11/18/47, 24.8; 3/30/48, 24.2; 5/12/48, 24.2; 11/30/48, 24.9; 3/23/49, 23.1; 11/17/49, 28.0; 3/22/50, 24.9; 10/3/50, 30.2; 3/28/51, 24.1; 11/14/51, 30.3; 4/6/52, 23.8.

17N/4E-29L1—Reference point—hole in pump base, elevation 80 feet, 1.02 miles west of Southern Pacific Railroad tracks, 0.30 mile south of South Honcut Creek. 12/1/48, 21.2; 3/23/49, 19.5; 11/17/49, 26.1; 3/22/50, 22.3; 10/31/50, 30.0; 3/28/51, 21.6; 11/27/51, 14.6; 4/6/52, 5.0.

17N/4E-33D1—Reference point—top of casing, elevation 96 feet, West side Southern Pacific Railroad tracks, 1.08 miles north along tracks from intersection with Ramirez Road. 11/18/47, 24.1; 3/15/48, 24.8; 12/1/48, 25.2; 3/23/49, 27.6; 11/17/49, 27.6; 3/22/50, 27.0; 10/31/50, 28.0; 3/28/51, 25.1; 11/14/51, 28.1; 4/6/52, 24.3.

17N/4E-35C1—Reference point—hole in pump base, elevation 122 feet, South side Iowa City Road, 1.20 miles east of La Porte Road. 3/15/48, 26.7; 11/17/49, 28.5; 3/28/51, 28.5; 11/14/51, 33.1; 4/6/52, 30.1.

TABLE 2

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by S. T. Harding
(Depths to water in feet meosured from reference point)

13N/2E-1 (Harding 43)—Reference point—top of pump house floor, elevation 35 feet, 1,800 feet north of east quarter corner of section. 9/20/31, 16.5; 12/2/32, 15.7.

13N/3E-2 (Harding 139)—Reference point—top of casing, elevation 43 feet, 30 feet north of east and west center line, 1,700 feet east of Garden Highway. 10/16/31, 22.7; 11/29/32, 18.0.

13N/3E-3 (Harding 76)—Reference point—top of casing, elevation 40 feet, 200 feet south and 1,400 feet east of center of section. 10/13/31, 21.3; 11/29/32, 19.2.

13N/3E-4 (Harding 141A)—Reference point—top of casing, elevation 39 feet, 800 feet south and 50 feet west of northeast corner of section. 10/9/31, 22.1; 12/2/32, 20.0.

13N/3E-4 (Harding 70)—Reference point—top of casing, elevation 40 feet, 20 feet west of Sawtelle Avenue at southeast corner of section. 10/8/31, 23.0; 12/2/32, 20.0.

13N/3E-5 (Harding 140)—Reference point—top of pit, elevation 36 feet, 550 feet south and 200 feet west of north quarter corner of section. 10/9/31, 23.0; 12/2/32, 20.7.

13N/3E-5 (Harding 141)—Reference point—top of casing, elevation 34 feet, 200 feet west and 300 feet north of east quarter corner of section. 10/9/31, 20.5; 12/2/32, 18.0.

13N/3E-7 (Harding 73)—Reference point—top of casing, elevation 33 feet, 1,300 feet east of west quarter corner of section. 10/8/31, 12.0; 12/2/32, 13.0.

13N/3E-9 (Harding 72)—Reference point—top of wall of pit, elevation 35 feet, 500 feet south of north quarter corner of section. 10/8/31, 18.5; 12/2/32, 13.1.

13N/3E-10 (Harding 69)—Reference point—top of wall of wooden pit, elevation 38 feet, 500 feet north and 500 feet south of northeast corner of section. 10/8/31, 17.0; 12/2/32, 17.1.

13N/3E-11 (Harding 75)—Reference point—top of wall of pit, elevation 40 feet, 2,000 feet south and 600 feet west of northeast corner of section. 10/8/31, 17.5; 12/7/32, 15.6.

13N/3E-13 (Harding 74)—Reference point—top of wall of pit, elevation 38 feet, 100 feet east and 1,000 feet north of southwest corner of section. 10/8/31, 16.8; 12/7/32, 17.1.

13N/3E-14 (Harding 64)—Reference point—top of wall of pit, elevation 35 feet, 500 feet north of intersection of Wilson Road and Garden Highway. 10/6/31, 15.5; 12/2/32, 15.2.

13N/3E-15 (Harding 63)—Reference point—top of casing, elevation 35 feet, West side of Southern Pacific Railroad, ¼ mile north of Wilson Road. 10/6/31, 15.0; 12/2/32, 13.8.

13N/3E-16 (Harding 62)—Reference point—top of casing, elevation 36 feet, 500 feet north of southeast corner of section. 10/6/31, 17.0; 12/2/32, 16.4.

13N/3E-16 (Harding 71)—Reference point—top of casing, elevation 31 feet, 1,300 feet east and 2,700 feet south of northwest corner of section. 10/8/31, 12.0; 12/2/32, 11.3.

13N/3E-23 (Harding 60)—Reference point—top of concrete pit wall, elevation 35 feet, 100 feet east of Garden Highway, 2,200 feet south of north quarter corner of section. 10/6/31, 15.5; 12/2/32, 12.5.

13N/3E-23 (Harding 61)—Reference point—top of casing, elevation 36 feet, 500 feet east and 200 feet south of northwest corner of section. 10/6/31, 16.4; 12/2/32, 15.2.

14N/2E-4 (Harding 51)—Reference point—top of casing, elevation 37 feet, 300 feet west and 200 feet south of northeast corner of section. 9/26/31, 8.3; 11/30/32, 6.6.

14N/2E-36 (Harding 47)—Reference point—top of casing, elevation 34 feet, 500 feet south of north quarter corner of section. 9/23/31, 12.0; 12/2/32, 11.6.

14N/2E-36 (Harding 42)—Reference point—top of casing, elevation 35 feet. At east quarter corner of section. 9/20/31, 14.0; 12/2/32, 13.2.

14N/3E-1 (Harding 99)—Reference point—top of casing, elevation 53 feet, 200 feet west of Feather River Boulevard and 1.5 miles south of Alicia Station. 10/16/31, 12.0; 12/5/32, 12.3.

14N/3E-2 (Harding 54)—Reference point—top of casing below ground, elevation 48 feet, 5,200 feet east of Southern Pacific Railroad and 1,500 feet north of latitude 39° 05′. 9/26/31, 21.3; 11/29/32, 18.5.

14N/3E-2 (Harding 79)—Reference point—top of casing, elevation 48 feet, 1,400 feet east and 700 feet south of northwest corner of section. 10/13/31, 19.5; 11/29/32, 16.0.

14N/3E-3 (Harding 66)—Reference point—top of casing, elevation 51 feet, 700 feet west of Southern Pacific Railroad, 1,700 feet south of north line of section. 10/7/31, 35.3; 12/1/32, 33.0.

14N/3E-4 (Harding 57)—Reference point—top of concrete pit, elevation 51 feet, 1,150 feet east and 800 feet south of north quarter corner of section. 9/28/31, 36.3; 11/30/32, 35.3.

14N/3E-4 (Harding 56)—Reference point—top of concrete pit, elevation 48 feet, 600 feet east and 360 feet south of west quarter corner of section. 9/27/31, 33.9; 11/30/32, 32.0.

14N/3E-8 (Harding 118)—Reference point—top of casing, elevation 44 feet, 1,500 feet north and 200 feet east of southwest corner of section. 9/28/31, 25.1; 11/30/32, 23.6.

14N/3E-9 (Harding 123)—Reference point—top of pit, elevation 46 feet, 300 feet east and 200 feet north of south quarter corner of section. 9/30/31, 32.5; 11/30/32, 31.0.

14N/3E-10 (Harding 116)—Reference point—top of pit, elevation 50 feet, 300 feet north of east and west center line, 550 feet west of Southern Pacific Railroad. 10/1/31, 36.0; 12/1/32, 32.6.

14N/3E-10 (Harding 115)—Reference point—top of casing, elevation 52 feet, 700 feet south and 200 feet west of northeast corner of section. 10/1/31, 33.8; 11/29/32, 29.0.

14N/3E-11 (Harding 55)—Reference point—top of casing, elevation 53 feet, 4,400 feet east of Southern Pacific Railroad, 100 feet south of latitude 39° 05′. 9/5/31, 30.1; 10/17/31, 29.0.

14N/3E-13 (Harding 100)—Reference point—top of wall of pit, elevation 50 feet, West of Feather River Boulevard, 500 feet north of Pearson Station. 10/16/31, 10.0; 12/5/32, 10.1.

14N/3E-15 (Harding 67)—Reference point—top of concrete pit, elevation 47 feet, 800 feet east and 150 feet south of northwest corner of section. 10/7/31, 32.7; 12/1/32, 29.2.

14N/3E-15 (Harding 124)—Reference point—top of concrete pit, elevation 48 feet, 1,600 feet south of north line and 200 feet east of Southern Pacific Railroad. 10/8/31, 30.8; 12/1/32, 25.2.

14N/3E-15 (Harding 122)—Reference point—top of concrete pit, elevation 45 feet, 2,150 feet north and 600 feet east of southwest corner of section. 10/17/31, 29.4; 12/1/32, 24.0.

14N/3E-16 (Harding 58)—Reference point—bottom of 6 x 6 strut across top of pit, elevation 45 feet, 750 feet north and 40 feet west of southwest corner of section. 9/29/31, 25.8; 11/30/32, 25.6.

14N/3E-16 (Harding 120)—Reference point—top of concrete pit, elevation 45 feet, 1,350 feet east and 200 feet north of south quarter corner of section. 10/17/31, 27.7; 12/1/32, 25.4.

14N/3E-17 (Harding 119)—Reference point—top of casing, elevation 42 feet, 1,500 feet north and 100 feet east of southwest corner of section. 10/3/31, 21.5; 11/30/32, 20.0.

14N/3E-18 (Harding 45)—Reference point—top of wall of concrete pit, elevation 39 feet, 1,100 feet east and 2,000 feet south of northwest corner of section. 9/21/31, 14.5; 11/30/32, 14.4.

14N/3E-19 (Harding 46)—Reference point—top of pit wall, elevation 38 feet, 1,800 feet east and 900 feet south of northwest corner of section. 9/21/31, 16.0; 11/30/32, 15.0.

14N/3E-20 (Harding 123A)—Reference point—top of casing, elevation 42 feet, 2,000 feet north and 130 feet west of southeast corner of section. 10/3/31, 29.7; 12/1/32, 26.4.

TABLE 2—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by S. T. Harding
(Depths to water in feet measured from reference point)

14N/3E-22 (Harding 68)—Reference point—top of concrete pit, elevation 45 feet, 1,100 feet south of north line of section and 350 feet west of Garden Highway. 10/8/31, 23.4; 11/29/32, 19.7.

14N/3E-23 (Harding 107)—Reference point—top of pit wall, elevation 50 feet. West end of Country Club Road on center line of section. 10/16/31, 20.5; 12/9/32, 19.7.

14N/3E-23 (Harding 129)—Reference point—top of casing, elevation 46 feet, 100 feet east of Garden Highway and 1,650 feet north of latitude 39° 32' 30". 10/13/31, 25.2.

14N/3E-27 (Harding 131)—Reference point—top of casing, elevation 42 feet, 700 feet east of Southern Pacific Railroad and 300 feet north of south line of section. 10/16/31, 25.0; 11/29/32, 21.7.

14N/3E-27 (Harding 130)—Reference point—top of casing, elevation 44 feet, 2,000 feet south of latitude 39° 32' 30" and 400 feet west of Garden Highway. 10/13/31, 25.2; 11/29/32, 21.2.

14N/3E-28 (Harding 128)—Reference point—top of concrete pit, elevation 40 feet, 500 feet east and 1,600 feet north of southwest corner of section. 10/12/31, 29.8; 12/1/32, 27.0.

14N/3E-28 (Harding 127)—Reference point—top of casing, elevation 42 feet, 150 feet west and 25 feet south of northwest corner of section. 10/12/31, 30.3; 12/1/32, 27.4.

14N/3E-29 (Harding 126)—Reference point—top of planks across top of pit, elevation 41 feet, 1,200 feet west and 1,600 feet south of northeast corner of section. 10/10/31, 29.0; 12/1/32, 26.7.

14N/3E-29 (Harding 125)—Reference point—top of concrete casing, elevation 42 feet, 750 feet north and 300 feet west of south quarter corner of section. 9/5/31, 29.2; 10/9/31, 28.3; 12/2/32, 25.5.

14N/3E-30 (Harding 77)—Reference point—top of casing, elevation 39 feet, 1,500 feet south and 250 feet west of northeast corner of section. 10/13/31, 23.1; 12/2/32, 20.7.

14N/3E-31 (Harding 44)—Reference point—top of concrete pit, elevation 37 feet, 1,000 feet west and 200 feet south of northeast corner of section. 9/20/31, 21.5; 12/2/32, 16.5.

14N/3E-32 (Harding 133)—Reference point—top of casing, elevation 36 feet, 2,000 feet north and 200 feet east of southwest corner of section. 10/14/31, 23.3; 12/2/32, 20.7.

14N/3E-32 (Harding 132)—Reference point—top of casing, elevation 37 feet, 250 feet south and 150 feet west of center of section. 10/14/31, 25.0; 11/29/32, 21.0.

14N/3E-33 (Harding 134)—Reference point—top of tile at hand pump, elevation 43 feet, 200 feet south and 1,410 feet east of northwest corner of section. 10/14/31, 27.6; 12/1/32, 24.8.

14N/3E-34 (Harding 135)—Reference point—top of pit, elevation 41 feet, 300 feet east and 40 feet south of northwest corner of section. 10/14/31, 27.8; 12/1/32, 24.9.

14N/3E-35 (Harding 138)—Reference point—top of wood pit, elevation 42 feet, 100 feet west of levee, 500 feet north of south line of section. 10/16/31, 18.3; 11/29/32, 17.5.

14N/3E-35 (Harding 137)—Reference point—top of casing, elevation 43 feet, 100 feet east of Garden Highway, 100 feet north of south line of section. 10/16/31, 25.4; 11/29/32, 22.1.

14N/3E-35 (Harding 136)—Reference point—top of wooden pit, elevation 42 feet, 200 feet east of Garden Highway, 1,100 feet north of south line of section. 10/16/31, 24.8; 11/29/32, 22.0.

14N/4E-8 (Harding 101)—Reference point—top of pit wall, elevation 56 feet, 700 feet west and 700 feet south of west quarter corner of section. 10/16/31, 12.0; 12/3/32, 12.8.

14N/4E-8 (Harding 103)—Reference point—top of casing, elevation 63 feet, 200 feet southeast of northwest corner of section. 10/16/31, 18.0; 12/3/32, 18.8.

14N/4E-19 (Harding 104)—Reference point—top of casing, elevation 49 feet. Immediately north of center of section. 10/16/31, 14.0; 12/3/32, 13.5.

14N/4E-31 (Harding 98)—Reference point—top of casing, elevation 59 feet, 50 feet east of bend in River Road, ½ mile above Alicia. 10/16/31, 18.0; 12/3/32, 17.0.

15N/2E-1 (Harding 18)—Reference point—top of casing, elevation 56 feet, 1,000 feet south and 180 feet west of northeast corner of section. 9/7/31, 11.8; 10/17/31, 11.3; 12/8/32, 10.2.

15N/2E-12 (Harding 17)—Reference point—top of casing in pit, elevation 51 feet, 1,600 feet south and 400 feet west of northeast corner of section. 9/7/31, 8.1; 10/17/31, 9.3; 12/8/32, 10.1.

15N/2E-12 (Harding 114)—Reference point—top of casing, elevation 54 feet, 200 feet south of Butte House Road on north side of east and west center line of section. 10/1/31, 8.5; 12/8/32, 11.9.

15N/2E-13 (Harding 35)—Reference point—top of highest horizontal flange on suction, elevation 51 feet, 1,800 feet west and 200 feet north of east quarter corner of section. 9/18/31, 14.5; 12/8/32, 14.6.

15N/2E-13 (Harding 113)—Reference point—top of casing, elevation 50 feet, 1,000 feet east and 500 feet north of west quarter corner of section. 10/1/31, 8.0; 12/8/32, 9.7.

15N/2E-26 (Harding 111)—Reference point—top of casing, elevation 44 feet, 2,000 feet west and 50 feet south of northeast corner of section. 10/1/31, 7.0; 11/30/32, 7.7.

15N/2E-28 (Harding 112)—Reference point—top of casing, elevation 43 feet, 500 feet west of east quarter corner of section. 10/1/31, 9.0; 11/30/32, 7.9.

15N/2E-35 (Harding 53)—Reference point—top of casing, elevation 38 feet, 0.25 mile west and 300 feet north of southeast corner of section. 9/26/31, 5.0; 11/30/32, 5.4.

15N/3E-1 (Harding 87)—Reference point—top of casing, elevation 64 feet. East side of State Highway 24, 0.5 mile north of Walnut Avenue. 10/15/31, 14.5; 12/5/32, 13.8.

15N/3E-1 (Harding 85)—Reference point—top of casing, elevation 66 feet, 200 feet north of Walnut Avenue, 0.25 mile west of State Highway 24. 10/15/31, 19.5; 12/5/32, 15.8.

15N/3E-1 (Harding 84)—Reference point—top of walls of pit, elevation 61 feet, 700 feet east of State Highway 24 and 1 mile north of railroad crossing. 10/15/31, 6.0.

15N/3E-1 (Harding 84A)—Reference point—top of casing, elevation 61 feet, 300 feet east of State Highway 24 and 1 mile north of railroad crossing. 12/5/32, 5.0.

15N/3E-2 (Harding 86)—Reference point—top of casing, elevation 68 feet, 500 feet north of west end of Walnut Avenue. 10/15/31, 25.5; 12/5/32, 24.1.

15N/3E-2 (Harding 109)—Reference point—top of casing, elevation 62 feet. West end of first road to left on State Highway 24 after crossing bridge ¼ mile north of cemetery. 10/20/31, 21.5; 12/5/32, 21.0.

15N/3E-2 (Harding 108)—Reference point—top of wall of pit, elevation 61 feet, 0.60 mile west of State Highway 24, on first left road after crossing bridge, ¼ mile north of cemetery. 10/20/31, 19.0; 12/5/32, 18.3.

15N/3E-3 (Harding 4)—Reference point—top of casing, elevation 61 feet, 250 feet south and 240 feet east of northwest corner of section. 8/31/31, 22.7; 10/17/31, 23.4.

15N/3E-4 (Harding 15)—Reference point—top of concrete pit, elevation 60 feet, 1,900 feet north and 900 feet west of southeast corner of section. 9/4/31, 25.5; 10/17/31, 25.5; 12/7/32, 23.7.

15N/3E-5 (Harding 14)—Reference point—2 inches above top of concrete pit, elevation 59 feet. On east line 1,800 feet north of southeast corner of section. 9/3/31, 24.5; 10/17/31, 24.5; 12/7/32, 22.8.

TABLE 2—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by S. T. Harding
(Depths to water in feet measured from reference point)

15N/3E-6 (Harding 16)—Reference point— top of casing, elevation 60 feet, 1,320 feet west and 1,200 feet north of southeast corner of section. 9/7/31, 18.2; 12/8/32, 17.1.

15N/3E-9 (Harding 22)—Reference point—top of concrete pit, elevation 58 feet, 1,000 feet south and 500 feet east of west quarter corner of section. 9/10/31, 28.1; 10/17/31, 27.9; 12/8/32, 25.7.

15N/3E-10 (Harding 19)—Reference point—top of concrete pit, elevation 63 feet. Near north quarter of section. 9/8/31, 30.7; 10/17/31, 30.5; 12/7/32, 28.0.

15N/3E-11 (Harding 82)—Reference point—top of casing, elevation 57 feet. Under Southern Pacific Railroad trestle 2 miles north of Yuba City. 10/20/31, 16.5; 12/6/32, 16.3.

15N/3E-13 (Harding 110)—Reference point—top of casing, elevation 62 feet, 50 feet east of road which runs north and south behind Marysville High School and 0.4 mile south of north end of road. 10/20/31, 12.0; 12/5/32, 12.6.

15N/3E-14 (Harding 83)—Reference point—top of wall of pit, elevation 56 feet, 400 feet east and 200 feet south of west quarter corner of section. 10/13/31, 21.5.

15N/3E-15 (Harding 21)—Reference point—top of concrete pit, elevation 60 feet, 500 feet west of highway and 100 feet south of north line of section. 9/8/31, 29.3; 10/17/31, 29.1; 12/7/32, 27.2.

15N/3E-16 (Harding 23)—Reference point—top of concrete pit, elevation 58 feet, 750 feet south and 850 feet west of northeast corner of section. 9/10/31, 30.2; 10/17/31, 29.7; 12/7/32, 27.7.

15N/3E-17 (Harding 29)—Reference point—top of concrete pit, elevation 56 feet, 1,100 feet east of Live Oak drain, south of Sacramento Northern Railroad. 9/19/31, 25.0; 12/8/32, 22.5.

15N/3E-19 (Harding 37)—Reference point—floor of pit, 8 feet deep, elevation 50 feet, 660 feet east and 500 feet south of northwest corner of section. 9/18/31, 16.0; 10/17/31, 17.5; 11/28/32, 16.9.

15N/3E-19 (Harding 36)—Reference point—top of concrete pit wall, elevation 50 feet, 1,320 feet north and 300 feet east of southwest corner of section. 9/18/31, 18.0; 12/1/32, 17.0.

15N/3E-20 (Harding 20)—Reference point—top of concrete pit, elevation 57 feet, 850 feet west and 40 feet south of northeast corner of section. 9/8/31, 31.4; 10/17/31, 31.0; 12/1/32, 28.6.

15N/3E-20 (Harding 28)—Reference point—floor of pump house or top of pit, elevation 56 feet, 220 feet east and 250 feet north of south quarter corner of section. 9/18/31, 32.1.

15N/3E-21 (Harding 24)—Reference point—top of casing, elevation 55 feet, 1,100 feet west and 400 feet south of northeast corner of section. 9/10/31, 28.1; 10/17/31, 28.5.

15N/3E-23 (Harding 27)—Reference point—top of casing, elevation 57 feet. In Yuba City, back of blacksmith shop, 150 feet south of Sutter Hotel. 9/17/31, 22.2; 11/29/32, 21.1.

15N/3E-26 (Harding 48)—Reference point—top of concrete pit, elevation 54 feet, 3,800 feet east and 700 feet south of northwest corner of section. 9/—/31, 26.5; 11/29/32, 26.0.

15N/3E-26 (Harding 80)—Reference point—top of casing, elevation 50 feet, 2,000 feet east of northwest corner of section. 10/13/31, 20.5.

15N/3E-26 (Harding 81)—Reference point—top of casing, elevation 55 feet, 100 feet west of toe of levee, 3,500 feet south of Yuba City south limit. 10/13/31, 23.5; 11/29/32, 25.5.

15N/3E-27 (Harding 25)—Reference point—top of casing, elevation 55 feet, 500 feet west and 300 feet south of north quarter corner of section. 8/17/31, 30.2; 12/1/32, 28.5.

15N/3E-27 (Harding 49)—Reference point—top of concrete pit, elevation 51 feet, 1,000 feet west and 1,300 feet north of south quarter corner of section. 9/1/31, 32.2; 11/30/32, 32.4.

15N/3E-28 (Harding 26)—Reference point—top of wood pit, elevation 53 feet. South side of highway, 1,100 feet west of northeast corner of section. 4/—/13, 17.0; 9/17/31, 31.4; 12/1/32, 28.4.

15N/3E-29 (Harding 31)—Reference point—top of concrete pit, elevation 50 feet, 150 feet north and 50 feet west of southeast corner of section. 9/22/31, 32.4; 11/30/32, 29.4.

15N/3E-29 (Harding 30)—Reference point—top of concrete pit, elevation 49 feet, 660 feet east and 660 feet north of southwest corner of section. 9/20/31, 25.2; 11/30/32, 22.6.

15N/3E-30 (Harding 39)—Reference point—top of frame of wooden pit, elevation 52 feet, 1,320 feet south of north quarter corner on east bank of Live Oak drain. 9/19/31, 22.5.

15N/3E-31 (Harding 40)—Reference point—top of wall of concrete pit, elevation 45 feet, 1,800 feet east and 200 feet north of southwest corner of section. 9/19/31, 17.5; 11/30/32, 17.3.

15N/3E-31 (Harding 38)—Reference point—top of wall of concrete pit, elevation 47 feet, 200 feet west and 200 feet south of northeast corner of section. 9/19/31, 22.0; 11/30/32, 21.8.

15N/3E-32 (Harding 32)—Reference point—top of concrete pit, elevation 50 feet, 600 feet east and 500 feet north of south quarter corner of section. 9/22/31, 32.7; 12/1/32, 29.1.

15N/3E-33 (Harding 33)—Reference point—top of concrete pit, elevation 50 feet, 1,150 feet east and 250 feet south of northwest corner of section. 9/23/31, 33.3; 11/30/32, 30.6.

15N/3E-34 (Harding 50)—Reference point—top of concrete pit, elevation 52 feet, 1,600 feet north and 400 feet east of south quarter corner of section. 9/—/31, 34.6; 12/1/32, 32.7.

15N/4E-32 (Harding 102)—Reference point—top of wall of pit, elevation 61 feet, 50 feet east of west line of section, 500 feet south of railroad crossing. 10/16/31, 17.0; 12/3/32, 18.0.

16N/3E-2 (Harding 95)—Reference point—top of casing, elevation 80 feet, 100 feet north of Ramirez Road, 0.50 mile east of State Highway 24. 10/15/31, 17.5.

16N/3E-11 (Harding 96)—Reference point—top of casing, elevation 76 feet. At west end of road running west from State Highway 24, 0.8 mile north of Magnolia Avenue. 10/15/31, 19.5; 12/6/32, 17.9.

16N/3E-14 (Harding 97)—Reference point—top of wall of pit, elevation 75 feet, 500 feet west of State Highway 24, 400 feet south of La Finca Lane. 10/15/31, 15.0; 12/6/32, 14.9.

16N/3E-19 (Harding 12)—Reference point—top of casing, elevation 67 feet, 1,260 feet east and 200 feet north of north quarter of section. 9/2/31, 10.1; 12/7/32, 10.1.

*16N/3E-21 (Harding 10)—Reference point—top of wood pit, west side, elevation 68 feet. Near southeast corner of section, 0.5 mile east of Southern Pacific Railroad. 9/2/31, 23.8; 10/17/31, 22.9; 12/7/32, 20.8.

16N/3E-24 (Harding 90)—Reference point—top of casing, elevation 70 feet. North of Woodruff Road, 1 mile east of State Highway 24. 10/15/31, 10.0; 12/6/32, 11.5.

16N/3E-27 (Harding 78)—Reference point—top of casing, elevation 69 feet, 500 feet north of east and west center line of section at toe of levee. 10/13/31, 25.0; 12/7/32, 22.4.

16N/3E-28 (Harding 8)—Reference point—top of concrete pit, west side, elevation 64 feet, 1,300 feet west of U. S. Highway 99E, 250 feet north of south line of section. 9/2/31, 21.8; 10/17/31, 20.6; 12/7/32, 19.1.

16N/3E-28 (Harding 9)—Reference point—top of casing, elevation 66 feet, 1,000 feet south of north line of section and 300 feet east of Southern Pacific Railroad. 9/2/31, 19.0; 10/17/31, 19.2; 12/7/32, 17.7.

16N/3E-29 (Harding 2)—Reference point—top of concrete pit, elevation 66 feet, 100 feet west and 120 feet south of northeast quarter of northwest quarter of section. 8/13/31, 13.5; 10/17/31, 13.2; 12/7/32, 12.6.

TABLE 2—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Made by S. T. Hording
(Depths to water in feet meosured from reference point)

16N 3E-29 (Harding 1)—Reference point—top of casing, elevation 65 feet, 1,880 feet north and 660 feet west of east quarter corner of section. 8/31/31, 15.5; 10/17/31, 14.8; 12/7/32, 13.7.

16N 3E-29 (Harding 6)—Reference point—top of casing, elevation 65 feet, 750 feet east and 1,100 feet north of south quarter corner of section. 8/31/31, 18.4; 10/17/31, 18.0; 12/7/32, 16.3.

16N 3E-29 (Harding 91)—Reference point—top of casing, elevation 71 feet. At cross roads at east end of Woodruff Road. 10/15/31, 6.5; 12/6/32, 6.0.

16N 3E-30 (Harding 11)—Reference point—top of casing, elevation 66 feet, 1,750 feet east and 500 feet north of southwest corner of section. 9/2/31, 10.1; 12/7/32, 12.0.

16N 3E-31 (Harding 34)—Reference point—top of timber frame, elevation 61 feet, 1,300 feet east and 300 feet north of south quarter corner of section. 9/17/31, 18.0; 10/17/31, 20.0; 12/7/32, 17.8.

16N 3E-32 (Harding 13)—Reference point—top of concrete pit, elevation 64 feet, 1,350 feet south and 300 feet east of north quarter corner of section. 9/2/31, 19.1; 10/17/31, 18.6; 12/7/32, 17.5.

16N 3E-32 (Harding 3)—Reference point—top of wood pit, west side, elevation 60 feet, 600 feet north and 300 feet east of south quarter corner of section. 8/31/31, 19.3; 10/17/31, 18.9; 12/7/32, 17.0.

16N 3E-33 (Harding 5)—Reference point—top of casing, elevation 64 feet, 3,300 feet west of U. S. Highway 99E, 200 feet south of north line of section. 8/31/31, 24.9; 10/17/31, 19.1; 12/7/32, 17.5.

16N 3E-33 (Harding 7)—Reference point—top of concrete base, elevation 60 feet, 1,100 feet east and 400 feet north of southwest corner of section. 9/1/31, 20.6; 12/7/32, 18.8.

16N 3E-35 (Harding 89)—Reference point—top of wall of pit, elevation 66 feet, 1,000 feet west of angle in Oroville Highway, 0.5 mile north of Ellis Road. 10/15/31, 18.0; 12/6/32, 16.4.

16N 3E-35 (Harding 88)—Reference point—top of wall of pit, elevation 65 feet, 0.75 mile north of Walnut Avenue, 0.50 mile west of Oroville Highway. 10/15/31, 20.0; 12/6/32, 19.1.

16N 3E-36 (Harding 92)—Reference point—top of wall of pit, elevation 65 feet, 600 feet south of Ellis Road, 500 feet west of Western Pacific Railroad. 10/15/31, 7.5; 12/5/32, 8.5.

TABLE 3

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Sutter County Farm Advisor
(Depths to water in feet and/or inches measured from reference point)

13N/3E-2C1—Reference point—air gage. 1/19/32, 18.2; 2/24/32, 17.5; 3/2/32, 17.9; 4/18/32, 19.0; 5/23/32, 17.1; 6/15/32, 20.4; 7/18/32, 23.0; 9/8/32, 19.8; 10/25/32, 19.0; 11/15/32, 19.3; 12/23/32, 19.0; 2/3/33, 18.5; 3/3/33, 18.6; 4/11/33, 21.4; 5/2/33, 19.8; 6/28/33, 24.2; 8/1/33, 35.0; 9/14/33, 32.0; 10/17/33, 31.0; 3/22/34, 27.0; 9/18/34, 31.5; 11/9/34, 30.0; 12/27/34, 29.3; 1/22/35, 27.8; 3/22/35, 26.3; 4/19/35, 23.7; 5/27/35, 22.7; 7/2/35, 57.8 (operating); 10/31/35, 28.4; 12/26/35, 27.6; 1/3/36, 26.0; 2/25/36, 22.0; 4/11/36, 23.0; 6/15/36, 29.0; 7/24/36, 33.0; 8/20/36, 28.0; 9/24/36, 27.8; 10/27/36, 27.8; 12/28/36, 27.0; 2/9/37, 26.0; 4/5/37, 20.0; 5/13/37, 20.0.

13N/3E-5E2—Reference point—top of pit. 5/16/31, 20′ 8″; 7/11/31, 24′ ¾″; 8/31/31, 21′ 7½″; 9/23/31, 21′ 7″; 10/16/31, 21′ ½″; 11/17/31, 20′ 7″; 12/17/31, 19′ 11″; 1/19/32, 18′ 11″; 2/24/32, 18′ 3¾″; 3/22/32, 17′ 11½″; 4/19/32, 18′ 5½″; 5/23/32, 19′ 6″; 6/23/32, 19′ 2″; 9/13/32, 19′ 11½″; 10/18/32, 19′ 10″; 11/30/32, 19′ 7″; 12/27/32, 19′ 6″; 2/6/33, 19′ 2″; 3/5/33, 18′ 10½″; 4/10/33, 19′ ¾″; 5/17/33, 20′ 5½″; 8/1/33, 22′ 4¾″; 9/14/33, 21′ 5¾″; 3/16/34, 19′ 5½″; 11/9/34, 20′ 7″; 12/11/34, 20′ 0″; 2/15/35, 17′ 7″; 3/22/35, 18.0; 4/19/35, 17.5; 5/24/35, 17.6; 7/2/35, 24.8 (operating); 8/21/35, 18.7; 9/25/35, 18.5; 10/31/35, 18.5; 12/26/35, 18.1; 1/24/36, 17.7; 2/25/36, 16.6; 4/14/36, 15.2; 4/22/36, 16.7; 8/18/36, 16.9; 9/28/36, 16.9; 10/21/36, 16.4; 12/28/36, 15.8; 2/9/37, 15.3.

13N/3E-24G1—Reference point—air gage. 5/6/31, 19.9; 7/15/31, 22.2; 8/28/31, 19.9; 9/22/31, 21.1; 10/14/31, 19.9; 11/17/31, 19.9; 12/17/31, 19.7; 1/2/32, 17.2; 1/19/32, 16.5; 2/25/32, 15.8; 3/2/32, 17.6; 4/26/32, 15.1; 6/22/32, 16.9; 7/18/32, 19.9; 9/8/32, 18.8; 10/18/32, 18.1; 11/15/32, 18.8; 12/22/32, 18.1; 2/3/33, 17.6; 3/3/33, 17.4; 4/11/33, 21.1; 5/2/33, 17.6; 6/28/33, 34.9 (operating); 8/1/33, 22.2; 9/14/33, 19.5; 10/17/33, 18.3; 3/22/34, 28.0; 6/29/34, 21.6; 9/18/34, 19.9; 11/9/34, 19.7; 12/27/34, 18.8; 1/22/35, 16.5; 3/22/35, 16.5; 4/19/35, 13.0; 5/27/35, 12.4; 7/2/35, 36.1 (operating); 8/19/35, 16.5; 9/25/35, 19.5; 10/31/35, 17.6; 12/26/35, 17.6; 1/30/36, 15.3; 2/25/36, 10.9; 4/6/36, 11.9; 8/10/36, 19.5; 9/3/36, 19.9; 9/24/36, 14.9; 10/27/36, 18.8; 12/28/36, 18.8; 2/9/37, 12.4; 4/5/37, 7.1; 5/19/37, 7.8; 9/13/37, 14.1; 12/30/37, 9.7; 2/24/36, 4.7; 3/23/38, 3.8; 4/25/38, 3.7; 6/3/38, 4.8; 6/21/38, 8.9; 7/22/38, 12.2; 9/8/38, 12.3; 2/25/39, 12.5; 4/10/39, 13.8; 8/2/39, 17.6; 10/11/39, 15.8; 11/29/39, 15.4; 2/8/40, 11.5; 3/22/40, 7.8; 5/20/40, 7.9; 8/24/40, 15.0.

13N/4E-13F3—Reference point—hole in pump base. 12/1/32, 18′ 6¾″; 1/12/33, 17′ 9½″; 2/3/33, 17′ 4½″; 3/10/33, 16′ 9½″; 4/3/33, 18′ 2″; 5/23/33, 20′ 8½″; 10/23/33, 22′ 1½″; 3/20/34, 23′ 3½″; 6/27/34, 30′ 6″; 9/26/34, 24′ 6″; 12/10/34, 20′ 11″; 2/14/35, 18′ 5″; 3/25/35, 17′ 4½″; 4/30/35, 15′ 6¾″; 5/28/35, 19′ 2″; 8/18/35, 26′ 3½″; 9/26/35, 20′ 7½″; 1/15/36, 16.7; 3/28/36, 14.2; 3/27/36, 20.6; 8/10/36, 25.3; 8/20/36, 22.6; 9/23/36, 21.0; 10/27/36, 19.4; 1/2/37, 16.7; 2/10/37, 15.6; 4/8/37, 11.6; 11/27/37, 17.0; 3/16/38, 11.0; 4/27/38, 10.7; 5/31/38, 14.0; 7/21/38, 32.2*; 9/8/38, 18.1; 12/29/38, 15.6; 2/16/39, 15.3; 6/15/39, 34.9; 10/12/39, 22.7; 12/6/39, 20.9; 2/19/40, 17.1; 3/27/40, 15.1; 5/15/40, 15.3; 8/6/40, 28.7.

13N/4E-13R2—Reference point—top of casing. 1/12/33; 16′ 3″; 2/3/33, 14′ 8¼″; 3/10/33, 15′ 0″; 4/3/33, 16′ 4½″; 5/23/33, 18′ 1″; 6/28/33, 26′ 3″*; 8/9/33, 25′ 1¾″; 9/15/33, 22′ 8″. Following measurements from new well, reference point—hole in side of pump, 3/20/34, 22′ 3½″; 12/10/34, 18′ 8″; 2/14/35, 16′ 3½″; 3/25/35, 14′ 11½″; 4/30/35, 13′ 5¼″; 5/28/35, 14′ 10″; 7/3/35, 22′ 4½″; 1/25/36, 11.2; 2/28/36, 16.2; 8/10/36, 20.7; 8/20/36, 19.0; 9/23/36, 19.6; 10/27/36, 15.4; 1/2/37, 13.4; 2/10/37, 11.9; 4/8/37, 7.6; 5/26/37, 9.7; 11/27/37, 13.6; 3/16/38, 6.9; 4/27/38, 6.6; 5/31/38, 7.8; 12/29/38, 11.6; 2/16/39, 9.2; 12/6/39, 16.5; 2/19/40, 13.3; 3/27/40, 11.3; 5/15/40, 9.7; 8/6/40, 21.5; 5/19/41, 6.4.

* Nearby well pumping.

13N/4E-14D1—Reference point—air gage. 2/14/33, 12.01; 3/8/33, 12.01; 4/5/33, 39.63 (operating); 6/27/33, 15.00.

13N/4E-15R1—Reference point—air gage. 2/14/33, 18.94; 3/8/33, 18.25; 4/5/33, 43.2 (operating); 5/23/33, 23.56; 6/26/33, 32.8; 9/26/33, 24.0; 10/23/33, 28.18; 3/20/34, 23.56; 6/27/34, 31.65; 9/26/34, 30.49; 12/10/34, 25.11; 2/14/35, 22.15; 3/25/35, 20.79; 4/30/35, 18.94; 5/28/35, 18.94; 6/24/35, 27.03; 8/6/35, 31.65; 9/26/35, 25.18; 1/15/36, 21.25; 2/28/36, 18.25; 3/29/36, 28.18; 7/23/36, 30.5; 8/20/36, 30.5; 9/23/36, 31.65; 10/27/36, 28.41; 1/2/37, 23.56; 2/10/37, 21.25; 5/26/37, 16.63; 7/21/37, 26.4.

13N/5E-7L1—Reference point—top of casing. 12/1/32, 22′ 2″; 2/3/33, 20′ 10½″.

13N/5E-16D1—Reference point—top of casing. 12/1/32, 1′ 3¾″; 1/12/33, 1′ ½″; 2/3/33, 0′ 10½″; 3/10/33, 0′ 6½″; 4/5/33, 0′ 6″; 5/23/33, 1′ 4″; 6/27/33, 2′ 8½″; 8/9/33, 7′ 1″; 9/15/33, 5′ 0″; 10/23/33, 4′ 8½″; 3/20/34, 1′ 4″; 6/27/34, 4′ 6½″; 9/26/34, 6′ ½″; 12/10/34, 4′ 4″; 2/14/34, 1′ 10¾″; 3/25/35, 0′ 2½″; 4/30/35, 0′ 9½″; 5/28/35, —0′ 1¾″; 7/3/35, 1′ 9″; 8/6/35, 3′ 0″; 9/26/35, 2′ 7″; 1/15/36, 13.0; 2/28/36, 9.1; 3/27/36, 9.3; 7/30/36, 14.3; 8/20/36, 13.7; 9/23/36, 13.3; 10/27/36, 13.1; 1/2/37, 12.7; 2/10/37, 11.3; 4/8/37, 6.5; 5/26/37, 9.1; 7/21/37, 14.7; 3/16/38, 5.1; 4/27/38, 6.4; 7/21/38, 12.5; 9/8/38, 13.5; 12/29/38, 11.5; 2/16/39, 11.4; 4/27/39, 14.4; 6/15/39, 15.9; 10/12/39, 17.5; 12/6/39, 15.6; 2/9/40, 12.9; 3/27/40, 9.8; 5/15/40, 8.7; 8/6/40, 16.8; 5/19/41, 6.7; 7/28/41, 14.2.

13N/5E-18C1—Reference point—hole in top of pump base. 12/1/32, 17′ 4½″; 1/12/33, 16′ 7″; 2/3/33, 16′ 2″; 3/10/33, 15′ 7″; 4/3/33, 18′ 4½″; 5/23/33, 19′ 9″; 6/28/33, 25′ 1″; 9/15/33, 22′ 6″; 10/23/33, 21′ 4″; 6/27/34, 30′ 3″; 9/26/34, 23′ 7½″; 12/10/34, 20′ ¼″; 2/14/35, 17′ 11½″; 3/25/35, 15′ 7½″; 4/30/35, 14′ 1½″; 5/28/35, 16′ 2″; 6/24/35, 21′ 4″; 8/6/35, 26′ 5½″; 9/26/35, 18′ 8½″; 8/10/36, 22.05; 8/20/36, 22.2; 9/23/36, 20.9; 10/27/36, 15.0; 1/2/37, 14.3; 2/16/37, 13.04; 4/8/37, 8.2; 5/26/37, 12.9; 11/27/37, 14.6; 3/16/38, 8.0; 4/27/38, 8.2; 5/31/38, 10.2; 7/21/38, 20.3; 9/8/38, 16.4; 12/29/38, 13.2; 5/19/41, 8.2; 7/28/41, 19.7.

15N/3E-7M2—Reference point—top of casing. 7/15/31, 17′ 6½″; 8/27/31, 17′ 11″; 9/17/31, 17′ 6″; 10/26/31, 16′ 11″; 11/19/31, 16′ 6½″; 12/16/31, 16′ ¾″; 4/18/32, 14′ 8½″; 2/23/32, 14′ 2″; 3/23/32, 14′ 2½″; 4/15/32, 14′ 6½″; 5/18/32, 14′ 7½″; 6/2/32, 15′ 3½″; 7/13/32, 15′ 9½″; 9/12/32, 16′ 2½″; 10/17/32, 17′ 11″; 11/30/32, 16′ 4″; 12/29/32, 16′ 3¾″; 1/26/33, 16′ 5½″; 3/3/33, 16′ 2¾″; 4/7/33, 16′ 5″; 5/12/33, 16′ 9½″; 6/20/33, 18′ 3″; 7/31/33, 18′ 6½″; 9/13/33, 17′ 2″; 10/17/33, 16′ 9½″; 11/8/33, 16′ 11½″; 3/12/34, 16′ 3″; 6/26/34, 17′ 8″; 11/2/34, 18′ 5½″; 1/28/35, 17′ 5″; 3/14/35, 16′ 3″; 4/18/35, 15′ 5½″; 5/23/35, 15′ 1¾″; 6/25/35, 16′ 0″; 7/27/35, 17′ 0″; 10/25/35, 15.2; 12/19/35, 15.2; 1/23/36, 14.8; 2/27/36, 13.2; 3/31/36, 11.7; 7/9/36, 12.0; 8/18/36, 12.8; 9/17/36, 12.5; 10/20/36, 13.3; 12/28/36, 13.2; 2/16/37, 12.2; 3/29/37, 9.4; 5/3/37, 8.8; 7/16/37, 10.7; 9/28/37, 12.2; 12/4/37, 14.2; 4/15/38, 4.6; 5/26/38, 6.6; 7/14/38, 8.5; 9/20/38, 10.3; 10/28/38, 9.5; 12/24/38, 10.5; 1/31/39, 10.6; 3/3/39, 10.9; 4/13/39, 11.6; 8/1/39, 14.7; 9/27/39, 14.6; 11/8/39, 14.2; 1/18/40, 13.2; 3/20/40, 9.6; 5/16/40, 7.9; 8/2/40, 11.2; 10/17/40, 12.7; 9/20/41, 10.3.

15N/3E-31A1—Reference point—top of pit plus 4-inch timber. 5/12/31, 21′ 10¾″; 6/26/31, 22′ 10¾″; 7/28/31, 24′ 0″; 8/31/31, 24′ 11″; 9/23/31, 24′ ¾″; 10/20/31, 23′ 8½″; 11/8/31, 23′ 1″; 12/17/31, 22′ 9½″; 1/19/32, 22′ 2″; 2/23/32, 21′ 4″; 3/22/32, 20′ 11½″; 4/18/32, 21′ 4½″; 5/23/32, 21′ 2″; 6/21/32, 21′ 5½″; 7/19/32, 22′ 4″; 9/13/32, 22′ 11″; 10/18/32, 22′ 6¾″; 11/22/32, 22′ 2½″; 12/27/32, 21′ 10″; 1/30/33, 21′ 3″; 4/10/33, 21′ 5″; 5/17/33, 22′ 2½″; 6/29/33, 23′ ¾″; 7/25/33, 24′ 5″; 10/18/33, 23′ 7½″; 12/8/33, 23′ 7½″; 3/13/34; 22′ 3½″; 6/26/34, 23′ 11″; 10/2/34, 24′ 7″; 11/5/34, 24′ ¾″; 12/11/34, 23′ 7½″; 2/15/35, 22′ 5″; 3/19/35, 21′ 11″; 4/19/35, 21′ 2″; 5/23/35, 20′ 5½″;

TABLE 3—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Sutter Caunty Farm Advisar
(Depths to water in feet and/ar inches measured fram reference point)

6/27/35, 21′ 2″; 7/30/35, 22′ 6″; 9/21/35, 23′ 1¾″; 10/25/35, 21.9; 12/20/35, 21.1; 1/23/36, 17.2; 2/25/36, 20.1; 4/14/36, 19.1; 7/22/36, 20.1; 8/18/36, 20.7; 9/17/36, 20.2; 10/21/36, 20.2; 12/28/36, 19.7.

16N/3E-30A1—Reference point—top of casing, 6 inches above ground level. 6/27/31, 11′ 10″; 7/28/31, 12′ 2″; 8/27/31, 12′ 3½″; 9/17/31, 12′ 6″; 10/26/31, 12′ 9″; 11/17/31, 13′ ½″; 12/16/31, 13′ 1½″; 1/18/32, 10′ ¼″; 2/18/32, 9′ 11″; 3/18/32, 10′ 1½″; 5/15/32, 10′ 10½″; 6/30/32, 10′ 6½″; 7/13/32, 10′ 9½″; 9/8/32, 11′ 10″; 10/17/32, 12′ 4¾″; 11/22/32, 12′ 8½″; 12/21/32, 13′ 2″; 1/26/33, 13′ 2½″; 3/3/33, 13′ 7¼″; 4/7/33, 12′ 11″; 5/11/33, 12′ 8½″; 6/20/33, 12′ 11″; 7/31/33, 12′ 11″; 9/13/33, 13′ 6½″; 10/17/33, 13′ 10″; 12/8/33, 14′ 4″; 3/12/34, 12′ 7½″; 6/26/34, 11′ 9″; 7/31/34, 12′ 1½″; 9/27/34, 12′ 6½″; 11/2/34, 13′ 4″; 12/11/34, 13′ 7¾″; 1/28/35, 11′ 4¼″; 3/14/35, 9′ 2″; 4/18/35, 9′ 6¼″; 5/22/35, 10′ 5″; 6/25/35, 10′ 8″; 7/29/35, 10′ 11½″; 9/19/35, 12′ 2″; 10/23/35, 11.9; 12/19/35, 12.6; 1/22/36, 11.2; 2/27/36, 7.5; 3/31/36, 9.1; 5/15/36, 9.7; 6/12/36, 10.2; 7/9/36, 10.7; 8/18/36, 11.7; 9/17/36, 12.1; 10/20/36, 12.2; 12/22/36, 12.7; 2/16/37, 9.1; 3/29/37, 6.6; 5/3/37, 8.6; 7/16/37, 10.1; 12/4/37, 10.2; 5/17/38, 7.9; 7/14/38, 9.5; 9/15/38, 11.2; 10/26/38, 11.8; 12/24/38, 12.4; 1/31/39, 12.6; 3/3/39, 12.7; 4/13/39, 13.1; 6/3/39, 12.1; 8/1/39, 12.5; 9/22/39, 11.6.

16N/3E-30C1—Reference point—top of casing, 4 inches above ground. 5/22/31, 11′ 8½″; 6/25/31, 11′ 7″; 7/29/31, 12′ 0″; 8/27/31, 11′ 9″; 9/17/31, 11′ 7½″; 10/21/31, 11′ ½″; 11/19/31, 10′ 7½″; 12/23/31, 10′ 2″; 1/18/32, 8′ 7″; 2/23/32, 8′ 4½″; 3/19/32, 8′ 4½″; 4/15/32, 8′ 11¾″; 5/17/32, 9′ 1″; 6/21/32, 8′ 9½″; 7/13/32, 9′ 1″; 9/12/32, 9′ 2⅝″; 10/17/32, 9′ 4½″; 11/30/32, 10′ 2½″; 12/29/32, 10′ 6½″; 1/26/33, 10′ 9¼″; 3/3/33, 10′ 6½″; 4/7/33, 10′ 10″; 5/12/33, 10′ 9½″; 6/20/33, 9′ 10″; 7/31/33, 9′ 7½″; 9/13/33, 9′ 3″; 10/17/33, 9′ 6″; 12/8/33, 10′ 4½″; 3/12/34, 10′ 0″; 6/26/34, 11′ 8½″; 9/27/34, 11′ 9″; 11/2/34, 12′ 9″; 12/11/34, 11′ 11½″; 1/28/35, 10′ 10¾″; 3/4/35, 9′ 8½″; 4/18/35, 9′ 4″; 5/23/35, 9′ 8″; 6/25/35, 10′ 5″; 7/29/35, 11′ 5½″; 9/21/35, 11′ 2½″; 10/25/35, 10′ 10¾″; 12/19/35, 11.1; 1/23/36, 10.7; 2/27/36, 9.5; 3/31/36, 8.3; 7/9/36, 9.4; 8/18/36, 9.8; 9/17/36, 9.6; 10/20/36, 9.7; 12/28/36, 10.3; 2/16/37, 6.5; 3/29/37, 6.9; 5/3/37, 8.5; 7/16/37, 8.6; 9/28/37, 8.2; 12/4/37, 8.6; 1/25/38, 6.5; 4/14/38, 3.2; 5/26/38, 6.3; 7/14/38, 6.9; 9/20/38, 8.5; 10/26/38, 8.0; 12/24/38, 8.7; 1/31/39, 8.9; 3/3/39, 9.2; 4/13/39, 10.3; 8/1/39, 11.2; 9/22/39, 12.1; 11/8/39, 10.6; 1/18/40, 10.2; 3/20/40, 6.5; 5/16/40, 6.7; 8/2/40, 9.7; 10/17/40, 10.3.

16N/3E-32G5—Reference point—top of casing, 1 foot 6 inches above ground surface. 6/25/31, 22′ 5″; 7/28/31, 26′ 2½″; 8/27/31, 24′ 6½″; 9/17/31, 20′ 5½″; 10/19/31, 18′ 11″; 11/19/31, 18′ 6″; 12/16/31, 18′ 2¾″; 1/2/32, 17′ 8½″; 1/18/32, 17′ 0″; 2/18/32, 15′ 9″; 3/18/32, 12′ 8½″; 4/15/32, 19′ 6″; 5/17/32, 15′ 1½″; 6/23/32, 23′ 10½″*; 7/13/32, 18′ 1″; 9/8/32, 18′, 2½″; 10/17/32, 17′ 10½″; 11/22/32, 17′ 8″; 12/29/32, 17′ 5″; 1/26/33, 17′ 3½″; 3/3/33, 18′ 1½″; 4/7/33, 25′ 4″ (operating); 5/11/33, 17′ 9½″; 6/20/33, 22′ 5½″; 7/31/33, 28′ 10″ (operating); 9/13/33, 21′ 10½″; 10/17/33, 21′ 0″; 11/18/33, 19′ 2½″; 3/12/34, 18′ 2″. Reference point—top of casing, ground level. 6/26/34, 24′ 5″; 7/31/34, 25′ 7″; 9/27/34, 23′ 9¾″; 11/2/34, 19′ 5″; 12/11/34, 18′ 5½″; 1/28/35, 16′ 10″; 3/14/35, 14′ 4½″; 4/18/35, 14′ ½″; 5/22/35, 12′ 2½″; 7/3/35, 16′ 5½″; 7/29/35, 20′ 0″; 8/27/35, 17′ 1″; 9/19/35, 19′ 17″; 1/22/36, 15.4; 2/27/36, 12.9; 3/31/36, 13.4; 7/9/36, 18.5; 8/18/36, 18.8; 9/17/36, 19.5; 10/23/36, 16.4; 12/22/36, 15.3; 2/16/37, 13.8; 3/29/37, 11.2; 5/3/37, 10.7; 7/16/37, 15.3; 12/4/37, 15.0; 1/25/38, 12.2; 2/25/38, 5.1; 4/14/38, 3.5; 5/26/38, 5.7; 7/14/38, 12.8; 9/15/38, 13.2; 10/26/38, 12.8.

* Nearby well operating.

APPENDIX F

RECORDS OF APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN SUTTER-YUBA AREA

APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN SUTTER-YUBA AREA IN 1948 AND 1949

Crop	Season	Map number	Well number	Method of irrigation	Soil type	Acres	Depth per irrigation, in inches							Total depth, in inches
							1st	2d	3d	4th	5th	6th	7th	
Alfalfa	1948	1	15N/1E-13E1	Border check	Clay adobe	8	5.8	8.1	7.3	7.3				28.5
	1948	2	11N/3E-15P1	Border check	Fine sandy loam	32	16.1	4.4	30.8	7.5	12.7	2.3		73.8
	1949	3	14N/5E-32R1 14N/5E-32R2	Border check	Loam	20	4.15	4.01	8.81	4.70	4.99	12.96	5.98	53.6
	1949	3	14N/5E-32R1 14N/5E-32R2	Border check	Loam	18	7.83	8.47	9.89	9.29	10.54	11.90	11.10	69.0
	1949	4	15N/5E-18B1	Border check	Loam	27								91.8
							Weighted mean depths: 1948 64.8 inches (5.4 feet) 1949 73.8 inches (6.1 feet) 1948–49 70.0 inches (5.8 feet)							
Almonds	1948	5	16N/3E-29R1	Contour check	Loam	13	5.1	5.0	6.2					16.3
	1948	6	16N/3E-26Q1	Contour check	Loam	50	7.5	7.3						14.8
	1948	7	15N/2E-8J1	Contour check	Loam	70	1.8	8.9						10.7
	1949	6	16N/3E-26Q1	Contour check	Loam	50	7.8	7.33	5.0					20.1
	1949	8	14N/3E-4F1	Contour check	Loam	20	6.4	7.65	3.75	3.75				21.5
							Weighted mean depths: 1948 12.8 inches (1.1 feet) 1949 20.5 inches (1.7 feet) 1948–49 15.4 inches (1.3 feet)							
Young Almonds Interplanting Beans	1948	9	16N/3E-23R2	Contour check	Loam	20	6.1	4.2	3.8					14.1
Beans	1948	10	13N/4E-7E1	Furrow	Silt loam	36								8.4
	1948	11	15N/4E-17J1 15N/4E-8R1	Furrow	Fine sandy loam	103	4.2	0.8	5.0	6.5				16.5
	1948	12	13N/5E-6D2	Furrow	Fine sandy loam	60	6.0	5.2						11.2
	1949	13	13N/4E-12C1	Furrow	Fine sandy loam	50	4.5	2.0	1.5	1.7	1.7			11.4
							Weighted mean depths: 1948 13.4 inches (1.1 feet) 1949 11.4 inches (1.0 foot) 1948–49 13.0 inches (1.1 feet)							
Cherries	1948	14	15N/3E-15G1	Contour check	Loam	18	6.8	6.8	2.5	4.4	1.9			22.4
	1948	15	15N/3E-3D1	Contour check	Loam	60	7.4	7.7	5.9	7.3	0.7			29.0
							Weighted mean depth: 1948 27.5 inches (2.3 feet)							
Egyptian Corn	1948	11	15N/4E-17J1 15N/4E-8R1	Furrow	Fine sandy loam	13	6.2	5.7	9.2	8.9	1.3			31.3
	1949	12	13N/5E-6D2	Furrow	Fine sandy loam	60	5.6	8.1	7.5					21.2
							Weighted mean depth: 1948–49 23.0 inches (1.9 feet)							
Flax	1948	16	12N/4E-2Q1	Contour check	Clay loam	55								10.4
Hops	1948	17	13N/5E-4J1	Furrow	Fine sandy loam	19	3.7	3.1	3.4	0.8				11.0
	1949	17	13N/5E-4J1	Furrow	Fine sandy loam	27.5	3.8	3.0	3.6					10.4
							Weighted mean depth: 1948–49 10.6 inches (0.9 foot)							
Pasture	1948	18	12N/4E-10A1	Border check	Loam	60								51.5
	1948	19	14N/4E-34C1	Contour check	Loam	120								26.2
	1949	18	12N/4E-10A1	Border check	Loam	75								71.0
	1949	4	15N/3E-18B1	Border check	Loam	30								84.6
	1949	20	14N/5E-21B1	Border check	Loam	172								79.8
							Weighted mean depths: 1948 34.6 inches (3.9 feet) 1949 78.0 inches (6.5 feet) 1948–49 60.7 inches (5.1 feet)							

APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN SUTTER-YUBA AREA IN 1948 AND 1949—Continued

Crop	Season	Map number	Well number	Method of irrigation	Soil type	Acres	Depth per irrigation, in inches							Total depth, in inches
							1st	2d	3d	4th	5th	6th	7th	
Peaches	1948	21	13N/4E-15K1	Contour check	Fine sandy loam	37	17.4	14.1	12.7					44.2
	1948	22	15N/3E-4C2	Contour check	Clay loam	38.5	1.8	7.3	11.5					20.6
	1948	23	13N/5E-7C2	Contour check	Fine sandy loam	55	6.8	5.7	7.7	6.5				26.7
	1948	24	13N/4E-16N1	Contour check	Fine sandy loam	22	4.1	8.0	7.8	7.1				27.0
	1948	25	15N/3E-33D1	Contour check	Loam	47	1.5	17.0	5.2	8.6				32.3
	1948	26	13N/3E-2L1	Contour check	Loam	15	4.0	7.4	5.6	5.2	6.5			28.7
	1948	27	15N/3E-9A1	Contour check	Loam	40	6.8	2.1	4.3	3.5				16.7
	1948	28	14N/3E-26M2	Contour check	Loam	56								31.6
	1948	29	15N/3E-34L1	Contour check	Loam	30								29.5
	1949	26	13N/3E-2L1	Contour check	Loam	15	6.0	5.0	4.7	6.9	11.9			34.5
	1949	23	13N/5E-7C2	Contour check	Fine sandy loam	55								27.0
	1949	30	13N/4E-13F1	Contour check	Fine sandy loam	34								36.1
	1949	24	13N/4E-16N1	Contour check	Fine sandy loam	22								30.6
	1949	29	15N/3E-34L1	Contour check	Loam	30								37.1
							Weighted mean depths: 1948 28.7 inches (2.4 feet)							
							1949 32.2 inches (2.7 feet)							
							1948–49 29.7 inches (2.5 feet)							
Prunes	1948	25	15N/3E-33F1	Contour check	Loam	108	7.1	4.7						12.0
	1948	31	16N/3E-36L1	Contour check	Loam	100	3.7	6.4						10.1
	1948	27	15N/3E-9A1	Contour check	Loam	20	2.5	1.8	3.7					8.0
	1948	32	16N/3E-17Q1	Contour check	Loam	20	13.1	9.8	8.1					31.0
	1949	32	16N/3E-17Q1	Contour check	Loam	20	11.75	9.9	10.2	9.35				41.1
							Weighted mean depths: 1948 12.5 inches (1.0 foot)							
							1949 41.1 inches (3.4 feet)							
							1948–49 14.6 inches (1.2 feet)							
Rice	1948	33	12N/4E-24F1	Contour check	Loam	80								63.5
	1948	34	11N/4E-9L1 11N/4E-9C1	Contour check	Clay adobe	150								88.5
	1948	35	15N/4E-23A1 14N1,14P1,24C1	Contour check	Loam	325								48.7
	1949	36	16N/4E-6N2	Contour check	Clay loam	120								66.0
	1949	37	12N/4E-20J1 R1, Q1	Contour check	Clay loam	185								171.5 56.2
	1949	35	15N/4E-23A1 14N1, 14P1, 24C1	Contour check	Loam	315								
							Weighted mean depths: 1948 60.6 inches (5.1 feet)							
							1949 92.5 inches (7.7 feet)							
							1948–49 77.5 inches (6.5 feet)							
Sugar Beets	1948	10	13N/4E-7E1 7M1, 18F1		Silt loam	224								17.5
Walnuts	1948	6	16N/3E-26Q1	Furrow	Loam	65	8.6	5.9	3.2					17.7
	1948	14	15N/3E-15G1	Contour check	Loam	12	6.7	6.7	2.6	4.4	1.9			22.3
	1948	11	15N/4E-17J1	Contour check	Fine sandy loam	35	16.6	13.7						30.3
	1948	38	15N/4E-20F1	Contour check	Fine sandy loam	40	6.3	8.1	6.0	6.2	4.3			30.9
	1949	6	16N/3E-26Q1	Furrow	Loam	65	6.2	5.1	4.0	4.6	2.8			22.7
							Weighted mean depths: 1948 24.4 inches (2.0 feet)							
							1949 22.7 inches (1.9 feet)							
							1948–49 23.9 inches (2.0 feet)							

APPENDIX G

RESERVOIR YIELD STUDIES

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YIELD STUDY
HONCUT CREEK RESERVOIR PLUS DIVERSION FROM FRENCH DRY CREEK (NOVEMBER-APRIL)

Capacity: 38,000 acre-feet **Yield: 24,000 acre-feet**

(In acre-feet)

Season	November-May				June-October							Spill, end of May	Deficiency, in percent
	Runoff	Diversion	Demand, 30% of annual demand	Storage, end of May	Demand, 70% of annual demand	Apparent storage, end of October	Apparent deficiency, end of October	Average summer storage	Evaporation	Storage, end of October	Deficiency, end of October		
1920-21	43,170	44,950	7,200	38,000	16,800	21,200		29,600	2,500	18,700		42,920	
1921-22	35,470	28,390	7,200	38,000	16,800	21,200		29,600	2,500	18,700		37,360	
1922-23	18,060	18,350	7,200	38,000	16,800	21,200		29,600	2,500	18,700		9,910	
1923-24	4,700	4,720	7,200	20,920	16,800	4,120		12,520	1,400	2,720			
1924-25	18,490	19,010	7,200	33,020	16,800	16,220		24,620	2,300	13,920			
1925-26	11,350	11,890	7,200	29,960	16,800	13,160		21,560	2,100	11,060			
1926-27	31,120	29,700	7,200	38,000	16,800	21,200		29,600	2,500	18,700		26,680	
1927-28	22,180	22,990	7,200	38,000	16,800	21,200		29,600	2,500	18,700		18,670	
1928-29	6,860	6,260	7,200	24,620	16,800	7,820		16,220	1,700	6,120			
1929-30	16,430	17,110	7,200	32,460	16,800	15,660		24,060	2,200	13,460			
1930-31	4,520	4,680	7,200	15,460	16,800		1,340	7,060	1,000		2,340		9.8
1931-32	21,130	19,720	7,200	33,650	16,800	16,850		25,250	2,300	14,550			
1932-33	8,100	6,120	7,200	21,570	16,800	4,770		13,170	1,500	3,270			
1933-34	6,200	6,320	7,200	8,590	16,800		8,210	190	50		8,260		34.4
1934-35	21,200	20,600	7,200	34,600	16,800	17,800		26,200	2,400	15,400			
AVERAGE	17,900	17,400	7,200		16,800						710	9,040	

YIELD STUDY
CAMP FAR WEST RESERVOIR

Capacity: 104,000 acre-feet **Yield: 90,000 acre-feet**

(In acre-feet)

Season	November-May				June-October							Spill, end of May	Deficiency, in percent
	Runoff	Diversion	Demand, 30% of annual demand	Storage, end of May	Demand, 70% of annual demand	Apparent storage, end of October	Apparent deficiency, end of October	Average summer storage	Evaporation	Storage, end of October	Deficiency, end of October		
1920-21	467,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		336,000	
1921-22	409,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		312,800	
1922-23	364,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		267,800	
1923-24	23,000		27,000	30,800	63,000		32,200				32,200		35.8
1924-25	239,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		108,000	
1925-26	223,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		116,800	
1926-27	450,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		353,800	
1927-28	296,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		199,800	
1928-29	112,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		15,800	
1929-30	355,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		258,800	
1930-31	145,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		48,800	
1931-32	234,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		137,800	
1932-33	51,000		27,000	58,800	63,000		4,200	27,300	3,100		7,300		8.1
1933-34	126,000		27,000	99,000	63,000	36,000		67,500	5,800	30,200			
1934-35	354,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		253,200	
AVERAGE	256,000		27,000		63,000						2,600	160,600	

YIELD STUDY

COON CREEK RESERVOIR PLUS COMBIE-OPHIR DIVERSION OF 100 SECOND-FEET (NOVEMBER-APRIL)

Capacity: 59,000 acre-feet

Yield: 56,000 acre-feet

(In acre-feet)

Season	November-May				June-October							Spill, end of May	Deficiency, in percent
	Runoff	Diversion	Demand, 30% of annual demand	Storage, end of May	Demand, 70% of annual demand	Apparent storage, end of October	Apparent deficiency, end of October	Average summer storage	Evaporation	Storage, end of October	Deficiency, end of October		
1920-21	44,600	35,700	16,800	59,000	39,200	19,800		39,400	2,500	17,300		4,500	
1921-22	40,000	35,700	16,800	59,000	39,200	19,800		39,400	2,500	17,300		17,200	
1922-23	33,500	35,700	16,800	59,000	39,200	19,800		39,400	2,500	17,300		10,700	
1923-24	5,900	35,700	16,800	42,100	39,200	2,900		22,500	1,800	1,100			
1924-25	24,600	35,700	16,800	44,600	39,200	5,400		25,000	2,000	3,400			
1925-26	22,300	35,700	16,800	44,600	39,200	5,400		25,000	2,000	3,400			
1926-27	48,200	35,700	16,800	59,000	39,200	19,800		39,400	2,500	17,300		11,500	
1927-28	30,200	35,700	16,800	59,000	39,200	19,800		39,400	2,500	17,300		7,400	
1928-29	11,500	35,700	16,800	47,700	39,200	8,500		28,100	2,100	6,400			
1929-30	19,000	35,700	16,800	44,300	39,200	5,100		24,700	2,000	3,100			
1930-31	5,900	35,700	16,800	27,900	39,200		11,300	8,300	900		12,200		21.8
1931-32	23,300	35,700	16,800	42,200	39,200	3,000		22,600	1,800	1,200			
1932-33	11,500	35,700	16,800	31,600	39,200		7,600	12,000	1,200		8,800		15.7
1933-34	11,200	35,700	16,800	30,100	39,200		9,100	10,500	1,100		10,200		18.2
1934-35	31,800	35,700	16,800	50,700	39,200	11,500		31,100	2,200	9,300			
AVERAGE	24,200	35,700	16,800		39,200						2,100	3,400	

APPENDIX H

ESTIMATES OF COST

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ESTIMATED COST OF PEACH BOWL PROJECT

(Based on prices prevailing in April, 1952)

Pumping plant capacity: 135 second-feet
Gross seasonal diversion: 24,000 acre-feet
Maximum monthly demand: (July) 6,450 acre-feet, 105 second-feet

Acreage served: Presently irrigated lands, 4,500 acres; irrigated lands to be developed, 2,500 acres

Item	Quantity	Unit price	Cost	
Capital Costs				
Pumping Plant				
Pumps, motors, and electrical equipment	3 each	$14,330	$43,000	
Discharge pipe and footings	3 each	5,700	17,100	
Sump and trash racks		lump sum	7,100	
Structure		lump sum	14,400	
Discharge structure and sand trap		lump sum	3,400	$85,000
Subtotal				$85,000
Administration and engineering, 10%				$8,500
Contingencies, 15%				12,800
Interest during construction				1,600
TOTAL				$107,900
Conveyance System				
Excavation	137,800 cu. yd.	$0.30	$41,400	
Trimming	195,900 sq. yd.	0.25	49,000	
Lining, concrete	10,900 cu. yd.	35.00	381,500	
Turnouts, 100 second-feet	14 each	1,100	15,400	
50 second-feet	20 each	830	16,600	
Crossings, 100 second-feet				
Railroad	1 each	5,800	5,800	
County road	1 each	3,200	3,200	
Crossings, 50 second-feet				
County road	4 each	2,300	9,200	
Farm road	6 each	1,400	8,400	
Right of way				
Orchard lands	52 acres	1,500	78,000	
Open lands	44 acres	750	33,000	$641,500
Subtotal				$641,500
Administration and engineering, 10%				$64,200
Contingencies, 15%				96,200
Interest during construction				12,000
TOTAL				$813,900

Item	Quantity	Unit price	Cost	
Capital Costs—Continued				
Distribution System				
Presently irrigated lands	4,500 acres	$70.00	$315,000	
Irrigable lands to be developed	2,500 acres	20.00	50,000	$365,000
Subtotal				$365,000
Administration and engineering, 10%				$36,500
Contingencies, 15%				54,800
Interest during construction				6,800
TOTAL				$463,100
Annual Costs				
Pumping Plant				
Interest, 3%				$3,200
Amortization, 0.887%				1,000
Replacement, 0.513%				600
Operation and maintenance, 5%				5,400
Electric energy				5,800
TOTAL				$16,000
Conveyance System				
Interest, 3%				$24,400
Amortization, 0.887%				7,200
Replacement, 0.50%				4,100
Operation and maintenance, 1.0%				8,100
TOTAL				$43,800
Distribution System				
Interest, 3%				$13,900
Amortization, 0.887%				4,100
Operation and maintenance				
Ditch tender service, $0.70 per acre-foot				16,800
Maintenance charge, $0.40 per acre				2,800
District overhead, $0.50 per acre				3,500
TOTAL				$41,100

ESTIMATED COST OF SOUTH HONCUT CREEK DAM AND RESERVOIR

(Based on prices prevailing in April, 1952)

Elevation of crest of dam: 910 feet, U.S.G.S. datum
Elevation of crest of spillway: 898 feet
Height of dam to spillway crest, above stream bed: 168 feet
Capacity of reservoir to crest of spillway: 38,000 acre-feet
Capacity of spillway with 4-foot freeboard: 10,000 second-feet

Item	Quantity	Unit price	Cost	
Capital Costs				
Dam				
Unwatering and care of stream		lump sum	$10,000	
Stripping and preparation of foundation				
Common	37,570 cu. yd.	$1.00	37,600	
Rock	7,760 cu. yd.	3.00	23,300	
Excavation for embankment				
From borrow pits	338,200 cu. yd.	0.45	152,200	
Tailings	451,900 cu. yd.	0.45	203,400	
Sand and gravel filter	101,200 cu. yd.	1.50	151,800	
Embankment				
Impervious from borrow	294,000 cu. yd.	0.25	73,500	
Sand and gravel filter	101,200 cu. yd.	0.50	50,600	
Tailings	451,900 cu. yd.	0.20	90,400	
Rock from salvage	71,600 cu. yd.	0.30	21,500	
Drilling grout holes	4,020 lin. yd.	3.00	12,100	
Pressure grouting	2,680 cu. ft.	4.00	10,700	$837,100
Spillway				
Excavation	86,620 cu. yd.	2.50	216,600	
Concrete	2,770 cu. yd.	35.00	97,000	
Reinforcing steel	207,000 lbs.	0.15	31,100	344,700
Outlet Works				
Excavation				
Common	200 cu. yd.	2.00	400	
Rock	1,980 cu. yd.	6.00	11,900	
Concrete				
Inlet structure	44 cu. yd.	100.00	4,400	
Trench backfill and cut-offs	1,590 cu. yd.	30.00	47,700	
Steel pipe, 42-inch diameter	112,000 lbs.	0.25	28,000	
Reinforcing steel	163,800 lbs.	0.15	24,600	
Capital Costs—Continued				
Outlet Works—Continued				
High pressure slide gates and controls, 30-inch diameter				
Trash rack steel	2 each	lump sum	$15,000	
Control house		lump sum	1,000	
Howell-Bunger outlet valve, 36-inch diameter		lump sum	1,000	
		lump sum	3,600	$137,600
Reservoir				
Land				
Improvements	906 acres	$125.00	$113,300	
Road to dam site		lump sum	60,000	
Clearing	2 miles	50,000	100,000	
	906 acres	150.00	135,900	409,200
Subtotal				$1,728,600
Administration and engineering, 10%				$172,900
Contingencies, 15%				259,300
Interest during construction				64,800
TOTAL				$2,225,600
Annual Costs				
Interest, 3%				$66,800
Amortization, 0.887%				19,700
Replacement, 0.07%				1,600
Operation and maintenance				6,300
TOTAL				$94,400

ESTIMATED COST OF FRENCH DRY CREEK DIVERSION AND CONDUIT

(Based on prices prevailing in April, 1952)

Elevation of crest of weir: 2,132 feet, U.S.G.S. datum
Height of crest of weir, above stream bed: 7 feet
Capacity of weir with 11-foot head: 10,000 second-feet
Capacity of diversion canal: 200 second-feet
Length of canal: 2 miles

Item	Quantity	Unit price	Cost	
Capital Costs				
Diversion Works				
Excavation	436 cu.yd.	$5.00	$2,200	
Concrete, weirs and headwall	363 cu.yd.	40.00	14,500	
Reinforcing steel	27,800 lbs.	0.15	4,200	
Trash rack steel	360 lbs.	0.30	100	
Headgates and sluice gate	3 each	1,000	3,000	$24,000
Conduit				
Excavation	12,680 cu.yd.	0.50	6,300	
Compacted fill	6,340 cu.yd.	0.50	3,200	
Shotcrete lining	21,100 sq.yd.	3.50	73,900	
Rights of way	15 acres	200.00	3,000	
Fencing	4 miles	1,500	6,000	
Clearing	15 acres	200.00	3,000	
Road crossings	3 each	500.00	1,500	96,900
Subtotal				$120,900
Capital Costs—Continued				
Administration and engineering, 10%				$12,100
Contingencies, 15%				18,100
Interest during construction, none				
TOTAL				$151,100
Annual Costs				
Interest, 3%				$4,500
Amortization, 0.887%				1,300
Replacement, 0.50%				800
Operation and maintenance, 1.0%				1,500
TOTAL				$8,100

ESTIMATED COST OF SOUTH HONCUT CREEK DIVERSION AND CONDUIT

(Based on prices prevailing in April, 1952)

Elevation of crest of weir: 609 feet, U.S.G.S. datum
Height of weir crest, above stream bed: 9 feet
Capacity of weir with 10-foot head: 10,000 second-feet
Capacity of conduit: 150 second-feet
Length of conduit: 4.7 miles

Item	Quantity	Unit price	Cost	
Capital Costs				
Diversion Works				
Excavation, rock	425 cu.yd.	$5.00	$2,100	
Concrete, weirs and headwall	518 cu.yd.	40.00	20,700	
Reinforcing steel	14,900 lbs.	0.15	2,200	
Trash rack steel	360 lbs.	0.30	100	
Headgates and sluice gate	3 each	1,000	3,000	$28,100
Conduit				
Excavation	35,200 cu.yd.	0.50	17,600	
Compacted fill	21,000 cu.yd.	0.50	10,500	
Shoterete lining	40,800 sq.yd.	3.50	142,800	
Siphon	1,500 lin.ft.	36.70	55,000	
Flume, metal	1,100 lin.ft.	23.40	25,800	
Rights of way	23.4 acres	200.00	4,700	
Fencing	9.4 miles	1,500	14,100	
Clearing	23.4 acres	200.00	4,700	275,200
Subtotal				$303,300
Capital Costs—Continued				
Administration and engineering, 10%				$30,300
Contingencies, 15%				45,500
Interest during construction, none				
TOTAL				$379,100
Annual Costs				
Interest, 3%				$11,400
Amortization, 0.887%				3,400
Replacement, 0.50%				1,900
Operation and maintenance, 1.0%				3,800
TOTAL				$20,500

ESTIMATED COST OF NORTHEAST ZONE DIVERSION, CONDUIT, AND DISTRIBUTION SYSTEM

(Based on prices prevailing in April, 1952)

Capacity of conduit: 75 second-feet at diversion, decreasing uniformly to 25 second-feet at terminus
Diversion: Temporary earthfill dam on Prairie Creek
Length of conduit: 6.3 miles
Distribution system: Unlined canals and ditches
Acreage served: 2,300 acres

Item	Quantity	Unit price	Cost	
Capital Costs				
Diversion Dam				
Stripping	60 cu.yd.	$1.00	$100	
Compacted fill	160 cu.yd.	1.00	200	$300
Subtotal				$300
Administration and engineering, 10%				$100
Contingencies, 15%				100
Interest during construction, none				
TOTAL				$500
Conduit				
Excavation	39,400 cu.yd.	$0.50	$19,700	
Compacted fill	30,800 cu.yd.	0.50	15,400	
Trimming	82,500 sq.yd.	0.30	24,800	
Concrete				
Shoterete, at road crossings	100 sq.yd.	3.50	1,400	
Reinforced, road crossings	80 cu.yd.	50.00	4,000	
Canal headwall and cutoff	15 cu.yd.	50.00	800	
Reinforcing steel	7,100 lbs.	0.15	1,100	
Headgate, 4′ x 5′ slide gate		lump sum	500	
Rights of way	46 acres	200.00	9,200	
Clearing	46 acres	200.00	9,200	
Fencing	12.6 miles	1,500	18,900	$105,000
Subtotal				$105,000
Administration and engineering, 10%				$10,500
Contingencies, 15%				15,800
Interest during construction, none				
TOTAL				$131,300
Capital Costs—Continued				
Distribution System	2,300 acres	$20.00	$46,000	$46,000
Subtotal				$46,000
Administration and engineering, 10%				$4,600
Contingencies, 15%				6,900
Interest during construction, none				
TOTAL				$57,500
Annual Costs				
Diversion Dam				
Construction cost				$500
Subtotal				$500
Conduit				
Interest, 3%				$3,900
Amortization, 0.887%				1,200
Replacement, 0.50%				700
Operation and maintenance, 1.0%				1,300
TOTAL				$7,100
Distribution System				
Interest, 3%				$1,700
Amortization, 0.887%				500
Operation and maintenance				
Ditch tender service, $0.50 per acre-foot				5,400
Maintenance charge, $0.40 per acre				900
District overhead, $0.50 per acre				1,200
TOTAL				$9,700

ESTIMATED COST OF BROWNS VALLEY DISTRIBUTION SYSTEM

(Based on prices prevailing in April, 1952)

Distribution system: Unlined canals and ditches — Acreage served: 2,600 acres

Item	Quantity	Unit price	Cost	
Capital Costs				
Distribution System	2,600 acres	$20.00	$52,000	$52,000
Subtotal				$52,000
Administration and engineering, 10%				$5,200
Contingencies, 15%				7,800
Interest during construction, none				
TOTAL				$65,000

Item	Quantity	Unit price	Cost
Annual Costs			
Interest, 3%			$2,000
Amortization, 0.887%			600
Operation and maintenance			
Ditch tender service, $0.80 per acre-foot			8,100
Maintenance charge, $0.60 per acre			1,600
District overhead, $0.80 per acre			2,100
TOTAL			$14,400

ESTIMATED COST OF CAMP FAR WEST DAM AND RESERVOIR

(Based on prices prevailing in April, 1952)

Elevation of crest of dam: 311 feet, U.S.G.S. datum
Elevation of crest of spillway: 300 feet
Height of dam to spillway crest, above stream bed: 155 feet
Capacity of reservoir to crest of spillway: 104,000 acre-feet
Capacity of spillway with 4-foot freeboard: 60,000 second-feet

Item	Quantity	Unit price	Cost	
Capital Costs				
Dam				
Diversion and care of stream		lump sum	$50,000	
Stripping and preparation of foundation	149,000 cu.yd.	$1.00	149,000	
Excavation for embankment				
From borrow pits	743,600 cu.yd.	0.65	483,300	
Stream bed gravel	1,243,100 cu.yd.	0.40	497,200	
Rock riprap	63,100 cu.yd.	2.00	126,200	
Embankment				
Common compacted	649,300 cu.yd.	0.25	162,300	
Pervious				
From excavation	1,055,600 cu.yd.	0.20	211,100	
From salvage	112,000 cu.yd.	0.30	33,600	
Sand and gravel filter	187,500 cu.yd.	0.50	93,800	
Rock riprap	63,100 cu.yd.	0.50	31,600	
Drilling grout holes	4,140 lin.ft.	3.00	12,400	
Pressure grouting	2,760 cu.ft.	4.00	11,000	$1,861,500
Spillway				
Excavation	200,000 cu.yd.	1.00	200,000	
Concrete	7,570 cu.yd.	35.00	265,000	
Reinforcing steel	559,400 lbs.	0.15	83,900	548,900
Outlet Works				
Tunnel, 8-foot diameter	950 lin.ft.	200.00	190,000	
Portal, excavation	8,500 cu.yd.	2.00	17,000	
Concrete (intake, gate chamber, saddles, plug, and walkway)	280 cu.yd.	60.00	16,800	

Item	Quantity	Unit price	Cost	
Capital Costs—Continued				
Outlet Works—Continued				
Reinforcing steel	28,000 lbs.	$0.15	$4,200	
Steel pipe, 66-inch diameter	210,000 lbs.	0.25	52,500	
High pressure 5′ x 5′ slide gate		lump sum	25,000	
Stilling basin		lump sum	8,800	
Needle valve				
60-inch diameter		lump sum	27,500	
36-inch diameter		lump sum	10,000	
Venturi meter		lump sum	5,000	$356,800
Reservoir				
Land and improvements	2,160 acres	$50.00	$108,000	
Clearing reservoir land	2,160 acres	100.00	216,000	$324,000
Subtotal				$3,091,200
Administration and engineering, 10%				$309,100
Contingencies, 15%				463,700
Interest during construction				115,900
TOTAL				$3,979,900
Annual Costs				
Interest, 3%				$119,400
Amortization, 0.887%				35,300
Replacement, 0.07%				2,800
Operation and maintenance				12,500
TOTAL				$170,000

ESTIMATED COST OF BEAR RIVER CANAL

(Based on prices prevailing in April, 1952)

Elevation of stilling basin: 187 feet, U.S.G.S. datum
Elevation of division box: 183 feet

Capacity of canal: 400 second-feet

Item	Quantity	Unit price	Cost	
Capital Costs				
Canal				
Excavation	43,600 cu. yd.	$1.50	$65,400	
Compacted fill	40,000 cu. yd.	0.50	20,000	
Lining, shoterete	24,000 sq. yd.	3.50	84,000	
Drainage structures	3 each	lump sum	1,500	$170,900
Division Box				
Excavation	230 cu. yd.	3.00	700	
Concrete	87 cu. yd.	60.00	5,200	
Gates and trash racks	4 each	600.00	2,400	8,300
Rights of Way				
Land	18 acres	50.00	900	
Clearing	18 acres	100.00	1,800	
Fencing	3 miles	1,500	4,500	7,200
Subtotal				$186,400
Administration and engineering, 10%				$18,600
Contingencies, 15%				28,000
Interest during construction, none				
TOTAL				$233,000
Annual Costs				
Interest, 3%				$7,000
Amortization, 0.887%				2,100
Replacement, 0.50%				1,200
Operation and maintenance, 1.0%				2,300
TOTAL				$12,600

ESTIMATED COST OF EAST CENTRAL ZONE SIPHON, CONDUIT, AND DISTRIBUTION SYSTEM

(Based on prices prevailing in April, 1952)

Capacity of siphon: 200 second-feet
Length of siphon: 800 feet
Capacity of conduit, initial 2.9 miles: 200 second-feet
Capacity of conduit, remaining 0.8 mile: 100 second-feet

Distribution system: Unlined canals and ditches
Acreage served: 8,500 acres

Item	Quantity	Unit price	Cost	
Capital Costs				
Siphon				
Excavation, trench	3,000 cu. yd.	$3.00	$9,000	
Backfill				
Concrete	540 cu. yd.	35.00	18,900	
Earth	1,800 cu. yd.	1.00	1,800	
Steel pipe, 66-inch diameter	140,500 lbs.	0.20	28,100	$57,800
Conduit				
Excavation	113,800 cu. yd.	0.50	56,900	
Trimming of canal	61,420 sq. yd.	0.30	18,400	
Compacted fill	16,780 cu. yd.	0.50	8,400	
Concrete				
Shoterete	9,060 sq. yd.	3.50	31,700	
Flume intake and outlet	40 cu. yd.	50.00	2,000	
Road crossings	63 cu. yd.	50.00	3,200	
Flume footings	20 cu. yd.	80.00	1,600	
Parshall flume	15 cu. yd.	70.00	1,100	
Reinforcing steel	11,800 lbs.	0.15	1,800	
Timber				
Road crossings	6.37 MBM	350.00	2,200	
Flume substructure	14.1 MBM	400.00	5,600	
Flume, metal	300 lin. ft.	30.00	9,000	
Flume, hardware	1,690 lbs.	1.00	1,700	
Rights of way	42 acres	200.00	8,400	
Clearing	42 acres	200.00	8,400	
Fencing	7.4 miles	1,500	11,100	$171,500
Subtotal				$229,300
Administration and engineering, 10%				22,900
Contingencies, 15%				34,400
Interest during construction, none				
TOTAL				$286,600
Distribution System	8,500 acres	$20.00	$170,000	$170,000
Subtotal				$170,000
Administration and engineering, 10%				17,000
Contingencies, 15%				25,500
Interest during construction, none				
TOTAL				$212,500
Annual Costs				
Siphon and Conduit				
Interest, 3%				$8,600
Amortization, 0.887%				2,500
Replacement, 0.50%				1,400
Operation and maintenance, 1.0%				2,900
TOTAL				$15,400
Distribution System				
Interest, 3%				$6,400
Amortization, 0.887%				1,900
Operation and maintenance				
Ditch tender service, $0.55 per acre-foot				16,500
Maintenance charge, $0.40 per acre				3,800
District overhead, $0.50 per acre				4,200
TOTAL				$32,800

ESTIMATED COST OF SOUTH SIDE ZONE CONDUIT AND DISTRIBUTION SYSTEM

(Based on prices prevailing in April, 1952)

Capacity of conduit, initial 11.0 miles: 200 second-feet
Capacity of conduit, remaining 7.8 miles: 100 second-feet

Distribution system: Unlined canals and ditches
Acreage served: 8,500 acres

Item	Quantity	Unit price	Cost	
Capital Costs				
Conduit				
Excavation	341,360 cu. yd.	$0.50	$155,700	
Compacted fill	81,840 cu. yd.	0.50	40,900	
Trimming	330,240 sq. yd.	0.30	99,100	
Concrete				
Shoterete	13,650 sq. yd.	3.50	47,800	
Flume transition structures	33 cu. yd.	50.00	1,700	
Road crossing	100 cu. yd.	50.00	5,000	
Substructure footings	20 cu. yd.	80.00	1,600	
Parshall flume	15 cu. yd.	70.00	1,100	
Siphon transition structure	30 cu. yd.	50.00	1,500	
Reinforcing steel	20,000 lbs.	0.15	3,000	
Timber				
Road crossings	12.5 MBM	350.00	4,400	
Flume substructure	11 MBM	400.00	4,400	
Flume, metal	420 lin. ft.	15.00	6,300	
Flume, hardware	1,320 lbs.	1.00	1,300	
Pipe, 48" corrugated metal	150 lin. ft.	20.00	3,000	
Jacking costs	100 lin. ft.	50.00	5,000	
Diversion dam at Markham Ravine		lump sum	1,500	
Rights of way	190 acres	300.00	57,000	
Fencing	37.6 miles	1,500	56,400	
Clearing	190 acres	200.00	38,000	$534,700
Subtotal				$534,700
Administration and engineering, 10%				53,500
Contingencies, 15%				80,200
Interest during construction, none				
TOTAL				$668,400

Item	Quantity	Unit price	Cost	
Capital Costs—Continued				
Distribution System	8,500 acres	$20.00	$170,000	$170,000
Subtotal				$170,000
Administration and engineering, 10%				17,000
Contingencies, 15%				25,500
Interest during construction, none				
TOTAL				$212,500
Annual Costs				
Conduit				
Interest, 3%				$20,100
Amortization, 0.887%				5,900
Replacement, 0.50%				3,300
Operation and maintenance, 1.0%				6,700
TOTAL				$36,000
Distribution System				
Interest, 3%				$6,400
Amortization, 0.887%				1,900
Operation and maintenance				
Ditch tender service, $0.55 per acre-foot				16,500
Maintenance charge, $0.40 per acre				3,800
District overhead, $0.50 per acre				4,200
TOTAL				$32,800

ESTIMATED COST OF COON CREEK DAM AND RESERVOIR

(Based on prices prevailing in April, 1952)

Elevation of crest of dam: 560 feet, U.S.G.S. datum
Elevation of crest of spillway: 552 feet
Height of dam to spillway crest, above stream bed: 207 feet
Capacity of reservoir to crest of spillway: 59,000 acre-feet
Capacity of spillway with 4-foot freeboard: 14,000 second-feet

Item	Quantity	Unit price	Cost	
Capital Costs				
Dam				
Diversion and care of stream		lump sum	$5,000	
Stripping and preparation of foundation	304,200 cu.yd.	$1.50	456,300	
Excavation for embankment				
From borrow pits	903,900 cu.yd.	0.75	677,900	
From Bear River, gravel	1,245,230 cu.yd.	0.75	933,900	
Embankment				
Impervious zone, compacted	786,040 cu.yd.	0.25	196,500	
Pervious zone				
From excavation	1,130,730 cu.yd.	0.20	226,100	
From salvage	128,300 cu.yd.	0.30	38,500	
Sand and gravel filter	115,500 cu.yd.	0.50	57,700	
Rock riprap (from salvage)	40,500 cu.yd.	0.50	20,300	
Drilling grout holes	8,400 lin.ft.	3.00	25,200	
Pressure grouting	5,600 cu.ft.	4.00	22,400	$2,659,800
Auxiliary Dams				
Stripping and preparation of foundation	55,260 cu.yd.	1.50	82,900	
Excavation for embankment				
From borrow pits	180,160 cu.yd.	0.75	135,100	
From quarry	251,410 cu.yd.	0.75	188,600	
Embankment				
Impervious zone	156,660 cu.yd.	0.25	39,200	
Pervious zone				
From excavation	176,510 cu.yd.	0.20	35,300	
From salvage	22,800 cu.yd.	0.30	6,800	
Sand and gravel filter	74,900 cu.yd.	0.50	37,400	
Rock riprap (from salvage)	17,900 cu.yd.	0.50	9,000	
Drilling grout holes	3,400 lin.ft.	3.00	10,200	
Pressure grouting	2,260 cu.ft.	4.00	9,000	553,500
Capital Costs—Continued				
Spillway				
Excavation	2,600 cu.yd.	$2.00	$5,200	
Concrete	3,962 cu.yd.	30.00	119,000	
Reinforcing steel	98,600 lbs.	0.15	14,800	$139,000
Outlet Works				
Excavation	2,000 cu.yd.	5.00	10,000	
Concrete				
Trench backfill	1,000 cu.yd.	30.00	30,000	
Intake structure	50 cu.yd.	100.00	5,000	
Outlet structure	20 cu.yd.	100.00	2,000	
Reinforcing steel	110,000 lbs.	0.15	16,500	
Steel pipe, 48-inch diameter ¼" plate	127,500 lbs.	0.25	31,900	
High pressure slide gates and controls, 30-inch diameter	2 each	lump sum	17,000	
Howell-Bunger valve, 42-inch diameter	1 each	lump sum	7,600	120,000
Reservoir				
Land and improvements	820 acres	75.00	61,500	
Clearing	820 acres	200.00	164,000	
Road across dam		lump sum	10,000	235,500
Subtotal				$3,707,800
Administration and engineering, 10%				370,800
Contingencies, 15%				556,100
Interest during construction				139,000
TOTAL				$4,773,700
Annual Costs				
Interest, 3%				$143,200
Amortization, 0.887%				41,200
Replacement, 0.07%				3,300
Operation and maintenance				8,500
TOTAL				$196,200

ESTIMATED COST OF COON CREEK DIVERSION, CONDUIT, AND DISTRIBUTION SYSTEM

(Based on prices prevailing in April, 1952)

Capacity of conduit: 100 second-feet
Length of conduit: 7.8 miles
Canal lined for first 0.5 mile

Distribution system: Unlined canals and ditches
Acreage served: 12,000 acres

Item	Quantity	Unit price	Cost	
Capital Costs				
Diversion Structure				
Stripping	320 cu.yd.	$0.50	$200	
Embankment	900 cu.yd.	0.50	400	
Timber, flashboards	1.2 MBM	250.00	300	
Crane for removing flashboards		lump sum	1,000	$1,900
Levee				
Stripping	1,500 cu.yd.	0.50	800	
Embankment	2,000 cu.yd.	0.50	1,000	
Concrete headwall and wing walls	22 cu.yd.	60.00	1,300	
Reinforcing steel	2,200 lbs.	0.15	300	
Headgate, 4' x 5'		lump sum	500	3,900
Conduit				
Excavation	72,810 cu.yd.	0.50	36,400	
Compacted fill	32,740 cu.yd.	0.50	16,400	
Trimming	101,830 sq.yd.	0.30	30,500	
Concrete				
Shotcrete	5,330 sq.yd.	3.50	18,700	
Flume transition structures	16 cu.yd.	50.00	800	
Road crossings	60 cu.yd.	50.00	3,000	
Substructure footings	4 cu.yd.	80.00	300	
Siphon transition structure	30 cu.yd.	50.00	1,500	
Reinforcing steel	14,000 lbs.	0.15	2,100	
Timber				
Road crossings	7.5 MBM	350.00	2,600	
Flume substructure	2.6 MBM	400.00	1,000	
Flume, metal	100 lin.ft.	15.00	1,500	
Flume hardware	310 lbs.	1.00	300	
Pipe, 48-inch corrugated metal	150 lin.ft.	20.00	3,000	
Jacking costs	100 lin.ft.	50.00	5,000	
Diversion dam at Markham Ravine		lump sum	1,500	
Rights of way	60 acres	300.00	18,000	
Fencing	15.6 miles	1,500	23,400	
Clearing	60 acres	200.00	12,000	178,000
Subtotal				$183,800
Capital Costs—Continued				
Administration and engineering, 10%				$18,400
Contingencies, 15%				27,600
Interest during construction, none				
TOTAL				$229,800
Distribution System	12,000 acres	$20.00	$240,000	$240,000
Subtotal				$240,000
Administration and engineering, 10%				24,000
Contingencies, 15%				36,000
Interest during construction, none				
TOTAL				$300,000
Annual Costs				
Diversion and Conduit				
Interest, 3%				$6,900
Amortization, 0.887%				2,000
Replacement, 0.50%				1,100
Operation and maintenance, 1.0%				2,300
TOTAL				$12,300
Distribution System				
Interest, 3%				$9,000
Amortization, 0.887%				2,700
Operation and maintenance				
Ditch tender service, $0.55 per acre-foot				23,100
Maintenance charge, $0.40 per acre				4,800
District overhead, $0.50 per acre				6,000
TOTAL				$45,600

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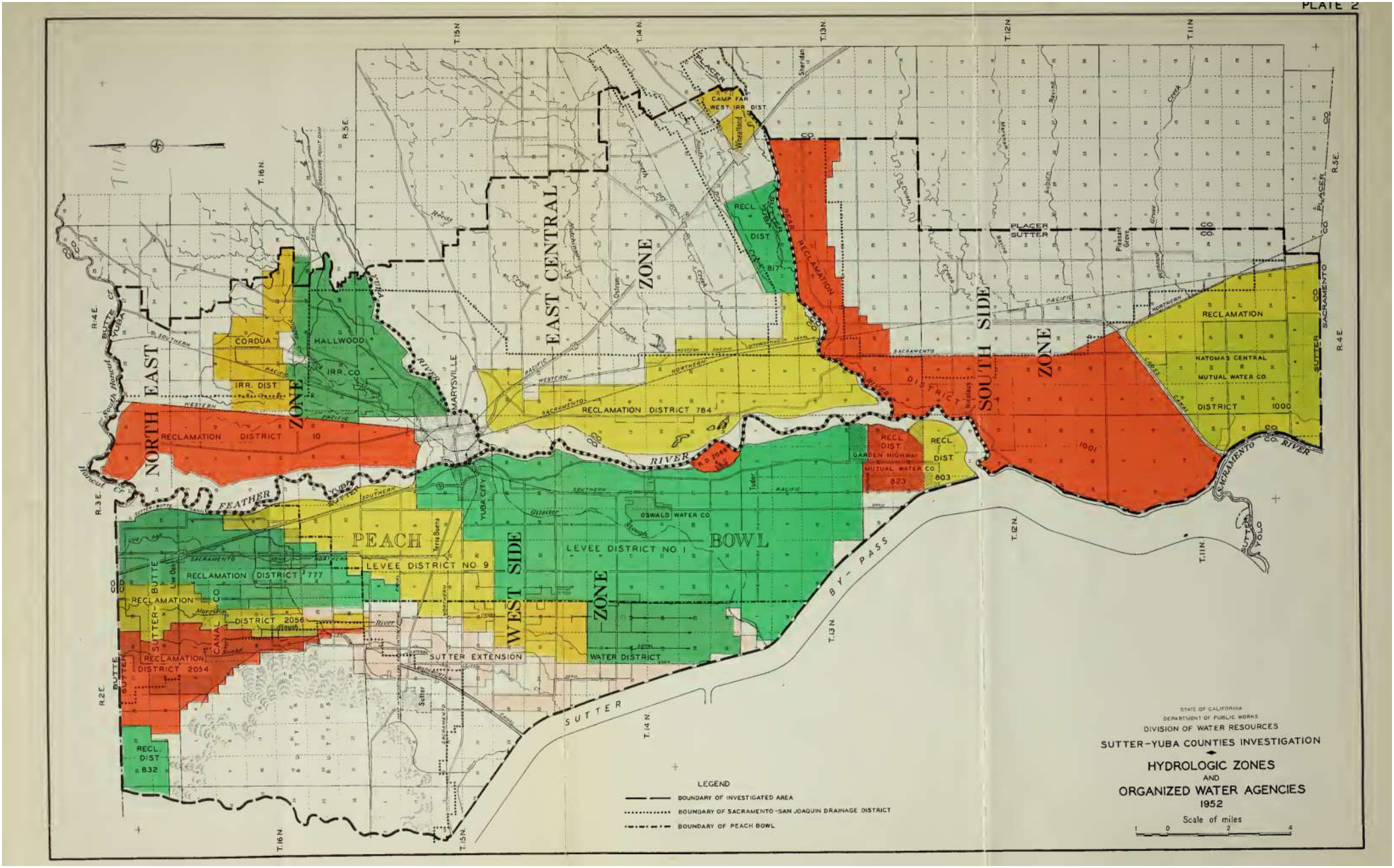
PLATE 1


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LOCATION OF
SUTTER-YUBA AREA
1952
OREGON
NEVADA
PACIFIC OCEAN
MEXICO
SISKIYOU
MODOC
TRINITY
SHASTA
LASSEN
HUMBOLDT
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
COLUSA
LAKE
NEVADA
PLACER
SONOMA
YOLO
SACRAMENTO
EL DORADO
ALPINE
MARIN
SOLANO
CONTRA COSTA
SAN FRANCISCO
ALAMEDA
AMADOR
CALAVERAS
TUOLUMNE
MONO
SAN MATEO
SANTA CLARA
SAN JOAQUIN
STANISLAUS
MARIPOSA
INYO
SANTA CRUZ
SAN BENITO
MERCED
MADERA
FRESNO
TULARE
MONTEREY
KINGS
KERN
SAN LUIS OBISPO
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL

PLATE 2



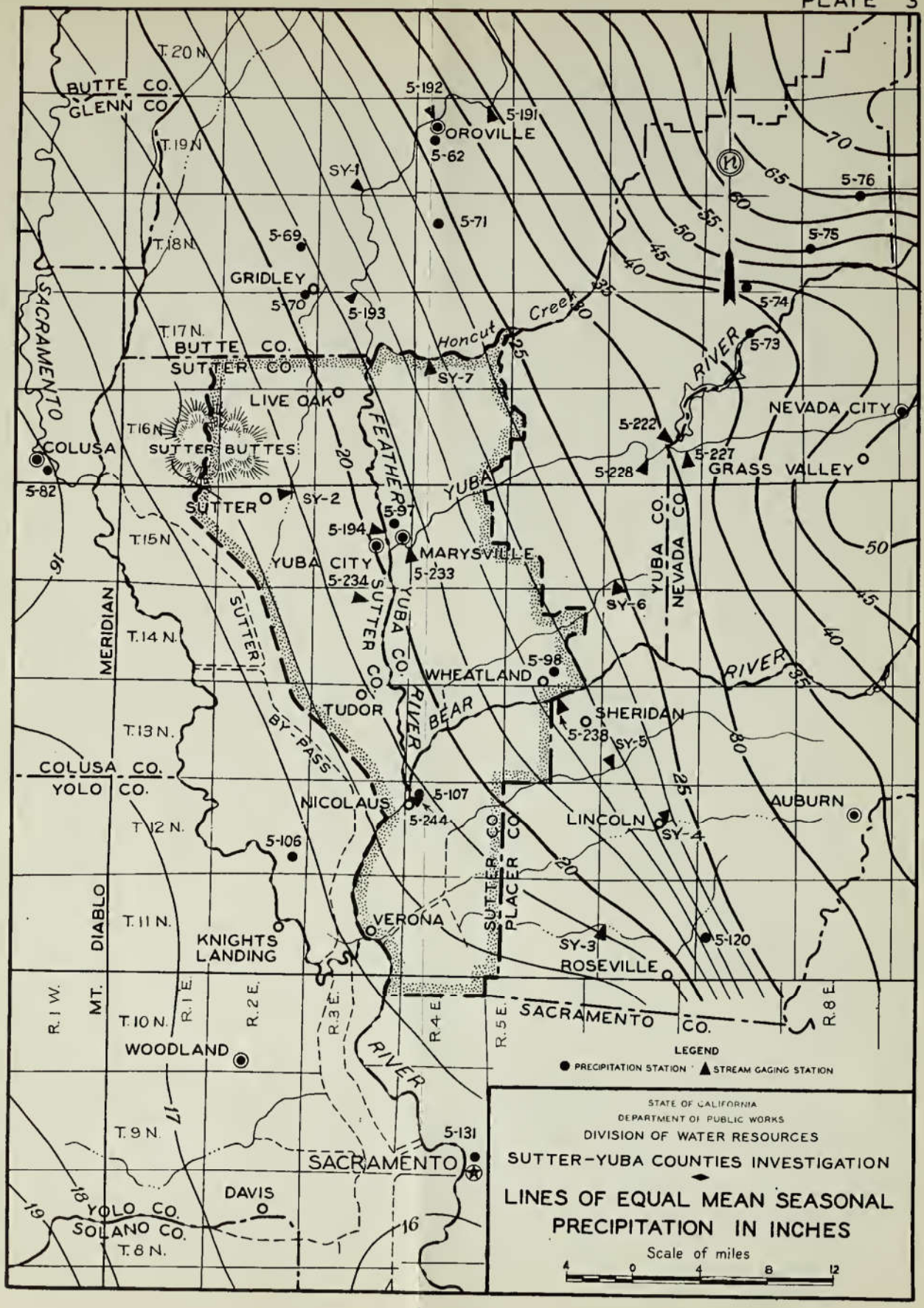
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

SUTTER-YUBA COUNTIES INVESTIGATION

HYDROLOGIC ZONES AND ORGANIZED WATER AGENCIES 1952

Scale of miles

PLATE 3



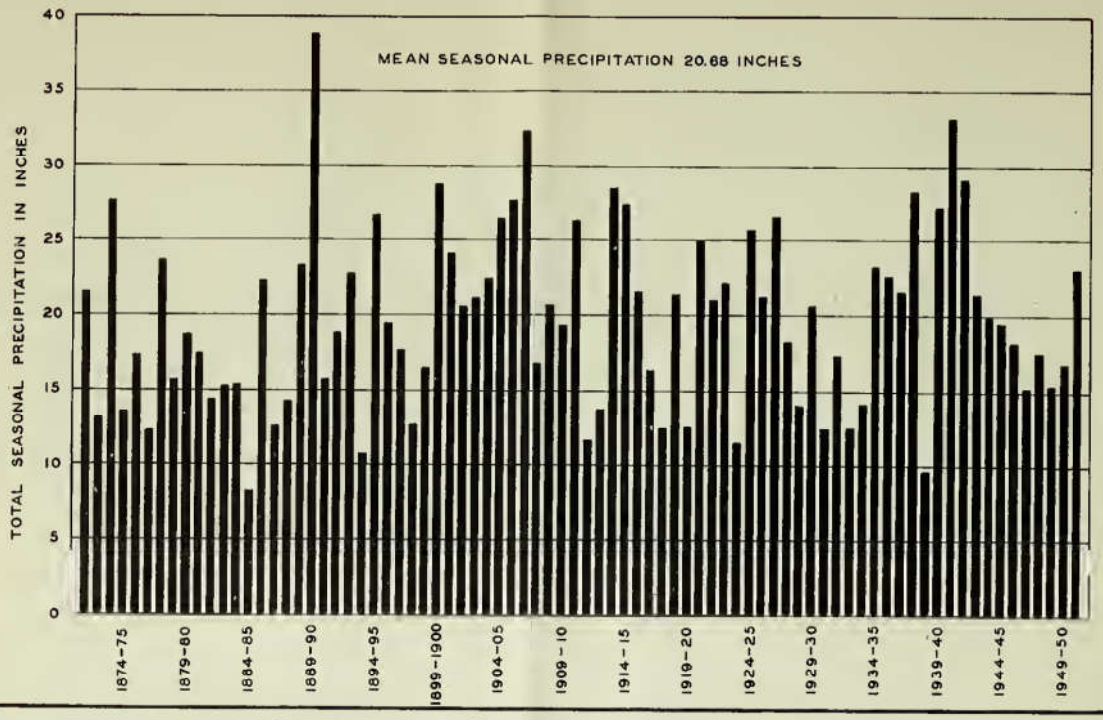
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION

LINES OF EQUAL MEAN SEASONAL PRECIPITATION IN INCHES

Scale of miles

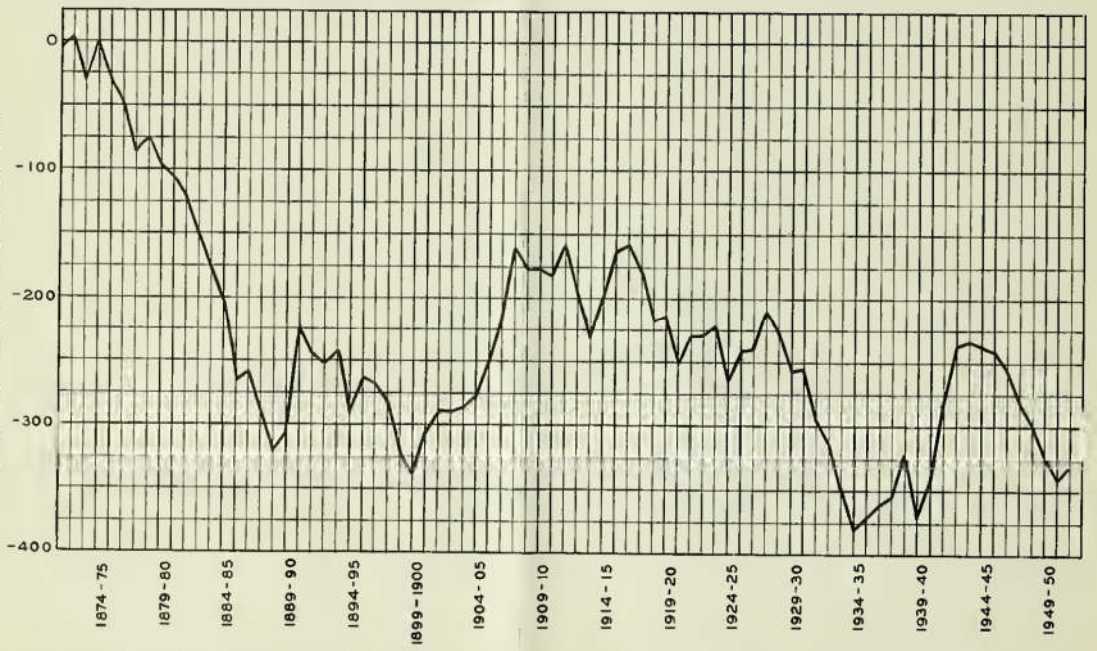
4 0 4 8 12

PLATE 4

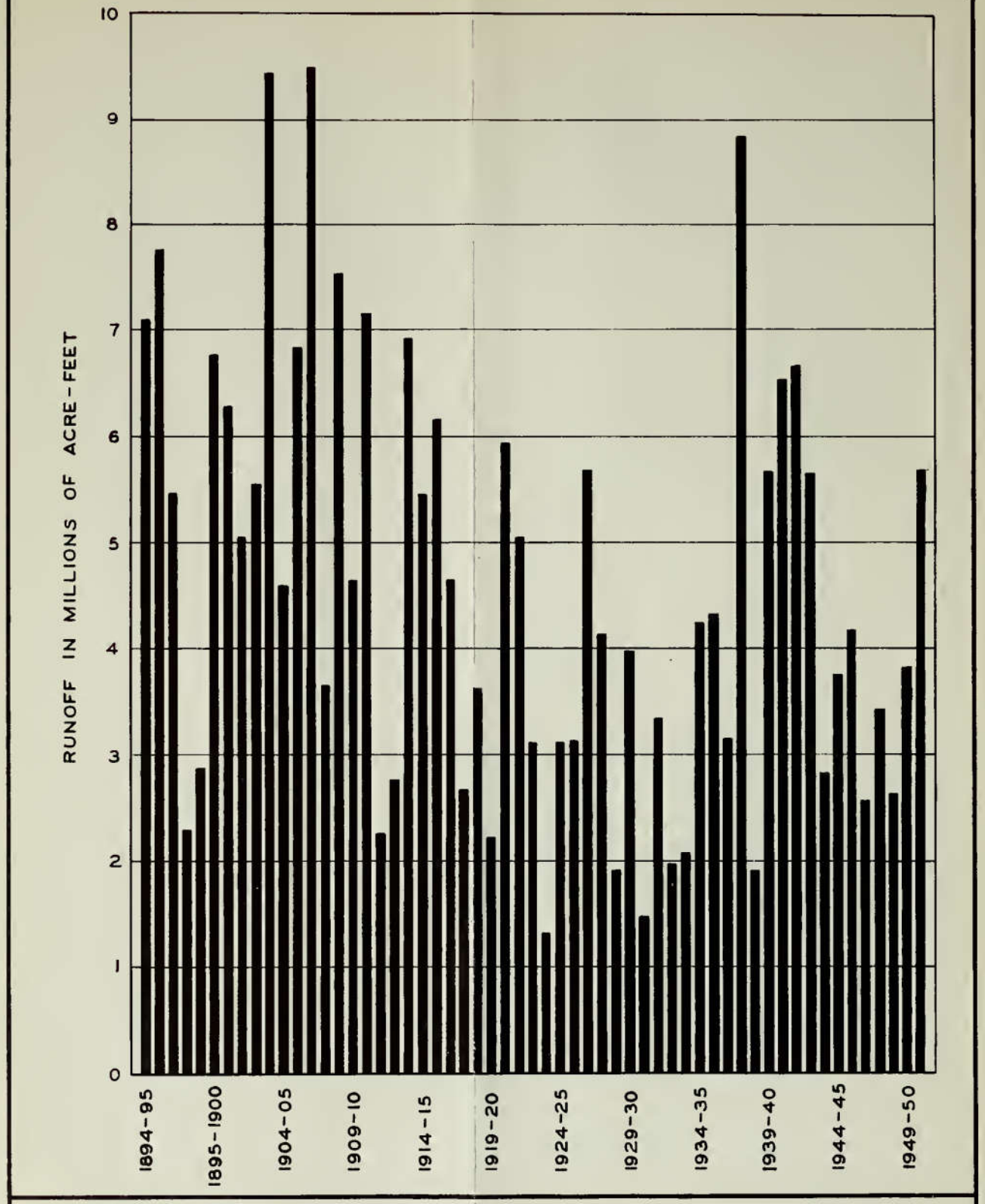


RECORDED SEASONAL PRECIPITATION AT MARYSVILLE

PLATE 5

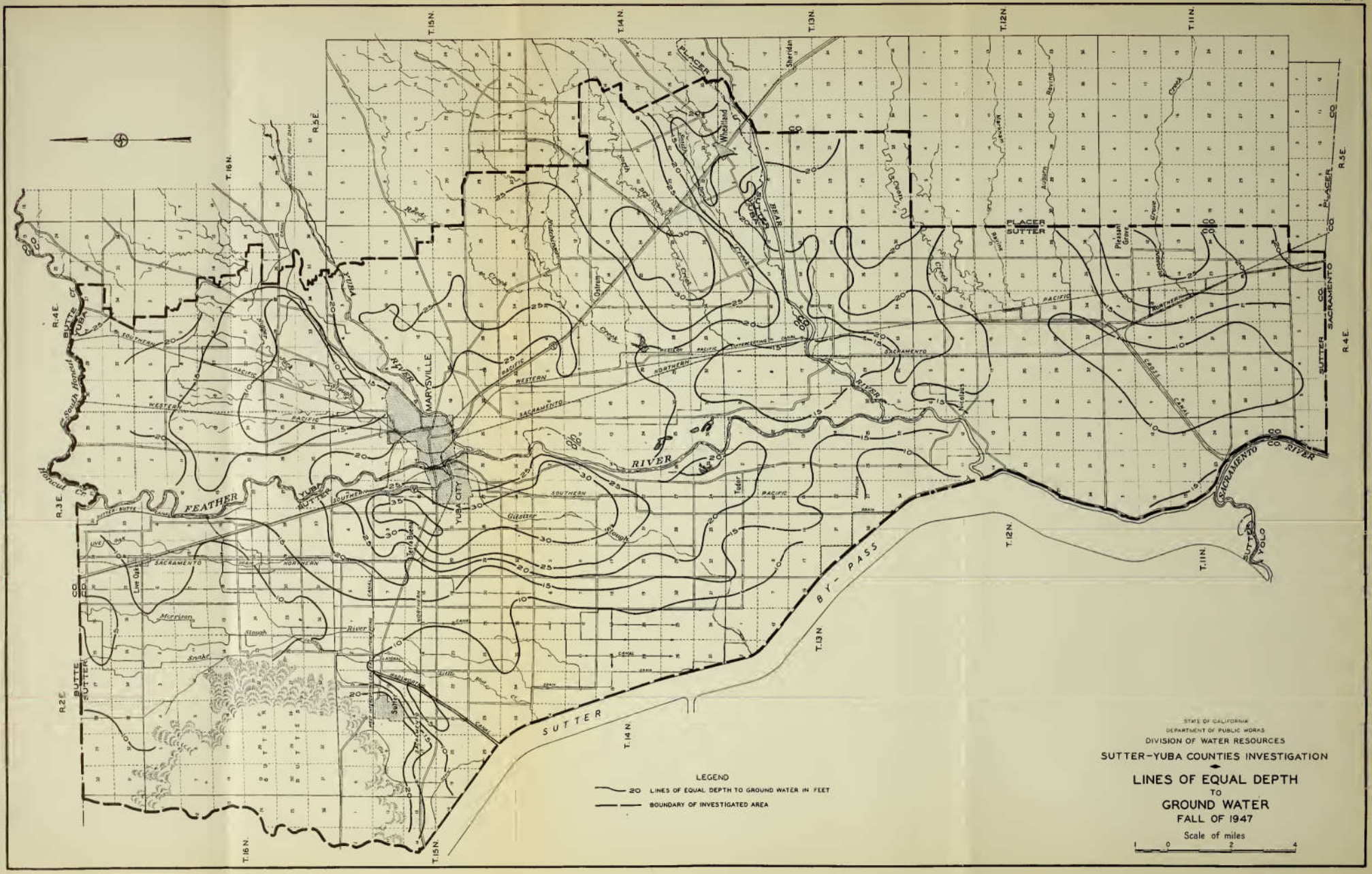


ACCUMULATED DEPARTURE FROM MEAN SEASONAL PRECIPITATION AT MARYSVILLE



ESTIMATED SEASONAL NATURAL RUNOFF OF FEATHER RIVER AT OROVILLE

PLATE 7



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LINES OF EQUAL DEPTH
TO
GROUND WATER
FALL OF 1947
Scale of miles
1 0 2 4
LEGEND
20 LINES OF EQUAL DEPTH TO GROUND WATER IN FEET
BOUNDARY OF INVESTIGATED AREA
MARYSVILLE
YUBA CITY
FEATHER
RIVER
SUTTER
BY-PASS
SACRAMENTO
PLACER
SUTTER
YUBA
BUTTE
YOLO
Wheatland
Sheridan
Pleasant Grove
Nicolaus
Tudor
Live Oak
Sutter
Ostrum
T.16N.
T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
R.2E.
R.3E.
R.4E.
R.5E.

PLATE 8

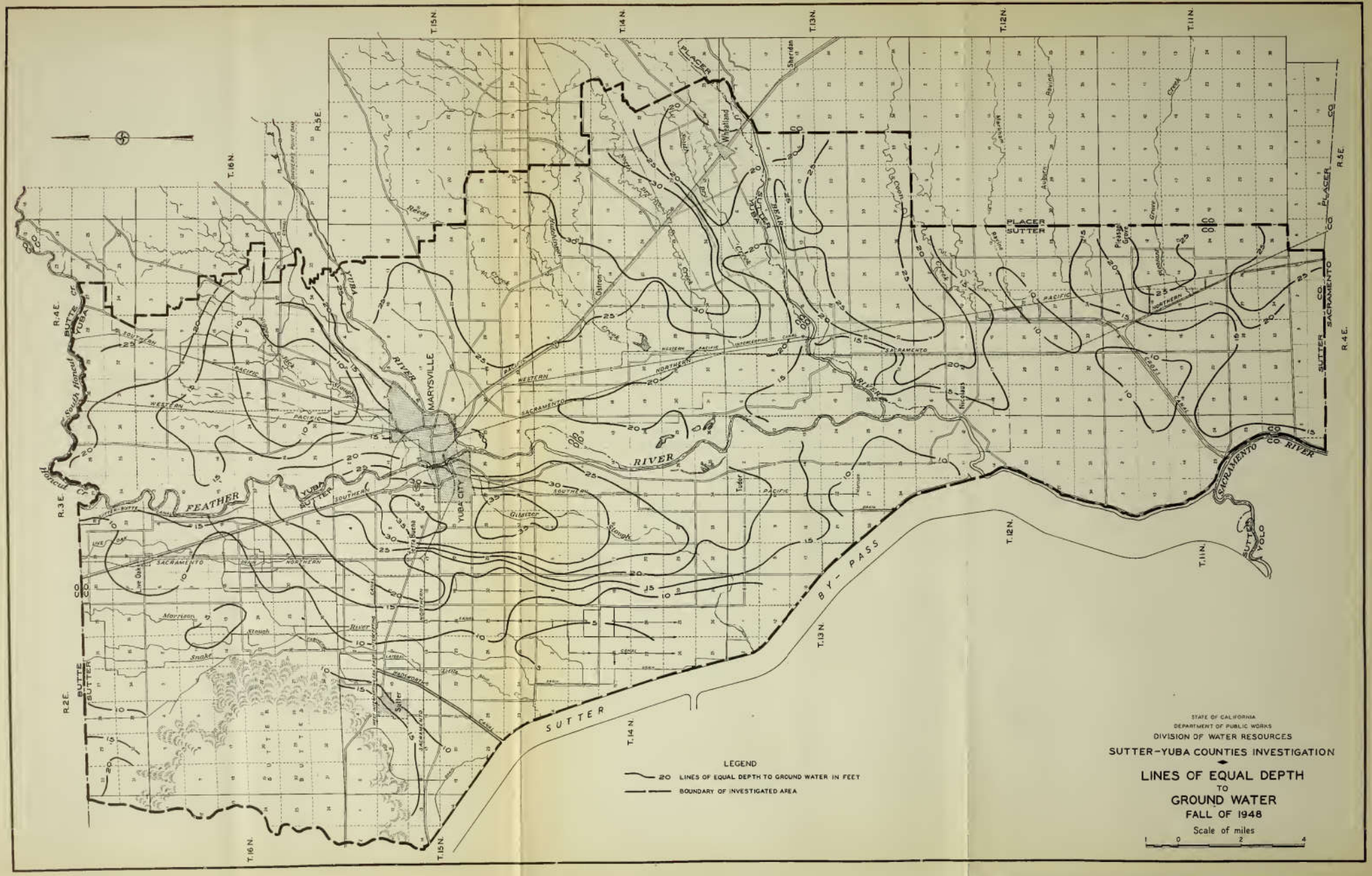
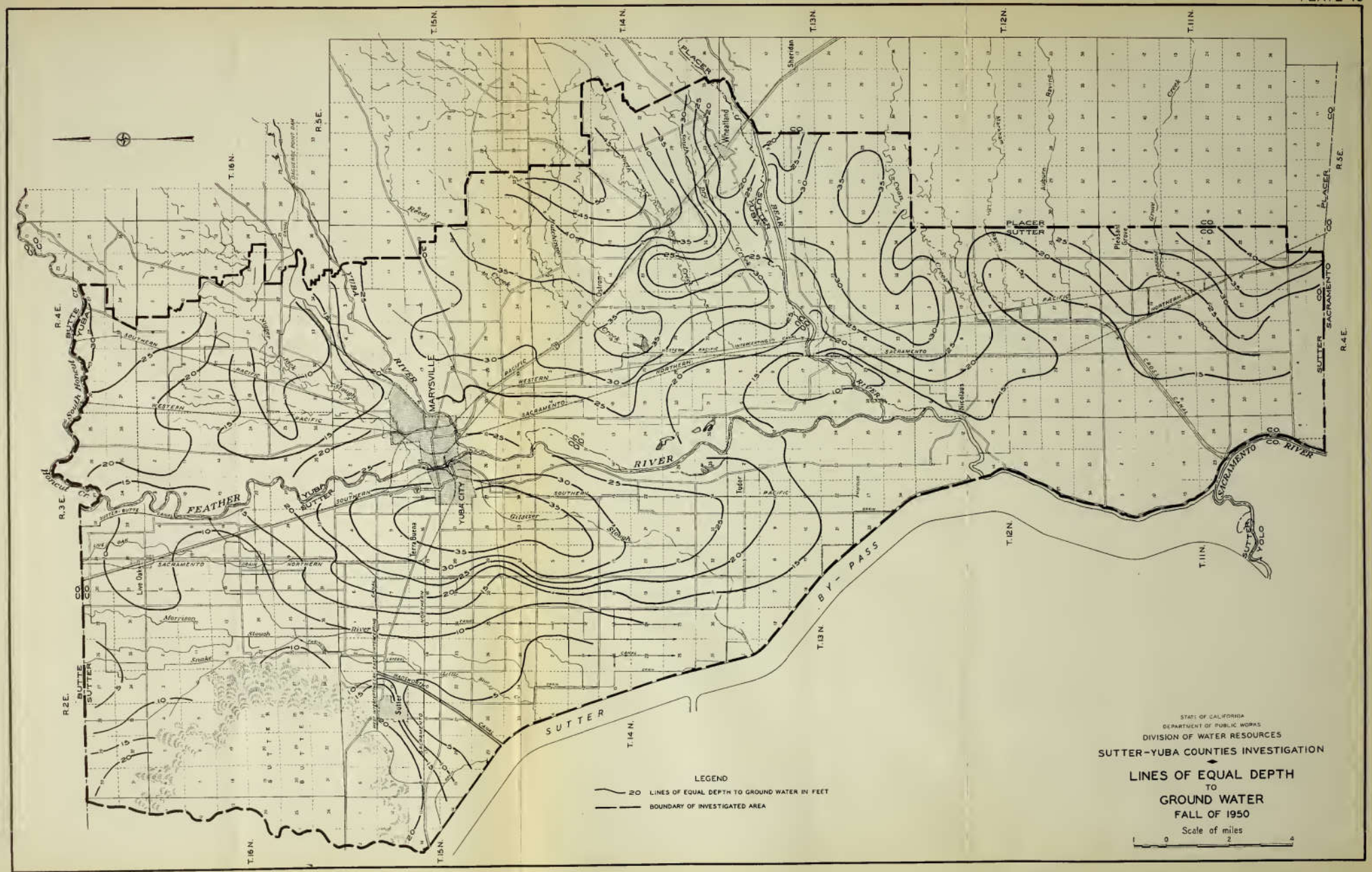

LEGEND
20 LINES OF EQUAL DEPTH TO GROUND WATER IN FEET
BOUNDARY OF INVESTIGATED AREA
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LINES OF EQUAL DEPTH
TO
GROUND WATER
FALL OF 1948
Scale of miles
0 2 4
MARYSVILLE
YUBA CITY
FEATHER RIVER
YUBA RIVER
BUTTE CREEK
SUTTER BY-PASS
PLACER
SUTTER
YUBA
BUTTE
SACRAMENTO
COLUSA
T.16N.
T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
R.2E.
R.3E.
R.4E.
R.5E.

PLATE 9



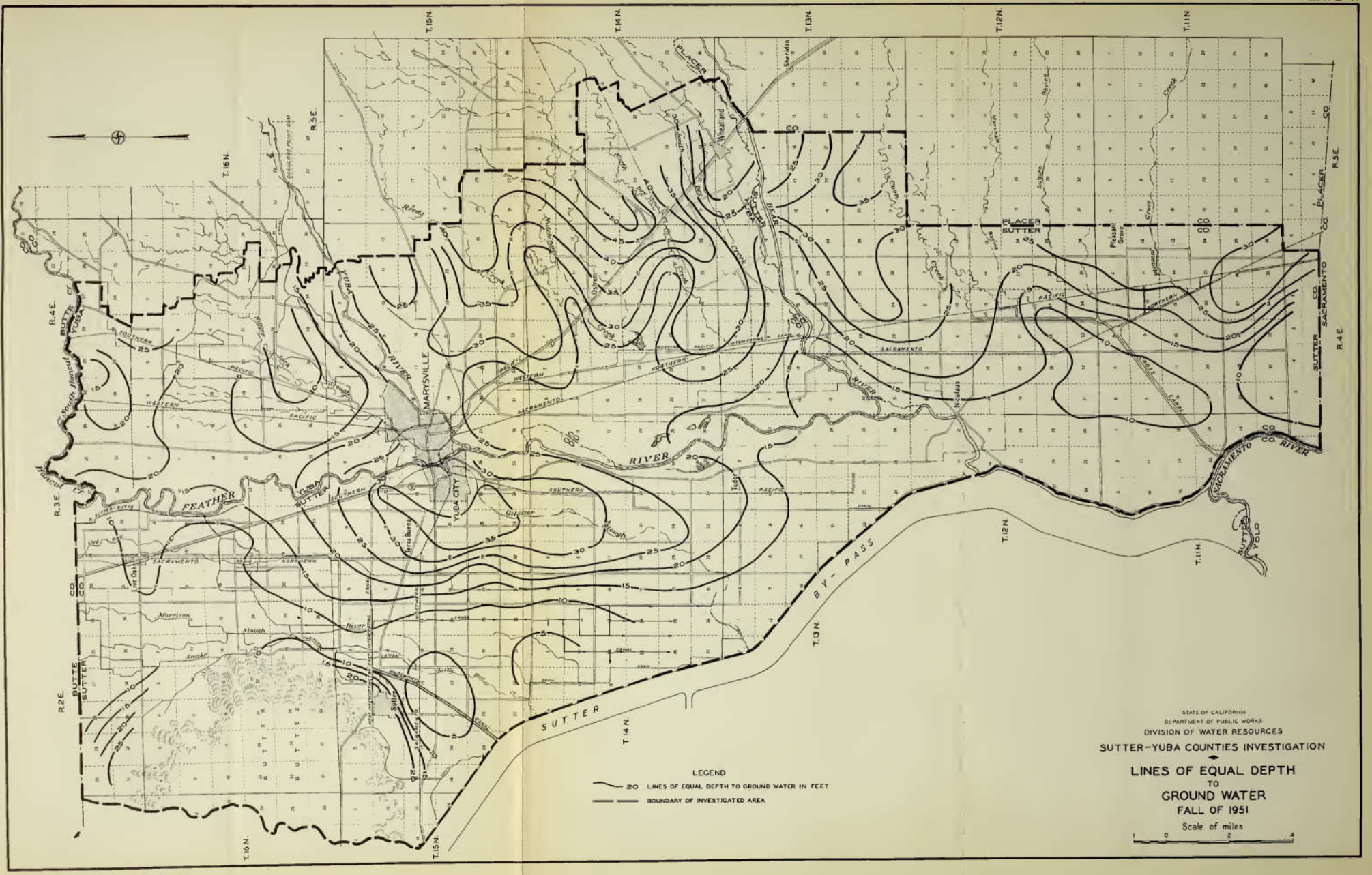
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LINES OF EQUAL DEPTH
TO
GROUND WATER
FALL OF 1949
Scale of miles
1 0 2 4
LEGEND
20 LINES OF EQUAL DEPTH TO GROUND WATER IN FEET
BOUNDARY OF INVESTIGATED AREA
MARYSVILLE
YUBA CITY
FEATHER RIVER
SUTTER BY-PASS
SACRAMENTO RIVER
PLACER
SUTTER
YUBA
BUTTE
SACRAMENTO
YOLO
Wheatland
Sheridan
Nicolaus
Tudor
Live Oak
Terra Buena
Pleasant Grove
Ostrom
Gilsizer Slough
Morrison Slough
Snake River
Little Bear Creek
Reeds Creek
Auburn Ravine
Cross Canal
Sutter
T.16N.
T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
R.2E.
R.3E.
R.4E.
R.5E.

PLATE 10



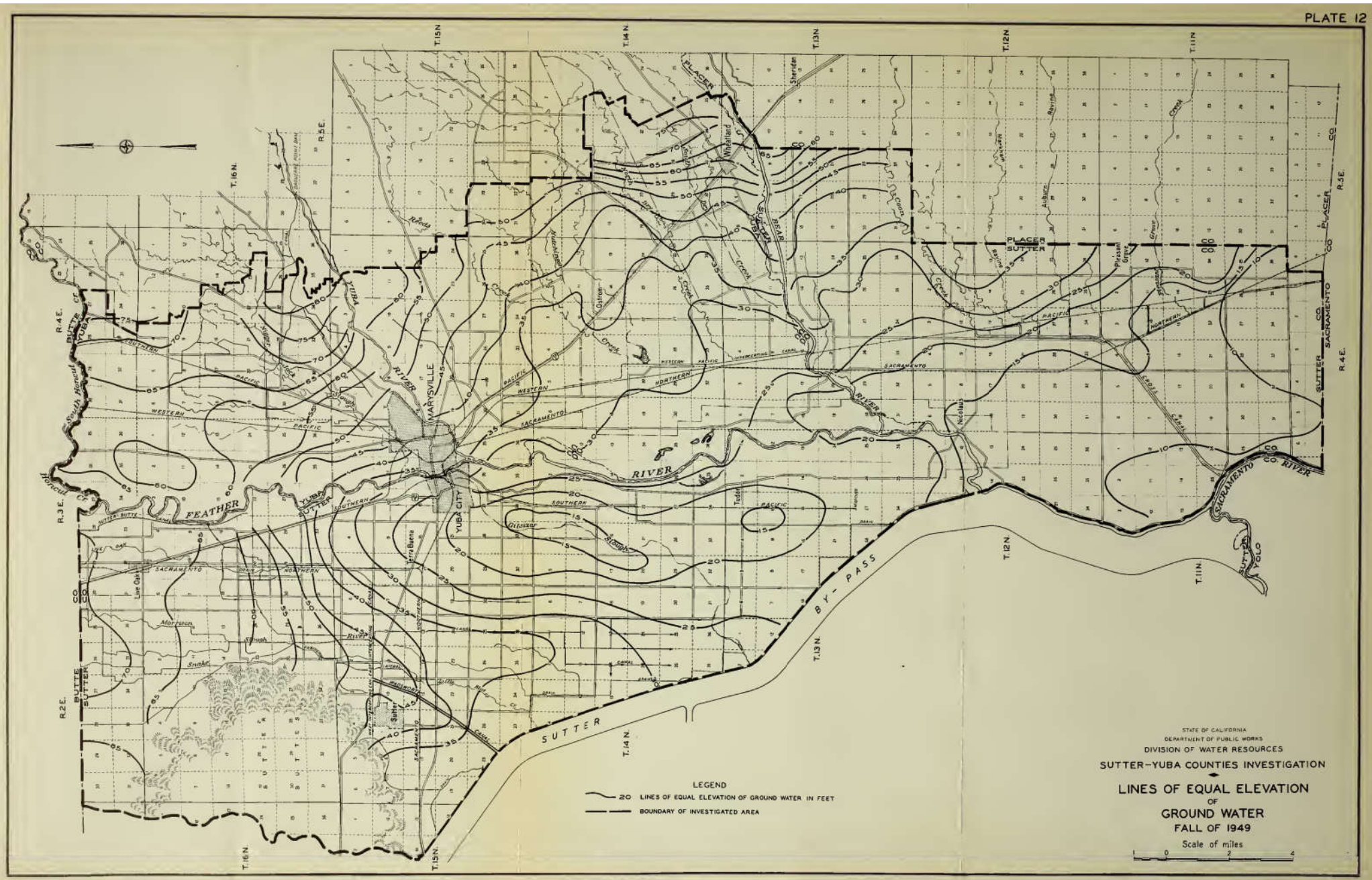
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LINES OF EQUAL DEPTH
TO
GROUND WATER
FALL OF 1950
Scale of miles
1 0 2 4
LEGEND
20 LINES OF EQUAL DEPTH TO GROUND WATER IN FEET
BOUNDARY OF INVESTIGATED AREA
MARYSVILLE
YUBA CITY
FEATHER RIVER
SUTTER BY-PASS
SACRAMENTO RIVER
PLACER CO
SUTTER CO
YUBA CO
BUTTE CO
SACRAMENTO CO
YOLO CO
Wheatland
Sheridan
Nicolaus
Tudor
Live Oak
Sutter
Terra Buena
Pleasant Grove
Ostrom
T.16N.
T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
R.2E.
R.3E.
R.4E.
R.5E.

PLATE II

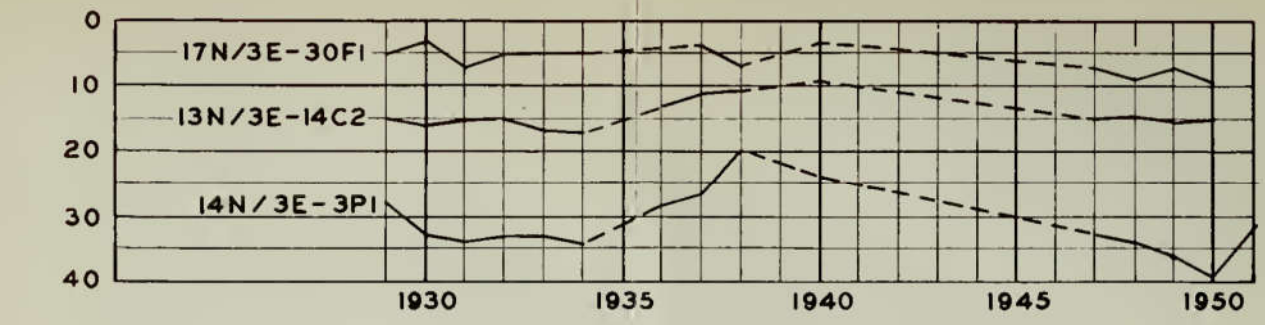


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LINES OF EQUAL DEPTH
TO
GROUND WATER
FALL OF 1951
Scale of miles
LEGEND
20 LINES OF EQUAL DEPTH TO GROUND WATER IN FEET
BOUNDARY OF INVESTIGATED AREA
MARYSVILLE
YUBA CITY
FEATHER
RIVER
SUTTER
BY-PASS
SACRAMENTO
YUBA
BEAR
PLACER
SUTTER
YOLO
Wheatland
Nicolaus
Sheridan
Live Oak
Terra Buena
Tudor
Pleasant Grove
T.16N.
T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
R.2E.
R.3E.
R.4E.
R.5E.

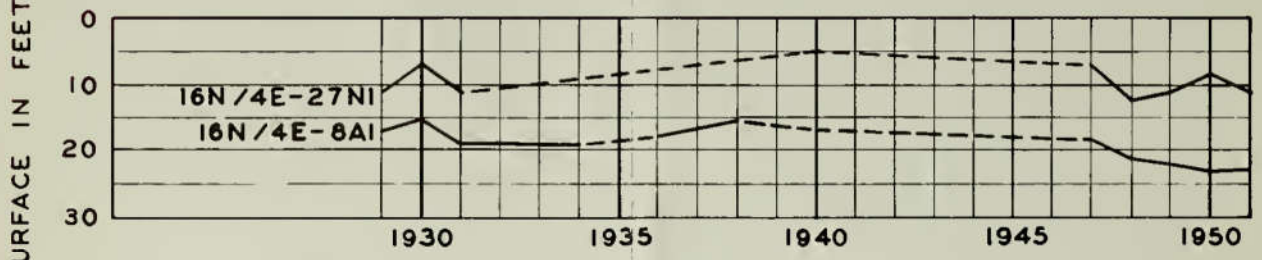
PLATE 12



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LINES OF EQUAL ELEVATION
OF
GROUND WATER
FALL OF 1949
Scale of miles
1 0 2 4
LEGEND
20 LINES OF EQUAL ELEVATION OF GROUND WATER IN FEET
BOUNDARY OF INVESTIGATED AREA
MARYSVILLE
YUBA CITY
Wheatland
Sheridan
Nicolaus
Tudor
Terra Buena
Live Oak
Sutter
FEATHER
RIVER
YUBA
SUTTER
BEAR
SACRAMENTO
SUTTER BY-PASS
PLACER
SUTTER
YOLO
BUTTE
SACRAMENTO
T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
T.16N.
R.5E.
R.4E.
R.3E.
R.2E.

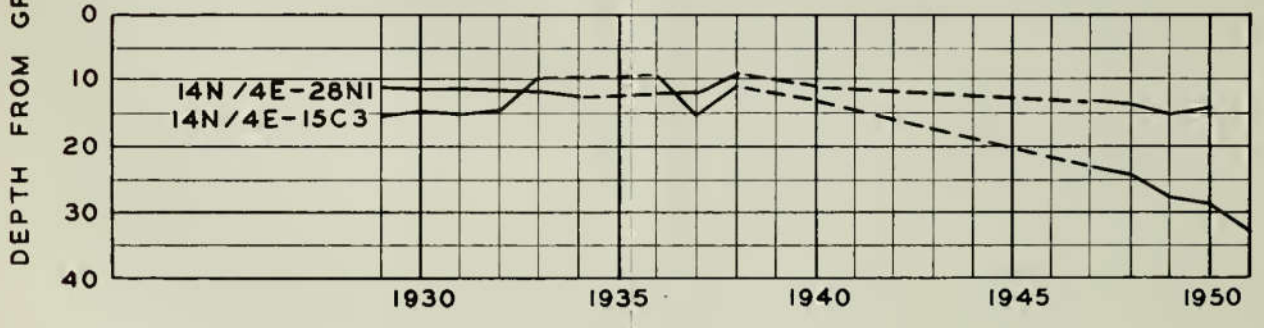


WEST SIDE ZONE

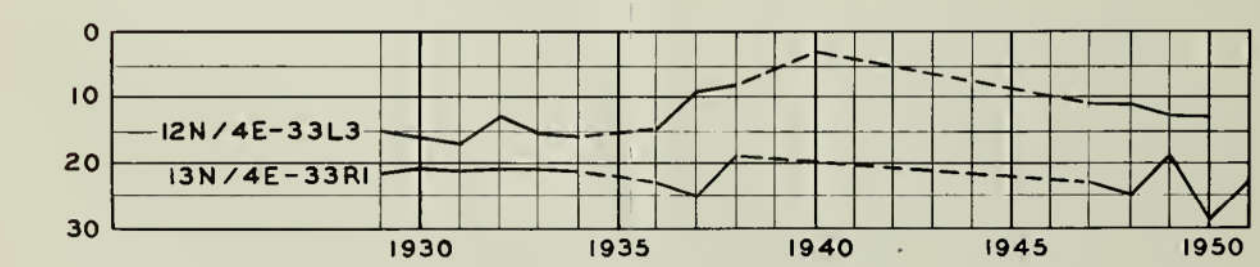


NORTHEAST ZONE

DEPTH FROM GROUND SURFACE IN FEET



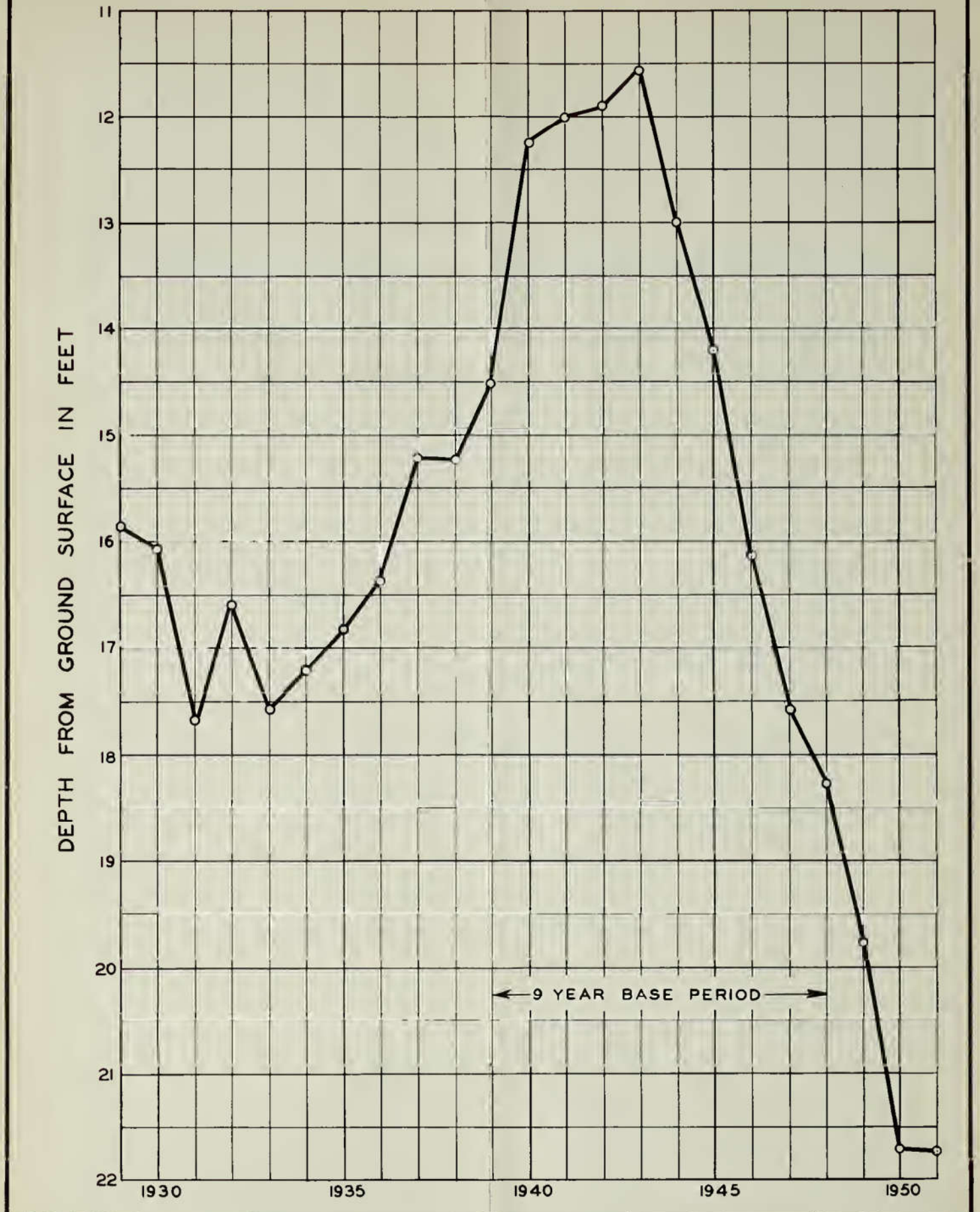
EAST CENTRAL ZONE



SOUTH SIDE ZONE

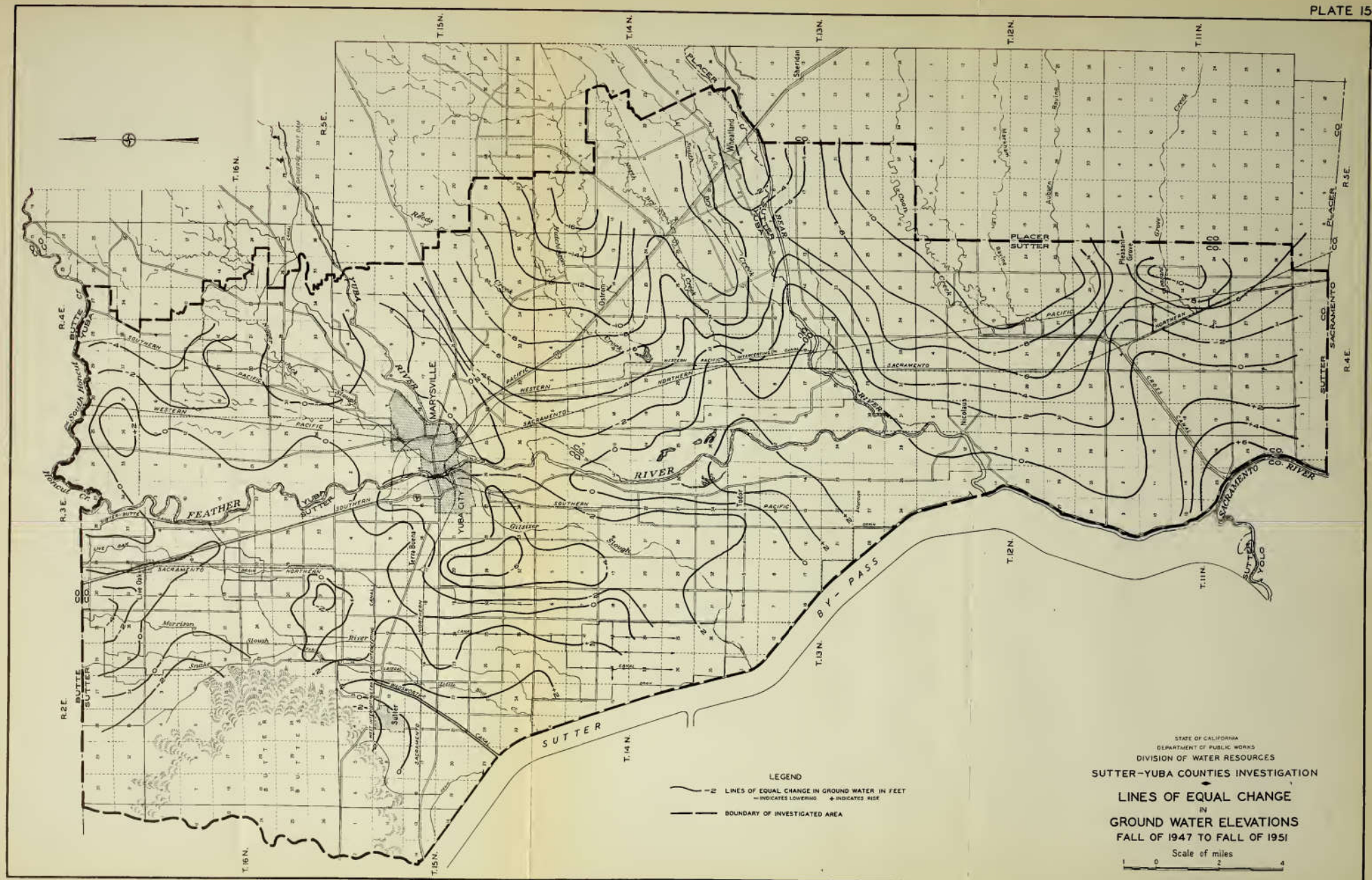
– – – – – – – INTERPOLATED DEPTHS

MEASURED FALL DEPTHS TO GROUND WATER AT REPRESENTATIVE WELLS



AVERAGE FALL DEPTH TO GROUND WATER

PLATE 15



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION

LINES OF EQUAL CHANGE IN GROUND WATER ELEVATIONS FALL OF 1947 TO FALL OF 1951

Scale of miles
1 0 2 4

PLATE 18

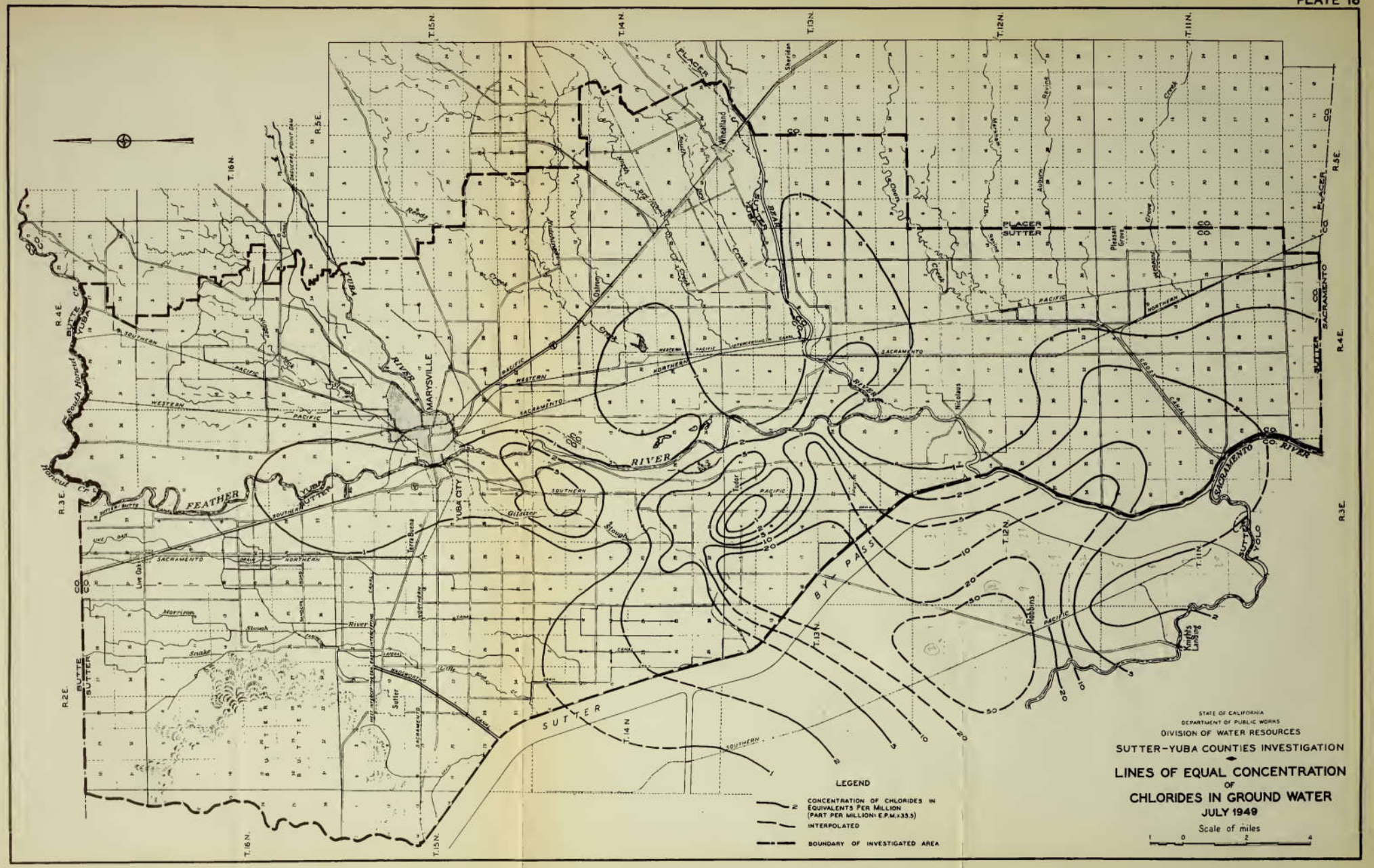
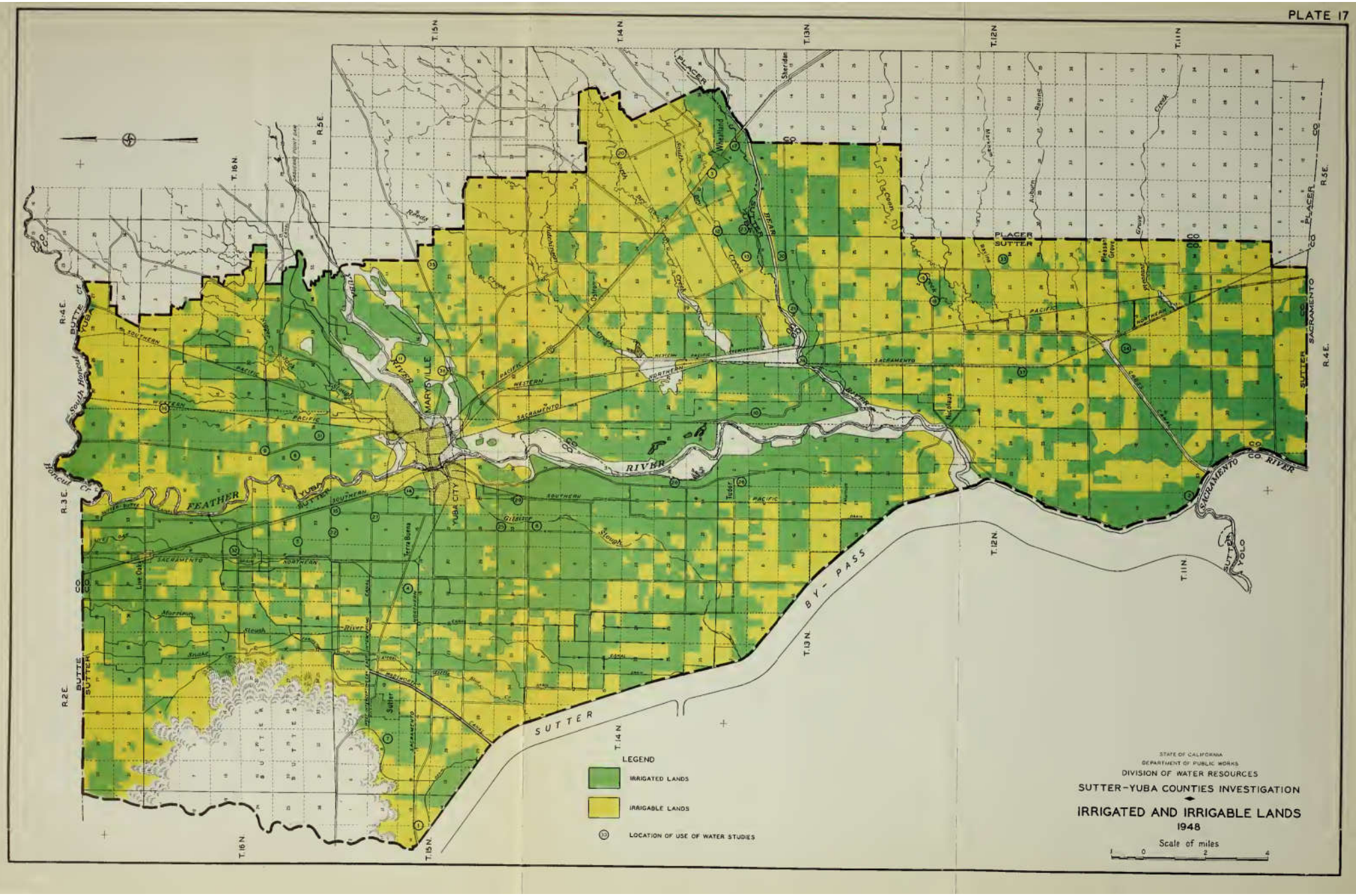

T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
T.16N.
R.5E.
R.4E.
R.3E.
R.2E.
PLACER
SUTTER
YUBA
BUTTE
SACRAMENTO
YUBA CITY
MARYSVILLE
FEATHER RIVER
BEAR RIVER
BY PASS
SUTTER BUTTES
Wheatland
Sheridan
Auburn
Ravine
Pleasant Grove Creek
Dry Creek
Bear River
Honcut Creek
Gilsizer Slough
Live Oak
Morrison Slough
Snake River
Sutter Canal
Robbins
Knights Landing
Tudor
Nicolaus
Cross Canal
Pacific
Southern Pacific
Western Pacific
Northern Pacific
Sacramento Northern
Southern Pacific Co. Lighterage Canal
Sutter-Butte Canal
Sacramento Co. River
Yuba Co. River
Sutter Co. River
Placer Co. River

PLATE 17



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

SUTTER-YUBA COUNTIES INVESTIGATION

IRRIGATED AND IRRIGABLE LANDS
1948

Scale of miles
1 0 2 4

PLATE 18

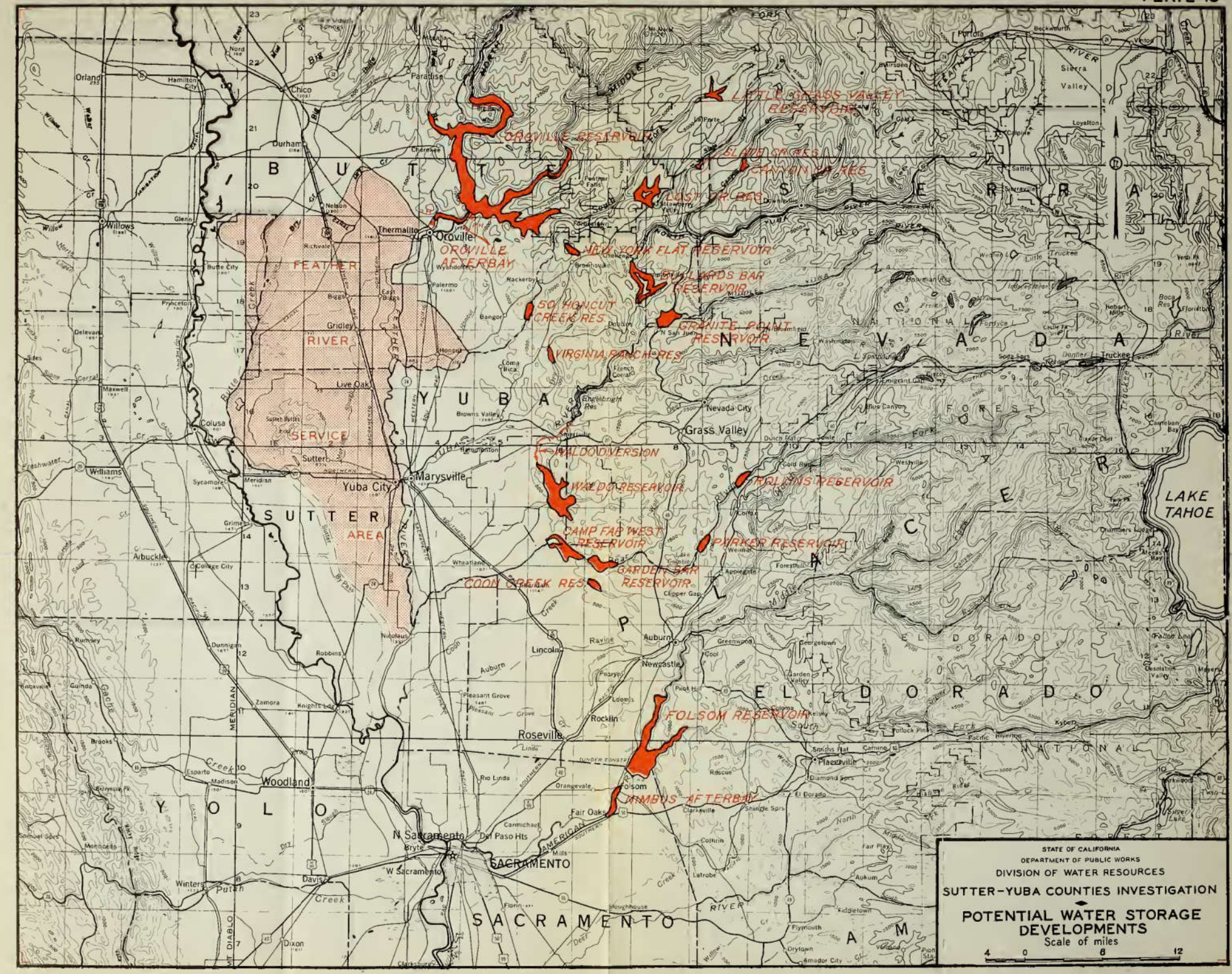
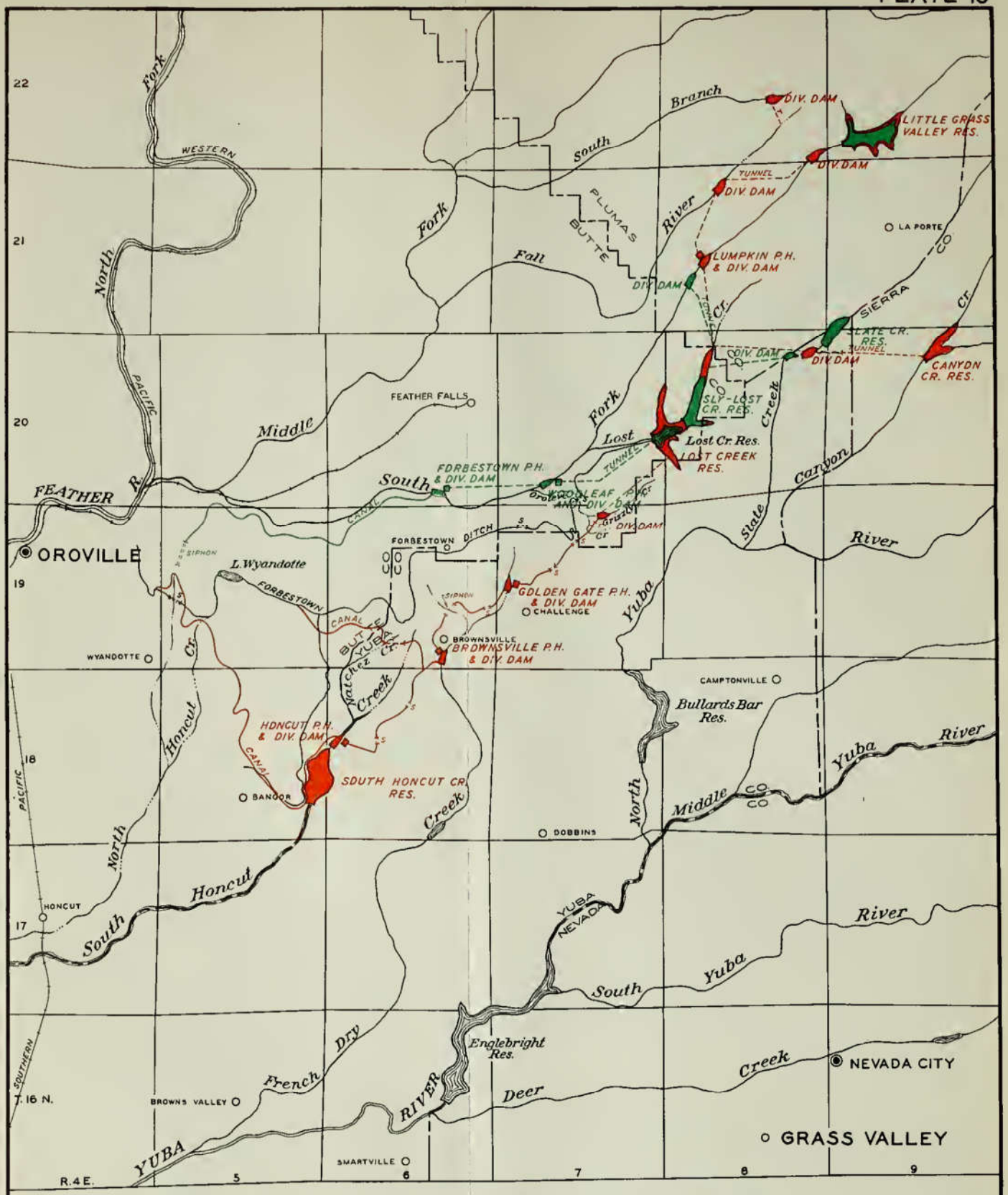

LITTLE GRASS VALLEY RESERVOIR
OROVILLE RESERVOIR
SLATE CREEK CANYON RES
LAST CHANCE RES
OROVILLE AFTERBAY
NEW YORK FLAT RESERVOIR
BULLARDS BAR RESERVOIR
SO. HONCUT CREEK RES
GRANITE POINT RESERVOIR
VIRGINIA RANCH RES
FEATHER RIVER SERVICE AREA
WILD DIVERSION
WILD RESERVOIR
ROLLINS RESERVOIR
CAMP FAR WEST RESERVOIR
PARKER RESERVOIR
GARDEN BAR RESERVOIR
COON CREEK RES
FOLSOM RESERVOIR
NIMBUS AFTERBAY
LAKE TAHOE
BUTTE
YUBA
SUTTER
YOLO
SACRAMENTO
EL DORADO
PLACER
NEVADA
Oroville
Marysville
Yuba City
Grass Valley
Nevada City
Truckee
Auburn
Roseville
Folsom
Woodland
Davis
Winters
Dixon
Sacramento
N. Sacramento
W. Sacramento
Colusa
Willows
Chico
Orland
Durham
Paradise
Thermalito
Gridley
Live Oak
Sutter
Yuba City
Williams
Arbuckle
College City
Lincoln
Rocklin
Newcastle
Loomis
Pleasant Grove
Rio Linda
Elverta
Folsom
Placerville
Diamond Springs
El Dorado
Shingle Springs
Cameron Park
Meyers
Kyburz
Strawberry
Tahoe City
Kings Beach
Incline Village
Crystal Bay
Carnelian Bay
Tahoe Vista
Homewood
Tahoma
Meeks Bay
Emerald Bay
Fallen Leaf Lake
Echo Lake
Desolation Valley
Loon Lake
Union Valley Reservoir
Ice House Reservoir
Jones Fork
Silver Fork
Rubicon River
Middle Fork
North Fork
South Fork
Feather River
Yuba River
Bear River
American River
Cosumnes River
Putah Creek
Cache Creek
Sacramento River
Mt. Diablo Meridian
Folsom South Canal
Western Pacific
Southern Pacific
Tunnel Canal
Lake Almanor
Bucks Lake
Quincy
Portola
Beckwourth
Loyalton
Sierraville
Downieville
Nelson Point
Paradise
Magalia
Stirling City
Cohasset
Forest Ranch
Butte City
Palermo
Biggs
Princeton
Delevan
Maxwell
Sycamore
Meridian
Grimes
Wheatland
Dunnigan
Robbins
Zamora
Knights Landing
Esparto
Madison
Brooks
Guinda
Rumsey
Knoxville
Capay
Monticello
Putah Creek
Cache Creek
Winters
Davis
Dixon
Vacaville
Fairfield
Suisun City
Benicia
Martinez
Pittsburg
Antioch
Rio Vista
Isleton
Walnut Grove
Courtland
Clarksburg
Freeport
Florin
Elk Grove
Galt
Lodi
Stockton
Manteca
Ripon
Oakdale
Modesto
Turlock
Merced
Los Banos
Gustine
Newman
Patterson
Crows Landing
Hughson
Waterford
La Grange
Coulterville
Groveland
Big Oak Flat
Sonora
Jamestown
Tuolumne
Columbia
Angels Camp
Murphys
Arnold
Copperopolis
Valley Springs
Mokelumne Hill
San Andreas
Jackson
Ione
Plymouth
Drytown
Amador City
Sutter Creek
Volcano
Pioneer
Fiddletown
Cobb Mountain
Lower Lake
Clear Lake
Kelseyville
Lakeport
Upper Lake
Middletown
Calistoga
St. Helena
Napa
Vallejo
Benicia
Martinez
Concord
Walnut Creek
Pleasant Hill
Lafayette
Orinda
Moraga
Berkeley
Oakland
Alameda
San Leandro
Hayward
Fremont
Newark
Union City
San Jose
Milpitas
Alviso
Santa Clara
Sunnyvale
Mountain View
Palo Alto
Menlo Park
Redwood City
San Mateo
Burlingame
San Francisco
Daly City
Pacifica
Half Moon Bay
Santa Cruz
Watsonville
Aptos
Capitola
Soquel
Scotts Valley
Boulder Creek
Big Basin
Felton
Ben Lomond
Brookdale
Los Gatos
Saratoga
Cupertino
Campbell
Morgan Hill
Gilroy
Hollister
San Juan Bautista
Salinas
Monterey
Carmel
Pacific Grove
Pebble Beach
Big Sur
Lucia
Gorda
Paso Robles
Templeton
Atascadero
San Luis Obispo
Arroyo Grande
Nipomo
Guadalupe
Santa Maria
Lompoc
Solvang
Buellton
Santa Ynez
Los Olivos
Ballard
Santa Barbara
Goleta
Carpinteria
Ventura
Oxnard
Port Hueneme
Camarillo
Moorpark
Simi
Thousand Oaks
Westlake Village
Malibu
Santa Monica
Beverly Hills
Hollywood
Los Angeles
Pasadena
Glendale
Burbank
San Fernando
Van Nuys
Sherman Oaks
Encino
Tarzana
Woodland Hills
Canoga Park
Chatsworth
Northridge
Sylmar
San Gabriel
Alhambra
Monterey Park
El Monte
Whittier
La Habra
Fullerton
Anaheim
Orange
Santa Ana
Tustin
Irvine
Laguna Beach
Laguna Niguel
Dana Point
San Clemente
Capistrano Beach
San Juan Capistrano
Mission Viejo
Lake Forest
Rancho Santa Margarita
Trabuco Canyon
Silverado
Modjeska Peak
Santiago Peak
Saddleback Mountain
Cleveland National Forest
Angeles National Forest
Los Padres National Forest
Sierra National Forest
Stanislaus National Forest
Tahoe National Forest
Plumas National Forest
Lassen National Forest
Shasta-Trinity National Forest
Mendocino National Forest
Klamath National Forest
Six Rivers National Forest
Redwood National Park
Point Reyes National Seashore
Golden Gate National Recreation Area
Channel Islands National Park
Death Valley National Monument
Joshua Tree National Monument
Mojave National Preserve
Lake Mead National Recreation Area
Lake Mohave
Lake Havasu
Colorado River
Imperial Dam
Laguna Dam
Yuma
Blythe
Needles
Parker
Parker Dam
Lake Havasu City
Kingman
Bullhead City
Laughlin
Searchlight
Boulder City
Las Vegas
Henderson
North Las Vegas
Nellis Air Force Base
Indian Springs
Pahrump
Beatty
Tonopah
Goldfield
Hawthorne
Yerington
Fallon
Lovelock
Winnemucca
Battle Mountain
Austin
Eureka
Ely
Wendover
Elko
Wells
Jackpot
Owyhee
Mountain City
Jarbidge
Rogerson
Gerlach
Empire
Sparks
Reno
Carson City
Virginia City
Dayton
Fernley
Wadsworth
Pyramid Lake
Nixon
Susanville
Herlong
Doyle
Portola
Beckwourth
Loyalton
Sierraville
Downieville
Nelson Point
Paradise
Magalia
Stirling City
Cohasset
Forest Ranch
Butte City
Palermo
Biggs
Princeton
Delevan
Maxwell
Sycamore
Meridian
Grimes
Wheatland
Dunnigan
Robbins
Zamora
Knights Landing
Esparto
Madison
Brooks
Guinda
Rumsey
Knoxville
Capay
Monticello
Putah Creek
Cache Creek
Winters
Davis
Dixon
Vacaville
Fairfield
Suisun City
Benicia
Martinez
Pittsburg
Antioch
Rio Vista
Isleton
Walnut Grove
Courtland
Clarksburg
Freeport
Florin
Elk Grove
Galt
Lodi
Stockton
Manteca
Ripon
Oakdale
Modesto
Turlock
Merced
Los Banos
Gustine
Newman
Patterson
Crows Landing
Hughson
Waterford
La Grange
Coulterville
Groveland
Big Oak Flat
Sonora
Jamestown
Tuolumne
Columbia
Angels Camp
Murphys
Arnold
Copperopolis
Valley Springs
Mokelumne Hill
San Andreas
Jackson
Ione
Plymouth
Drytown
Amador City
Sutter Creek
Volcano
Pioneer
Fiddletown
Cobb Mountain
Lower Lake
Clear Lake
Kelseyville
Lakeport
Upper Lake
Middletown
Calistoga
St. Helena
Napa
Vallejo
Benicia
Martinez
Concord
Walnut Creek
Pleasant Hill
Lafayette
Orinda
Moraga
Berkeley
Oakland
Alameda
San Leandro
Hayward
Fremont
Newark
Union City
San Jose
Milpitas
Alviso
Santa Clara
Sunnyvale
Mountain View
Palo Alto
Menlo Park
Redwood City
San Mateo
Burlingame
San Francisco
Daly City
Pacifica
Half Moon Bay
Santa Cruz
Watsonville
Aptos
Capitola
Soquel
Scotts Valley
Boulder Creek
Big Basin
Felton
Ben Lomond
Brookdale
Los Gatos
Saratoga
Cupertino
Campbell
Morgan Hill
Gilroy
Hollister
San Juan Bautista
Salinas
Monterey
Carmel
Pacific Grove
Pebble Beach
Big Sur
Lucia
Gorda
Paso Robles
Templeton
Atascadero
San Luis Obispo
Arroyo Grande
Nipomo
Guadalupe
Santa Maria
Lompoc
Solvang
Buellton
Santa Ynez
Los Olivos
Ballard
Santa Barbara
Goleta
Carpinteria
Ventura
Oxnard
Port Hueneme
Camarillo
Moorpark
Simi
Thousand Oaks
Westlake Village
Malibu
Santa Monica
Beverly Hills
Hollywood
Los Angeles
Pasadena
Glendale
Burbank
San Fernando
Van Nuys
Sherman Oaks
Encino
Tarzana
Woodland Hills
Canoga Park
Chatsworth
Northridge
Sylmar
San Gabriel
Alhambra
Monterey Park
El Monte
Whittier
La Habra
Fullerton
Anaheim
Orange
Santa Ana
Tustin
Irvine
Laguna Beach
Laguna Niguel
Dana Point
San Clemente
Capistrano Beach
San Juan Capistrano
Mission Viejo
Lake Forest
Rancho Santa Margarita
Trabuco Canyon
Silverado
Modjeska Peak
Santiago Peak
Saddleback Mountain
Cleveland National Forest
Angeles National Forest
Los Padres National Forest
Sierra National Forest
Stanislaus National Forest
Tahoe National Forest
Plumas National Forest
Lassen National Forest
Shasta-Trinity National Forest
Mendocino National Forest
Klamath National Forest
Six Rivers National Forest
Redwood National Park
Point Reyes National Seashore
Golden Gate National Recreation Area
Channel Islands National Park
Death Valley National Monument
Joshua Tree National Monument
Mojave National Preserve
Lake Mead National Recreation Area
Lake Mohave
Lake Havasu
Colorado River
Imperial Dam
Laguna Dam
Yuma
Blythe
Needles
Parker
Parker Dam
Lake Havasu City
Kingman
Bullhead City
Laughlin
Searchlight
Boulder City
Las Vegas
Henderson
North Las Vegas
Nellis Air Force Base
Indian Springs
Pahrump
Beatty
Tonopah
Goldfield
Hawthorne
Yerington
Fallon
Lovelock
Winnemucca
Battle Mountain
Austin
Eureka
Ely
Wendover
Elko
Wells
Jackpot
Owyhee
Mountain City
Jarbidge
Rogerson
Gerlach
Empire
Sparks
Reno
Carson City
Virginia City
Dayton
Fernley
Wadsworth
Pyramid Lake
Nixon
Susanville
Herlong
Doyle
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
POTENTIAL WATER STORAGE DEVELOPMENTS
Scale of miles
4 0 8 12

PLATE 19



LEGEND

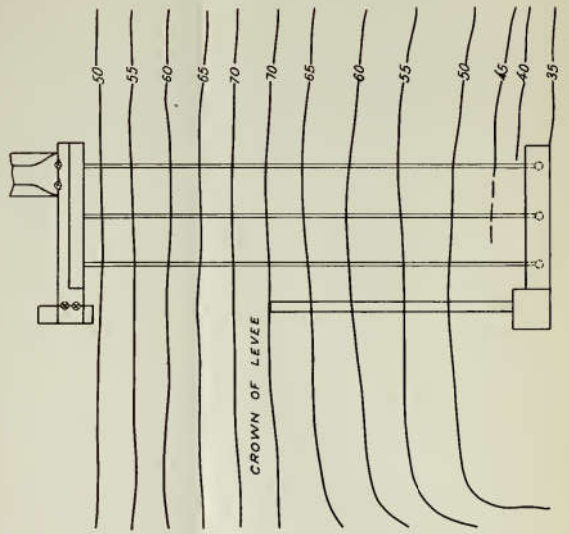
OROVILLE-WYANDOTTE IRRIGATION DISTRICT PLAN

ALTERNATIVE PLAN

PLANS FOR DEVELOPMENT
OF
SOUTH FORK OF FEATHER RIVER

SCALE 1 0 1 2 3 4 MILES

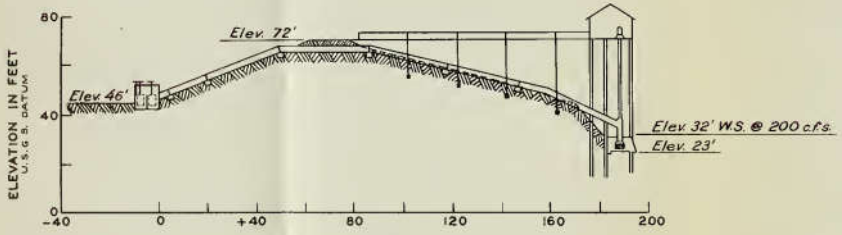
DIVISION OF WATER RESOURCES



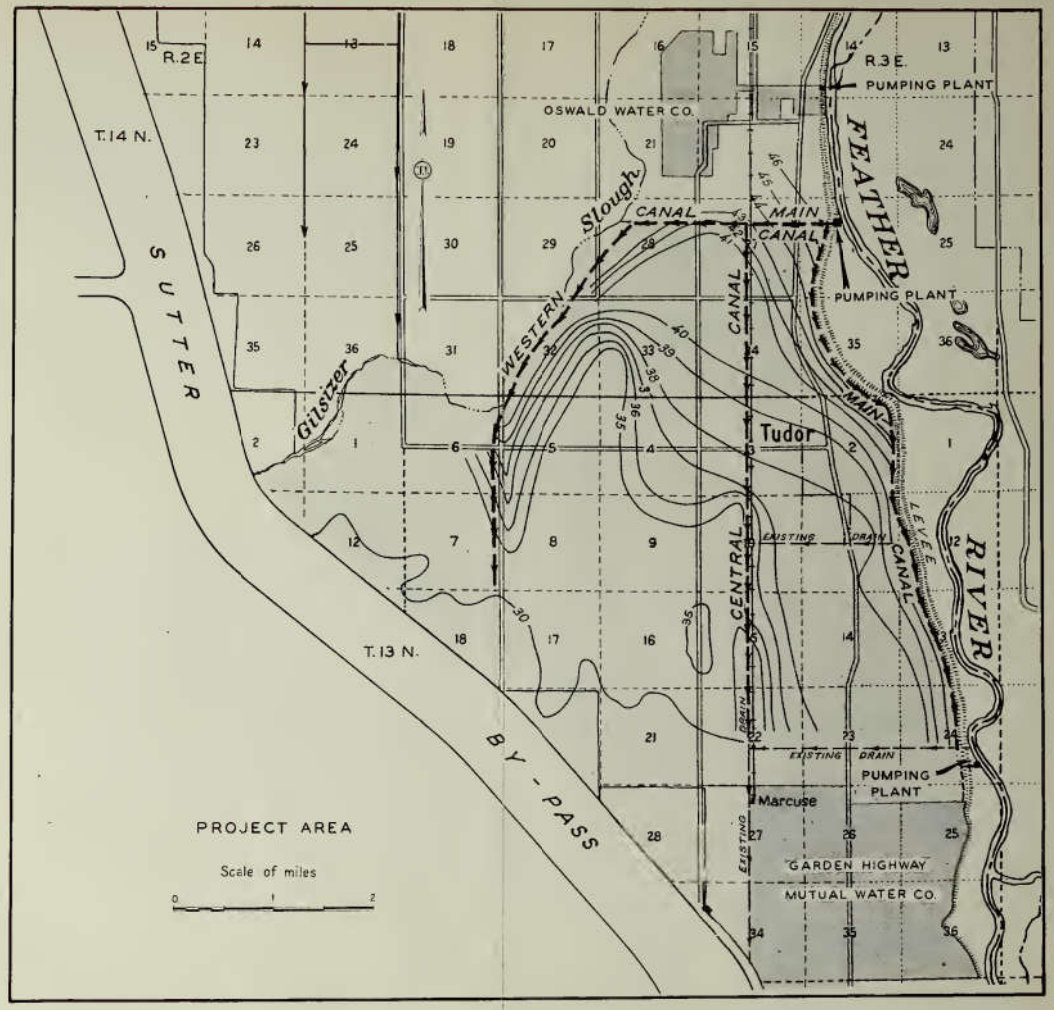
PLAN OF PUMPING PLANT

Scale of feet

0 40 80

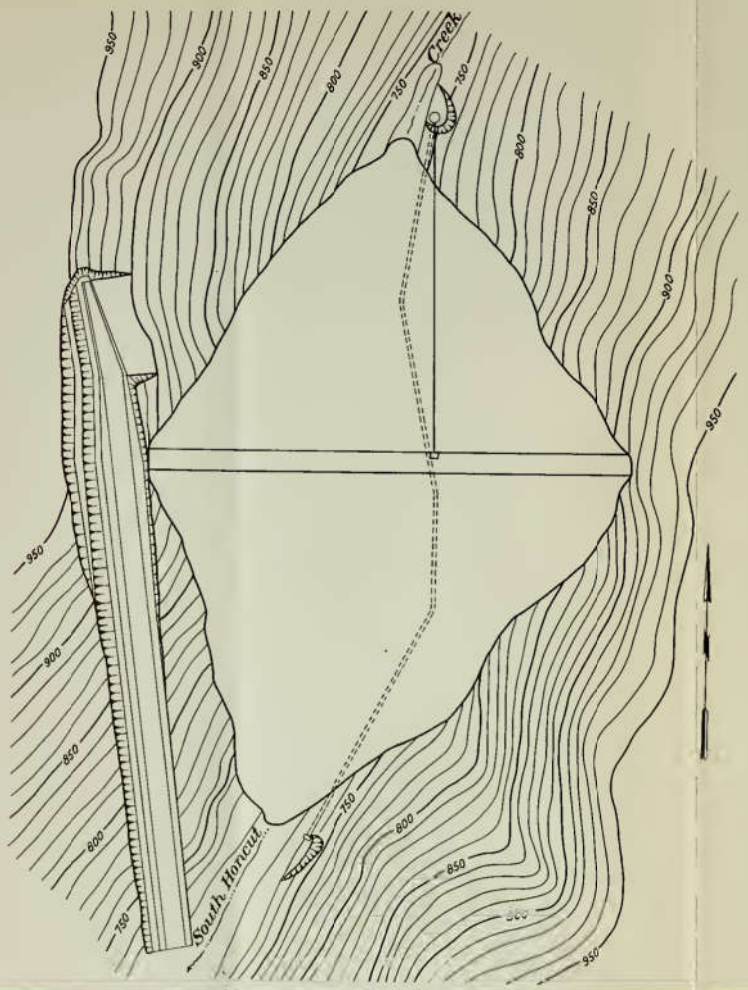


PROFILE OF PUMPING PLANT



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION

PEACH BOWL PROJECT



GENERAL PLAN OF DAM

SCALE OF FEET
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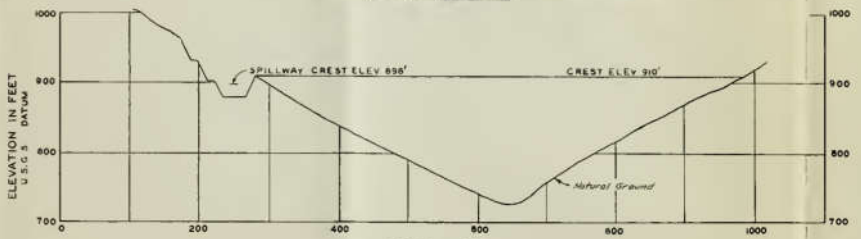
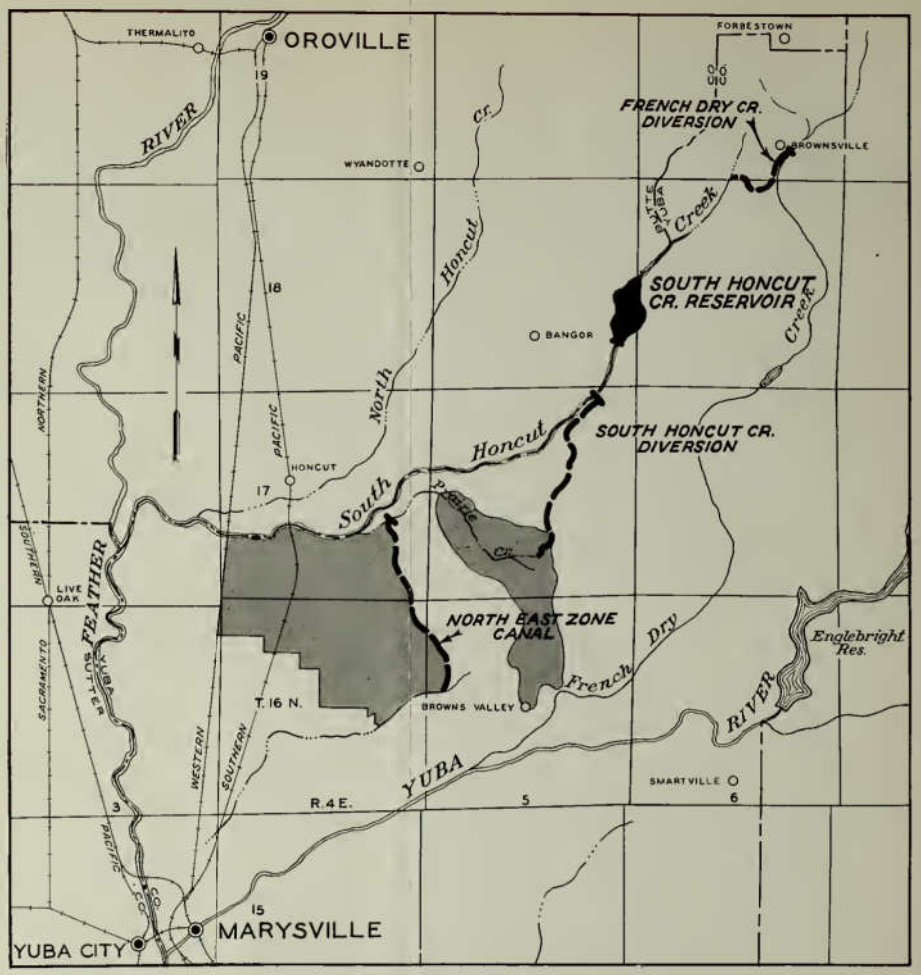


PROFILE OF DAM
LOOKING UPSTREAM



PROJECT AREA
Scale of miles
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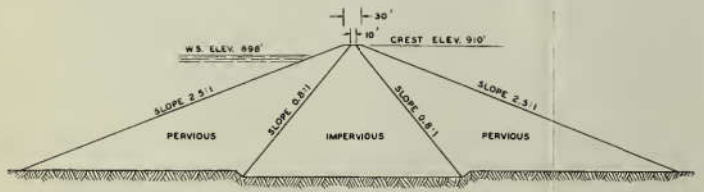

SECTION OF DAM
SCALE OF FEET
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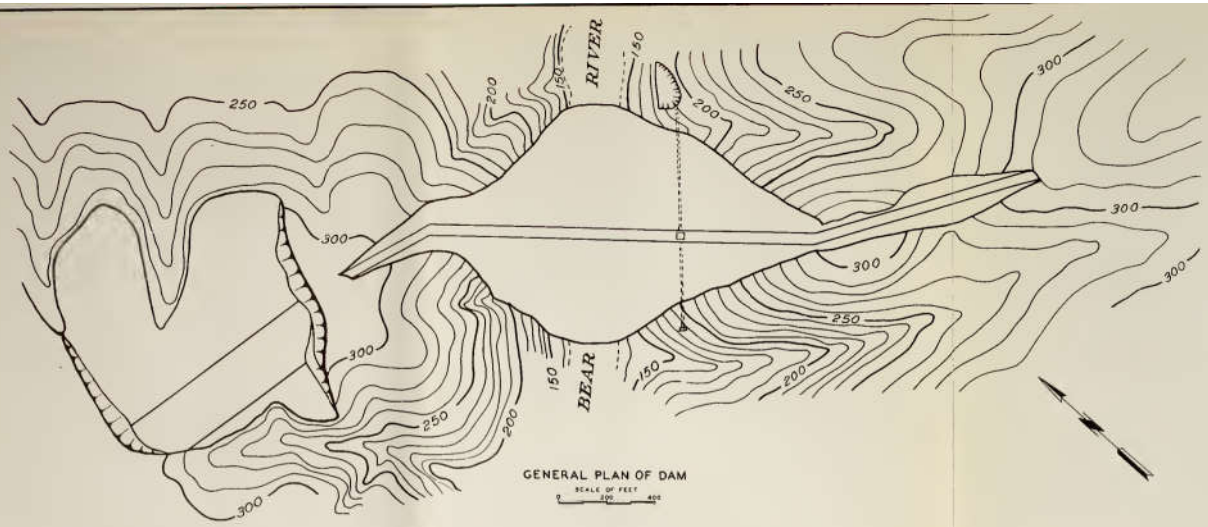
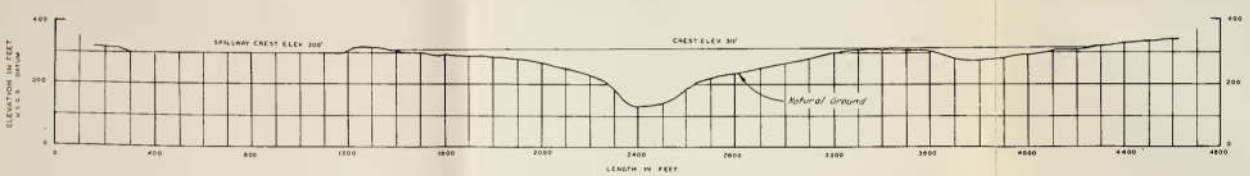
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION

SOUTH HONCUT CREEK PROJECT



GENERAL PLAN OF DAM

SCALE OF FEET



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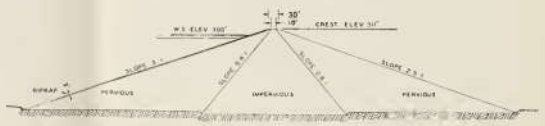

SECTION OF DAM

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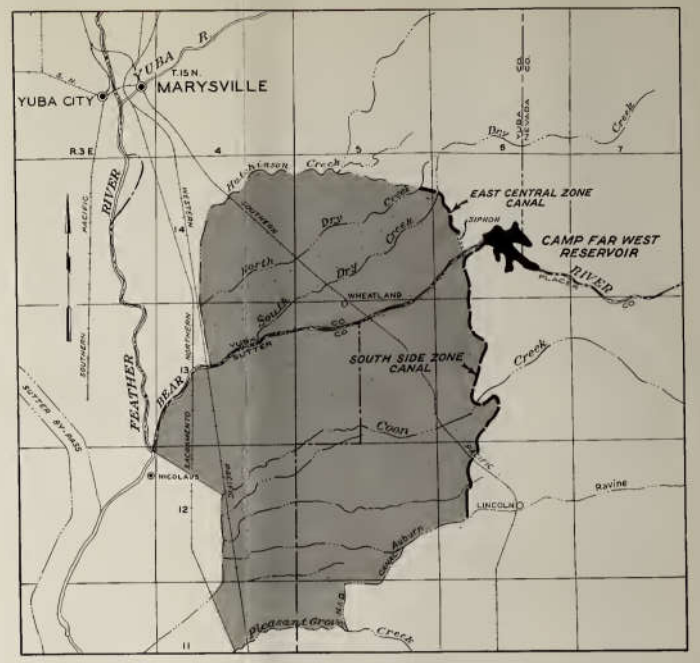

PROJECT AREA

Scale of miles

2 0 2 4

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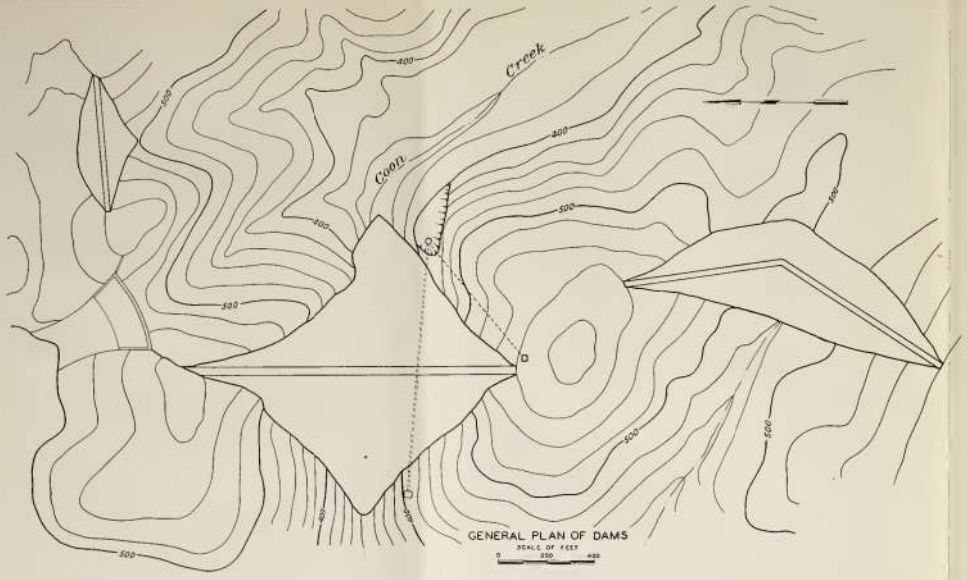
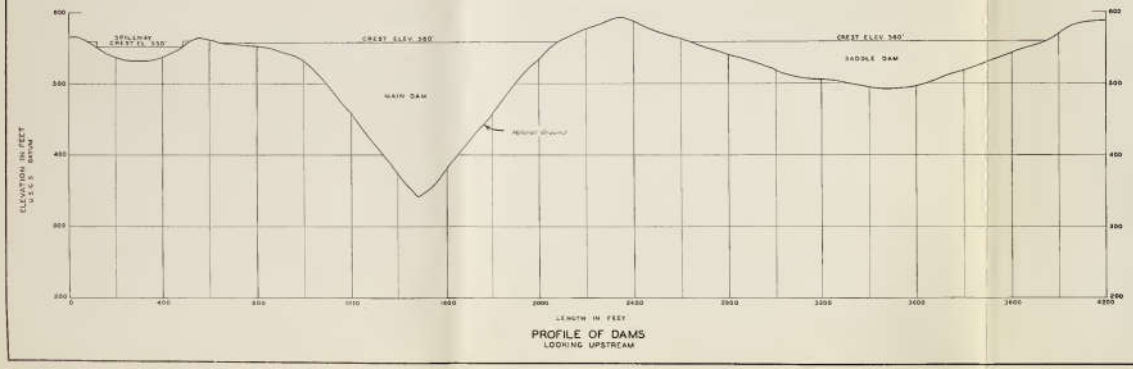
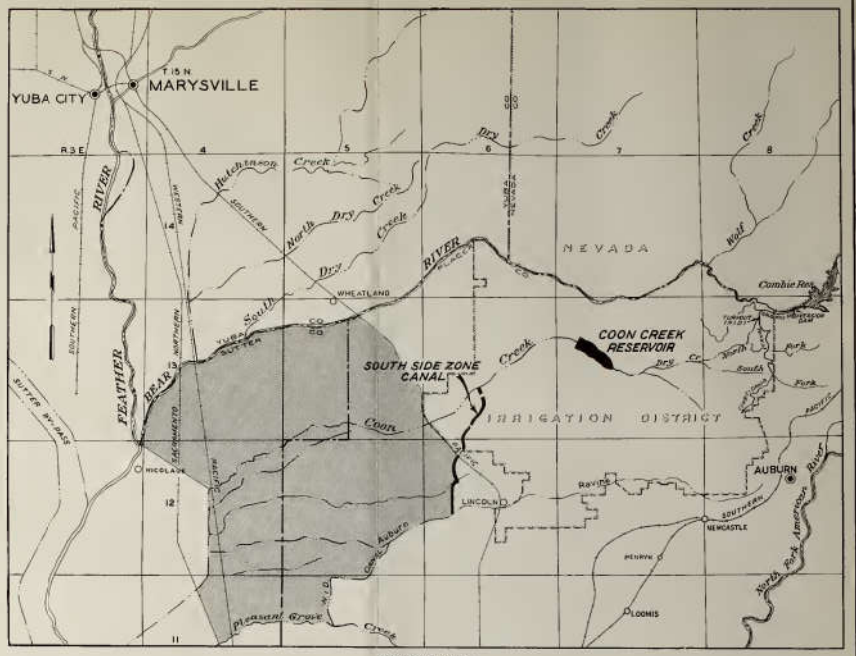
CAMP FAR WEST PROJECT

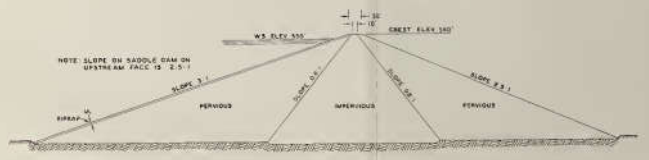




PROFILE OF DAMS
LOOKING UPSTREAM



PROJECT AREA
Scale of miles
0 2 4



SECTION OF DAMS
SCALE OF FEET
0 100 200

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HYDROGEOLOGY OF THE SUTTER BASIN, SACRAMENTO VALLEY, CALIFORNIA

by

George Curtin

A Thesis Submitted to the Faculty of the

DEPARTMENT OF GEOSCIENCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN GEOLOGY

In the Graduate College

THE UNIVERSITY OF ARIZONA

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STATEMENT BY AUTHOR

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This thesis has been approved on the date shown below:

Jerome J. Wright — March 23, 1971

JEROME J. WRIGHT
Associate Professor of Geology

Date

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ABSTRACT

A mound of saline water exists in continental sediments between two fresh water rivers in the Sutter Basin of the Sacramento Valley, California. This saline water has moved from the marine sediments, at depth, upward along the Sutter Basin Fault and then through 2,000 feet of alluvium.

The hydraulic head required to move the connate water is supplied by the high topographic position of the Cretaceous sediments carried up by the Sutter Buttes intrusives and exposed at the surface some 250 to 400 feet above the valley floor. Around the Buttes the marine sediments have been flushed with fresh water to depths of over 2,000 feet. The displaced saline connate water has moved south where it intercepts the Sutter Basin Fault.

The geologic section consists of about 5,500 feet of Cretaceous and Eocene marine sediments which have been deposited atop the basement complex (the western extension of the Sierra Nevada fault block) and capped by 2,000 feet of post-Eocene alluvium.

Chemical analyses of the ground water indicate sodium chloride water is being introduced from depth, and as the rising connate water moves northerly into the

orchard area it changes to a calcium-magnesium chloride type water.

INTRODUCTION

Purpose of the Investigation

When a mound of saline ground water exists between two fresh water rivers in alluvial sediments 2,000 feet thick, there must be an explanation. Two principal theories have been offered to account for the saline ground water mound that exists in the South Central portion of the Sutter Basin in California. Wilcox (1948) was the first to propose that the saline water was rising from depth. Wolfe (1958) advanced the theory that the saline water resulted from residual evaporites.

It is the thesis of this investigator that the salinity of the mound is due to the hydraulic head between the elevation of the Kione Sands, at their outcrop (recharge area) in the Sutter Buttes, and the elevation of the top of the saline ground water mound in the Sutter Basin. Fresh water has infiltrated and flushed the Kione Sands to depths of approximately 2,000 feet. The displaced marine connate water has moved south and rises along the Sutter Basin Fault, thence through the overlying alluvial sediments to the surface of the basin. A number of other geologic features are involved in the process.

The physical evidence to support the hypothesis was obtained through a study of the subsurface geology, the

hydraulic continuity of the strata and structures and the chemistry of the water.

Maps display the strata, ground water hydrology and chemistry to support the statements that underly this thesis.

Location and Extent of the Area

The saline ground water mound with which this study is concerned lies north of the town of Robbins, California, in the middle of the Sacramento Valley, between the Sacramento and Feather Rivers. Under the saline ground water mound are approximately 2,000 feet of alluvial and non-marine basin sediments. The base of the fresh water that overlies the saline mound lowers in all directions from its center. The salinity of the ground water mound appears to increase with depth.

The area, generally known as the Sutter Basin, is bounded on the west by the Sacramento River, and by the Sutter Bypass on the east. It extends from the alluvial fans of the Sutter Buttes, some 30 miles southeast, to the confluence of the Sacramento and Feather Rivers. The basin lies wholly in Sutter County, California and consists of 114,500 acres of flat, topographical, low, poorly drained land.

To properly evaluate the ground water conditions of the Sutter Basin, the area of investigation was extended to include 1,026 square miles of land lying in all or part of

Township 10 North to Township 16 North, and Range 1 West to Range 4 East, Mount Diablo Base & Meridian. This includes parts of Colusa, Sacramento, Sutter, Yolo and Yuba Counties (Fig. 1).

Previous Investigations

The Division of Soil Management and Irrigation of the United States Department of Agriculture conducted a series of studies in cooperation with the Sutter Mutual Water Company during 1931, 1932, 1933, 1946 and 1947. These studies showed that the amount of dissolved solids in water drained from lands in the southern half of the Sutter Basin greatly exceeded the amount brought onto the land in irrigation water. The salt output during the study periods, expressed as proportion of the input, is reported to have ranged between 248 and 655 percent, with the average about 407 percent. It should be pointed out that all irrigation water for this area is diverted from the Sacramento River. The water table of the basin is controlled by extensive drainage ditches; the drain water is pumped out of the system back into the Sacramento River.

The investigator for the U. S. Department of Agriculture (Wilcox, 1948) concluded that the increase in salt content of the drainage water was due to rising connate water and said (pg. 48):



FIGURE 1 MAP OF CALIFORNIA SHOWING AREA OF INVESTIGATION

> Analyses show that the underground water is moderately to very saline, the lowest concentration observed being several times that of the input irrigation water. Also, all of the wells show a strong artesian pressure. Water in the domestic wells stands at or near the soil surface while the deep wells flow. It appears probable, therefore, that due to the upward pressure, substantial quantities of underground water are intercepted and carried off by the drains.

In September, 1952 the California State Water Resources Board published Bulletin No. 6, "Sutter-Yuba Counties Investigation." In this Bulletin reference is made to the Sutter Basin studies of the U. S. Department of Agriculture and indicates it is in agreement with the report as to the origin of these high chloride waters. Bulletin 6 states (pg. 35):

> The opinion was expressed in a report on the foregoing 1946 salt balance study that the salt in the drainage water was probably derived from saline waters underlying the area. Preliminary studies made by the Division of Water Resources similarly indicated that the chloride salinity in many of the wells was due to admixture of deep-seated brines with native fresh ground waters. There is evidence that such brines may underlie aquifers of good quality throughout large areas of the Sacramento and San Joaquin Valleys--such brines sometimes appear in water pumped from the deep wells in the two valleys, or from areas wherein the fresh ground water levels are markedly lowered through over-draft. In many instances these relatively deep-seated brines are under considerable pressure and readily rise to the surface through defective, abandoned, or improperly constructed wells. A case in point is a natural gas well located near the town of Robbins which yields water under artesian and/or gas pressure at a rate of 200 gallons a minute.

Included in the Resources Board's report was a geochemical study by Davis and Olmsted (1952) to determine the

cause of the high saline water. A complete chemical analysis was run on water samples collected from 38 scattered wells located in Sutter Basin. The water analyses were classified into eight groups according to the range of concentration of total anions. Group 1 was considered unaltered normal ground water and Group 8 was considered briny contaminate. The chemical constituents, in e.p.m. (equivalent parts per million), of Group 1 were subtracted from the chemical constituents of Groups 2 through 7. The resulting chemical constituents, together with Group 8, were tabulated as to percentage. This tabulation indicated that (pg. 37):

> Irrespective of variations in concentration, the character formula of the degradant in each of the ground water Groups 2 through 7 is strikingly similar to that of the brines comprising Group 8. This is especially true of the anions which are not subject to base exchange reactions. This similarity in composition, together with apparent absence of any other like degradant, indicates that the degradation of the native ground water is due to admixture of deep-seated brines of the type exemplified by Group 8.

However, in the U. S. Geological Survey Water-Supply Paper 1497, Olmsted and Davis (1961, page 136) say:

> Its origin is problematical, however; it may be the result of upward migration of deep marine connate waters through defective, abandoned, or improperly constructed deep wells, as suggested by the California State Water Resources Board (1952, page 35); or, on the other hand, it may be merely a large body of evaporation residue in the Sutter Basin.

This conclusion is interesting because some nine years later these two geologists have added evaporation

residue as an alternate theory for the occurrence of saline water in the Sutter Basin.

John Wolfe prepared an office report (Wolfe, 1958) for the California Department of Water Resources and summarized reasons for the theory of rising saline connate water as: (1) subsurface geologic structural highs in marine sediments; (2) artesian and/or gas pressure on connate brines which enable them to rise to the surface through poorly constructed or improperly abandoned water or gas wells; (3) artesian and/or gas pressure on connate brines which permit them to rise through permeable zones in the sediments; and (4) acceleration of rising connates due to lowering of the water table by heavy pumping.

Wolfe still believes (oral communique, 1969) that the geologic conditions favorable to the theory of rising connate water do not exist in the Sutter Basin, and brings forth the following points: (1) there is no known evidence of any structural anomalies in the Sutter Basin; (2) bad water conditions existed in the area before any deep wells were drilled; (3) the area is largely underlain by highly impervious silt and clay; (4) artesian pressure would not be augmented by gas pressure; and (5) an excess of salt and water in the discharge from a basin is no proof of rising saline connate waters.

Wolfe concluded that the saline water in the Sutter Basin is most probably caused by evaporative residues. He

based his conclusion on the observation that salinity and well depth do not seem to correlate, and alkali or salts are known to accumulate in the basin sediments. To support his arguments he quoted Kirk Bryan (1923).

Kirk Bryan, geologist with the U. S. Geological Survey, conducted the first comprehensive ground water investigation of the Sacramento Valley. The field work for his water-supply paper was conducted during 1912 and 1913, a time when the Sacramento Valley was still subject to devastating floods and the basin lands were first being reclaimed and used for rice growing. Bryan (1923, page 85) commented on the accumulation of alkali in the Valley:

> Although there are in the valley large areas that have a shallow water table, which is favorable to evaporation and the accumulation of alkali, only comparatively small areas are unfitted for agriculture from this cause. This condition seems to be due to the following reasons: (1) The ground waters are of good quality. (2) The water table is very flat over the basins, and movements of the ground water are sluggish. Water is supplied more freely at the bases of the slopes, and for this reason the principal concentration of alkali occurs at the edges of the basins. This is particularly the case on the west side, where alkaline patches and areas of salt grass border the basins along their western edges. (3) The heavy winter rains leach out much of the salts concentration at the surface. Similarly flood waters wash out the salts in over-flowed lands, and on the edges of the plains the same waters deposit mud or sediment, which often covers up the alkali.

Bryan mentioned buried alkaline spots along the east side of Colusa Basin and suggested better water could be obtained by casing off the well and going deeper. He

also suggested that the salty spots are usually small in extent. He thought the same conditions might exist along the west side of Sutter Basin.

In the east Sutter Basin area, Bryan spoke of Gilsizer Slough. This slough cuts southwest across the area from Yuba City to the central part of the Sutter Basin (Fig. 4). It is a depression that ranges in width from a hundred yards to a quarter of a mile. Bryan states that the ground water lay close to the surface and evaporation concentrated alkali in the soil. The slough was later drained by a ditch and the land reclaimed and placed under cultivation. However, the water quality of the wells in the Gilsizer Slough area seems to have been little affected by this shallow saline condition (Fig. 6).

History and Methods of the Investigation

During the early 1960s the California Department of Water Resources was conducting a comprehensive study of the ground water in the Sacramento Valley. Among the duties of this investigator was the compilation of a base-of-the-fresh-water map of the Valley. Electric-logs, run in gas wells, were used for the interpretive work. An apparent resistivity of 25 ohm-meters was designated as the dividing point between fresh and brackish ground water. Results of the study confirmed the mound of saline water in the central portion of the Sutter Basin; and further, that the Ione Sand of Eocene age contained fresh water to a depth

of over 2,000 feet around the south central part of the Sutter Buttes. Elsewhere the Ione Sand contains saline connate water.

Correlation section #6, published by the American Association of Petroleum Geologists Committee on Stratigraphic Correlation, shows the stratigraphy of the Sacramento Valley from Red Bluff to Rio Vista. A portion of this section cuts across the Sutter Basin. On this section the Ione Sand crops out in the Sutter Buttes at an elevation of between 250 and 400 feet above the valley floor, is confined by the Nortonville Shale from the Buttes to Humble Oil and Refining Company's "Sutter Basin" #1 well in Section 24, T.13N., R.2E., M.D.B.&M. (well 201 on Fig. 4), and is in contact with the overlying continental sediments in the area of the saline ground water mound in the Sutter Basin. It was therefore believed that here were the conditions necessary for the hydraulic gradient requisite to move the saline water up through the non-marine sediments to the surface in the Sutter Basin.

Permission was obtained from the Department of Geology, University of Arizona, to investigate this phenomenon as a thesis topic.

During the Summer of 1969 the author was employed by the California Department of Water Resources and permitted to use the office facilities during weekends and evenings to collect and analyze data. Some 550 gas well

locations were plotted and electric-logs from more than 400 wells were collected and correlated. Further data were taken from the Department's detailed study of the water quality along both sides of the Feather River, 1964-67, as well as water analyses of wells made during the Department's regular yearly program for succeeding years. Part of this information is displayed graphically on Figure 6 (in pocket), the rest is contained in Appendix A.

Well-numbering System

The customary method of identifying gas and oil wells is to use the name of the operator and the name of the well. To be done legibly would require more space than is available on the base map used in this report. Therefore, each well was assigned a number. In general, the numbering began in Township 10 North, Range 1 West, and moved across to Range 4 East, etc. This places the low numbers in the lower left hand corner of the base map (Fig. 4, in pocket) and the highest numbers in the upper right hand corner. During the process of the investigation the size of the base map was reduced, so as to include only that area most relevant to the study; hence, not all of the wells originally numbered are plotted on the base map.

The water well numbering system used in the study is that of the California Department of Water Resources, and shows the location of wells according to the rectangular system for the subdivision of public land. For

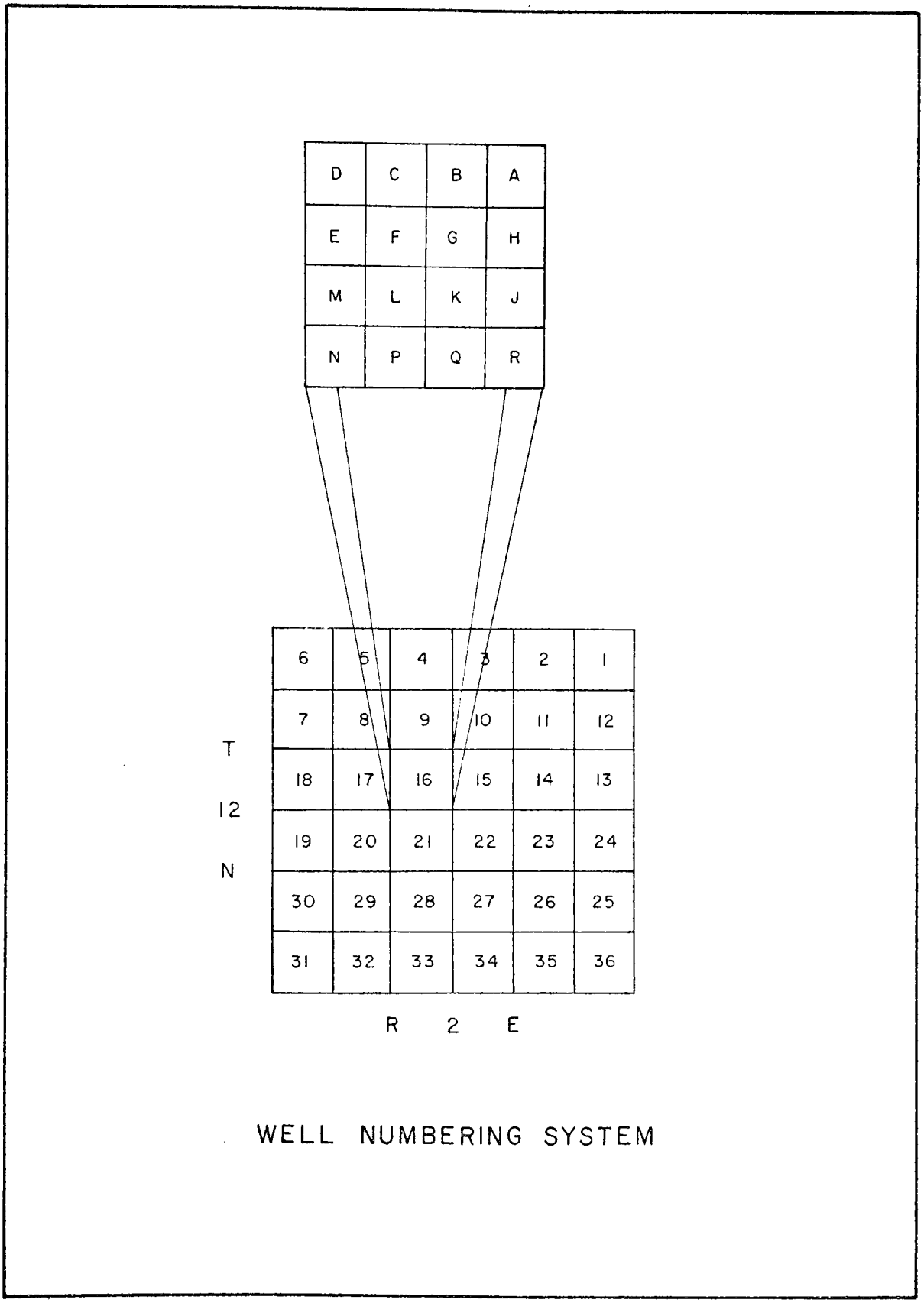


FIGURE 2 DIAGRAM SHOWING WELL NUMBERING SYSTEM

example, in well number 12N/2E-16B2, the segment of the number and letter preceding the bar indicates the Township (T.12N.); the number and letter between the bar and the hyphen, the Range (R.2E.); the digits between the hyphen and the letter, the Section (sec. 16); and the letter following the section number indicates the 40-acre subdivision of the section, as shown in Figure 2. Within each 40-acre tract the wells are numbered serially, as indicated by the final digit. Thus, Well 12N/2E-16B2 is the second well to be listed in NW1/4 NE1/4 Sec. 16, T.12N., R.2E., M.D.B.&M.

Parts of the study area lie in old Mexican land grants and have never been public land; for these, the rectangular system of subdivision has been projected for reference purposes only.

GEOGRAPHY

Topography

The Sacramento Valley is the northern one-third of the Great Central Valley of California and takes its name from the principal river which flows through it. The Sacramento Valley, as defined by Bryan (1923), extends from Red Bluff to the mouth of the Sacramento River at Suisun Bay, a distance of 150 air miles, or about 240 miles by river. The area of the Valley is approximately 5,000 square miles.

The Valley floor slopes southward from an elevation of nearly 300 feet at the north, near Red Bluff, to sea level at Suisun Bay and varies in width from five miles at the north end to 45 miles in the southern part.

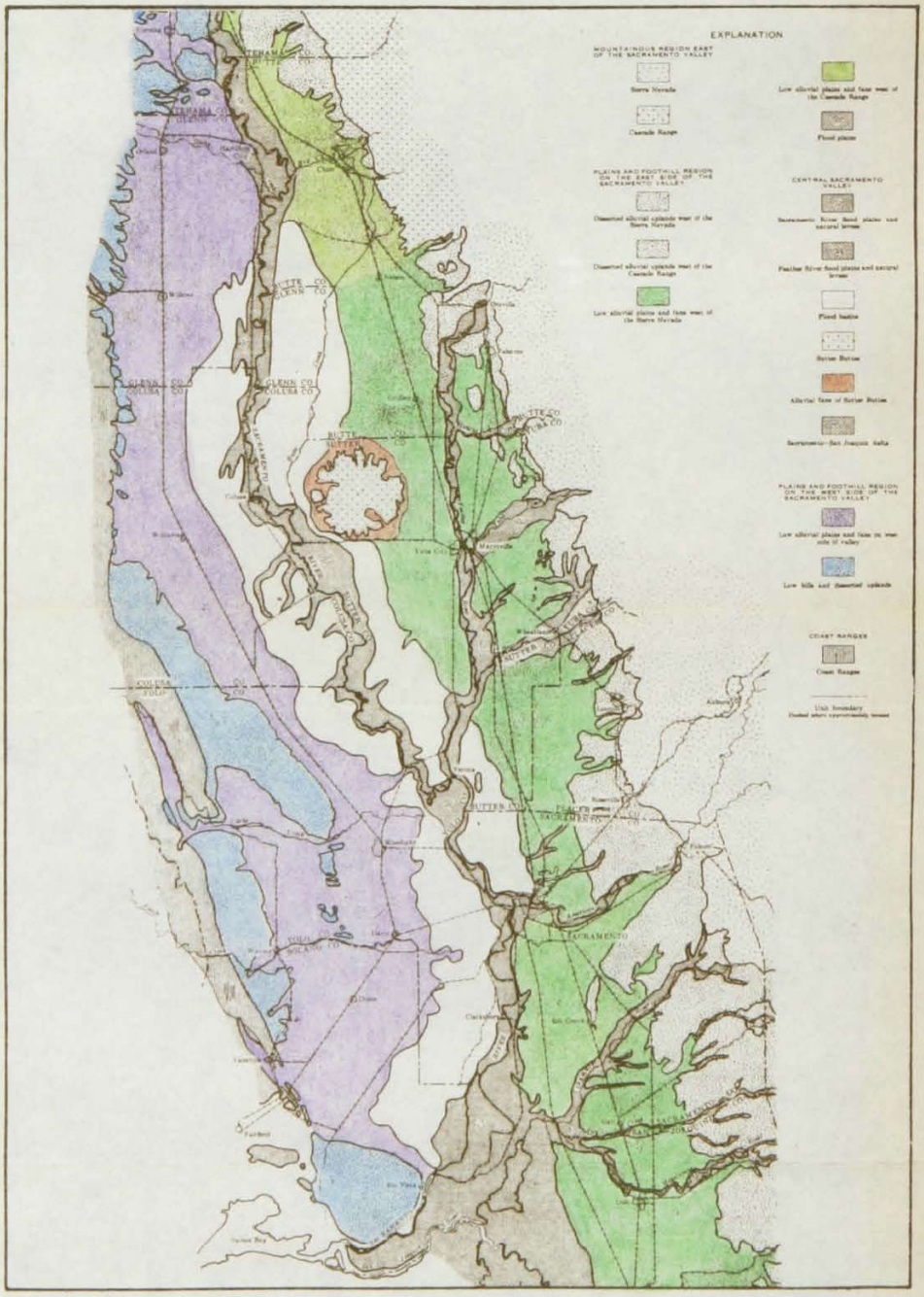
The western boundary of the Valley is the North Coast Ranges, which consist of a series of parallel ridges and inter-montane valleys trending slightly west of north. The ridges rise to elevations of 3,000 feet.

The mountainous regions east and northeast of the Valley include the Sierra Nevada and the Cascade Range. The Sierra Nevada has been described (Lindgren, 1911; Matthes, 1930; Piper et al., 1939) as a single block of the earth's crust which has been uplifted along fractures on its eastern margin and tilted westward. The average slope

of the western surface is $1^{o}40'$ and becomes steeper as it extends beneath the floor of the Sacramento Valley. The crest of the Sierra Nevada, to the east of the valley, varies from 6,000 to 10,000 feet in elevation. The Cascade Range, to the northeast, consists mainly of volcanic rock. It contains Mount Lassen, which is considered the only active volcano in California.

The Sacramento Valley has been divided into 16 geomorphic units by the U. S. Geological Survey (Fig. 3).

The study area for this report (Fig. 4) lies in the central portion of the Sacramento Valley. In this area the major topographic feature is the Sutter Buttes. It is the erosional remnant of a laccolith and volcano formed during late Pliocene time. The outline of the Buttes is an almost perfect circle, 10 miles in diameter, with the highest peak--South Butte--rising to an elevation of 2,117 feet. The only other prominent topographic feature is the Dunnigan Hills on the west flank of the Valley, which consist of Pliocene and Pleistocene sediments which have been folded into a gentle anticline with the axis trending approximately South 40° East. The Hills are severely dissected but the summits are rounded and rise to nearly the same height. The summits decline from an average altitude of 400 feet at the north end to about 200 feet near the south end.


EXPLANATION
MOUNTAINOUS REGION EAST OF THE SACRAMENTO VALLEY
Sierra Nevada
Cascade Range
PLAINS AND FOOTHILL REGION ON THE EAST SIDE OF THE SACRAMENTO VALLEY
Dissected alluvial uplands west of the Sierra Nevada
Dissected alluvial uplands west of the Cascade Range
Low alluvial plains and fans west of the Sierra Nevada
Low alluvial plains and fans west of the Cascade Range
Flood plains
CENTRAL SACRAMENTO VALLEY
Sacramento River flood plains and natural levees
Feather River flood plains and natural levees
Flood basins
Butte Basins
Alluvial fans of Butte Basins
Sacramento–San Joaquin delta
PLAINS AND FOOTHILL REGION ON THE WEST SIDE OF THE SACRAMENTO VALLEY
Low alluvial plains and fans on west side of valley
Low hills and dissected uplands
COAST RANGES
Coast Ranges
Unit boundary
Dashed where approximately located
TEHAMA CO.
GLENN CO.
BUTTE CO.
COLUSA CO.
YOLO CO.
SUTTER CO.
SACRAMENTO
Marysville
Yuba City
Oroville
Woodland
Davis
Winters
Dixon
Vacaville
Fairfield
Suisun Bay
Rio Vista
Auburn
Folsom
Elk Grove
Clarksburg
Courtland
Isleton
Galt
Lodi
Ione
Jackson
Plymouth
Sutter Buttes
Colusa
Willows
Orland
Chico
Oroville
Gridley
Biggs
Princeton
Arbuckle
Williams
Maxwell
Sites
Knights Landing
Grafton
Cache Creek
Capay
Esparto
Madison
Zamora
Clear Lake
Lower Lake
Middletown
Calistoga
St. Helena
Napa
Vallejo
Benicia
Martinez
Antioch
Pittsburg
Concord
Walnut Creek
Pleasant Hill
Lafayette
Orinda
Moraga
Berkeley
Oakland
Alameda
San Leandro
Hayward
San Mateo
Redwood City
Palo Alto
Mountain View
Sunnyvale
Santa Clara
San Jose
Milpitas
Fremont
Newark
Union City
Livermore
Pleasanton
Dublin
San Ramon
Danville
Alamo
Brentwood
Oakley
Byron
Tracy
Manteca
Ripon
Escalon
Lathrop
Stockton
Linden
Lockeford
Lodi
Woodbridge
Acampo
Thornton
Walnut Grove
Isleton
Rio Vista
Collinsville
Suisun City
Fairfield
Vacaville
Dixon
Winters
Davis
Woodland
Knights Landing
Colusa
Williams
Arbuckle
Maxwell
Willows
Orland
Chico
Oroville
Gridley
Biggs
Princeton
Sites

The other topographic features in the study area are of low relief and are related to the fluvial deposition of the Sacramento River and its tributaries. They include the alluvial fans on the west and east sides of the Valley and around the Sutter Buttes, the flood plains and natural levees and the flood basins. These fluviatile features have had a marked influence on the agricultural development of the area.

Drainage

The average annual runoff of the Sacramento River and its tributaries during a 40-year period starting in 1904 was 21,750,000 acre-feet. In the years past most of this flow took place during December to April. Only in the driest years was the Sacramento Valley free from flooding. During the wetter years the flood water would extend from the alluvial fans on the west side of the Valley to the alluvial fans east of the Feather River. Bryan (1923) estimated that before any reclamation had been accomplished, sixty percent of the Valley was subject to overflow--including, in addition to the basins, the river lands and a considerable portion of the low plains. In recent years the construction of levees along the major streams, flood-water bypasses through the Sutter and Yolo Basins, and the building of Shasta Dam on the Sacramento River and Oroville Dam on the Feather River, has greatly limited the large-scale flooding of the basins.

Between Colusa and Verona, the Sacramento River follows a sinuous course, with meanders and oxbow lakes. Over a distance of 63.5 miles the average descent is about 0.4 feet per mile. The channel is narrow--averaging 150 to 600 feet in width--with well-defined broad natural levees. The natural levees are concave upward and relatively flat. In effect, the river is flowing along a broad upraised trench, flanked on either side by poorly drained, low-lying flood basins. The Colusa Basin lies to the West, and the Sutter Basin to the East.

South of Verona at the mouth of the Feather River, the aspect of the Sacramento River changes completely, and the course of the river consists of broad, gentle bends and relatively long straight reaches. The channel averages 600 to 1,200 feet in width, and bars and islands are uncommon. The natural levees are well defined, but are generally narrower than those upstream; the belt of river lands averages about two miles in width.

The Feather River, the principal tributary of the Sacramento River, leaves the Sierra Nevada foothills at Oroville. It follows a southwesterly course for about six miles, then turns sharply south and flows across the Victor Formation of Pleistocene age. Upstream from Marysville, the Feather River flood plain is one to two miles wide and lies 10 to 15 feet below the adjoining low plains. The river pursues a meandering course on its flood plain, and

lakes and abandoned channels are common features, indicating frequent changes in course.

South of Marysville, the Feather River is joined by the Yuba River, and in turn by the Bear River. Here the river occupies a broad channelway, as much as a mile wide, that is choked with sand and gravel contributed by the Yuba and Bear Rivers. This channel aggradation is a direct result of hydraulic mining in the Sierra Nevada.

In the seven-mile reach upstream from its junction with the Sacramento River, the Feather River occupies a channel ridge similar to that of the Sacramento River. The prominent natural levees slope a mile or more toward the Sutter Basin to the west, and the American Basin to the east. Well-formed channel ridges of flood distributaries extend laterally toward the flood basins, and bends and abandoned channels are noticeably absent, suggesting long-continued channel stability.

The average grade of the Feather River from Marysville to the Sacramento River is 1.1 feet per mile.

Climate

The climate of the Sutter area is characterized by dry summers with high daytime temperatures and warm nights, and wet winters with moderate temperatures. More than eighty percent of the precipitation occurs during the five-month period from November to March, inclusive. The eighty-year average precipitation for the City of Marysville is

20.68 inches, with an annual high of 38.91 inches and an annual low of 8.15 inches. The growing season is long, the forty-year recorded average for Marysville being 273 days between killing frosts. Temperatures at Marysville have ranged from 16°F. to 118°F., and the monthly average ranges from 46.9°F. in January to 79.3°F. in July.

Culture

The native vegetation in the study area consisted of grasses and occasional oak trees on the alluvial fans. The swamp and overflow land supported a heavy growth of tules, or rushes, that gave the area its coloquial name of the "Tules." The natural levees supported a heavy growth of trees, predominantly Sycamore and Cottonwood.

It was a natural step for the early settlers to substitute grain such as wheat and barley for the native grasses. The commercial production of wheat in this area was begun by General John Sutter in 1843 on his Hock Farm south of Yuba City. With the influx of settlers during and after the gold rush, a large portion of the higher land was converted to the growing of dry-farmed grain crops and livestock.

The continuing wave of settlers in the area caused an increase in land value and the subdivision of lands into small farms which had to be capable of producing consistently high-value crops in order to support the owners. To the purchasers of such tracts the advantages of

irrigation were apparent. The colonizing of subdivided lands became a business whereby large blocks of land were purchased and surveyed into small tracts with provisions for roads and perhaps for a town site. Irrigation works were provided for some of the subdivided acreages; in others, a demonstration well and pumping plant was built to persuade the settlers of the advantages of installing their own individual wells and pumps. Settlers were attracted by agents and by advertisements in the eastern newspapers of the United States.

The development of the flood basin and overflow land was slowed by recurring floods. However, many public agencies were organized in the area to deal with the problems of land reclamation and drainage. The provisions of California reclamation district laws have been used extensively to effect the unwatering of low lands and their protection from overflow. A canal was excavated to remove the flood and drainage water from Colusa Basin. The function of Sutter Bypass is to receive and convey excess floodwater of the Sacramento River and Butte Basin through Sutter Basin (Fig. 4).

The highest and best use for most of the basin land, because of the heavy soil, is rice production. In 1966, some 66,000 acres of basin land in Sutter County alone, or one quarter of the entire County, were used for the cultivation of rice. The rest of the basin land is

used mainly as irrigated pasture for the raising of livestock.

Other annual crops in the area consist of beans, tomatoes, safflower, corn, hops, sugar beets, and alfalfa seed. Along the Feather River the land is used mainly for deciduous orchards--peaches, apricots, pears, prunes, almonds and walnuts.

Industry in the area is supported largely by agricultural production. About 100 plants are operated during the harvest seasons to can fruits and vegetables and to dehydrate fruits, nuts, rice and seed crops. Packing houses for packing fresh fruits and melons, and cold storage and refrigeration plants, have also been placed in operation.

Following are the population figures for the three counties that comprise most of the study area, and the county seat for each.

	1960	1970
Sutter County	33,380	41,894
Yuba City	11,507	13,740
Yuba County	33,859	43,934
Marysville City	9,553	10,100 (est.)
Colusa County	12,075	11,896
Colusa City	3,518	3,825 (est.)

GEOLOGY

Stratigraphy

The west side of the Sacramento Valley contains one of the thickest and most nearly complete late Mesozoic sections in North America. The Upper Jurassic, Lower Cretaceous, and Upper Cretaceous sequences have a maximum aggregate thickness of sediments in excess of 50,000 feet (not illustrated).

The classification of the Upper Cretaceous by Kirby (1943), the Upper Cretaceous faunal zones of Goudkoff (1945), and the faunal zones of Laiming (1943) for the Paleocene and Eocene sediments have been used in this report (Fig. 5). Where there appear to be differences in opinion as to the stratigraphic relations of the sub-surface geology, Correlation Section No. 6, 1954, "Sacramento Valley from Red Bluff to Rio Vista," of the A.A.P.G. Committee on Stratigraphic Correlations was used as the guide. Where this investigator differs from the A.A.P.G. Committee, these differences are based on electric-log interpretations and discussions with geologic consultants who have worked in the Sacramento Valley.

Upper Cretaceous Units

Forbes Formation.(Figs. 5 and 7, in pocket) The Forbes Formation is the basal member for sub-surface

correlations illustrated, and has the most extensive distribution of any of the units correlated. It crops out along the western margin of the Sierra Nevada and along the eastern margin of the Coast Range. It is believed (Weagant, 1964) to have been deposited in a moderately deep-water environment, too far offshore to be affected by shoreline winnowing processes, and is the result of turbidity currents.

The thickness of the Forbes Formation varies from 2,750 feet to 3,000 feet in the study area. It is dominantly a gray, marine shale with fairly thick, fine-grained sandstone interbeds.

Kione Formation. (Figs. 5 and 7) The Kione Formation represents the shallowing of the Forbes basin, which resulted in the development of a shallow near-shore environment. The Kione sands were probably deposited in a series of deltas that lay at the mouths of the major drainages coming off the Sierran land areas to the east. These deltaic sands were further distributed along the east side of the valley by action of along-shore currents and by normal shoreline processes.

The Kione Formation was named and described by Johnson (1943). It is a medium-grained, well sorted, massive, friable sandstone of granitic origin with shale interbeds. The Kione is in gradational contact with the underlying Forbes Formation. Around the Sutter Buttes the

Kione has a thickness of between 800 and 1,000 feet. To the West, the Kione becomes more broken, tending to turn to shale, and to the south it thins and shales out. In the study area it is everywhere conformably overlain by the "Sacramento Shale", except in the Colusa area where it is reported to occur at a shallow depth and is overlain by the Tehama Formation.

"Sacramento Shale." (Figs. 5 and 7) This marine deposit has not been identified in outcrop, although it is possible that it crops out around the Sutter Buttes. For the purpose of this report it will be identified by the description as shown on A.A.P.G., Pacific Section, 1960, Correlation section from Red Bluff to Rio Vista, Sacramento Valley, "the siltstone which conformably overlies the Kione Sand and is conformably overlain by the 'Winter Sand'." The "Sacramento Shale" is typically 150 to 300 feet thick and light gray in color. It is everywhere present in the study area, and is an excellent electric-log marker.

"Winter Sands and Shales." (Figs. 5 and 7) The main source of the marine "Winters Sands and Shales" appears to have been older Cretaceous deposits, reworked and redeposited. In the Dunnigan Hills the shale is described (Rofe, 1962) as a medium-dull, gray, firm, massive, silty, muscovitic, fossiliferous claystone, grading locally into siltstone. The sand beds are light gray, fine to medium-grained, poorly sorted, massive, silty, micaceous sand with subordinate amounts of claystone that grade upward to well sorted, clean sand.

It is possible that the "Winters" crops out on the south side of the Sutter Buttes but has not been identified. It is not present north of the Buttes, it thins to the north and east, thickens to the south, and its western extent is obscured by uplift and erosion during post-Cretaceous time. The unit unconformably underlies the Starkey Sands in the area south of the Sutter Buttes.

"Starkey Sands." (Figs. 5 and 7) The "Starkey" represents a very shallow sea environment with deposition of a series of regressive-transgressive beach or near-beach sands. The deposits were derived from the east and northeast as the Sierran and northern Sacramento Valley areas were uplifted and eroded. The "Starkey" grades from a medium-grained, clean sand into a shale from east to west. The "Starkey" is everywhere confined by the Martinez Silt of Paleocene age or the Capay Shale of Eocene age, except in the southern Sutter Basin where it is unconformably overlain by the post-Eocene non-marine sediments (Fig. 7). The sand thins or has been removed by erosion to the north and west. To the south it occurs at ever-increasing depths and thickens to approximately 1,900 feet before thinning and shaling out in the Delta area.

Tertiary Units

Meganos-Martinez Formations Undifferentiated.

(Figs. 5 and 7) This group of sediments conformably

overlies the "Starkey Sands" in the southeast portion of the study area.

The type locality of the Martinez Formation is near the town of Martinez on Carquinez Strait, west of Suisun Bay, and was described by Dickerson (1914). Lithologically, it is predominantly a massive, well-sorted, quartzose sandstone with interbedded shale and local conglomerate lenses. Much of the detritus of the Martinez was derived from Cretaceous Formations. A basal shale member is referred to as the Martinez Silt and is an excellent electric-log marker where it overlies the "Starkey Sand." The Martinez contains Laiming's (1943) E fauna zone and is Paleocene in age.

The type locality for the Meganos Formation is in Contra Costa County in the Mount Diablo region and was described by Clark (1918). It consists of friable, fine to medium-grained, micaceous, carbonaceous gray sand and hard, mostly light to dark brown shale with streaks of lignite. For the purpose of this report, it is considered to be those sediments containing Laiming's D fauna zone, and is Lower Eocene in age.

The thickness of the Meganos-Martinez group, in the study area, varies from zero to 240 feet. It occurs only in the south central portion of the study area where it is truncated or pinches out to the north and dips to the south.

Capay Shale. (Figs. 5 and 7) The type section for the Capay Formation is in Capay Valley, to the west of Dunnigan Hills, and was described by Crook and Kirby (1935). Unfortunately, the type section is atypical of most of the Capay in the Sacramento Valley. It consists of as much as 2,000 feet of beds resting unconformably on the Upper Cretaceous rocks, ranging from channel conglomerate to fine-grained estuarine deposits. The source of the detritus was said by Crook and Kirby to have been local. It is now believed that this part of the Capay was deposited in the southern extension of the Princeton Gorge. When the Eocene sea transgressed, the gorge was inundated first and coarse sediments were contributed from immediately adjacent sources. As the sea continued to rise, it topped the gorge and spread out over the floor of the Valley. It was then that the Capay Shale was so extensively deposited.

At Dunnigan Hills the Capay Shale is described by Rofé (1962) as medium gray to dark gray, massive, micaceous, glauconitic, pyritic, fossiliferous claystone with a dark gray, medium-grained, poorly sorted, massive basal gritstone, which is a more typical description of the Capay Shale and is probably the upper part of the Capay Formation. In the study area the Capay Shale is considered Lower Eocene in age.

The Capay Shale acts as a cap rock for many of the gas fields in the Valley. It is present throughout the area except where it has been removed by erosion in the Sutter Basin south of the Sutter Basin Fault, in the "Markley Gorge," and along the western margin of the study area. The Capay Shale varies in thickness from zero to 558 feet and thins to the East. The base of the Capay is one of the major unconformities in the Valley. The Capay progressively overlies older Cretaceous rocks in a northern and eastern direction.

Ione-Domengine Formation. (Figs. 5 and 7) Stewart (1949) divided the Domengine Formation of Clark (1926) into two formations: the Lower Ione Formation, consisting of quartz sand; and the Upper Domengine Formation, consisting of green and brown sand. Both are placed in Middle Eocene and contain Laiming's B-1 faunal assemblage.

In the Dunnigan Hills (Rofé, 1962), the Domengine Formation is 19 to 62 feet thick and consists of dark gray to greenish gray, fine-grained, well sorted, silty sands. It appears that the Lower Ione Formation of Stewart (1949) is not present at this location.

Throughout most of the area, the Middle Eocene is represented by the Ione Formation of Stewart. In the Sutter Buttes, the Ione is described by Johnson (1943) as a white, quartzose, friable sandstone, and probably represents deltaic deposits that have been winnowed by

off-shore currents. Figure 5 indicates that the Ione-Domengine Formation is of rather limited extent in the study area, having been removed by erosion to the west and south. It ranges in thickness from zero to 250 feet.

The Ione-Domengine Formation conformably overlies the Capay Shale of Lower Eocene age and is conformably overlain by the Nortonville Shale of Upper Eocene age.

Nortonville Shale. (Figs. 5 and 7) Stewart (1949) divided the Kreyenhagen Formation of Upper Eocene age into the Nortonville Shale member, the Markley Sandstone member, and the Sidney Shale member, in ascending order. Only the Nortonville Shale has been identified in the study area, and then only in gas wells at Dunnigan Hills and in the Sutter Basin. The extent of the Nortonville sea is obscured by subsequent erosion, but probably did not extend further north than the Sutter Buttes and was not as widespread as the Capay sea.

In the Dunnigan Hills, the Nortonville Shale is described (Rofé, 1962) as blue and brown, firm, mottled, micaceous, sandy claystone, interbedded with grayish green, gritty sands. Its thickness varies from 92 to 235 feet, and contains Laiming's A-1 faunal assemblage.

"Markley Gorge" Fill. (Fig. 5) The "Markley Gorge," a deep canyon that was eroded during Upper Eocene, extends from north of the Bear River, near the foothills of the Sierras, southwest to the northflank of Mount

Diablo. This sub-surface feature is more than 45 miles long and nine miles wide, and reaches a maximum depth of 5,700 feet below sea level. Probably a better name for this feature would be the Sacramento Canyon, but at present it is referred to as the so-called "Markley Gorge."

Davis (1953) first described the Gorge, and believed that it was filled with Upper Eocene deposits. Almgren and Schlax (1957) believed the fill is Oligocene and, in part, possibly Miocene in age. Despite the later conclusions, most geologists with a working knowledge of the "Markley Gorge" Fill believe that it is no older than Late Eocene (Sacramento Petroleum Association, 1962).

The "Markley Gorge" Fill consists of shales, sandstone, and conglomerate which have considerable lateral and vertical lithologic variation. The shales are light olive-gray to grayish, brown, silty, and generally barren of microfauna. Sandstones are of two dominant types: one confined to the lower part of the fill is grayish green to greenish brown, earthy, poorly sorted and consists largely of grains of various volcanic rock types, and subangular to sub-rounded pebbles of gray shale and siltstone occur locally; the other dominant type of sandstone is blue, generally coarse-grained and fairly well sorted.

Post-Eocene Non-Marine Sediments. (Figs. 5 and 7) This classification is a catch-all for the alluvial sediments that have been deposited in the Valley by the

Sacramento River and its tributaries from both an eastern and western source. In the study area it has no commercial accumulation of gas and therefore is of little or no interest to the petroleum industry. Petroleum geologists usually call the entire interval the Tehama Formation, which does make up a large percentage of the sediments.

It appears that the Oligocene epoch was a time of uplift and erosion with little or no sediments being deposited in the study area. The Miocene epoch is represented by sedimentary rocks of volcanic origin. The rocks from the Sierra Nevada are a sequence of fragmental volcanic rocks, the source of which lay near the present crest of the Sierras, about 50 miles east of the Sacramento Valley. These rocks, predominantly andesitic, are extensively exposed on the western slope of the Sierra Nevada and extend westward beneath much of the Valley. They probably extend beyond the Sacramento River in the study area. This unit is believed to be related to the Mehrten Formation of Piper et al. (1939).

The sedimentary rocks of volcanic origin that crop out on the west side of the Valley are a sequence of volcanic shale, sandstone and conglomerate beds. Weaver et al. (1944) assigned most of these rocks to the Neroly Formation (Upper Miocene) of Clark and Woodford (1927), but their age and correlation are in considerable doubt.

Five wells (282, 291, 292, 293, and 296) have been drilled through a basalt flow that is approximately 150 feet thick. This island of basalt in Township 13 North, Range 2 East, is believed to be Upper Miocene in age and lies at the base of the Tehama Formation.

The Pliocene sediments consist of continental deposited Laguna Formation of Piper et al. (1939) and the Tehama Formation of Anderson and Russell (1939).

The Laguna Formation (not illustrated) is a sequence of predominantly fine-grained, poorly bedded, somewhat compacted continental sedimentary deposits derived from the Sierra Nevada. The Laguna appears to form a wedge of alluvial material thinning near the Sierra Nevada and thickening toward the axis of the Valley. The maximum thickness of these deposits may be more than 1,000 feet.

The Tehama Formation (Fig. 4) consists of alluvial material derived from the Coast Ranges. It was inaugurated by the orogeny at the beginning of Late Pliocene time, which raised the present Northern Coast Ranges, and was closed by a Middle Pleistocene orogeny. The Formation has been assigned to the Upper Pliocene and possibly the Lower Pleistocene by Anderson and Russell (1939). They state the Formation consists of poorly sorted fluviatile sediments, comprising massive sandy silt, silty sand, and clayey silt enclosing lenses of crossbedded sand and gravel.

The Tehama forms a thick wedge of sediments that thicken to the east and interfinger with the Laguna Formation beneath the Valley floor. In the study area, the Tehama Formation has a maximum thickness of approximately 2,500 feet.

The Sutter Beds of Williams (1929) which crop out in the Sutter Buttes are correlative to the Tehama Formation according to Johnson (1943). They are comprised of continental fine-grained sediments, tuff, sand, silt, and gravel some 1,800 feet in outcrop. Both Williams (1929) and Johnson (1943) believed that the Sutter Beds had a Sierran source because they are petrologically similar to the Sierran andesites. If this be true, then the Sutter Beds are better correlated to the Laguna Formation of Piper et al. (1939).

Quaternary-Recent Units

During Pleistocene time, some 1.2 million years ago, as indicated by radioactive dating according to Dr. Howel Williams (oral communique, 1969), a series of volcanic episodes--the intrusion of rhyolite porphyry volcanic necks followed by the intrusion of an andesite porphyry plug--resulted in the formation of the Sutter Buttes. The final igneous episode was the explosive phase--the formation of a volcano within the andesite plug--the ejecta of which mantles the slopes with andesitic tuff and breccia.

Along the east side of the study area, the alluvial fans and flood-plain deposits of Pleistocene age have been termed the Victor Formation by Olmsted and Davis (1961), after the type Victor Formation of Piper et al. (1939). The Victor Formation consists of an heterogeneous assemblage of clay, silt, sand and gravel, transported by shifting streams from the Sierra Nevada, and has a maximum thickness of 150 feet. The base of the Victor in most places is in conformable contact with the Laguna Formation. Toward the center of the Valley, it is at many places conformably overlain by basin and river deposits of Recent age. In general, the Victor Formation is not appreciably consolidated, although some of the beds have a high proportion of clay and silt which act as a binder. Hardpan layers, representing buried soil zones, occur at various depths, though most are within six feet of the surface.

The Red Bluff Formation is a poorly sorted gravel which has a distinctly reddish silty or sandy matrix and lies on an erosion surface cut on the Tehama Formation. This Pleistocene deposit is of no importance with regard to this report.

The sediments of Recent age include the river and flood-basin deposits. The river deposits consist predominantly of well-sorted sand, gravel, and silt along the channels, flood plains, and natural levees of the major streams. The basin deposits are largely silt and clay

deposited in the flood basins during floods on the major streams. The sediments of Recent age range in thickness from zero to 100 feet.

Geologic Structure

Regional Features

The Sacramento Valley is a large structural basin filled with sedimentary rocks ranging in age from Early Cretaceous to Recent. The Valley trough is asymmetrical; the deepest part of the basin lies near the western margin of the Valley, west of the present axis and plunges to the south. The plunge of the Valley trough results in the southern part of the Valley--the Rio Vista Basin--containing the thicker and more complete geologic section.

The basement complex, beneath the Valley floor, is a continuation of the Sierra Nevada fault block that has been tilted toward the southwest. Geophysical evidence indicates that the basement lies some 20,000 feet below the surface along the western edge. Deep wells that have cored the basement complex in the Sacramento Valley indicate that the surface of the block slopes more steeply beneath the central part of the Valley than it does to the east.

The western part of the Valley is bounded by strike ridges underlain by Cretaceous and Lower Tertiary marine sedimentary rocks. Compressive forces deformed the

Coast Ranges sediments into tightly folded anticlines, synclines, and local thrust faults. Vaughan (1943) suggested that these same compressive forces caused the tilting of the rigid Sierra Nevada block by forcing its western part down below its position of isostatic equilibrium.

Sutter Buttes

The Sutter Buttes comprise the major structural and topographic feature in the study area, rising some 2,000 feet above the flat Valley floor. The Buttes are the surface expression of an intrusion of rhyolite porphyry, followed by andesite porphyry (Johnson, 1943) that forced its way upward from an unknown, but great depth, through at least a portion of the underlying "Basement Complex" platform, into and through some 7,500 feet of Cretaceous and Tertiary sediments. The rising laccolith greatly disturbed the sediments intruded and not only sharply tilted them away from the locus of intrusion, but produced an intricate series of radial and peripheral faults. Furthermore, radial and lateral anticlines and synclines were developed, some of them of sufficient amplitude to involve all of the exposed sediments.

After a period of quiescence and erosion, a series of violent explosions of steam and mud took place and a mile-wide central crater located just west of the middle of the great andesitic plug. Great angular masses of andesite and rhyolite, some of them measuring 30 feet

or more in diameter, were thrown from this opening and were swept by mudflows down the slopes of the volcano to find a resting place about its periphery.

Erosive processes have brought the Sutter Buttes to their present form. The present-day Buttes are 10 miles in diameter and form an almost perfect circle. The Buttes can be divided into three concentric zones of rock types: the central core, the saddles and low areas surrounding the central core, and an outermost ring of tuff-breccia slopes.

The central core is a roughly circular area three to four miles in diameter, dominated by a cluster of sharp, steep-sided erosional remnants of a laccolith, with South Butte rising to a height of 2,117 feet.

The saddles, low hills, and ridges surrounding the central core are underlain by sedimentary rocks of Tertiary and Late Cretaceous age that were pushed up and fractured when the core was emplaced. This zone is approximately one mile in width and ranges in elevation from 200 to 500 feet above the valley floor.

The tuff-breccia slopes which form the outermost ring are two to three miles wide and have been dissected by erosion. The altitudes range from about 500 to 800 feet at the top of the slopes, and 50 to 100 feet at the foot of the slopes.

Dunnigan Hills Anticline

The Dunnigan Hills structure is an asymetrical anticline, steep on the east flank and gentle on the west flank, and is about 20 miles in length. The anticline plunges to the south, resulting in the subsequent burial of the deformed Tehama and Red Bluff Formations beneath younger valley alluvium along the southern portion. The time of folding is believed to have been during Late Pleistocene.

Faults

The only fault identified in this report is the Sutter Basin Fault (Figs. 5, 6 and 7). The location of this fault is based on electric log correlation and geophysical evidence. It is depicted as a vertical fault, striking N70°W, 11 miles in length, with the south block moving up approximately 500 feet in relation to the north block. The eastern extension of the fault is concealed by the "Markley Gorge," and to the west of the fault appears to die out as it is not discernable in wells further west. The age of the faulting appears to be Upper Eocene.

Around the Sutter Buttes numerous faults occur as the result of the igneous intrusives. The surface expressions of some of these faults have been mapped on Figure 4.

Published investigations of gas fields in the area reveal numerous faults to the south of the Buttes and along

the west side of the Valley. Most of the faulting to the south of the Buttes is confined to the Forbes Formation. The few faults that extend above the Forbes (Weagant, 1964) are strike-slip faults trending to the north or northwest, and terminate at the base of the Capay Shale. Since the strike of the faults is approximately parallel to the direction of the ground water flow and the Capay Shale appears to act as a barrier to the upward migration of saline water, these faults have not been illustrated on Figure 5.

In general, the fault systems can be divided into three groups: (1) those that are confined to the Upper Cretaceous sediments only; (2) those that cut the Eocene and Cretaceous rock units; and (3) those that were formed by the Sutter Buttes intrusives during Upper Pliocene time.

Historical Geology

The first geologic event pertinent to the hydrogeology of the Sutter Basin was the deposition of the Upper Cretaceous sediments. According to Weagant (1964), in F-zone time (Forbes Formation), there was transgression of the sea and sediments were deposited by progressive onlap on the Lower Cretaceous shale. East of the central portion of the study area the Lower Cretaceous sediments are fully overlapped by the F-zone. The Forbes Formation was deposited in a moderately deep water environment too far from the shore to be affected by shore-line winnowing

processes. These sediments consist of interbedded dark gray claystones and siltstones, and gray, fine-grained friable, lenticular sands. The eastern limit of the F-zone transgression is not known but members of the Forbes Formation crop out along the eastern side of the Sacramento Valley.

The rate of sedimentation was slightly greater than the rate of subsidence, so that the basin gradually shallowed and the E-zone Kione sands as well as some of the uppermost F-zone sands are near-shore sands associated with the shallowing.

The Kione sands were probably deposited in a series of deltas that lay at the mouth of the major drainages coming off of the Sierran land areas to the east. These deltaic sands were further distributed along the east side of the valley by action of along-shore currents and by normal shoreline processes.

Basinal shallowing was accompanied by uplift along the western basin margin with the regression of the sea to a position southwest of the Grimes gas field (Fig. 4). The basin then subsided rapidly, and the Sacramento Shale sea transgressed the area. The Sacramento shales were deposited in a moderately deep water basin.

Again the basin became shallow as the Winters Shales and Sands were deposited. The Starkey represents a very shallow sea environment with deposition of a series

of regressive-transgressive beach or near-beach sands.

Following the deposition of the Upper Cretaceous sediments, probably in Late Paleocene time, the basin was uplifted, tilted southerly, and folded into a broad syncline with a north-south trending axis. The eastern margin of the sea was upwarped (Olmsted and Davis, 1961) and a land mass created east of the present position of the Sutter Buttes. The area then underwent extensive peneplanation.

The sea did not completely withdraw from the Sacramento Valley during Paleocene time, as attested by the deposition of the marine sediments of the Martinez Formation, in the southern part of the Valley. The Paleocene sea in which the Martinez Formation was deposited was confined to a restricted portion of the Delta area by barrier beaches (Safonov, 1962). Behind these beaches, lagoonal, swamp, and flood-plain deposits of sand and silt were laid down. The numerous beds of coal and the erratic character of the sediments as shown on electric logs attest to the predominantly nonmarine nature of the Martinez in this area. In late Paleocene time, the sea readvanced, continuing to do so into early Eocene Meganos time.

At the close of Meganos time, gradual subsidence allowed the Eocene sea to continue to spread over the entire Sacramento Valley area. The basin remained

relatively quiet as the Capay Shale was deposited. The Capay Shale marks the last major sea transgression into the Sacramento Valley. Being widespread and conspicuous on electric-logs, it is an excellent marker bed. The Capay Shale reflects the post-Capay movement of the Valley, the southerly tilt, and the trough effect.

During Middle Eocene time the sea shallowed again and the deltaic deposits of the Ione-Domengine Formation of Stewart (1949) were laid down. To the east, the alluvial and lagoonal sediments of the Ione Formation of Allen (1929) were deposited. Lignite seams and severely weathered sediments of the Ione Formation attest to a warm, humid climate.

Following the Capay transgression a minor transgression of the sea in Upper Eocene time is reflected in the deposition of the Nortonville Shale member of the Kreyenhagen Formation. Then the sea began to withdraw from the Sacramento Valley.

Near the end of Eocene time the area was again uplifted, and eroded. The "Markley Gorge" of Davis (1953) was being carved and the entire study area was undergoing erosion. Almgren and Schlax (1957) believe that the "Markley Gorge" Fill was predominantly nonmarine deposits of Oligocene and possibly Miocene time.

Commencing in the Middle or Late Eocene and continuing sporadically into Miocene time, volcanic eruptions

deposited rhyolitic, andesitic, and basaltic pyroclastic and flow rocks near the present crest of the Sierra Nevada (Piper et al., 1939). The streams eroded this material and redeposited it in the valley as water-laid tuff, tuffaceous sand and volcanic gravel. After a period of erosion and relative quiet, predominantly andesitic eruptions began during the Late Miocene in the northern Sierra Nevada and sent a flood of mudflow breccia and ash down the western slopes. Streams continually reworked these deposits and spread them over broad areas to the west.

The volcanic activity waned and died out and the latter part of the Pliocene epoch was marked by erosion in the Sierra Nevada and subaerial deposition (Laguna Formation) in the Sacramento Valley.

In the Middle or Late Pliocene time (Olmsted and Davis, 1961) an uplift of the present northern Coast Ranges inaugurated a period of erosion in the mountains and deposition of coarse detritus to the east. The Sacramento Valley trough began to assume approximately its present outline. Fluviatile deposition continued through the Pliocene and possibly into the early Pleistocene. The streams continually shifted across broad, low flood plains and deposited the Tehama Formation.

During Middle Pleistocene both the Coast Ranges and the Sierra Nevada appear to have been subjected to orogenic processes, and it is possible that this is the

time that the Sutter Buttes were formed. The Coast Ranges were folded, faulted, and elevated and began to assume their present general outline and form. The Pliocene to Pleistocene (?) fluviatile sediments (Tehama Formation) and older rocks were involved in the folding and uplift. Dunnigan Hills anticline was formed at this time. During and after this mountain-building activity, erosion was vigorous, and much of the Tehama Formation was removed and redeposited in the center of the Valley or carried southward by the Sacramento River. Poorly sorted, gravelly material (Red Bluff Formation) eventually was deposited on the eroded surface of the Tehama.

The rejuvenated streams cut laterally and truncated the soft sediments of the Laguna Formation that had been deposited during the Late Pliocene. Most of the detritus was carried westward to be deposited near the axis of the Valley, and in this report is considered part of the Victor Formation.

The present cycle is one of continued erosion of the Coast Ranges, the Sierra Nevada and low hills, and deposition in the Valley.

WATER QUALITY

Connate Water

The term "connate water" has been used several times in this report. Connate water, as originally defined by A. C. Lane (1908) is "water that has remained since burial with the specific rocks in which it occurs, and that its chemical composition has remained unchanged." D. E. White (1965) has summed up the more recent ideas about connate water by saying (pg. 345):

> Much recent evidence indicates that (1) the original interstitial water of sediments normally undergoes diagenetic changes related to bacterial activity and decomposition of organic matter; (2) inorganic reactions between mineral phases and interstitial water occur during early and late diagenesis and also during metamorphism; (3) compaction always occurs, at least to some extent, in response to sediment load, so water must migrate either locally or extensively in directions of decreasing potential; (4) 'salt-sieving' mechanisms, only slightly understood until very recent years, account for changes in salinity of probably all deep waters of sedimentary basins; and (5) other mechanisms, even less well understood, account for changes in chemical composition of saline waters.
>
> Connate water, as here defined, generally is similar in age or somewhat younger, since last direct contact with the atmosphere, than the age of its associated rocks. Most connate waters are probably marine in origin and are associated with normal marine sediments, but some are suspected of being connate to marine and nonmarine evaporites. The dilute meteoric water 'born with' normal nonmarine sediments is probably never preserved in

> its original relationships but is normally displaced after burial by other dilute waters and eventually by any saline water (with higher density) that has access to the sediments.

In this report the water with a high chloride content is believed to have been derived from a marine source when the sediments were deposited in the open sea or in embayments with limited access to the sea. The latter case seems true for the sands of the Upper Cretaceous and Eocene deposits, because their chloride content is about half of that of normal sea water. These waters are termed "connate" under the definition of White (1965).

Basic Data

One hundred thirty-seven water quality analyses were obtained from the files of the California Department of Water Resources for use in this investigation. As many as space would allow are depicted with circle diagrams on Figure 6. Most of the analyses were determined during the 1964-67 period and consist of the standard analyses (i.e., only the major ions were determined). All of the chemical analyses are tabulated in Appendix A.

Approximately 400 electric-logs were used to correlate the formations and zones in the study area. These logs were also used as a guide to the quality of the ground water. The large differences in resistivity for potable and saline water are easily interpreted. Problems

arise when one attempts to relate resistivity to degree of salinity. Besides the many assumptions that must be made, it is necessary to compute the resistivity of the formation from cores or drill cuttings, or have water quality samples from the formation in question. Lacking this, the electric-logs can be used only in a general way for determining water quality.

Variations of Water Quality

Vertical Variation

The entire study area is underlain at varying depths with saline water of marine origin. East of the Feather River, the base of the fresh water is at or near the base of the post-Eocene non-marine sediments. The fresh-water base slopes from near surface, at the areas of outcrop along the eastern margin of the Valley, to depths of 1,100 feet below the town of Verona and approximately 650 feet beneath Yuba City.

Throughout most of the Sutter Basin the base of the fresh water is at a depth of less than 500 feet and in the southern part of the Basin it rises to the surface. Along the western edge of the Sutter Basin the base of the fresh water again deepens and reaches a maximum depth of over 2,300 feet in T.10N., R.1E. A trough of fresh water trends to the northwest beneath Colusa Basin and also shallows to the northwest.

To the west of the trough the base of the fresh water again shallows and is at or near the base of the Tehama Formation along the western boundary of the Valley.

Around the Sutter Buttes the marine sands of the Ione-Domengine and the Kione Formations have been flushed with fresh (meteoric) water to depths of over 2,100 feet. Between the Buttes and the City of Colusa is another mound of saline water which is associated with the near-surface occurrence of Cretaceous beds.

If the base of the fresh water south of the Sutter Buttes were to coincide with the base of the nonmarine sediments, then there would be a gradual deepening of the base of the fresh water across the Sutter and Colusa Basins toward the trough of the Valley. Instead, the base of the fresh water shallows in the Sutter Basin and then deepens in the Colusa Basin.

Horizontal Variation

The river water that flows through the area is very good in quality. It is a calcium bicarbonate type with a total dissolved solid (TDS) content of between 50 and 150 parts per million (ppm). When the river water enters the ground water basin by influent seepage it is in a new environment and changes in quality to reach equilibrium with its new environment. It increases in total dissolved solids and changes to a magnesium bicarbonate type

water. This is due to the large percentage of andesitic and basaltic debris that is present in the alluvial material.

In contrast to the magnesium bicarbonate type fresh water is the poor quality sodium chloride water that occurs in the Sutter Basin between Tisdale Weir and the town of Robbins (Fig. 6). The sodium chloride type water is unlike either the river water or ground water elsewhere in the area. The development of a pumping trough to the northwest along the Feather River has caused the saline water to move into this area and contaminate the ground water. This movement has been continuous over the years and has caused the farmers to abandon their water wells and resort to Feather River water for irrigation.

HYDROCHEMICAL PROCESS

Recharge Waters and Equilibrium

Recharge of the ground water basin is coming from three main sources: infiltration of rain water, river water, and excess irrigation. These three sources consist of water of high quality. One of the conclusions of this paper is that rising connate water is contaminating the ground water basin.

For saline water to move up and displace the fresh water in 2,000 feet of alluvial material requires a driving force or hydraulic head. The saline connate water was originally contained in the marine sediments of Upper Cretaceous and Eocene age. When the igneous intrusives of the Sutter Buttes forced their way up through the overlying sediments they dragged up the marine sediments and exposed them at the surface around the central zone of the Buttes. The marine sediments now stand some 250 to 400 feet above the surrounding flocr of the Valley. In time (some 1,200,000 years) runoff water of meteoric origin infiltrated the Ione-Domengine and Kione sands, both at outcrop and along faults and fractures, and displaced the saline water of marine origin.

Electric-logs run in wells around the southern half of the Buttes indicate that the fresh water has displaced

the connate water to depths of over 2,000 feet. The displaced connate water in the Ione-Domengine Formation has many avenues of escape (Fig. 5) and has contributed saline water to the lower part of the nonmarine sediments in the ground water basin. The hydraulic gradient or head that developed in the Kione Formation, from the Buttes south to the Sutter Basin, has only one avenue of release and that is up the Sutter Basin Fault (Figs. 5, 6 and 7). Therefore it is proposed that the connate water in the Kione Formation moves south from the Sutter Buttes and up the fault, causing a mound of saline water to move to the surface. This movement of high chloride water continues to the present as fresh water infiltrates the Kione sands at the Sutter Buttes. It is possible that the connate water in the Ione-Domengine Formation is also contributing some saline water to the mound, but it appears that the major contributor is the Kione Formation.

There is not enough information available now to determine whether the Sutter Basin Fault zone is pervious and allows the connate water to move through it or that it acts as a barrier and forces the saline water to rise along the north side of the fault.

For a time this investigator thought that the Starkey Sands of Upper Cretaceous age was the main contributor of the saline water. But it now appears that the presence of the Starkey Sands in contact with the

overlying nonmarine alluvium (Fig. 6) beneath the mound of saline water in the Sutter Basin has nothing to do with the saline phenomenon. It was hypothesized that the overburden on the confined portion of the Starkey would develop the required pore pressure to move the connate water up through the valley alluvium to the surface. However, a check of "closed in" pressures conducted in gas wells drilled into the Starkey Sands revealed that the pore pressure was approximately equal to the hydraulic load. This means that no abnormal pore pressure has been developed in the Starkey, and therefore there is no hydraulic head to move the saline water through the alluvium and up to the surface in the Sutter Basin.

Base Exchange

When ground water comes in contact with solid phase materials different from the ones it had been in contact with previously, chemical reactions may occur. This is particularly true when the water comes in contact with finely divided solids such as silt and clay that have an adsorptive capacity. One type of adsorption is termed "ion exchange" and is the replacement of adsorbed ions by ions in solution. The capacity for ion exchange is mostly a result of unsaturation of the chemical bonding in the crystal lattice of the solid having this capacity. In most cases there is an excess of negative bonds in certain areas of the crystal lattice, and positively

charged ions are attracted to these areas. Most of the ion exchange reactions involve cations (calcium, magnesium, potassium, and sodium) and are therefore called base exchange.

After the ground water has been in contact with the solids a sufficient length of time, cations in solution and the adsorbed ions held by the exchange material constitute a system in chemical equilibrium. The degree and readiness for displacement of the equilibrium to the right or left is governed by the law of mass action, which means that if water or mineral holds some base in large excess, the exchange of that base for another proceeds more readily. The replacing power of the different metallic cations differ widely. Calcium possesses high replacing power; magnesium stands next, followed by potassium and then by sodium. Normally, calcium and magnesium ions from solution replace adsorbed sodium on the exchange material and the water is naturally softened. However, under certain conditions explained by the Le Chatelier's principle the system can be reversed and the ground water will undergo a hardening process. According to the principle of Le Chatelier any equilibrium system subjected to a stress tends to change so as to relieve the stress. For a system in chemical equilibrium, changing the concentration of one of the components constitutes a stress (Sienko and Plane, 1966). Thus, if we introduce a large supply of sodium ions into

the ground water body that has reached chemical equilibrium a stress has been applied. Now the adsorbed calcium and magnesium ions will be replaced by the sodium ions in solution and the replacement will continue until the system is again in chemical equilibrium. This is exactly the procedure used in many domestic water softening systems. The water flows in contact with zeolites which act as an ion exchanger. Calcium ions are exchanged for sodium ions being held by the zeolite molecules. Once the exchanger has given up its supply of sodium ions it cannot soften water further. However, it can be regenerated by exposure to a concentrated solution of sodium chloride which reverses the reaction.

Piper et al. (1953) in their study of the contaminated ground water in the Long Beach-Santa Ana area of California found that the introduction of sea water or oil field brines high in sodium chloride resulted in the substitution of calcium (and locally some magnesium) for a large part of the sodium in the contaminating water. In other words, the strongly contaminated waters had been hardened by base exchange reactions, and the degree of hardening was greater than could be explained by the simple admixture of sea water and fresh water. They postulated that the influx of ocean water into the zones of native calcium bicarbonate type water released previously adsorbed calcium and magnesium by base exchange. This

condition is also found in the Sutter Basin, where the rising connate water, high in sodium chloride, comes in contact with the calcium-magnesium bicarbonate type ground water of low total dissolved solids, and is changed to a calcium-magnesium chloride type with a high total dissolved solids. In both instances, we see a case of water being hardened by base exchange.

Source and Movement of Ions

Bicarbonate-Carbonate

There is a very limited occurrence of bicarbonate minerals in the Sutter Basin and the drainage areas of the Sacramento River and its tributaries. Based on the work of Bear (1964), this investigator concludes that the bicarbonate and carbonate anions in the ground water come mostly from the carbon dioxide contained in the soil, and in a small part from the precipitation that has been in contact with carbon dioxide in the atmosphere.

The following chemical equations indicate how these reactions might take place:

$$CO_2(gas) + H_2O = CO_2(aqueous) + H_2O$$
$$CO_2(aqueous) + H_2O = H_2CO_3$$
$$H_2CO_3 = H^+ + HCO_3^-$$
$$HCO_3^- = H^+ + CO_3^{--}$$

Of the 137 water analyses tabulated in Appendix A, 106 samples have the bicarbonate ion as the major anion. This bicarbonate type water is considered the normal condition for the ground water basin and is

found on all sides of the mound of high chloride type water.

Sulfate

Feth, J. H., Robertson, C. E., and Polzer, W. L. (1964) propose that most of the sulfate ions in the runoff water of the Sierra Nevada come from water rising along fault zones. The author is aware of a source of sulfur in the upper Feather River drainage called Sulfur Point. The concentration of the sulfur compounds at Sulfur Point is so high that the stream is uninhabitable for fish within a mile below the Point.

The Bear River carries more sulfate ions than the other rivers flowing through the study area. Surface water samples contain as much as 0.56 equivalent parts per million (epm) with a TDS of 180 ppm. Water in well 13N/4E-21A1 is classified as a magnesium sulfate type and is the only well water that has sulfate as the major anion. Well 13N/4E-17J1, which is also near the Bear River (Fig. 6), has the second highest sulfate content among the ground water analyses used in this report.

Throughout the rest of the area the sulfate ions make up the minor constituent of the anion group. This is particularly true for the ground water with a high chloride content. A case in point is well 12N/2E-2J1 that has a TDS of 3525 ppm and a sulfate content of 2.0 ppm. Several other wells with high chloride water, in the same area,

have no discernible amounts of sulfate in the water analyses.

Hem (1970) has proposed the following reaction for sulfate reduction:

$$SO_4^{--} + CH_4 \text{ (bacteria) } HS^- + H_2O + HCO_3^-$$

This formula suggests that in the reduction of the sulfate the anaerobic bacteria is the most active agent. Methane gas is known to be present in the area. Bear (1964, p. 279) suggests that though the mechanism of sulfate reduction has still not been completely worked out, the activities of sulfate-reducing organisms are chiefly restricted to heavy clays or water logged soils. Such conditions are found in the Sutter Basin. One of the by-products of sulfate-reducing organisms is hydrogen sulfide with its characteristic odor. Bryan (1923) reported that much of the ground water in the eastern part of the Sutter Basin contained small quantities of hydrogen sulfide and that "many local people prefer the 'sulphur' water for drinking."

Chloride

A study of Figure 6 shows that there is a body of high chloride water in the central part of the Sutter Basin. Possible explanations for this are: (1) concentration of the chloride ion by evaporation of the ground water at or near the surface, (2) buried beds of sodium chloride salt, and (3) connate water rising from marine sediments. Byran (1923) noted that the conditions for

residual evaporates existed in the basins of the Sacramento Valley but they were found only in small, isolated bodies. His reasons for the absence of extensive evaporates has already been cited. Drilling has not revealed any buried salt bodies such as exist in the Phoenix area of Arizona. Therefore, it appears most logical that the chloride ions are the result of marine connate water. In the past, the major stumbling block to this theory was that the high chloride occurs in nonmarine alluvial material with a thickness of approximately 2,000 feet.

Chloride ions are resistant to ion exchange, hence maintain their identity as ions after introduction into a ground water body. They are, therefore, ideal for use as tracers in ground water studies. Notice on Figure 6 the area between the Sutter Basin Fault and the Pumping trough to the north, west of the Feather River. The pumping for irrigation water has reversed the natural gradient of ground water and has resulted in the saline water slowly moving north and degrading the ground water. What is of interest to this thesis is that even though the degrading saline water has been diluted and subject to base exchange, the water still maintains a high percentage of chloride ions.

Sodium and Potassium

Feth et al. (1964) state that the igneous rock in the Sierra Nevada contained almost equal portions of sodium and potassium, however, once the ions have been taken into solution by the ground water, the potassium ions are subject to base exchange and rapidly disappear from the ground water, while the sodium ions persist and are carried by the rivers down to the valley ground water basin. This is confirmed in the water analyses in the study area. In both the surface water and the ground water, the sodium ions far outnumber the potassium ions. The two ions have been grouped together in the circle diagrams on Figure 6.

Throughout most of the area, sodium is the minor constituent in the cation group. As the water percolates through interstices of the alluvial material, normally the sodium ions are released to the ground water at the expense of the calcium and magnesium ions in solution. This process of base exchange is known as natural "softening" of the water. There is some evidence that this process is taking place, but in general it is masked by the infiltration of irrigation water diverted from the rivers.

Water analyses of the two deep wells (12N/2E-18 SW1/4 and 12N/2E-24L1, Appendix A) show that the deep waters contain 73.8 and 73.5 percent (of total anion reactance) sodium ions, respectively. South of the Sutter Basin Fault

the deep connate water does not change chemically as it rises to the surface. Yet, as this same water moves Northward it becomes harder by changing from a sodium chloride type to a calcium-magnesium chloride type. As previously stated, this phenomenon was observed by Piper et al. (1953) in the Long Beach-Santa Ana area where fresh ground water was being contaminated with sea water. There, as in the Sutter Basin, the contaminated zone contains water which is higher in calcium and magnesium than can be explained by assuming a simple admixture of the saline water and fresh water involved. The best explanation is that previously adsorbed calcium and magnesium ions are being released by base exchange in the presence of the high sodium ion solution. That is to say, the water moving to the North is undergoing a base exchange, or hardening process. And on the other hand, the water moving Southwesterly from the Sutter Basin Fault is moving through soil that now has a deficiency of exchangeable calcium and magnesium ions and maintains its identity as a sodium chloride type water--the difference being that the saline water has been moving north only since the ground water trough was developed by irrigation pumping, whereas the ground water had been moving in a southerly direction for many thousands of years.

Calcium and Magnesium

The river water flowing through the area and recharging the ground water basin is a calcium-magnesium

bicarbonate type with a TDS of between 50 and 150 ppm. Once it has infiltrated the basin, it changes to a magnesium-calcium type. The probable explanation for this is that the alluvium has a high content of ferromagnesium minerals due to the presence of andesitic volcanic debris. By the law of mass action and through base exchange, the magnesium ions are released to the ground water and the calcium ions are adsorbed by the soil particles.

Boron

The Feather River and its tributaries are free of boron although a trace is reported from time to time along the lower reaches. The ground water being recharged by the Feather River and its tributaries is also free of boron. Along the eastern edge of the Sacramento Valley, some of the water from wells contains boron that is believed to be coming from marine sediments that occur at shallow depths.

The streams and rivers draining the Coast Ranges generally have a high boron content. Cache Creek, in Capay Valley, has a boron content of up to 4 ppm. The ground water recharged by the western streams normally contains one to two parts per million boron.

Within the mound of saline water in the Sutter Basin the boron content ranges from 10.8 ppm at a depth of 1,500 feet to 1.5 ppm at a depth of 285 feet. As the

rising connate water moves laterally away from the mound of saline water, the boron content gradually decreases until it is no longer detected in the analyses. The rapid decrease in boron over a vertical distance of some 1,200 feet is assumed to be largely the result of adsorption.

CONCLUSIONS

On the basis of the findings of this investigation, it is concluded that:

Subsurface Geology

The Kione Formation of Upper Cretaceous age is the chief contributor to the rising connate water in the Sutter Basin.

The Ione-Domengine Formation of Middle Eocene age also contributes saline water to the ground water basin but not in sufficient quantities to raise the base of the fresh water to the surface.

The "Starkey Sands" of Upper Cretaceous age are in direct contact with the overlying alluvial sediments in the southern portion of the Sutter Basin. This happenstance has nothing to do with the mound of saline water in the same area.

Hydraulic Continuity

The Sutter Basin Fault cuts the Upper Cretaceous marine sands and allows the saline water in the Kione Formation to rise along the fault into the post-Eocene alluvium.

Hydraulic Gradient

The head required to move the saline connate water from the underlying marine beds up through 2,000 feet of alluvium is supplied by the position of the Kione Formation which has been dragged up by the Sutter Buttes Intrusives and exposed at elevations between 250 and 400 feet above the Valley floor. The marine sands have been flushed with fresh water to depths of over 2,000 feet below sea level around the south side of the Buttes. The displaced saline water has moved south and up the Sutter Basin Fault and then through the overlying alluvial sediments to the surface.

Water Chemistry

The mound of saline water in the Sutter Basin is coming from connate water related to the marine sediments which underlie the entire area. The connate water is of a sodium chloride type that changes into a calcium-magnesium chloride type due to base exchange as the water moves into an area which previously contained calcium-magnesium bicarbonate type water.

APPENDIX A

ANALYSES OF GROUND WATER

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value						parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
10N/1E-15H2	176	1.95 33.6	2.14 36.9	1.71 29.5	4.24 71.7	0.54 9.1	1.13 19.1	1.5	270	204
10N/2E-17J3	243	2.05 34.8	2.14 36.3	1.71 29.0	4.24 74.3	0.40 7.0	1.07 18.7	1.5	278	207
11N/1E-4R1	-	1.30 11.1	4.59 39.2	5.82 49.7	9.43 77.8	1.39 11.5	1.30 10.7	4.2	695	295
11N/1E-16P1	172	1.85 32.2	2.06 35.9	1.83 31.9	4.74 80.2	0.23 3.9	0.93 15.8	1.3	304	195
11N/2E-14F4	330	1.35 24.9	1.73 31.9	2.35 43.3	4.78 86.3	0.20 3.6	0.56 10.1	0.7	277	153
11N/2E-32G1	-	1.45 13.1	5.85 52.9	3.75 33.9	7.26 68.7	1.00 9.5	2.31 9.5	3.3	604	366
11N/3E-3N2	112	0.75 39.5	0.25 13.2	0.90 47.4	1.73 91.0	0.08 4.2	0.02 5.3	0.1	131	50
11N/3E-14N2	-	3.59 28.8	3.40 27.2	5.49 44.0	4.30 34.1	0.18 1.4	8.10 64.0	0.3	705	351
11N/3E-14R1	236	1.20 10.0	0.30 2.5	10.51 87.5	4.83 40.0	0.06 0.9	7.17 59.1	0.2	718	75
11N/3E-24D1	145	2.18 30.8	2.88 40.4	2.05 28.8	6.92 93.4	0.15 2.3	0.31 4.3	0.2	365	253
11N/3E-36L1	140	0.37 9.5	0.23 5.9	3.33 84.7	3.20 82.5	0.20 5.2	0.48 12.4	0.3	246	30
11N/4E-3P2	305	2.30 40.6	2.38 42.0	0.99 17.5	4.49 82.1	0.11 2.0	0.87 15.9	0.0	295	234

Well Number	Depth ft.	Chemical constituents equivalents per million / percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
11N/4E-9D1	-	1.40 42.2	1.32 39.7	0.60 18.1	2.60 76.3	0.50 14.7	0.31 9.0	0.1	184	138
11N/4E-14D2	204	0.83 26.1	0.99 31.1	1.36 42.8	2.16 77.7	0.08 2.9	0.54 19.4	0.2	152	91
11N/4E-19E2	-	1.35 31.4	1.41 32.8	1.54 35.8	3.00 69.3	0.31 7.2	1.02 23.5	0.1	262	138
12N/1W-21A1	405	1.50 32.7	2.30 50.3	0.78 17.0	4.20 97.5	0.00 0.0	0.11 2.5	0.0	214	189
12N/2E-2J1	100	30.37 28.2	35.30 33.4	39.90 37.8	4.10 4.0	0.05 0.0	99.45 96.0	0.6	5610	205
12N/2E-9B2	-	1.35 20.6	0.03 4.0	5.17 79.0	3.89 65.2	0.33 5.5	1.75 29.3	0.5	402	69
12N/2E-11N1	-	1.55 12.5	1.15 9.3	9.70 78.2	4.30 36.0	0.00 0.0	7.61 64.0	0.9	728	135
12N/2E-14B1	-	7.58 18.3	9.21 22.2	24.65 59.5	3.12 7.9	0.00 0.0	38.63 92.1	0.8	2790	841
12N/2E-16R1	-	2.25 21.5	0.72 6.9	7.46 71.6	7.13 70.0	0.35 3.5	2.68 26.5	0.6	577	148
12N/2E-18SW	1500	19.83 19.2	7.22 7.0	76.12 73.8	2.71 2.5	0.08 0.1	99.98 97.4	10.8	5870	166
12N/2E-23Q1	-	1.15 12.1	0.55 5.8	7.82 82.1	4.50 48.4	0.01 0.0	4.79 51.6	0.7	571	85

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
12N/2E-24G1	446	0.70 7.6	0.72 7.9	7.61 84.5	4.00 47.4	0.35 4.1	4.09 48.5	0.1	670	-
12N/2E-24L1	1565	19.81 19.3	7.23 7.2	75.21 73.5	2.70 2.6	0.08 0.1	100.03 97.3	10.8	5940	-
12N/2E-24L2	146	19.81 36.5	9.29 17.1	25.23 46.4	3.47 8.1	0.02 0.0	39.48 91.9	1.1	2452	-
12N/2E-26A1	-	1.40 13.3	0.72 6.8	8.41 79.9	4.64 44.8	0.00 0.0	5.72 55.2	0.6	608	107
12N/2E-35SW	44	4.09 15.3	5.84 21.7	16.88 63.0	4.20 15.4	0.01 0.0	23.41 84.6	0.4	1628	-
12N/3E-13F1	285	0.85 20.3	0.47 11.2	2.87 68.5	2.91 69.8	0.02 0.5	1.24 29.7	0.2	266	66
12N/3E-16H2	-	2.15 19.0	4.45 39.3	4.73 41.7	5.28 47.1	2.21 19.7	3.71 32.2	0.0	620	330
12N/3E-23G1	120	6.47 36.6	4.72 26.7	6.49 36.7	2.82 15.9	0.23 1.3	14.72 82.8	0.4	1060	561
12N/3E-25A1	155	2.05 41.3	1.45 29.2	1.46 29.4	4.02 79.2	0.25 5.0	0.76 15.1	0.1	286	175
12N/25C2	97	3.79 50.1	2.20 29.1	1.58 20.9	4.13 54.9	0.75 10.0	2.65 35.2	0.1	435	252
12N/3E-26R1	-	2.99 42.2	1.64 23.1	2.46 34.7	3.52 48.6	0.17 2.4	3.55 49.0	0.1	423	234

Well Number	Depth ft.	Chemical constituents equivalents per million			percent reactance value			parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
12N/3E-30H1	232	4.64 13.9	2.96 8.9	25.71 77.2	3.18 9.7	0.19 0.6	29.34 89.7	1.5	1970	380
12N/4E-4N2	89	1.45 36.2	1.75 43.6	0.81 20.22	2.72 68.3	0.19 4.8	1.07 26.9	0.0	257	160
12N/4E-6G1	82	2.50 26.2	4.30 45.0	2.76 28.8	6.20 69.0	2.17 24.1	0.62 6.9	0.2	491	340
12N/4E-7R1	100	0.95 32.3	1.35 45.9	0.64 21.8	2.63 92.9	0.02 0.7	0.18 6.4	0.0	181	115
12N/4E-32J1	-	4.39 42.8	4.19 40.8	1.68 16.4	4.25 41.6	2.08 20.4	3.89 38.1	0.0	682	427
13N/1W-15R2	-	1.80 33.3	1.23 22.8	2.37 43.9	4.03 75.9	0.21 4.0	1.07 20.5	0.5	287	153
13N/1W-36Q2	36	1.75 38.6	1.15 24.9	1.72 36.5	3.31 74.3	0.15 3.4	0.99 22.3	0.3	276	145
13N/1E-22J1	-	2.84 52.4	1.48 27.3	1.10 20.3	3.71 69.6	0.17 3.2	1.44 27.0	0.1	327	216
13N/1E-36Q1	-	1.75 37.9	1.15 24.9	1.72 37.2	3.31 74.4	0.15 3.4	0.99 22.2	0.3	276	145
13N/2E-23B1	72	17.41 28.0	21.18 38.7	20.87 33.3	3.54 5.6	0.00 0.0	59.80 94.4	0.4	5970	2080
13N/3E-2C4	190	3.64 36.8	3.67 37.1	2.58 26.1	5.94 61.2	0.98 10.1	2.79 28.7	0.2	486	-

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
13N/3E-14G1	-	5.56 21.5	14.18 54.9	6.08 23.6	2.98 11.2	3.39 12.9	20.01 75.9	0.1	1994	987
13N/3E-15B1	95	6.99 31.5	9.01 40.6	6.20 27.9	2.75 12.5	0.06 0.3	19.18 87.2	0.1	1400	800
13N/3E-15C2	90	8.53 37.6	10.85 44.0	5.29 21.4	4.18 16.8	0.06 0.2	20.68 83.0	0.1	1580	970
13N/3E-23C1	105	13.40 41.9	13.00 40.6	5.60 17.5	5.92 18.7	0.10 0.3	25.60 80.8	0.2	1884	1320
13N/3E-23H1	-	5.10 30.7	7.70 46.4	3.80 22.9	3.43 20.7	0.46 2.8	12.65 76.5	0.1	900	640
13N/3E-24D1	-	7.80 26.2	11.80 39.6	10.21 34.2	1.46 4.8	0.23 0.8	28.50 94.4	0.5	2140	980
13N/4E-3D1	130	1.30 22.2	3.30 56.3	1.26 21.5	3.93 68.0	0.19 3.3	1.66 28.7	0.0	320	230
13N/4E-17J1	200	2.45 39.5	2.75 44.3	1.01 16.3	3.33 56.7	2.00 34.1	0.54 9.2	0.02	387	260
13N/4E-21A1	-	3.59 36.3	5.26 53.2	1.04 10.6	4.31 42.9	5.45 54.3	0.28 2.8	0.0	565	445
13N/4E-27M1	196	0.70 29.4	1.02 42.9	0.66 27.7	1.92 84.2	0.02 0.9	0.34 14.9	0.0	163	86
13N/4E-32N1	84	0.95 23.4	1.43 35.2	1.68 41.4	2.41 83.1	0.12 4.1	0.37 12.8	0.0	200	119

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
13N/4E-33J2	154	1.95 35.7	2.55 46.6	0.97 17.7	4.56 85.6	0.09 1.7	0.68 12.8	0.0	312	-
14N/1W-2D1	-	2.84 31.8	2.47 27.6	3.63 40.6	3.67 40.6	1.64 18.2	3.72 41.2	0.2	493	268
14N/1W-12A1	-	1.05 17.6	0.09 1.5	4.83 80.9	4.41 74.7	0.02 0.3	1.47 24.9	0.5	319	57
14N/1E-1A1	-	3.24 45.5	2.63 36.9	1.25 17.6	6.05 88.1	0.37 5.4	0.45 6.6	0.0	344	294
14N/1E-24N1	125	1.60 34.0	1.73 36.0	1.42 30.0	3.99 86.0	0.441 10.0	0.19 4.0	0.1	248	166
14N/2E-13L1	79	1.20 29.6	1.81 44.7	1.04 25.7	3.90 96.3	0.06 1.5	0.09 2.2	0.0	205	150
14N/2E-17E1	330	1.25 25.9	1.25 25.9	2.32 48.2	3.93 83.6	0.33 7.0	0.48 9.4	0.1	298	196
14N/2E-30R1	188	1.90 27.8	1.58 23.1	3.37 49.1	5.22 77.5	0.21 3.1	1.30 19.4	0.1	386	174
14N/3E-4E5	160	2.20 26.0	4.12 48.7	2.14 25.3	5.61 71.0	1.44 18.2	0.85 10.8	0.0	455	316
14N/3E-5A3	106	4.39 34.5	5.18 40.8	3.14 24.7	8.30 66.4	2.08 16.6	2.12 17.0	0.1	670	481
14N/3E-5D2	150	1.50 29.8	2.10 41.7	1.44 28.6	4.54 91.9	0.17 3.4	0.23 4.7	0.0	266	180

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
14N/3E-6A1	100	2.50 32.9	3.29 43.4	1.80 27.7	6.54 89.3	0.58 7.9	0.20 2.7	0.0	363	180
14N/3E-7H1	105	1.90 23.9	4.18 52.6	1.86 23.4	6.06 77.5	0.58 7.4	1.18 15.1	0.0	401	304
14N/3E-9K1	230	2.99 33.2	3.57 39.6	2.45 27.2	3.65 41.5	0.19 2.2	4.96 56.3	0.1	628	328
14N/3E-13D1	650	1.00 37.6	0.68 25.6	0.98 36.8	2.01 76.4	0.00 0.0	0.62 23.6	0.2	198	84
14N/3E-14E2	90	1.10 44.7	1.07 43.5	0.29 11.8	2.25 91.8	0.10 4.1	0.10 4.1	0.0	118	104
14N/3E-16B2	99	4.09 29.3	7.15 51.1	2.74 19.6	4.18 29.8	1.60 11.4	8.23 58.7	0.1	895	564
14N/3E-18A2	125	2.69 35.1	3.29 42.9	1.69 22.0	6.39 81.2	0.58 7.4	0.90 11.4	0.1	396	301
14N/3E-20H3	105	2.59 34.4	3.19 42.3	1.74 23.1	5.35 73.5	0.58 8.0	1.35 18.5	0.1	385	289
14N/3E-23M2	83	0.90 37.2	1.16 47.9	0.36 14.9	2.41 97.6	0.02 0.8	0.04 1.6	0.0	385	289
14N/3E-24M1	-	1.75 34.3	2.06 40.3	1.30 25.4	3.56 71.8	0.69 13.9	0.71 14.3	0.1	280	191
14N/3E-24P1	-	1.15 41.7	0.53 19.2	1.08 39.1	1.95 72.8	0.00 0.0	0.73 27.2	0.2	184	84

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
14N/3E-25D3	85	1.10 41.4	0.90 33.8	0.66 24.8	2.11 79.6	0.06 2.3	0.48 18.1	0.0	159	102
14N/3E-26D4	110	0.77 32.9	0.05 2.1	1.52 65.0	1.61 95.3	0.05 3.0	0.03 1.8	0.2	136	11
14N/3E-27K1	180	2.89 24.8	3.91 33.6	4.84 41.6	5.60 49.1	0.31 2.7	5.50 48.2	0.2	665	340
14N/3E-28E1	-	1.25 22.2	2.46 43.6	1.93 34.2	3.52 62.4	0.24 4.3	1.88 33.3	0.2	286	185
14N/3E-29Q1	-	5.12 26.9	6.52 34.2	7.40 38.9	2.92 15.6	0.10 0.5	15.67 83.8	0.4	1000	581
14N/3E-31B1	63	1.30 20.5	2.86 45.2	2.17 34.3	5.51 88.9	0.21 3.4	0.48 7.7	0.0	317	208
14N/3E-32F1	-	5.63 26.4	7.08 33.2	8.60 40.4	3.42 16.1	0.05 0.2	17.76 83.7	0.3	1135	635
14N/3E-33A1	-	3.99 30.3	6.04 45.9	3.13 23.8	2.60 19.7	0.05 0.4	10.54 79.9	0.1	682	501
14N/3E-33C1	-	3.04 21.0	7.76 53.7	3.64 25.2	3.06 21.0	0.13 0.9	11.37 78.1	0.2	806	540
14N/3E-34F1	84	3.49 28.1	4.31 34.7	4.63 37.3	4.96 40.5	0.00 0.0	7.28 59.5	0.1	750	390
14N/3E-34J1	-	1.80 18.9	5.80 60.8	1.94 20.3	3.62 38.3	1.29 13.6	4.55 48.1	0.1	481	380

Well Number	Depth ft.	Chemical constituents equivalents per million			percent reactance value			parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
14N/4E-6H1	112	1.00 44.4	0.58 25.8	0.67 29.8	1.86 81.6	0.07 3.1	0.35 15.4	0.0	116	79
14N/4E-7M1	83	2.25 35.3	2.87 45.0	1.26 19.7	3.51 56.3	2.19 35.1	0.54 8.7	0.0	528	395
14N/4E-9J1	100	1.64 33.3	2.06 41.8	1.23 25.0	3.54 73.1	0.15 3.1	1.15 23.8	0.0	242	165
14N/4E-22H1	400	0.70 31.3	0.64 28.6	0.90 40.2	1.52 70.4	0.02 0.9	0.62 28.7	0.0	191	67
14N/4E-27N1	510	0.80 36.0	0.50 22.5	0.92 41.4	1.92 86.9	0.06 2.7	0.23 10.4	0.0 0.0	148	65
15N/1E-16R1	-	1.90 27.5	3.78 54.7	1.23 17.8	5.84 85.8	0.35 5.1	0.62 9.1	0.1	355	283
15N/1E-35H1	108	2.20 35.1	2.96 47.2	1.11 17.7	5.22 85.6	0.20 3.3	0.28 4.6	0.0	225	-
15N/1E-35R1	-	3.84 47.4	3.53 43.6	0.73 9.0	5.28 66.1	0.62 7.8	2.09 26.2	0.0	466	370
15N/2E-1R1	49	2.10 36.5	2.55 44.3	1.01 17.5	4.69 88.2	0.46 8.7	0.17 3.2	0.0	310	231
15N/2E-22D1	306	1.05 36.0	0.99 33.9	0.83 28.4	2.54 89.4	0.10 3.5	0.10 7.0	0.0	184	100
15N/2E-26D2	-	3.24 40.9	2.79 35.2	1.90 24.0	5.23 74.2	0.44 6.2	1.38 19.6	0.1	447	304

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
15N/3E-4C2	147	3.04 34.2	4.52 50.9	1.32 14.9	5.72 69.3	1.77 21.5	0.76 9.2	0.1	558	379
15N/3E-9C2	200	2.20 34.9	2.28 36.2	1.82 28.9	5.52 88.0	0.44 7.0	0.31 4.9	0.1	350	224
15N/3E-11H4	60	0.94 39.2	1.13 47.1	0.33 13.7	2.17 90.0	0.11 4.6	0.13 5.4	0.0	127	103
15N/3E-13F1	350	1.80 50.9	0.92 26.0	0.82 23.1	2.68 77.5	0.50 14.5	0.28 8.0	0.0	239	136
15N/3E-13J2	300	1.10 44.2	0.54 21.7	0.85 34.1	1.90 74.2	0.01 0.4	0.65 25.4	0.0	201	82
15N/3E-14N1	350	0.70 24.4	0.72 25.1	1.45 50.5	2.34 81.3	0.00 0.0	0.54 18.8	0.3	182	71
15N/3E-15C1	170	1.15 28.3	0.65 16.0	2.27 55.8	3.59 87.4	0.01 0.2	0.51 12.4	0.3	257	90
15N/3E-15E2	188	1.64 24.4	1.92 28.6	3.15 46.9	4.96 76.0	0.27 4.1	1.30 19.9	0.4	329	178
15N/3E-15H4	133	3.49 41.8	3.95 47.3	0.91 10.9	6.65 81.4	0.20 2.5	1.32 16.1	0.0	483	373
15N/3E-15J2	160	0.55 9.1	4.35 71.7	1.17 19.3	3.99 75.9	0.71 13.5	0.56 10.7	0.0	354	245
15N/3E-15Q1	-	0.70 16.8	0.86 20.6	2.61 62.6	3.61 84.6	0.04 0.9	0.62 14.5	0.3	262	-

Well Number	Depth ft.	Chemical constituents equivalents per million / percent reactance value						parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
15N/3E-19M1	75	0.94 30.2	1.39 44.7	0.78 25.1	2.79 92.1	0.09 3.0	0.15 5.0	0.1	150	117
15N/3E-21C1	185	1.30 23.6	2.86 51.9	1.35 24.5	4.47 81.1	0.25 4.5	0.79 14.3	0.0	328	208
15N/3E-22N1	115	3.49 34.4	4.75 46.8	1.90 18.6	7.42 74.6	0.75 7.5	1.78 18.0	0.0	529	412
15N/3E-23C1	118	0.75 46.3	0.65 40.1	0.22 13.6	1.41 92.2	0.05 3.3	0.07 4.6	0.0	99	70
15N/3E-23D1	125	2.25 38.3	3.30 51.5	0.60 10.2	5.19 90.1	0.29 5.0	0.28 4.9	0.0	325	264
15N/3E-24F1	130	2.84 42.8	2.59 39.0	1.21 18.2	4.71 69.4	0.58 8.5	1.50 22.1	0.1	334	261
15N/3E-26C1	163	1.35 30.0	1.71 38.0	1.44 32.0	4.03 90.2	0.10 2.2	0.34 7.6	0.0	262	153
15N/3E-26M1	250	1.45 32.6	1.23 27.6	1.77 39.8	3.97 89.4	0.10 2.3	0.37 8.3	0.2	241	134
15N/3E-27C1	80	3.89 32.2	6.02 49.8	2.17 18.0	8.85 77.2	0.92 8.0	1.69 14.8	0.2	557	496
15N/3E-27L1	150	2.15 31.6	3.05 51.3	1.59 17.0	4.93 86.1	0.33 6.3	1.41 7.6	0.0	370	260
15N/3E-29G1	90	3.09 34.3	4.27 47.4	1.65 18.3	7.20 85.7	0.75 8.9	0.45 5.4	0.0	488	367

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
15N/3E-29G2	110	2.84 31.6	4.61 51.3	1.53 17.0	7.35 86.1	0.54 6.3	0.65 7.6	0.0	487	373
15N/3E-30D1	65	2.64 37.9	3.44 49.4	0.89 12.8	6.10 94.0	0.23 3.5	0.16 2.5	0.0	384	304
15N/3E-34N2	80	3.80 22.9	10.38 62.5	2.43 14.6	7.02 42.8	2.02 12.3	7.36 44.9	0.1	831	709
15N/4E-8D1	333	1.87 43.8	1.82 42.6	0.58 13.6	3.04 73.3	0.90 21.7	0.21 5.1	0.1	220	184
15N/4E-16P1	450	1.15 41.8	1.07 39.0	0.53 19.2	2.21 81.6	0.42 15.5	0.08 2.9	0.0	184	111
15N/4E-20J2	271	1.60 36.9	2.14 49.3	0.60 13.8	3.13 73.0	0.98 22.8	0.18 4.2	0.0	271	187
15N/4E-29H1	145	1.35 36.2	1.75 46.9	0.63 16.9	2.96 80.2	0.54 14.6	0.19 5.2	0.0	187	155
15N/4E-31A1	157	1.05 39.5	1.07 40.2	0.54 20.3	2.32 89.9	0.02 0.8	0.24 9.3	0.0	172	105
16N/1W-29J1	-	1.30 31.3	1.48 35.7	1.37 33.0	3.82 94.1	0.00 0.0	0.24 5.9	0.1	199	139
16N/3E-14G1	63	4.34 46.7	4.22 45.4	0.73 7.9	6.78 76.9	1.19 13.5	0.85 9.6	0.0	472	428
16N/3E-16B1	46	0.84 46.9	0.80 44.7	0.15 8.4	1.49 87.1	0.12 7.0	0.10 5.9	0.0	90	82

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value						parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
16N/3E-23B1	160	1.13 40.1	1.08 38.3	0.61 21.6	2.38 90.5	0.10 3.8	0.15 5.7	0.0	160	110
16N/3E-26Q1	416	1.40 46.1	0.80 26.3	0.84 27.6	2.40 81.6	0.17 5.8	0.37 12.6	0.1	218	110
16N/3E-31C1	72	1.32 30.8	2.04 47.7	0.92 21.5	3.92 92.7	0.16 3.8	0.15 3.5	0.0	318	168
16N/3E-36E1	85	2.16 37.1	2.84 48.7	0.83 14.2	5.04 92.5	0.02 0.4	0.39 7.2	0.0	280	250

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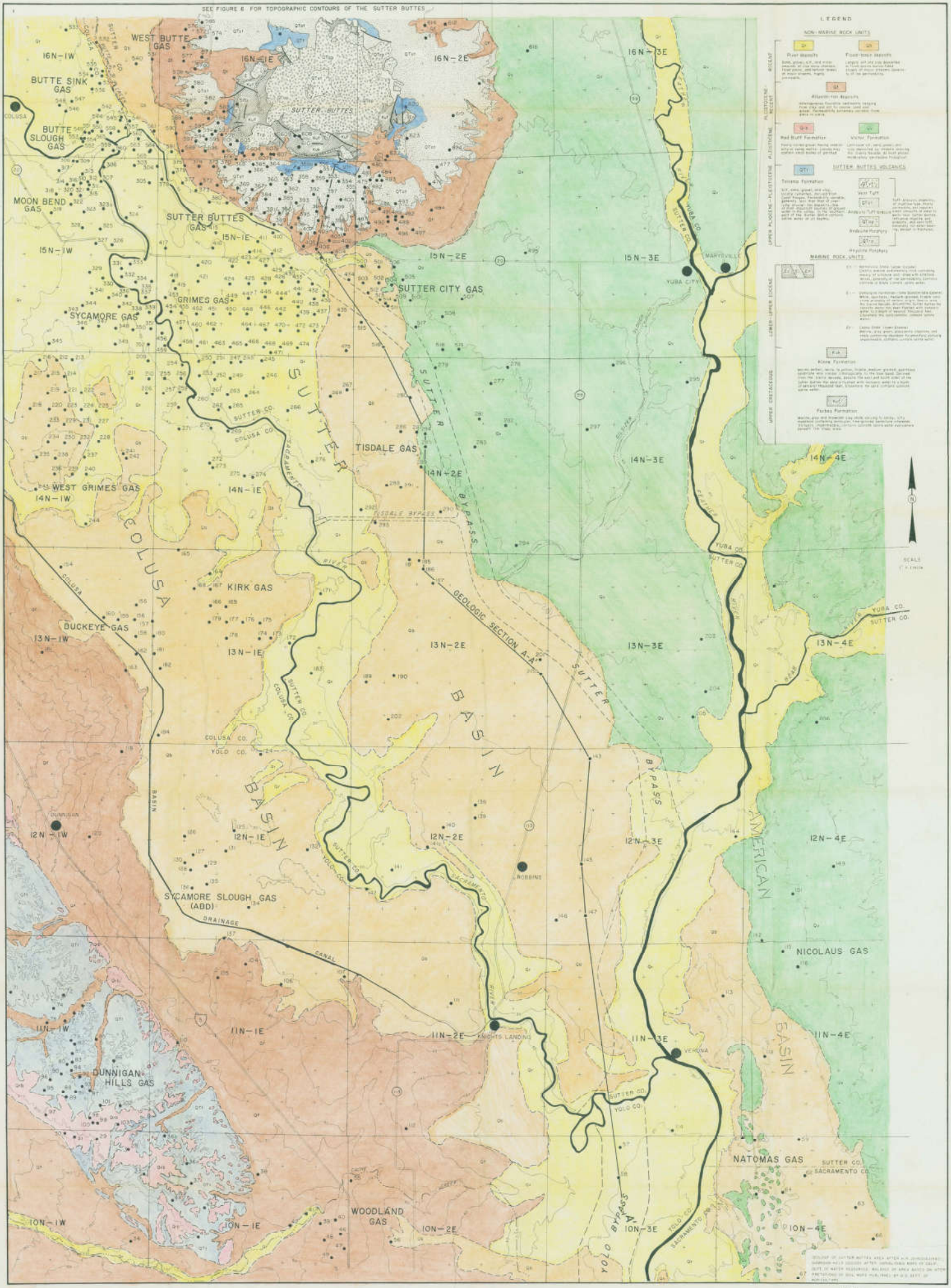

FIGURE 4

SURFICIAL GEOLOGY OF THE SUTTER BASIN AREA, SACRAMENTO VALLEY, CALIFORNIA

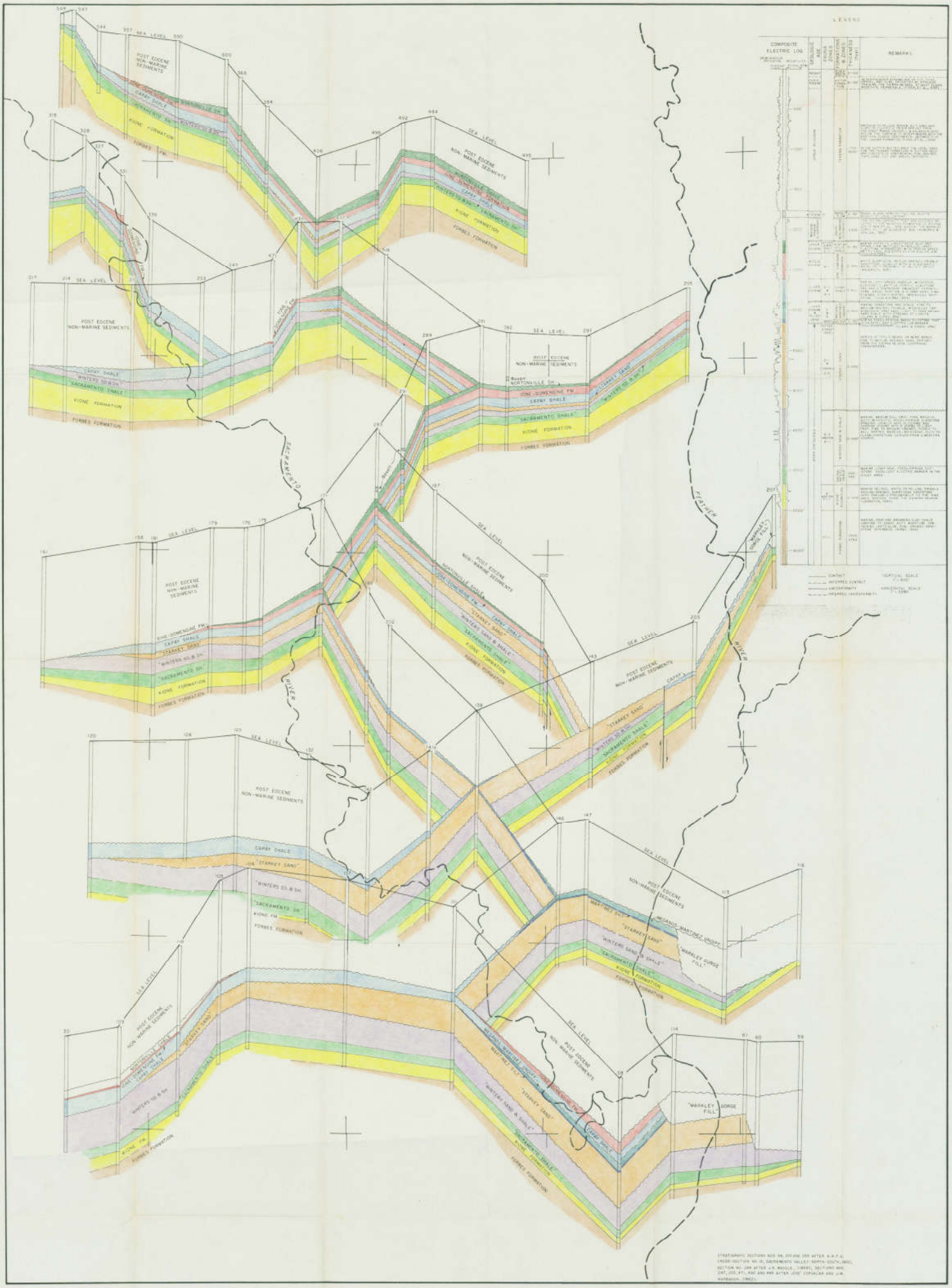

FIGURE 5

PANEL DIAGRAM SHOWING THE STRATIGRAPHY OF THE SUTTER BASIN AREA, SACRAMENTO VALLEY, CALIFORNIA

CURTIN
THESIS, GEOLOGY 1961

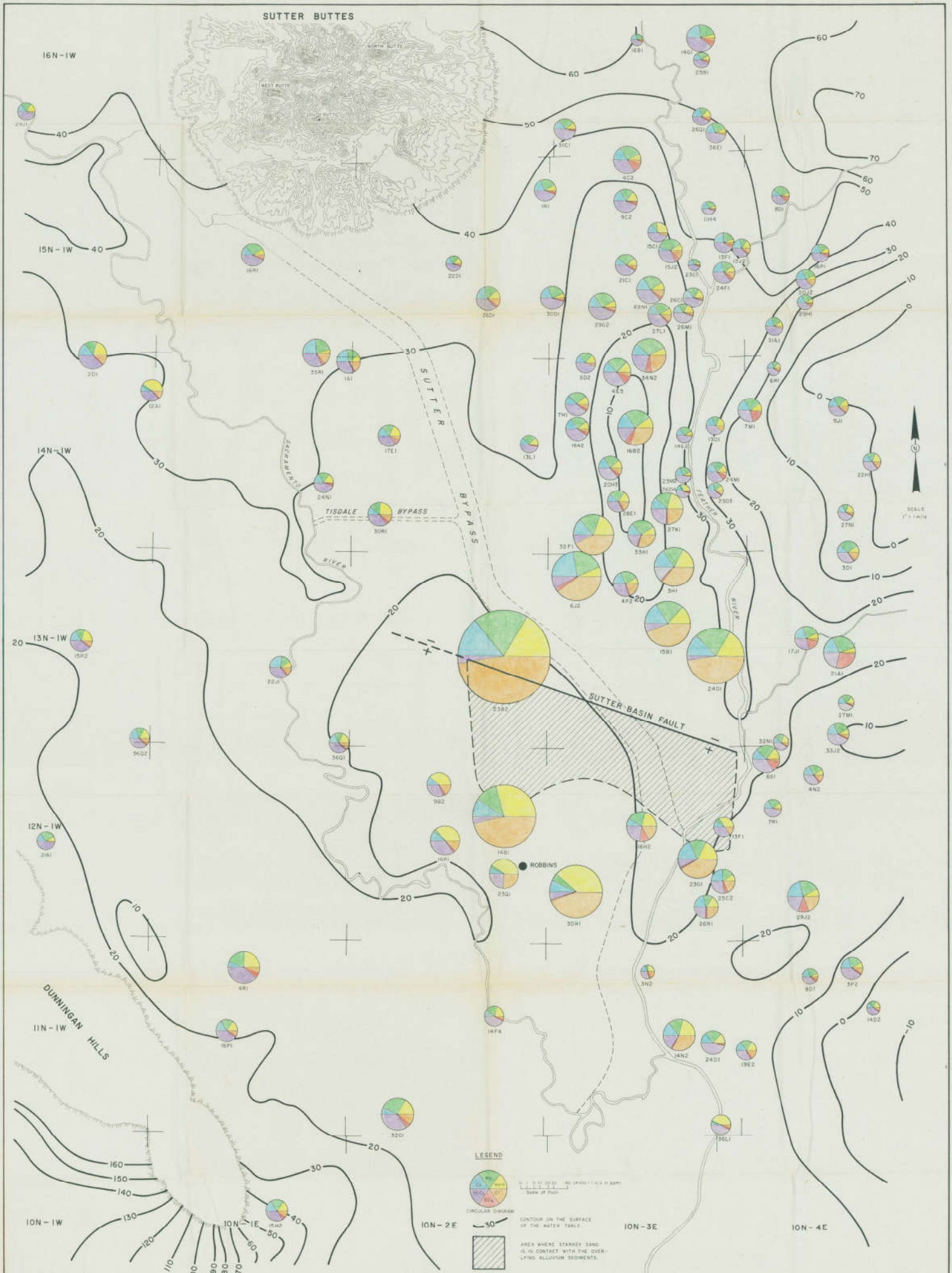

FIGURE 6 WATER QUALITY AND CONTOUR ELEVATION OF WATER IN WELLS, SPRING 1966 (SEA LEVEL DATUM) SUTTER BASIN AREA, SACRAMENTO VALLEY, CALIFORNIA

CURTIN THESIS, GEOLOGY (67)

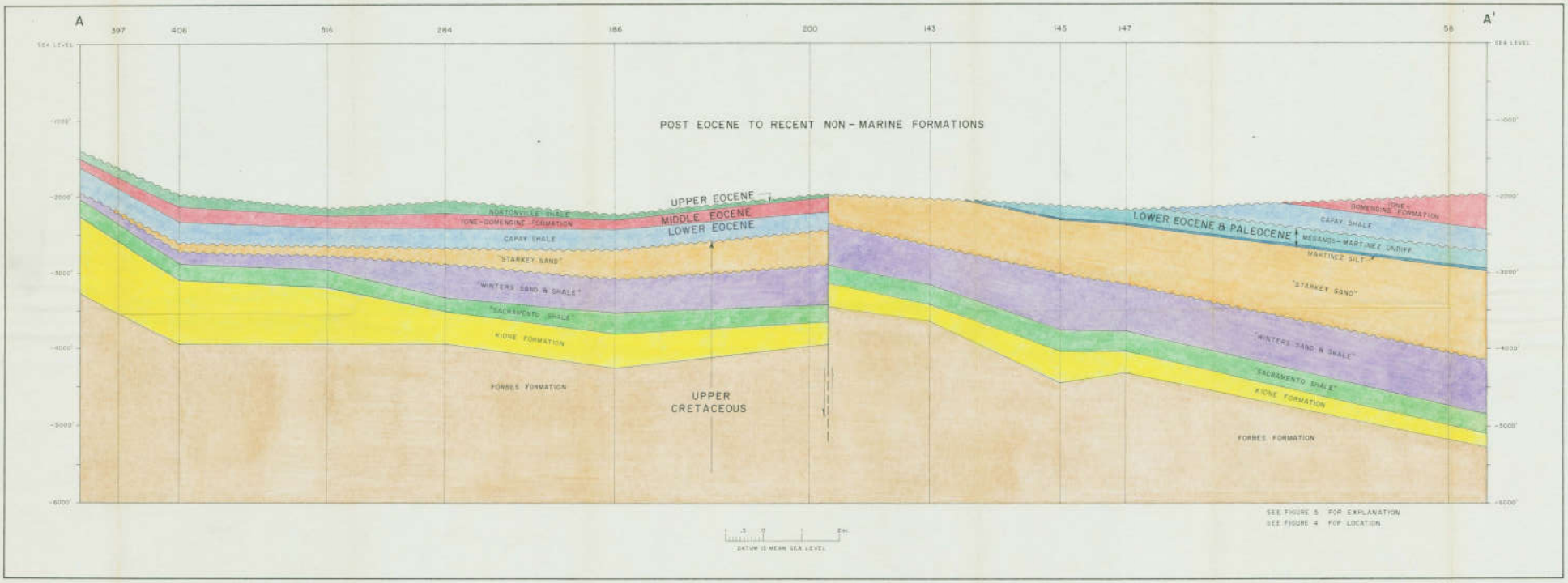

FIGURE 7

GEOLOGIC SECTION A-A', SUTTER BASIN, SACRAMENTO VALLEY, CALIFORNIA

CURTIN
THESIS, GEOLOGY 1971

From:	Ben King
To:	Mary Fahey; Gosselin, Paul
Cc:	Buck, Christina; Ben King
Subject:	Arsenic and Connate Sea Water Contamination around the Sutter Buttes
Date:	Monday, July 06, 2020 1:17:17 PM
Attachments:	Sutter_County_Final_GMP_20120319 (1).pdf Sutter County GMP Figures.pdf CA-Arsenic-Report.pdf

CAUTION: This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Hi Mary, Paul and Christina,

I wanted to follow up regarding my public comment on the last Butte Basin call. As mentioned in my call, my concern is that the connate seawater under the Sutter Buttes is contaminating groundwater and drinking water quality.

I have previously sent the SWCB Bulletin No. 6 from 1952 and the PHD Paper by George Curtin from 1971. Bulletin No. 6 reported that pumping depressions were drawing salt brines to the surface causing groundwater contamination. Curtin's paper proposes that the connate seawater is moving laterally through faults around the Buttes and researched several hundred gas well logs to express this opinion.

According to the Sutter County GMP on Page 23 "The Sutter Buttes Rampart consists largely of gravel, sand, silt and clay sediments which were deposited circumferentially around the Buttes as a geologic apron. These sediments may extend up to 15 miles north and west beyond the Sacramento River. " On Page 32 the GMP addresses the arsenic contamination issue - "… recent data analysis suggest a possible correlation between elevated arsenic concentrations and the presence of volcaniclastic material of the Sutter Buttes Rampart formation." Since the Colusa and Butter Basins are within the 15 mile circumference of the Sutter Buttes this would impact the analysis for Lower Water Quality and potentially Seawater Intrusion SGMA Sustainability metrics. I am mentioning the Seawater Intrusion metric because of the hydraulic components of pumping depressions and the physics of natural occurring contaminants moving laterally from higher elevations to lower elevations in combination of the force of pulling water to the surface by the operation of groundwater wells.

You will see the elevated EC levels and arsenic levels in the GMP Figures attachments. On Figure 19, there was an observation at T15NR3E of arsenic at 350 ppm and an EC of 1126. To the south at 14NR2E the observation of arsenic at 370 ppm and an EC of 1400. Since this study was focused on Sutter County there were not observations for Colusa County and Butter County. For Colusa County – the attached report regarding Arsenic contamination in public drinking water systems has the Grimes water district at 23.9 ppm which is the worse levels of toxicity of any public system in the Sacramento Valley. To the northwest of the Buttes there is a USGS Gamma well ESAC 21 which seems to be located in the Colusa County portion of the Butte Basic which has an arsenic reading of 80 ppm. Finally ESAC 11 which is due north of the Buttes and appears to be located in Grey Lodge

has an arsenic level of 70.

I can also note that the EPA assessment of the wastewater treatment facility for Yuba City reported that the high levels of arsenic in the wastewater was apparently from the portion of the Yuba infrastructure. Since most of the source of the water for Yuba City is surface water from the Feather River the arsenic contamination is pronounced where ground water is used. Finally as I mentioned in the past you probably are aware that the EPA has entered into an mitigation agreement with Sutter County regarding the arsenic contamination at Robbins. As you know Robins is at lower elevation and due south of the Buttes which would explain the contamination so far away from the Buttes. Robbins arsenic levels are less than the levels observed at Grimes.

I will send the Yuba City EPA report and the USGS Gamma documents next.

My suggestion would be to pick up where the SWRCB left off in 1952 and examine salt water and arsenic levels within a 15 mile circumference around the Buttes and set up a monitoring network to monitor changes in ground water quality going forward. This would not only focus on the southern part of the Buttes but within the whole circumference.

Thank you for your time and consideration.

Best Regards,

Ben

From:	Ben King
To:	Mary Fahey; Gosselin, Paul; Buck, Christina
Cc:	Ben King
Subject:	Arsenic Attachments Part II
Date:	Monday, July 06, 2020 1:38:28 PM
Attachments:	USGS Water Quality.pdf EPA Arsenic yuba_city_2004-05-28_inspection.pdf

CAUTION: This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Hi Mary, Paul and Christina

The 2006 USGS Study presents the observations wells on Figure 3 – Page . I have attached a photo of the link to the USGS GAMMA website sorting for Arsenic. I have also include USGS Laux Road which is ESAC 21 and USGS Gray Lodge which is ESAC 11. On the website you can see the actual locations on the satellite imagery.

The 2004 EPA assessment for the Yuba City Sewage infrastructure addresses the arsenic issue on Page 10. It ascribes more than half of the arsenic contamination to groundwater.

Thanks again for your time and consideration

Best Regards,

Ben

ARSENIC IN CALIFORNIA DRINKING WATER

Three Years After EPA Notice of Noncompliance to State, Arsenic Levels Still Unsafe in Drinking Water for 55,000 Californians



ENVIRONMENTAL INTEGRITY PROJECT

SEPTEMBER, 2016

ACKNOWLEDGEMENTS

This report was researched and written by Tom Pelton, Courtney Bernhardt, and Eric Schaeffer of the Environmental Integrity Project. The map was created by Kira Burkhart and the graphics by Alana Natke.

THE ENVIRONMENTAL INTEGRITY PROJECT

The Environmental Integrity Project (http://www.environmentalintegrity.org) is a nonpartisan, nonprofit organization established in March of 2002 by former EPA enforcement attorneys to advocate for effective enforcement of environmental laws. EIP has three goals: 1) to provide objective analyses of how the failure to enforce or implement environmental laws increases pollution and affects public health; 2) to hold federal and state agencies, as well as individual corporations, accountable for failing to enforce or comply with environmental laws; and 3) to help local communities obtain the protection of environmental laws.

For questions about this report, please contact EIP Director of Communications
Tom Pelton at (202) 888-2703 or
tpelton@environmentalintegrity.org.

PHOTO CREDITS

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Arsenic in California Drinking Water

More than three years after the U.S. Environmental Protection Agency found California in noncompliance with the federal Safe Drinking Water Act, 95 community water systems in the state, serving more than 55,000 people, are still providing water with illegal levels of arsenic, according to an examination of state data for the last two years.[1] Arsenic occurs naturally in the soil and groundwater in parts of California and is a known carcinogen that may also damage the developing brains of children and cause other health problems.[2] Many of the people drinking excessive levels of arsenic are poor and/or Latino or African-American, with a cluster in the San Joaquin Valley.[3] Nearly all have been exposed to excessive arsenic levels for at least five years and probably longer.[4]

California requires public water systems to notify their customers when arsenic fails to meet federal health standards. But strangely, the state's language for mailed advisories suggests the water is still safe to drink no matter how high the contimation levels or how long they persist, with the notices telling residents: "You do not need to use an alternative water supply (e.g., bottled water)." [5] That advice conflics with what California tells private well owners (who aren't covered by federal standards) on a state website: "If you suspect that your well may have arsenic, you should not use the water until it is tested, and you take appropriate measures to protect yourself and your family from potential chronic health effects if arsenic is present."[6] Whatever the intention, California's language for people on public water systems is likely to encourage them to drink contaminated water. (For the full text of the California's language, see Appendix A). As the state continues a multi-year effort to solve the contamination problem, it should immediately fix a communications problem so that it clearly warns people not to drink arsenic-tainted tap water.

The highest levels of arsenic in drinking water in California from 2011 through 2015 were in a group home for troubled teenage boys, the Valley Teen Ranch in Madera County. About 50 boys assigned by the courts to the facility have been living in a home with water that has arsenic at concentrations averaging more than 12 times the federal limit (10 parts per billion, or ppb) over these five years, according to state records.[7] "Nobody wants to drink the water because it's brown and nasty,"said Connie R. Clendenan, CEO of the nonprofit organization that runs the group home.[8] "It looks bad."



It is bad. Although California has made substantial progress in addressing

drinking water problems, the state still has 13 school districts, serving a total of 8,822 students, with arsenic in their drinking water that exceeded the federal limit from 2011 to 2015.[9] Twelve mobile home parks in California, serving 889 people, had arsenic in their tap water that averaged up to five times the legal limit. The average annual concentrations of arsenic in the drinking water of 58 residential communities (other than trailer parks) exceeded the legal limit during this time period, as did a military base, three wineries, two food preparation businesses and two campgrounds.

In many of the schools, the group home and military base, administrators say they verbally warn people not to drink tap water. They also provide bottled water as an alternative. But in the residential neighborhoods and trailer parks, it is not clear what warning – if any -- people are receiving. "There is no warning not to drink it. There is no 'non-drink' order out there," said Robert Johnson, President of the Shaver Lake Point 2 Mutual Water Company, which supplies 210 homes in Fresno County with tap water that has seven times the legal limit of arsenic. When asked if these residents should drink bottled water instead of his arsenic-tainted tap water, Johnson said: "It's one of those things, if you want to do it, that's your deal. It's not being recommended. We're not suggesting it. This is per the state of California. We are following their guidance."

The drinking water crisis in Flint, Michigan, was a reminder of how important it is for state governments to issue clear warnings to people with unhealthy tap water. California's mixed message is nearly identical to the one issued by Texas to homeowners with illegal levels of arsenic in their drinking water. Texas also tells consumers with excessive levels of arsenic: "You do not need an alternative water supply."[10] Many other states, however, are more direct in warning people not to drink water with excessive amounts of arsenic, at least for private well owners. Wisconsin, Michigan, Maine, and Washington, for example, simply tell residents not to consume water with more than 10 ppb arsenic (a health standard set by EPA in 2001). Wisconsin advises private well owners: "If your arsenic level is more than 10 ppb, the Wisconsin Department of Health Services recommends that you stop using your water for drinking or food preparation."[11] Florida advises its consumers to avoid water where arsenic contamination persists.[12] The U.S. Department of Health and Human Services makes similar recommendations.[13] If anything, the most recent science suggests that the current 10 ppb arsenic standard is not protective enough and that the IQ of children may be damaged at much lower exposures.[14]

In the wake of a 2013 EPA notice of noncompliance to California over its failure to invest enough money in its drinking water systems, the state has taken several important steps to fix its problems. Over the last three years, the state has more than doubled the amount of funding to build water treatment plants, pipelines, and new wells. The state and counties have filed compliance orders with local utilities to push them to upgrade their systems and are directing small, underfunded water systems to merge with larger utilities. Because of these measures, EPA announced in May 2016 that California was back in compliance with the federal Safe Drinking Water Act.

But in fact, the work is far from done – as witnessed by the 55,985 people in 95 communities across California who still have illegal levels of the carcinogen in their tap water, according to state records.[15] Why the delays? Local officials say that in some cases, bureaucratic

negotiations are holding up projects, which are sometimes stalled because of conflicts between county and state rules. In other cases, local water districts struggle with indecision or a lack of money.

Until these important water system improvements are complete, California and EPA must do a better job of warning consumers to stop drinking water that fails federal health standards. This report recommends:

- California and EPA should revise their regulations and guidance to require that local utilities warn people to stop drinking or cooking with water that fails to meet federal arsenic standards (10 ppb), especially when the contamination persists over several years. The advice should be sensitive to the additional risks posed when children and other sensitive populations drink contaminated water. If there is no reason for consumers to take precautions, there is no reason for Safe Drinking Water Act standards in the first place.

- Public notices mailed to consumers should inform them of options for treating contaminated water at home, e.g., through filtration systems that have proven to be effective. Conversely, the public should be told what doesn't work. For example, boiling water will not reduce arsenic concentrations.

- Federal and state authorities should provide enough money to these 95 California communities to allow them to install water filtration systems or take other steps to eliminate contamination problems. Although the state has already boosted its funding, it still faces a projected $30 billion plus in needed capital improvement projects to help its inadequate systems provide safe drinking water trough 2026.[16]

The big picture is that stepped-up investment in crumbling public infrastructure is sorely needed across the U.S., and it should be regarded as a top priority for both Congress and California lawmakers. But the state also needs to improve its efforts to better inform consumers so people can protect their own health. California does not have to wait for EPA action to strengthen its warnings because the state is already empowered to act independently of EPA.

Public health advisories that are contradictory and confusing – as they are in California -- are as bad as no warnings at all, because they undermine action and weaken public confidence in government.

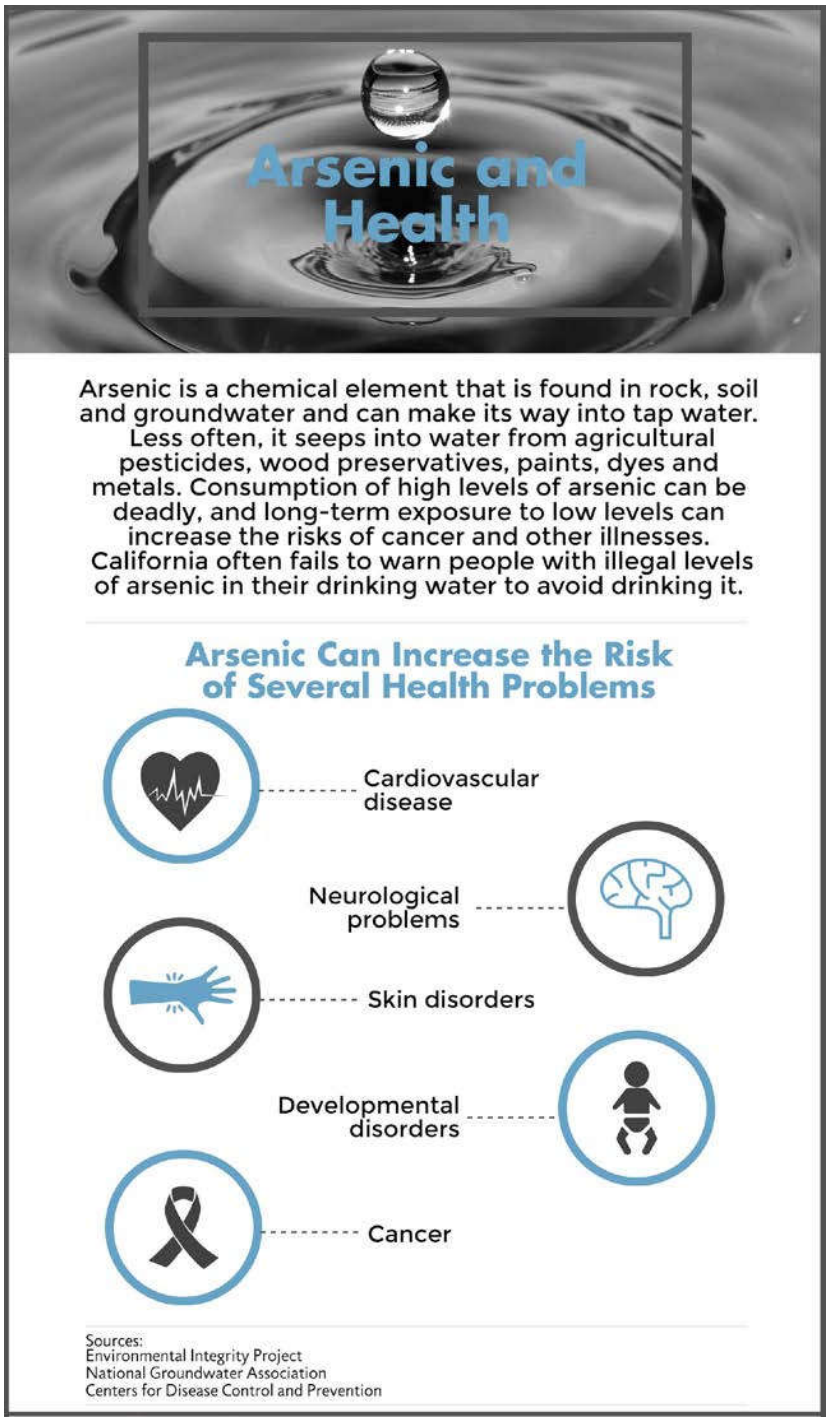
Table 1. Top 20 Arsenic Concentrations in California Public Water Systems

Water System (in Order of Arsenic Levels)	County	Pop. Served	2014-2015 avg (ppb)	2011-2015 avg (ppb)
Lakeview Improvement Association #1	Fresno	160	86.88	86.88*
Fountain Trailer Park Water	Kern	68	85.75	83.90
Hungry Gulch Water System	Kern	33	72.56	70.04
Corral De Tierra Estates WC	Monterey	45	72.50	78.40
Keeler Community Service District	Inyo	50	71.25	75.63
Quail Valley Water District- Eastside System	Kern	60	70.06	69.11
CSA 70 W-4 Pioneertown	San Bernardino	625	64.52	61.55
MD #06 Lake Shore Park	Madera	130	64.25	71.94
Valley Teen Ranch	Madera	50	62.00	120.80
Sierra East Mobile Home Community	Mono	50	54.63	47.03*
Shaver Lake Point #2	Fresno	210	52.31	42.88*
Winterhaven Mobile Estates	Los Angeles	40	52.13	53.35
Olam Spices And Vegetables Inc.	Kings	75	48.38	46.70
The Village Mobile Home Park	Los Angeles	70	45.05	47.04
Callier Water System	San Bernardino	1000	42.13	49.21*
Black Stallion Winery	Napa	25	41.75*	41.75*
Ironwood Camp	San Bernardino	1000	38.38	38.55
Boron CSD	Kern	2500	38.07	37.98
Edgewater Mobile Home Park	Sacramento	40	38.00	37.59
Prunedale MWC	Monterey	252	35.7	32.0

Note: The federal limit for arsenic is 10 ppb. * Average concentrations do not include concentrations from every year. For example, Lakeview Improvement Assn. #1 changed from a non-community water system to a community water system in 2013, and sampling data was only available from 2014 and 2015. Sampling results for Black Stallion Winery were only available for 2015. See Appendix B for annual concentrations in all systems that averaged above 10 ppb.

Health Risks Posed by Arsenic

Arsenic is a chemical element that occurs naturally in geological formations in California and elsewhere, and is also used in a variety of industrial products, including pesticides, paint, and wood preservatives.[17] It is a well-known poison at high doses. At lower doses, researchers have concluded it can cause cancers of the lung, kidney, bladder, skin, and other



organs with prolonged exposure. Any level of exposure, however, carries some risk.[18] According to EPA, the risk of developing cancer after drinking water containing 10 ppb arsenic over a lifetime is 1 in 2,000.[19] This level of risk is almost never 'acceptable' from a regulatory perspective. The agency usually tries to limit lifetime cancer risk to no more than 1 in 10,000, at most. EPA's risk estimate assumes that the cancer risk is linear, meaning if water contains 20 ppb arsenic, those who drink it over a long period of time have a 1 in 1,000 chance of developing cancer. People exposed over shorter periods of time have lower risks, but exposure during childhood may have a greater impact than exposure during adulthood.[20]

Morever, these risk calculations reflected the old thinking. New evidence suggests that the actual cancer risk may be much higher. EPA is currently revising its assessment of cancer risks from arsenic to incorporate more recent science. A 2010 draft of the assessment indicated that the risk of getting cancer from drinking water containing 10 ppb of arsenic is closer to 1 in 136, more than 17 times higher than current assumptions.[21] In addition to causing cancer, arsenic is also a neurotoxin that can harm developing brains at levels at or below the allowable limit.[22] One recent study in Maine, for example, found significant reductions in IQ and other problems in children exposed to arsenic concentrations of 5 to 10 ppb.[23] Specifically, children in homes with more than 5 ppb arsenic in the tap water tested roughly 6 points lower on a full-scale IQ test.[24] While EPA's

Scientific Advisory Board and the most recent studies suggest that the 'safe' level of arsenic is likely much lower than 10 ppb, any concentration higher than 10 is clearly unsafe.

Background on California's Problem

On April 19, 2013, EPA sent a letter to the California Department of Public Health notifying the state that it was out of compliance with the federal Safe Drinking Water Act.[25] The reason was that California's drinking water system was inadequate – providing contaminated water in many poor, rural communities – and the state was not investing enough money to fix the problem. A state investigation that year revealed that 680 community water systems serving 21 million people relied on groundwater that was compromised by one or more contaminants, with the most common being arsenic.[26]

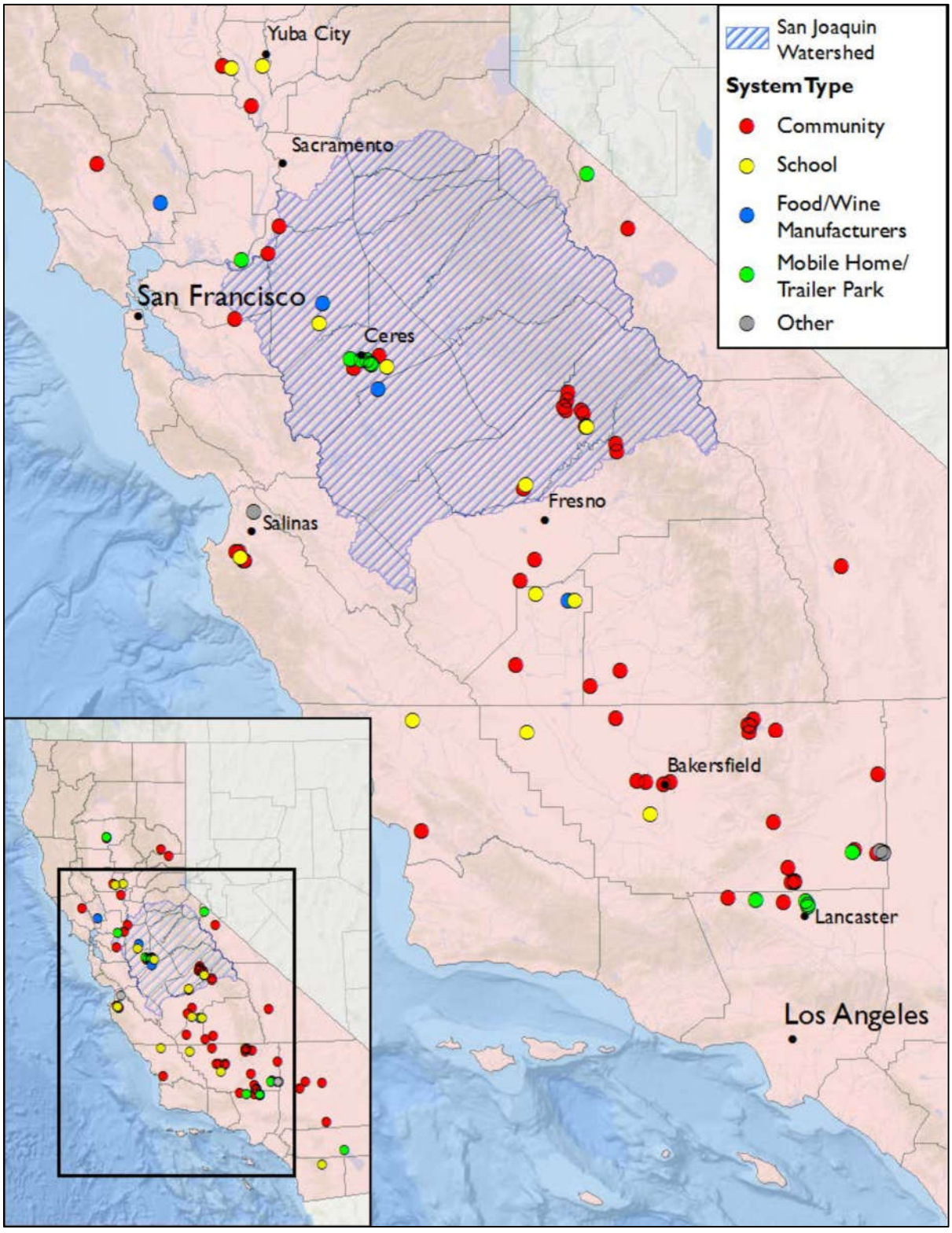
Not all of these 680 water systems provided tap water that had levels of contaminants in excess of federal health standards. In most wealthier and urban communities, the local water utilities treated the groundwater or diluted it with clean water from other wells so that it met the requirements of the federal Safe Drinking Water Act. But in 265 of these communities – often with small populations in rural, isolated areas – the tap water provided to customers had at least one violation of federal standards from 2002 to 2010 for a variety of contaminants, including nitrates from farm fertilizer, according to a 2013 report by the California Department of Health.[27]

In a separate study, researchers at the University of California, Berkeley, examined 464 community water systems serving 1.1 million people in California's San Joaquin Valley, one of the poorest regions in the state, and found that 15 percent of the systems and 14 percent of the people had tap water with arsenic above the federal limit.[28] Of the people exposed, 61 percent were either Latino or African-American. "Community water systems serving higher percentages of people of color had a 260 percent higher chance of having at least one (arsenic) violation," researcher Dr. Carolina L. Balazs and colleagues wrote.[29]

In response to the chronic drinking water problem, Congress had approved $1.5 billion to California over a decade to upgrade its water systems through a program called the Safe Drinking Water State Revolving Fund.[30] Yet because of bureaucratic obstacles and inefficiencies, the state by 2013 had not spent $455 million of those funds – the largest unspent balance of any state. According to EPA's 2013 letter of noncompliance to the California Department of Health, this violated a federal requirement that the state "make *timely* loan or grants using *all available* drinking water funds."[31]

EPA ordered the state to accelerate its efforts to fix public water systems. California Governor Jerry Brown's administration took action in several steps. These included switching control of the state's drinking water program from the Department of Health (where policy focus was dispersed among numerous problems, including drug abuse and AIDS), to the California State Water Resources Control Board (whose only focus is water) under the California Environmental Protection Agency. Since the EPA issued its

Map 1. Public Water Systems with Illegal Levels of Arsenic, 2014-2015



2013 letter of noncompliance, the state has more than doubled the amount of money it is distributing for water system upgrade projects, to an average of $738 million per year, compared to $366 million per year in the period of 2008 to 2012.[32] The unspent balance in the drinking water fund dropped to about $100 million.[33] As a result, EPA in May 2016 decided that California's system was back in compliance.[34]

Recent Analysis of California Records

The problem, however, is still far from fixed. An examination of California's online records by the Environmental Integrity Project (EIP) in May 2016 revealed that there were still 95 community water systems in the state, serving 55,985 people, providing drinking water with levels of arsenic that exceed the federal standard of 10 ppb in 2014 and 2015, according to two-year averages over those years. [35]

Over a longer period of time, 2011 through 2015, state records show 70 systems serving 46,772 residents, that each year have averaged higher than the limit in the Safe Drinking Water Act. These do not include homes on individual private wells, which are not covered by the federal Safe Drinking Water Act.

For a detailed discussion of the methods used to arrive at these numbers, please see Appendix C.

Examples of Drinking Water Contamination

Some of the worst water in community systems in California can be found in the Lakeview Community Association, which serves 160 residents in Shaver Lake (northeast of Fresno, in Fresno County). This community had an average arsenic concentration of nearly nine times the federal limit – 87 ppb – in 2014 and 2015, according to state data.[36]

Four water systems in the unincorporated community of Boron, in San Bernardino County, provided water to about 5,200 residents that had at least three times the safe limit of arsenic in 2014 and 2015.[37] In the city of Keyes in Stanislaus County, 4,891 people have tap water with arsenic concentrations that averaged above the federal limit each year for the last five years. The Pixley Public Utilities District, serving 3,310 residents, had arsenic levels in its drinking water that averaged 50 percent higher than health standards in 2011-2014.

Twelve school districts, serving a combined total of 5,462 students, had arsenic levels that averaged from 30 percent higher to three times the federal limit over the last five years. (See Table 4. Some of these school districts provided explanations, which will be discussed on pages 15 and 16 of this report).

Across California, there were 12 mobile home parks serving 889 people that had average arsenic levels ranging from 20 percent over legal limits to five times the federal standards from 2011 through 2015.[38]

Table 2: Top 10 Mobile Home Parks for Arsenic Contamination

Water System	County	People Served	2014-2015 Avg. (ppb)	2011-2015 Avg. (ppb)
Fountain Trailer Park Water	Kern	68	85.8	83.9
Sierra East Mobile Home Community	Mono	50	54.6	47.0*
Winterhaven Mobile Estates	Los Angeles	40	52.1	53.4
The Village Mobile Home Park	Los Angeles	70	45.1	47.0
Edgewater Mobile Home Park	Sacramento	40	38.0	37.6
Mitchell's Avenue E Mobile Home Park	Los Angeles	26	21.3	21.0
Millstream Mobile Home Park	Tehama	80	20.5	20.0
Country Western Mobile Home Park	Stanislaus	120	20.4	22.2
Saint Anthony Trailer Park	Riverside	300	19.7	21.5
New Orchard Mobile Home Park LLC	Tehama	125	19.6	19.0

Note: federal limit is 10 ppb arsenic. The 2011-2015 average for Sierra East Mobile Home Community reflects fewer than 5 years.

Response from California Officials

The Environmental Integrity Project asked the California State Water Resources Control Board why so many people are still exposed to contaminated drinking water after the state supposedly returned its system to compliance. Officials at the state agency replied in an interview and emails that they had issued orders to nearly all of the local utilities to fix the arsenic problem, but that some local government still need more time to upgrade their systems. In some cases, local utilities are building water filtration systems to remove arsenic, or digging new wells in an effort to extract cleaner water.

"The State Water Board Division of Drinking Water is working with each of these communities to return them to compliance," said Cindy Forbes, Deputy Director of the Division of Drinking Water at the Water Resources Board.[39] "District Office staff are working with these communities to evaluate alternative solutions, including new treatment options, new wells or modification of existing wells, and in some instances consolidation with larger water systems that can provide drinking water that meets all standards. The State Water Board is also helping communities that are struggling financially to reach compliance by offering financial assistance to solutions through low-interest loans and grants."

Public Notification of Drinking Water Violations

As the work continues to upgrade the drinking water systems, however, many citizens of California have not been given warnings to avoid drinking contaminated water.

The background is this: As part of the federal Safe Drinking Water Act, local water utilities are required to periodically test public drinking water systems that serve at least 25 people. When those results show more than 10 ppb arsenic (a standard imposed by EPA in 2001), the utilities must notify residents of the violation in writing by mail "as soon as practical, but within 30 days."[40] In California, however, the warning notices provide a mixed message, stating: "Our water system recently violated a drinking water standard," but also, "you do not need to use an alternative water supply (e.g., bottled water). This is not an emergency…. However, some people who drink water containing arsenic in excess of the (federal limit) over many years may experience skin damage or circulatory system problems, and may have an increased risk to getting cancer."[41] (For the full text of California's notice template for local utilities to use, see Appendix A)

This advisory says two contradictory things: Warning, you have a problem with your water. But don't worry – keep drinking it. If consumers are being told to ignore the federal health standards and keep drinking the contaminated water, there is no reason for the federal Safe Drinking Water standards for arsenic to exist. As stated previously in this report, California is much more clear about warning private well owners to "protect yourself and your family" from arsenic-tainted tap water. And other states – including Wisconsin, Michigan, Maine, and Washington – bluntly advise people not to drink private well water with more than 10 ppb arsenic.

In addition to receiving advisories about violations when they occur, customers also receive annual reports from their local water utilities called "Consumer Confidence Reports." These reports list the levels of more than a dozen different potential contaminants, including bacteria, lead, copper, nitrates and arsenic. When arsenic levels exceed the limit of 10 ppb, these reports provide the numbers and say: "Some people who drink water containing arsenic in excess of the MCL (maximum contaminant level) over many years may experience skin damage or circulatory system problems, and may have an increased risk of getting cancer."[42] But the reports do not tell consumers to stop drinking water with excessive levels of arsenic, and instead hint that it might not be a problem, saying: "Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants."

We asked the California State Water Resources Control Board why the agency doesn't tell people to avoid drinking water with illegal levels of arsenic. In response, Forbes, the deputy director for water, said that the state does provide this kind of blunt and immediate warning for other contaminants that can make consumers sick immediately, such as fecal bacteria. But for arsenic, she said, the threat is more long term. "Arsenic is categorized as a chronic contaminant that poses possible health risks after long-term exposure – 70-plus years of drinking two liters of arsenic-contaminated water a day above the maximum contaminant level," Forbes said. "There are no known acute/immediate health effects that would cause consumers to immediately stop drinking the water."

This answer, however, ignores the fact that many of these California residents have been drinking arsenic-contaminated water for decades. For example, Drs. Carolina Balazs and Isha Ray in 2014 published a study in the American Journal of Public Health in which they interviewed residents with contaminated tap water and found that the current notification requirements are poorly serving people with long-term exposure to pollutants.[43] "A resident from the community of Cutler explained that for years she had received Consumer Confidence Reports indicating that dibromochloropropane levels in the water exceeded the MCL (maximum contaminant level)," Balazs and Ray wrote. "These reports noted that residents should not worry because health impacts were not based on immediate exposure, but rather on lifetime exposure... She had lived in her community for nearly 30 years—so, she asked, should she worry or not? In these situations, water systems simply leave residents to cope with contaminated drinking water as best they can….In these instances, Safe Drinking Water Act regulations ultimately fail the (low-income) household."[44]

California's records identify more than 46,772 people whose tap water has had average levels of arsenic that have exceeded the federal standards for at least five years, from 2011 to 2015. But there is no reason to believe that these people received cleaner water before this. The longer a person drinks water contaminated with excessive levels of arsenic, the higher the increased risk of cancer. In much the same way, smoking a single cigarette is not an immediate health threat, in that it will instantly kill a person. But the longer a person smokes, the worse the health threat. For this reason, California would better protect public health if it told people to stop drinking arsenic-tainted water now, just as health warnings on tobacco required by the U.S. Food and Drug Administration advise, "WARNING: Quitting smoking now greatly reduces serious risks to your health." These advisories do not state, "WARNING: You do not need to change your smoking habits."

Evolution of the Science on Arsenic

One reason for stronger warning language is that scientific research continues to show that arsenic causes health problems – including brain damage in children -- at lower levels than previously thought.

The history of EPA's arsenic rule reflects the continuing evolution of scientific knowledge about the harms that even low levels of the element can cause. Back in 1996, Congress amended the Safe Drinking Water Act and directed EPA to establish new limits for arsenic to replace the old standard of 50 ppb. Based on the best available research, EPA proposed a limit of 5 ppb in 2000. Because arsenic is a carcinogen, some public health experts consider any level above zero to pose some risk. EPA then revised its proposal, based in part on cost considerations, and finalized a new arsenic standard of 10 ppb in 2001.

The EPA Administrator at the time, Christine Todd Whitman, explained that "the 10 ppb protects public health based on the best available science and ensures that the cost of the standard is achievable."[45] The new regulations required that public water systems across the U.S. meet the new standard by January 23, 2006.[46] The law allowed states to grant exemptions until January 23, 2015, for some small community water systems that had trouble complying.[47]

The 2014 Maine study discussed earlier in this report found found significant reductions in IQ in children exposed to arsenic concentrations of 5 to 10 ppb.[48] With this new information, EPA should change its own guidance for notification language so that people – especially parents of young children -- receive a clearer warning not to drink contaminated water. A template for warning language on the federal agency's website for drinking water systems with chemical contaminants such as arsenic advises utilities to tell their customers: "Some people who drink water containing arsenic in excess of the MCL (maxiumum contaminant level) over many years may have an increased risk of getting cancer." But the notices also say: "There is nothing you need to do….If you have specific health concerns, consult your doctor."[49] This is a problem, because many lower-income people do not have doctors with whom they can regularly consult about questions like water quality.

Responses from Local Drinking Water Systems

When asked about their drinking water violations by EIP, some of the utilities in California with illegal levels of arsenic replied that their attempts to fix the problem have been hindered by bureaucratic obstacles at the local level. Others indicated they are taking steps to solve the problem, but simply need more time or money. Not all public systems were contacted by EIP or provided answers.

Table 3. Top 10 Residential Water Systems for Arsenic Contamination (Excluding Mobile Home Parks)

System	County	Population Served	2014-2015 avg (ppb)	2011-2015 avg. (ppb)
Lakeview Improvement Association #1	Fresno	160	86.9	86.9*
Corral De Tierra Estates WC	Monterey	45	72.5	78.4
Keeler Community Service District	Inyo	50	71.3	75.6
Quail Valley Water District-Eastside System	Kern	60	70.1	69.1
MD #06 Lake Shore Park	Madera	130	64.3	71.9
Valley Teen Ranch	Madera	50	62.0	120.8
Shaver Lake Point #2	Fresno	210	52.3	42.9
Boron Community Service District	Kern	2500	38.1	38.0
Monterey Park Tract Comm. Service District	Stanislaus	186	31.9	34.3
North Edwards Water District	Kern	600	31.5	31.6

Note: The federal limit is 10 ppb arsenic. Lakeview had fewer than five years of data available.

At the **Lakeview Improvement Association** in Fresno County, 160 people have been receiving drinking water with more than eight times the legal limit of arsenic on average for

at least the last five years, according to state data. State records show that on May 16, 2016, the California Water Resources Control Board issued a citation to the association's water system, imposing a fine of $1,000 for its failure to follow the directives of two earlier compliance orders, in 2014 and 2015. "The water system continues to violate the arsenic maximum contaminant level (MCL) and does not appear to be making progress toward the compliance deadline," says the most recent letter from the state. "Additionally, the water system has failed to routinely conduct the public notification of the arsenic MCL violation, as required."

Philip Dutton, an engineer for surrounding Fresno County, said that the Lakeview Association's plan, as expressed verbally, is to test some in-home water filtration systems and see how well they perform.[50] "They've got a few of these (filtration systems) installed in homes, but they are sampling from different technologies to try and identify what is going to be the best long-term alternative," Dutton said. The California State Water Resources Control Board's website already lists which types of filtration technologies work well to remove arsenic.[51]

In **Kettleman City**, in Kings County, 1,450 residents have had tap water with excessive levels of arsenic for decades. The average from 2011 to 2015 was 20 percent above the legal limit, according to state data. "I have a daughter, a little one, who's still brushing her teeth with contaminated water, taking a bath in contaminated water," said Maricela Mares-Alatorre, a city resident, during a recent public hearing of the state water board.[52] The Kettleman City Community Services District has promised local residents that it will build a $9 million water treatment plant, but the project has been repeatedly delayed – with a target to open in the fall of 2016 recently pushed back to 2018.[53]

At the **Corral De Tierra Estates** subdivision in Monterey County, 45 people have been exposed to drinking water with arsenic levels almost eight times the legal limit from at least 2011 through 2016, state records indicate. This small water system has received 10 violations notices from the state for excessive levels of arsenic over the last decade, with the most recent in the first quarter of 2016, when it had 77 ppb of the contaminant (compared to the 10 ppb limit).

The manager of Monterey County's drinking water program, Cheryl Sandoval, said Corral De Tierra Estates is among at least five privately-owned water systems that have been issued corrective orders by the county because they are in violation of the arsenic standard. Solving the problem is taking longer than expected, Sandoval said, and some of the local water utilities are still debating the best path forward. "Dealing with the problem is very complicated," Sandoval said.[54] "They haven't made a lot of progress toward compliance, but they are going to have to." One challenge is that a water treatment plant for even a small system can cost hundreds of thousands of dollars and cause new waste disposal problems, because the plants produce concentrated arsenic sludge that must be handled carefully as a hazardous material. Corral De Tierra Estates and other subdivisions want to try in-home water treatment systems as a systemic solution, but county rules don't allow that, Sandoval said. However, debate over this in-home option continues, because new state regulations may open the door for in-home filtration as a systemic solution in the future.

Meanwhile, as the bureaucratic discussions continue, residents are receiving confusing advice about whether they should drink the water pouring from their taps with illegal levels of arsenic. One recent report from Corral de Tierra Estates to local water consumers, displayed on the state website and sent to homeowners in July 2014, advised people that arsenic levels were eight times above the legal limit.[55] But that fact was buried in the middle of a dense report with lots of numbers that also gave the impression that the exceedance was not a problem. The report told homeowners: "The presence of contaminants does not necessarily indicate that the water poses a health risk."[56]

At the **Quail Valley Water District-Eastside System** in Kern County, 60 residents have been receiving drinking water with seven times the legal limit of arsenic over the last five years, state records show. In April 2015, the state issued a compliance order to the local utility and mandated that it fix the problem by April 2018.

Randy Hardenbrook, Director of the Quail Valley Water District, said the problem should be solved within the next two years because a $5.8 million grant from the state is allowing the district to build a new pipeline. The pipe will be about 8.5 miles long and will connect a part of the system with arsenic-tainted water to a well that has good water.[57] In the interim, local residents receive quarterly letters with data on the arsenic exceedances but are not being provided with bottled water. More importantly, they are not being told to refrain from consuming the contaminated water. "We're not telling them not to drink it," Hardenbrook said, "but we are telling them there are long-term health effects."[58]

At the **Shaver Lake Point #2** subdivision in Fresno County, 210 people have been receiving tap water with more than four times legal levels of arsenic for at least the last five years, according to state data. In January 2015, the state wrote to the water system's administrators and ordered them to come into compliance with the federal and state arsenic limits by December 31, 2016.

With only four months left until the deadline, the arsenic levels remain illegally high and Robert Johnson, President of the Shaver Lake Point Mutual Water Company, said he is still thinking about what to do about the problem.[59] "Currently, it's being researched. We have engineers involved. We have water experts involved, and we are trying to figure it out," Johnson said. He added that building a water filtration system could cost as much as $250,000, so the subdivision is considering trying to blend water from its arsenic-tainted wells with cleaner water from different wells.

Meanwhile, nobody in the community is being warned to avoid the contaminated water. "There is no warning not to drink it. There is no 'non-drink' order out there," said Johnson.[60] When asked if his customers should drink bottled water as a precaution instead of the arsenic-tainted tap water, Johnson said: "It's one of those things, if you want to do it, that's your deal. It's not being recommended. We're not suggesting it. This is per the state of California."

Group Home for Troubled Children

The **Valley Teen Ranch**, a Christian residential treatment group home for 32 court-referred abused and neglected boys in Madera County, has arsenic in its tap water that averaged more than 12 times the federal limit from 2011 through 2015, according to state records.[61] "We've been out of compliance, but no children have gotten sick, no adults have gotten sick," said Connie R. Clendenan, CEO of the nonprofit organization that runs the group home. "Nobody wants to drink the water here because it's brown and nasty."[62]

About five years ago, the state approved a $5 million grant to help the group home solve the problem by linking its small water system to a larger one run by the county. But the work has not started yet. Because of ongoing negotiations at the county level, the fix could still be three years or more away, Clendanan said. Meanwhile, children are being given bottled water and are verbally warned not to drink tap water, although there are no warning signs posted above sinks.

"I want to get out of the water business. I'm in the kid business," Clendenan said. Of the continuing delays in fixing the problem with contaminated water, she said: "Nobody's mad. But it's government, and it takes a lot of time. It's just the stupid county."

Table 4. Schools with Excessive Arsenic in Drinking Water

System	County	Population Served	2014-2015 avg. (ppb)	2011-2015 avg. (ppb)
Kit Carson Elem. School	Kings	510	34.7	34.7*
Washington School WS	Monterey	250	26.1	27.7
MUSD-Nile Garden School	San Joaquin	804	20.9	22.8
Liberty High School	Madera	1340	17.9	20.5*
Island Union School	Kings	300	11.9	18.8
Winship Elementary School	Sutter	38	16.4	17.3*
Lakeside School	Kern	800	16.3	16.9
Barry Elementary School	Sutter	650	15.2	15.3
Pleasant Valley Elementary	San Luis Obispo	100	13.8	14.1
Gratton School	Stanislaus	110	13.5	13.5
North Fork Union School	Madera	350	12.9	12.4
Warner Unified School District	San Diego	250	10.9	11.4
Central Union Elementary	Kings	320	10.1	13.5

*Note: federal limit is10 ppb arsenic. *Indicates systems with monitoring gaps (less than five years available data)*

Arsenic in School Drinking Water

At the **Washington School in Salinas,** California, the tap water serving about 250 students has had almost three times the federal limit of arsenic for the last five years, 28 ppb on average over this time period, compared to the limit of 10 ppb.[63] School Principal Whitney Meyer said that the local school district has been discussing the problem for several years but does not yet have a solution. Meanwhile, students are given bottled water, she said.

"We remind them over and over that they cannot drink the water," Meyer said.[64] "Many of the students live out in this area and their homes are similarly impacted (with arsenic), so they also hear the message at home. We have drinking stations with clean water in every classroom, teaching space, and hallway. The fountains have all been shut down."

At the **Barry Elementary School in Yuba City**, California, the arsenic levels have averaged 50 percent above the federal limit for arsenic over the last five years. Because of the violations, the state issued a compliance order to the school in May 2015. Tom Butcher, Director of Maintenance and Facilities for the school system, said that the school has not yet solved the problem, but is giving bottled water to students as officials try to figure out a solution.[65] Adminstrators of the water system are discussing a consolidation with a larger neighboring system that has better water. "The (state) Water Board indicates a best case scenario of a consolidation in approximately 1.5 years," Butcher said. "Until the consolidation is completed (the school district) will continue to provide bottled drinking water."

At the **Kit Carson Elementary School**, in Hanford, Ca., arsenic levels in drinking water averaged more than three times the legal limit in 2011 through 2014, according to state records. In January 2015, the school solved the problem by connecting its pipes to the water system of the surrounding city,[66] whose arsenic levels are below the federal limits.

At the **Lakeside School in Bakersfield,** California, the arsenic levels in the drinking water averaged more than 70 percent above the federal limit for arsenic over the last five years, 17 ppb compared to the limit of 10 ppb. Ty Bryson, District Superintendent, said that the school notified all families by sending home notice letters with the students and by posting warnings in the office. "We provide bottled drinking water for students and staff," Bryson said. "We drilled an alternate well, but that also had unacceptable levels of contaminant. We are now pursuing an alternative source of drinking water by connecting to a local municipal water source via pipeline."

At the **Gratton School in Denair,** California, the drinking water system has had arsenic levels that averaged 40 percent above the federal limit for arsenic over the last five years, state records indicate. The school's superintendent, Shannon Sanford, said that students have been provided bottled water for the last two years. "Students were initially warned (not to drink the water) and signs were used until fountains were disabled," Sanford said. More recently, the school drilled a new well that will be used for the 2016-2017 school year that should solve the problem.

At the **Island Union School in Lemoore,** California, arsenic levels in the drinking water were nearly twice the federal limit from 2011 to 2015, averaging 18.8 ppb compared to

federal limit of 10 ppb, according to state records. Superintendent Charlotte Hines said the school dug a new well in 2015, and provided students and warnings and bottled water in the interim. "We know that bottled water is only a temporary solution," Hines said. "And in an effort to find a permanent solution, the school requested -- and was awarded -- state funding to drill a new well that would meet all primary drinking water standards."[67]

Military Base with Contaminated Water

At the **U.S. Army Base Fort Irwin** in San Bernardino County, 16,000 soldiers live in facilities that have had arsenic in some tap water at levels 50 percent higher than the federal limit from 2011 through 2015, state records indicate. For the last three years, the Army Corps of Engineers has been building a new $100 million water treatment plant at the base to solve the problem. The plant is now undergoing testing and is scheduled to go online in October 2016, base officials indicate.

"The new plant will treat all Fort Irwin water to comply with Safe Drinking Water act Standards for ALL pollutants of concern including …arsenic," said Muhammad A. Bari, Director Public Works at Fort Irwin.[68]

In the interim, soldiers have been provided with bottled water and warned which faucets to avoid, according to base managers.

Vineyards with High Arsenic Levels

In San Joaquin County, the **Delicato Family Vineyards** had arsenic levels in the tap water that averaged 18 ppb from 2011 through 2014, which was 80 percent higher than the federal limits, state records indicate. Kylie Barnett, a spokeswoman for the company, said that the vineyards worked with county officials in 2014 to build a new drinking water system, including by digging two new wells, which brought the arsenic levels down below the federal standard in 2015 and 2016.[69] "The drinking water is not used in production of our wine," Barnett noted. Before the repair, people working at the vineyards and visiting were provided bottled water, she said.

In Napa County, the **Larkmead Vineyards** had drinking water with six times more arsenic than allowed from 2011 through 2013, according to state records. No results were listed for 2014 or 2015, and it is unclear if the drinking water system, which serves 25 people, is used for workers or guests. (Wine making does not generally use tap water.) Emails sent to managers of the vineyard asking about the water were not returned. The researchers of this report also received no response from the **Black Stallion Winery** in Napa County, whose tap water had four times legal limits of arsenic from 2011 through 2015, according to state records.

Conclusion

California is making progress toward solving its drinking water contamination problem. The state has reorganized its drinking water agency, and increased its financial assistance to local utilities to build water treatment systems, dig new wells, and take other steps to resolve the issue. The work, however, is expected to take many more years. In the meantime, tens of thousands of people continue to be exposed to drinking water with illegal levels of arsenic, a carcinogen that could damage the developing brains of children and cause other health problems. And yet, the warnings that some of these residents receive from the government are contradictory and confusing.

Both California and the federal government need to do more to protect consumers, especially the young. This report recommends:

1) California and EPA should both revise the language for written notifications of violations of arsenic standards, so that people are clearly advised to stop drinking contaminated water. If the violations are in schools or group homes, warning signs should also be posted over all sinks and drinking fountains. The state should help provide bottled water as an interim solution.

2) Consumers should be provided more information through the mail about what works and what does not work to remove arsenic from tap water. Residents need to know, for example, that boiling water will not help, but that certain filtration systems can remove the carcinogen. In some cases, residents may need technical help from the state in understanding how to use filtration systems properly.

3) Both Congress and the state government should increase investments in upgrades to California's drinking water systems. This is not only an environmental justice issue, but also a sensible strategy to boost the local economy through the hiring of engineers, construction workers and others to improve local infrastructure.

Counter arguments made by California officials – that the state is already taking action, and that arsenic is not an immediate threat to public health – do not hold water. Although the state has issued enforcement orders to local utilities, some local officials clearly still need more prodding and money to upgrade their water systems. A growing amount of scientific research suggests that arsenic increases the risk of cancer and other diseases and may do so at a lower level than expressed in current federal regulations. Years more of exposure to arsenic-tainted water will only raise the risk of cancer or neurological damage for California residents.

The state and federal governments should advise people to stop drinking contaminated water immediately, just as public health experts urge smokers to change their habits sooner rather than later because it will increase their odds of survival.

With public health warnings, simple and direct is better than bureaucratic and complex, because safe is better than sorry when people's lives and minds are at risk.

APPENDIX A: California's Language for Public Notices about Arsenic Violations

IMPORTANT INFORMATION ABOUT YOUR DRINKING WATER

Este informe contiene información muy importante sobre su agua potable.
Tradúzcalo o hable con alguien que lo entienda bien.

[System] Has Levels of Arsenic Above the Drinking Water Standard

Our water system recently violated a drinking water standard. Although this is not an emergency, as our customers, you have a right to know what you should do, what happened, and what we are doing to correct this situation.

We routinely monitor for the presence of drinking water contaminants. Water sample results received on [date] showed arsenic levels of [level and units]. This is above the standard, or maximum contaminant level (MCL), of 0.010 milligrams per liter.

What should I do?

- **You do not need to use an alternative water supply (e.g., bottled water).**
- This is not an emergency. If it had been, you would have been notified immediately. However, *some people who drink water containing arsenic in excess of the MCL over many years may experience skin damage or circulatory system problems, and may have an increased risk to getting cancer.*
- If you have other health issues concerning the consumption of this water, you may wish to consult your doctor.

What happened? What is being done?

[Describe corrective action]. We anticipate resolving the problem within [estimated time frame].

For more information, please contact [name of contact] at [phone number] or [mailing address].

Please share this information with all the other people who drink this water, especially those who may not have received this notice directly (for example, people in apartments,

nursing homes, schools, and businesses). You can do this by posting this public notice in a public place or distributing copies by hand or mail.

Secondary Notification Requirements

Upon receipt of notification from a person operating a public water system, the following notification must be given within 10 days [Health and Safety Code Section 116450(g)]:

- SCHOOLS: Must notify school employees, students, and parents (if the students are minors).
- RESIDENTIAL RENTAL PROPERTY OWNERS OR MANAGERS (including nursing homes and care facilities): Must notify tenants.
- BUSINESS PROPERTY OWNERS, MANAGERS, OR OPERATORS: Must notify employees of businesses located on the property.

This notice is being sent to you by [system].

State Water System ID#: _____. Date distributed: _____.

APPENDIX B: Listing of All California Public Drinking Water Systems with Arsenic Levels that Averaged Over the Federal Limit over the Last Five Years

System Name	County	Pop. Served	2014-2015 Avg (ppb)	2011-2015 Avg (ppb)	
Lakeview Improvement Association #1	Fresno	160	86.9	86.9	^
Fountain Trailer Park Water	Kern	68	85.8	83.9	*
Hungry Gulch Water System	Kern	33	72.6	70.0	*
Corral De Tierra Estates WC	Monterey	45	72.5	78.4	*
Keeler Community Service District	Inyo	50	71.3	75.6	*
Quail Valley Water District-Eastside System	Kern	60	70.1	69.1	*
CSA 70 W-4 Pioneertown	San Bernardino	625	64.5	61.6	*
MD #06 Lake Shore Park	Madera	130	64.3	71.9	*
Valley Teen Ranch	Madera	50	62.0	120.8	*
Sierra East Mobile Home Community	Mono	50	54.6	47.0	^
Shaver Lake Point #2	Fresno	210	52.3	42.9	^
Winterhaven Mobile Estates	Los Angeles	40	52.1	53.4	*
Olam Spices And Vegetables Inc.	Kings	75	48.4	46.7	*

System Name	County	Pop. Served	2014-2015 Avg (ppb)	2011-2015 Avg (ppb)	
The Village Mobile Home Park	Los Angeles	70	45.1	47.0	*
Callier Water System	San Bernardino	1000	42.1	49.2	^
Black Stallion Winery	Napa	25	41.8	41.8	^
Ironwood Camp	San Bernardino	1000	38.4	38.6	*
Boron CSD	Kern	2500	38.1	38.0	*
Edgewater Mobile Home Park	Sacramento	40	38.0	37.6	*
Prunedale MWC	Monterey	252	35.7	32.0	
Kit Carson Elem. School	Kings	510	34.7	34.7	^
Darr Water Co.	San Bernardino	1000	34.3	36.0	*
Monterey Park Tract Community Service District	Stanislaus	186	31.9	34.3	*
North Edwards WD	Kern	600	31.5	31.6	*
Desert Lake Community Service District	Kern	700	31.0	32.5	*
Locke Water Works Co [SWS]	Sacramento	80	29.5	29.1	*
Lucky 18 On Rosamond, LLC.	Kern	73	28.0	24.3	*
Washington School WS	Monterey	250	26.1	27.7	*
Rancho Marina	Sacramento	250	24.0	30.1	*
Colusa Co. WWD #1 - Grimes	Colusa	500	23.9	24.7	*
Bridgeport PUD	Mono	850	23.3	24.0	*
Country Hills Estates	San Luis Obispo	60	23.0	26.8	^
Doubletree Ranch Water System	Contra Costa	49	21.6	22.4	*
Mitchell's Avenue E Mobile Home Park	Los Angeles	26	21.3	21.0	*
Vista Del Toro WS	Monterey	87	21.0	20.4	*
MUSD-Nile Garden School	San Joaquin	804	20.9	22.8	*
Country Villa Apts.	Stanislaus	30	20.8	21.1	*
Millstream Mobile Home Park	Tehama	80	20.5	20.0	*
Country Western Mobile Home Park	Stanislaus	120	20.4	22.2	*
Saint Anthony Trailer Park	Riverside	300	19.7	21.5	*
New Orchard Mobile Home Park LLC	Tehama	125	19.6	19.0	*
MD #24 Teaford Meadow Lakes	Madera	150	19.0	12.5	
William Fisher Memorial Water Company	Kern	53	19.0	18.4	*
Ceres West Mobile Home Park	Stanislaus	161	18.9	18.0	*
Boulder Canyon Water Association	Kern	28	18.4	17.9	*
Lakeview Ranchos Mutual Water Company	Kern	120	18.1	22.4	*
Liberty High School	Madera	1340	17.9	20.5	^
Sutter Co. WWD #1 (Robbins)	Sutter	350	17.9	18.1	*
MD #42 Still Meadow	Madera	100	17.7	17.7	^
Maher Mutual Water Company	Kern	150	17.7	20.8	*
Cedar Valley Mutual Water Co.	Madera	137	17.6	18.6	^
First Mutual Water System	Kern	35	17.5	15.1	*
Sierra Co. W.W.D #1 Calpine	Sierra	225	17.0	14.1	*
Bar-Len MWC	San Bernardino	124	16.6	16.2	*

System Name	County	Pop. Served	2014-2015 Avg (ppb)	2011-2015 Avg (ppb)	
Winship Elementary School	Sutter	38	16.4	17.3	^
Lakeside School	Kern	800	16.3	16.9	*
Lanare Community Services Dist	Fresno	660	16.2	17.3	*
Delicato Vineyards	San Joaquin	25	15.6	18.3	^
Fourth Street Water System	Kern	56	15.6	14.0	*
Barry Elementary School	Sutter	650	15.2	15.3	*
Rand Communities Water District	Kern	450	15.1	15.3	*
US Army Fort Irwin	San Bernardino	16000	14.9	15.4	*
Pond Mutual Water Company	Kern	48	14.7	14.4	^
Alpaugh Community Services District	Tulare	1026	14.5	17.8	
Lands Of Promise Mutual Water Associatio	Kern	190	14.4	15.0	*
Pixley Public Util Dist	Tulare	3310	14.4	15.0	*
Caruthers Comm Serv District	Fresno	2497	14.3	15.4	*
Nord Road Water Association	Kern	32	14.2	15.0	*
Lancaster Park Mobile Home Park	Los Angeles	53	14.2	15.0	*
Mesa Del Toro MWC	Monterey	90	14.2	13.1	*
Green Run Mobile Estates	Stanislaus	100	14.0	15.1	*
Pleasant Valley Elementary	San Luis Obispo	100	13.8	14.1	*
Loch Haven Mutual Water Company	Sonoma	50	13.8	13.1	*
Gratton School	Stanislaus	110	13.5	13.5	*
Hillview Water Co-Raymond	Madera	290	13.4	17.8	
Mettler Valley Mutual	Los Angeles	100	13.0	13.1	*
Mobile Plaza Park	Stanislaus	125	13.0	12.7	*
Hilmar Cheese Company	Merced	1000	13.0	13.3	
North Fork Union School	Madera	350	12.9	12.4	*
Yosemite Forks Est Mutual	Madera	110	12.8	11.6	
MD #08 North Fork Water System	Madera	264	12.8	13.9	^
Keyes Community Services Dist.	Stanislaus	4891	12.3	12.8	*
Countryside Mobile Home Park	Stanislaus	60	12.1	12.5	*
Land Project Mutual Water Co.	Los Angeles	1500	12.1	13.5	*
El Adobe POA, Inc.	Kern	200	12.1	12.1	*
Island Union School	Kings	300	11.9	18.8	
Plumas Eureka CSD	Plumas	325	11.6	11.4	*
Kettleman City CSD	Kings	1450	11.4	12.0	*
Laguna Seca WC	Monterey	162	11.1	11.7	*
Los Molinos Comm. Services Dist.	Tehama	1500	11.1	9.0	
R.S. Mutual Water Company	Kern	67	11.0	11.1	*
Oasis Property Owners Association	Kern	100	10.9	10.8	^
Warner Unified School District	San Diego	250	10.9	11.4	^
MD #07 Marina View Heights	Madera	200	10.5	9.3	
Central Union Elementary	Kings	320	10.1	13.5	^

Note: Click on the hyperlink in the name of the system to view the state records for each water system.

** Indicates a system that has had annual concentrations averaging over the federal limit (10 ppb) each year 2011-2015*

^ Indicates that the 2011-2015 average includes years for which data was not available.

APPENDIX C:

Methods

This report is based on public data available from the California Environmental Protection Agency's State Water Resources Control Board (SWRCB) as of May 2016. We downloaded the SWRCB's Water Quality Analyses Database Files for 2011-2016 and identified public water systems that had arsenic concentrations that exceeded the 10 ppb Maximum Contaminant Level, targeting the systems with frequent exceedances between 2011 and 2015. The SWRCB database contained results for each water source used by a drinking water system, such as wells, treated or blended water, and standby wells that are only allowed to be used for a few days during a year. SWRCB warns users of its database that results in the database may not reflect the quality of water that systems actually served their customers.

Calculating average arsenic concentrations

- We calculated the average arsenic concentration from each individual water source at each water system using the sampling results available in SWRCB's database as of May 2016. Some sampling results from the end of 2015 may not have been available in the database at the time we downloaded the data in May.

- We reviewed each water system's source descriptions to determine which sources represented water served to consumers and whether the source should be included in the system-wide average arsenic concentration. For example, if the database showed that a system had two groundwater wells and a 'treated' source, we assumed that consumers would be served the treated source if results for that treated source were available each year. If the database listed a treated source in 2011, for example, but contained no data from that source for the following years, we excluded that source from the average because it was not clear if the system continued treating water for arsenic. If a system listed a source as inactive or as a 'standby' option, we excluded that source from the analysis because we could not determine when or if the water was used. We compared the selected sources with available Consumer Confidence Reports available through California's Drinking Water Watch system and narrative information in public SWRCB enforcement action documents to verify, to the extent possible, that the sources we selected represented water that was provided to consumers. If no information was available for a particular system, we relied on the

assumptions described above (i.e. inactive and standby sources were not used, treated sources were used instead of untreated sources when concentrations were available for each year). We did not include purchased water sources.

- After identifying individual sources, we calculated the system's annual average arsenic concentration using the annual average concentrations from each source. The average concentrations during the two-year period between 2014 and 2015 and the five year period between 2011 and 2015 are time-weighted average concentrations (i.e. we averaged the annual average concentrations from each year). This method is similar to how the California EPA's Office of Environmental Health Hazard Assessment calculated average concentrations at drinking water systems for use in it's 2014 CalEnviroScreen 2.0 tool, except we focused on annual average concentrations from 2011-2015, rather than a single average concentration from 2005-2013.

- We excluded entire systems from the analysis if a) they were inactive, b) the available data and source descriptions did not allow us to confidently assume that customers received the sampled water at their taps, and c) the average concentration over the most recent two years (2014-2015) fell below the MCL.

Mapping Public Water Systems

To map water system locations, we found the centroids of public water system boundaries from the California Environmental Health Tracking Program's Water Systems Geographic Reporting Tool, or Water Boundary Tool (WBT). For systems without boundaries in the WBT, we determined coordinates from the addresses in the SWRCB Water Quality Analysis database files and the California Drinking Water Watch system.

Notes

[1] Based on averages for 2014-2015. Numbers in this report from the California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed May, 2016.
[2] U.S. EPA (1998), Integrated Risk Information System, Inorganic Arsenic, available at http://www.epa.gov/iris/subst/0278.htm.
[3] Carolina L. Balazs, Rachel Morello-Frosch, Alan E. Hubbard and Isha Ray, "Environmental justice implications of arsenic contamination in California's San Joaquin Valley: a cross-sectional, cluster-design examining exposure and compliance in community drinking water systems," Environmental Health, 2012. Link: https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-11-84
[4] California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed May. Records show 51,306 residents receiving drinking water from 2011-2015 with annual averages of more than 10 ppb.

[5] California Code of Regulations Title 22, Chapter 15, Section 64463.4(b)] reglations require notifications for arsenic exceedances. The California State Water Resources Board template for the language in notifications to be sent out by local water utilities is available on state agency's website at: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Notices.shtml.

[6] California State Water Resources Control Board website, link: http://www.waterboards.ca.gov/drinking_water/certlic/device/watertreatmentdevices.shtml
[7] Ibid.
[8] Telephone interview with Connie R. Clendenan, CEO of the Valley Teen Ranch nonprofit organization, on August 1, 2016.
[9] Ibid.
[10] Texas Commission on Environmental Quality Notice of Drinking Water Arsenic Violation. Available at https://www.tceq.texas.gov/assets/public/permitting/watersupply/pdw/notices/chemical/arsenic.pdf
[11] Wisconsin Department of Natural Resources, Arsenic, Available at: http://dnr.wi.gov/topic/groundwater/arsenic/, accessed 3/7/2016.
[12] Florida Department of health, Brueau of Environmental Health, "Chemicals in Private Drinking Water Wells Fact Sheet- Arsenic," Available at: http://www.floridahealth.gov/environmental-health/drinking-water/_documents/arsenic-fs.pdf. Accessed 3/7/2016.
[13] See e.g. U.S. Department of Health and Human Services, (2004), "Health Consultation: Arsenic in Private Drinking Water Wells, Cornville, Yavapai County, Arizona," available at: http://www.atsdr.cdc.gov/HAC/pha/ArsenicInPrivate061504-AZ/ArsenicInPrivateHC061504.pdf, accessed 3/8/2016.
[14] Wasserman et al. (2014), A Cross-Sectional Study of Well Water Arsenic and Child IQ in Maine Schoolchildren, Environ Health 13:23-32.
[15] Based on averages for 2014-2015. Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016.
[16] Letter from Jared Blumenfeld, Director of EPA's Region 9 office, to California Department of Public Health Director Dr. Ron Chapman, April 19, 2013. Link: https://www3.epa.gov/region9/water/grants/pdf/CDPHNoticeofNonCompliance.pdf
[17] U.S. Centers for Disease Control, fact sheet on arsenic. Available at http://www.cdc.gov/biomonitoring/pdf/Arsenic_FactSheet.pdf
[18] U.S. EPA (1998), Integrated Risk Information System, Inorganic Arsenic, available at http://www.epa.gov/iris/subst/0278.htm.

[19] The EPA describes arsenic's cancer-causing potency with a 'slope factor' (because it describes the slope of the dose-response curve). The current EPA slope factor for arsenic is 1.5 per mg/kg-d. This number represents the risk that can be expected from consuming one milligram of arsenic per kilogram of body weight per day. The EPA also translates the slope factor into a 'drinking water unit risk' of 5×10^{-5} per µg/L. For carcinogens, the formal MCL Goal is always zero. Zero is an unattainable goal, so in most cases the EPA will reduce exposure to carcinogens to a level of 'acceptable risk,' something between 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000).[19] One way of looking at this range is to assume that risks less than 1 in 1,000,000 are always 'acceptable,' while risks greater than 1 in 10,000 never are. The risks of drinking arsenic at the MCL of 10 µg /L are much higher than 1 in 10,000.

[20] See, e.g., National Research Council, Critical Aspects of EPA's IRIS Assessment of Inorganic Arsenic – Interim Report, 82 – 83 (2013). For health endpoints like childhood IQ, the critical window of exposure is obviously much less, encompassing in utero development and childhood.

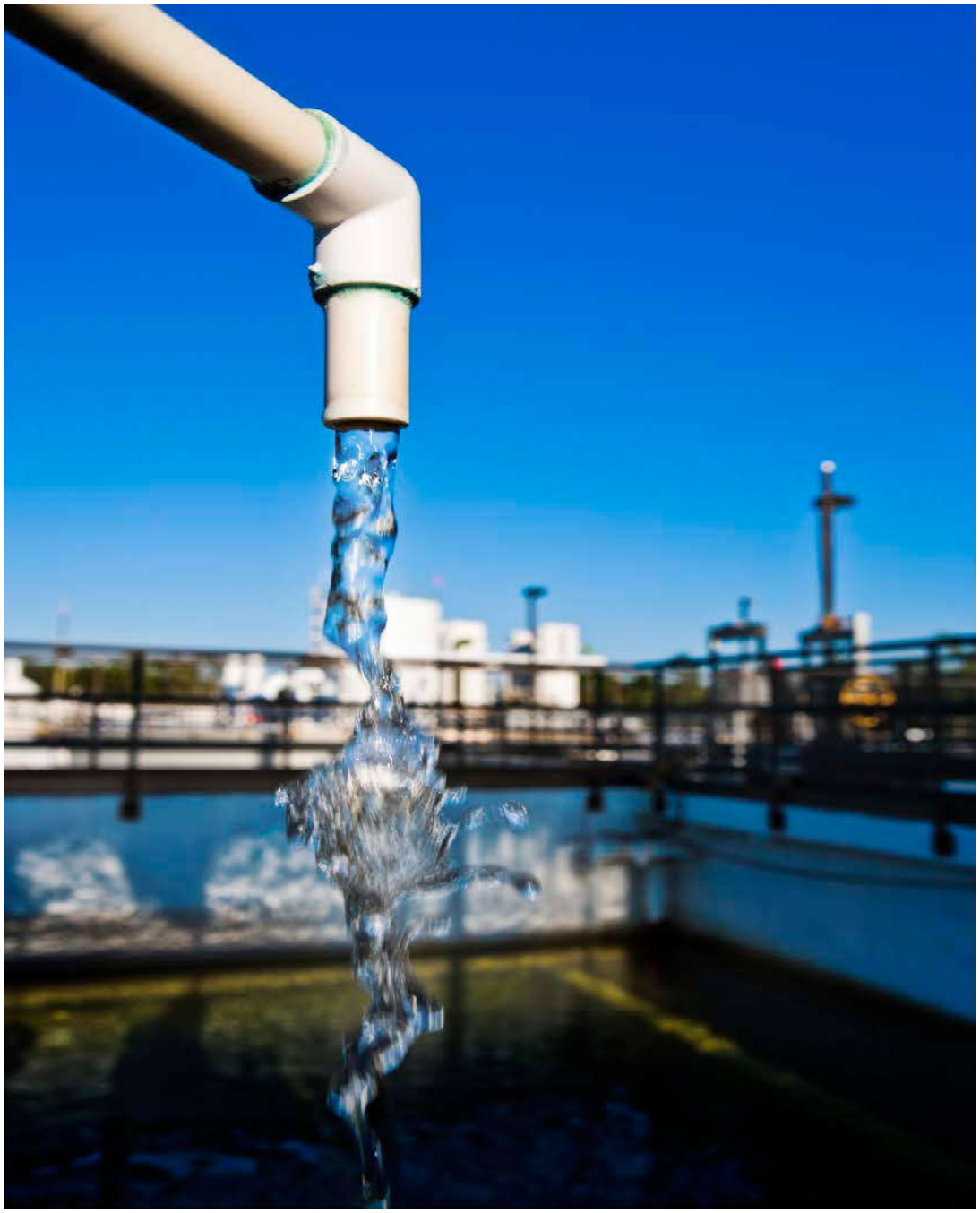
[21] EPA web page, "Drinking Water Arsenic Rule History," available at: https://www.epa.gov/dwreginfo/drinking-water-arsenic-rule-history.
[22] ATSDR (2007), Toxicological Profile for Arsenic; Grandjean and Landrigan (2014), Neurobehavioural Effects of Developmental Toxicity, *Lancet Neurol* 13:330-338.

[23] Wasserman et al. (2014), A Cross-Sectional Study of Well Water Arsenic and Child IQ in Maine Schoolchildren, *Environ Health* 13:23-32.

[24] Ibid.

[25] Ibid.
[26] California Water Resources Board report to the California legislature, "Communities that Rely on a Contaminated Groundwater Source for Drinking Water," January 2013. Link: http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/docs/ab2222.pdf
[27] California Water Resources Board report to the California legislature, "Communities that Rely on a Contaminated Groundwater Source for Drinking Water," January 2013. Link: http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/docs/ab2222.pdf
[28] Carolina L. Balazs and colleagues, "Environmental Justice Implications of Arsenic Contamination In California's San Joaquin Valley: a Cross-Sectional, Cluster-Design Examining Exposure and Compliance in Community Drinking Water Systems," Environmental Health, November 14, 2012. Link: https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-11-84
[29] Ibid.
[30] Letter from Jared Blumenfeld, Director of EPA's Region 9 office, to California Department of Public Health Director Dr. Ron Chapman, April 19, 2013. Link: https://www3.epa.gov/region9/water/grants/pdf/CDPHNoticeofNonCompliance.pdf
[31] Ibid.
[32] California Water Boards press release, "State Water Board, Drinking Water Revolving Fund Return to Safe Drinking Water Act Compliance," May 26, 2016. Link: http://www.waterboards.ca.gov/press_room/press_releases/2016/pr052616_cap_release.pdf
[33] Ibid.
[34] Ibid.
[35] Based on averages for 2014-2015. Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016.
[36] Ibid.
[37] Ibid.
[38] Ibid.
[39] Email from Andrew DiLuccia, Public Information Officer for the California State Water Resources Control Board, containing quote from Cindy Forbes, Deputy Director of the Division of Drinking Water, on August 8, 2016. Telephone interview with Forbes on August 4, 2016.
[40] California State Water Resources Board, template for public notification of Arsenic MCL Exceedance, Link: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Notices.shtml
[41] Ibid.
[42] Example of Consumer Confidence Report for a California system can be found on the state website: https://sdwis.waterboards.ca.gov/PDWW/JSP/WaterSystemDetail.jsp?tinwsys_is_number=370&tinwsys_st_code=CA&wsnumber=CA1000071#
[43] Carolina L. Balazs and Isha Ray, "The Drinking Water Disparities Framework: On the Origins and Persistence of Inequities in Exposure," American Journal of Public Health, April 2014, Vol 104, No. 4. Link: http://www.ncbi.nlm.nih.gov/pubmed/24524500.
[44] Ibid.
[45] Ibid.
[46] Ibid.
[47] 40 CFR 142.20(a)(2)
[48] Wasserman et al. (2014), A Cross-Sectional Study of Well Water Arsenic and Child IQ in Maine Schoolchildren, Environ Health 13:23-32.
[49] U.S. EPA public notification template on EPA website: https://www.epa.gov/dwreginfo/public-notification-templates-community-and-non-transient-non-community-water-systems
[50] Telephone interview on August 25, 2016 with Philip Dutton, engineer for Fresno County.
[51] California State Water Resources Control Board website, http://www.waterboards.ca.gov/drinking_water/certlic/device/watertreatmentdevices.shtml
[52] KFSN-TV, ABC-30 in Fresno, report "Kettleman City Residents Get Answers to Questions about Construction of Water Treatment Plant," August 31, 2016. Link: http://abc30.com/society/kettleman-city-residents-get-answers-to-questions-about-construction-of-water-treatment-plant/1493726/
[53] Ibid.

[54] Telephone interview on August 26, 2016, with Cheryl Sandoval, Supervising Environmental Health Specialist and Manager of Monterey County's drinking water program.
[55] Corral de Tierra Water Company 2013 Consumer Confidence Report, dated July 11, 2014.
[56] Ibid.
[57] Telephone interview on August 26, 2016, with Randy Hardenbrook, Director of the Quail Valley Water District.
[58] Ibid.
[59] Telephone interview on August 25, 2016, with Robert Johnson, President of the Shaver Lake Point 2 Mutual Water Company.
[60] Ibid.
[61] Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016.
[62] Telephone interview with Connie R. Clendenan, CEO of the Valley Teen Ranch nonprofit organization, on August 1, 2016.
[63] Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016
[64] Email from Whitney Meyer, Principal of the Washington School in Salinas, California, on August 1, 2016.
[65] Email from Robert Shemwell, Assistant Superintendent of Business Services of the Yuba City Unified School District, containing quote from Tom Butcher,Director of Maintenance and Facilities, on August 12, 2016.
[66] Email on August 24, 2016, from Liliana Stransky of the Kings County Department of Public Health.
[67] Email from Superintendent Charlotte Hines of the Island Union School in Lemoore, California, August 4, 2016.
[68] Email from Kenneth Drylie, Public Affairs Specialist at Fort Irwin, containing quotes from Muhammad A. Bari, Director Public Works at the forst, on August 11, 2016.
[69] Email from Kylie Barnett, Director Public Relations at Delicato Family Vineyards, August 10, 2016.



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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

May 28, 2004

Mike Paulucci
Treatment Plants Chemist
City of Yuba City
302 Burns Drive
Yuba City, California 95991

Re: 2004 Pretreatment Evaluation

Dear Mr. Paulucci:

Enclosed is the April 30, 2004 report for our pretreatment evaluation of Yuba City. We ask that the City provide short written responses to each of the findings in Sections 2.0 to 8.0 of this inspection report by **July 30, 2003.** We expect to follow this inspection report with an Administrative Order that establishes a 12-month schedule for upgrading the pretreatment program, starting with the budget cycle on July 1.

The new NPDES permit incorporates a number of permit limits for pollutants that were unregulated in the past. There are now many pollutants of concern for which the City must develop and implement a source control program. One noteworthy finding of this inspection is that for most of the new pollutants of concern, the effluent levels for Yuba City exceed those for sewer districts representative of the industrialized Central Valley. Yuba City=s levels are partly explained by the ground water supply (*arsenic, barium*), water delivery system (*copper*), and the fact that the other districts perform advanced treatment, either nutrient removal or tertiary filtration, and thus have higher removal rates (*chromium, manganese, iron, silver*). Nevertheless, for a number of metals, non-domestic contributions appear to be the primary or at least a significant source in the Yuba City effluent (*aluminum, arsenic, copper, iron, manganese, mercury, molybdenum, selenium, and zinc*).

Otherwise, the most significant findings involve the unrepresentative self-monitoring by the industrial users over their reporting periods, the under-developed industrial user inventory, the incorrectly permitted significant industrial users, the lack of an updated sewer use ordinance as approved in 1995, and outdated local limits. Some of these issues were advanced in the EPA inspection reports and follow-up Administrative Orders to three significant industrial users in Yuba City. It is expected that their efforts to meet the requirements of their Administrative Orders will partly address the issues in this report.

Much of the City=s past efforts to regulate non-domestic contributions to the sewers will not have to be reconsidered or redone. In particular, the work done by the City to identify pollutant sources can be built upon, and the annual reports are informative. But the City will have to provide resources to do a number of required functions to address the deficiencies found in this inspection. Local limits will have to be redetermined. The ordinance will have to be

updated and adopted. Permits will have to be reissued to most significant industrial users. Self-monitoring requirements will have to be re-evaluated. Fact sheets will have to be prepared. All of these requirements are outlined in the enclosed inspection report.

Thank you for your cooperation during and after this inspection. Please do not hesitate to call (415) 972-3504 or e-mail arthur.greg@epa.gov.

Sincerely,

Original signed by:
Greg V. Arthur

Greg V. Arthur
Clean Water Act Compliance Office

cc: Melissa Hall, RWQCB

U.S. ENVIRONMENTAL PROTECTION AGENCY

REGION 9

CLEAN WATER ACT COMPLIANCE OFFICE

PRETREATMENT PERFORMANCE EVALUATION INSPECTION REPORT

NPDES Permittee:	City of Yuba City 302 Burns Drive, Yuba City, California 95991 Wastewater Treatment Plant (NPDES CA0079260) WDRs Orders R5-2003-0085
Dates of Inspection:	August 5, August 20-21, August 27, 2003
Data Review:	Influent and Effluent Conventional: 2003 – 2004 Influent and Effluent Toxics: 2000 – 2004 Sludge toxics: 2000 – 2004

Inspection Participants:

US EPA:	Greg V. Arthur, CWA Compliance Office, (415) 972-3504 Meg Masquelier, CWA Compliance Office, (415) 972-3536
RWQCB:	No Representative
Yuba City:	Mike Paulucci, Chemist, (530) 822-7695 Al Butterfield, Chief Plant Operator
Industrial Users:	Sunsweet Growers, Jerry Ramsey, Engr Mgr, (530) 751-5278 Greenleaf Unit 2, Diane Tullos, Compliance Mgr, (530) 821-2074 Custom Chrome, Gene Hutchinson, Owner, (530) 673-2360

Report Prepared By:	Greg V. Arthur, Environmental Engineer April 30, 2004

Section 1

Introduction and Background

1.0 Scope and Purpose

In April 2004, EPA completed a performance evaluation of the regulatory control of non-domestic wastewaters discharged into the City of Yuba City wastewater treatment plant ("WWTP"). This performance evaluation was one of a series of reviews of small publicly-owned treatment works that accept non-domestic contributions, many of which are not large enough to be mandated to operate EPA-approved pretreatment programs. Yuba City is large enough and has operated an EPA-approved pretreatment program since 1982.

The scope of this performance evaluation comprised:

- Sampling inspection of the Yuba City wastewater treatment plant on August 27, 2003;
- Review of the 2003-2004 Yuba City self-monitoring reports;
- Review of the 2000-2004 influent and effluent sampling records for toxic pollutants;
- Inspections of three significant industrial users including the sampling of two of them;
- Review of the 2000-2003 sampling records for the significant industrial users inspected;
- Interviews with City representatives on August 5, August 20-21, and August 27, 2003;
- Review of the industrial responses to their inspection reports and enforcement actions.

The purpose of this evaluation was to determine if non-domestic discharges into the Yuba City sewer system are properly controlled. The evaluation findings were measured against two fundamental performance objectives. The first is the prevention of sewage treatment works pass-through, interference and sludge contamination as shown by compliance with the Federal sludge limits, the discharge permit limits, and any expected future Clean Water Act requirements. The second is the consistent compliance by the industrial users with their own Clean Water Act requirements, in particular with the Federal best-available-technology standards that apply to certain industrial categories, and any national prohibitions and local limits for pollutants associated with treatment works non-compliance.

This report covers the performance of the pretreatment program as it currently exists in Yuba City. Some pertinent findings from the industrial user inspections are also incorporated. The significant industrial users received individual reports and enforcement actions. Arthur collected samples on August 20, 21, and 27, 2003 for delivery to the EPA Richmond Lab.

1.1 Yuba City Wastewater Treatment Plant

The Yuba City WWTP is a pure-oxygen activated sludge plant that discharges either by diffuser to the Feather River in the winter wet-season or to 120 acres of percolation ponds

Section 1 – Introduction and Background

located alongside the river in the summer dry-season. The wastewater treatment plant provides high-rate treatment of higher-than-typical-strength wastewaters. It has a dry-weather design capacity of 7.0 million gallons per day ("mgd") and a wet-weather design capacity of 11.0 mgd. The average and calculated peak flows were 6.60 and 8.05 mgd in 2003. See Figure 1.

- Primary and Secondary Treatment - The headworks, which provide grinding and aerated grit removal, is followed by primary sedimentation. Ammonia and phosphates are added, usually in the summer, in order to precondition the high-strength and nutrient-poor contributions from Sunsweet Growers. Primary effluent is then aerobically biodegraded in three treatment trains each with four compressed-gas pure-oxygen aeration cells followed by three secondary clarifiers. Activated sludge returns without re-aeration in order to strip carbon dioxide, and does so at rates to support a mean cell residence time of around 3 days. Real-time metering for dissolved oxygen, solids, and redox potential are used to better ensure the treatment plant can respond to the contributions from Sunsweet.

- Advanced Treatment - There is no capability to provide nitrification or denitrification. There is also no tertiary polishing of secondary effluent and, as a result, no capability to reuse treated wastewater off-site.

- Solids Handling - Waste secondary activated sludge and primary sludge are digested in two anaerobic digestors each with detention times of 25 days and operated in series. Digested sludge dosed with anionic polymer is dewatered through belt pressing, with the cake further dewatered in on-site sludge drying beds for off-site disposal as landfill cover. Grit is hauled off-site to a landfill. The waste activated sludge is first thickened in two polymer-aided dissolved air flotation units. Belt press filtrate returns to the lateral leading into the headworks. Dissolved air flotation subnatant returns to the aeration cells.

- WWTP Sampling - The influent sampling point, located upstream of the headworks is designated as IWD-YC1 for the purposes of this report. All return flows except the belt press filtrate rejoin treatment downstream of influent sampling. The effluent compliance sample point, sited immediately after final dechlorination, is designated as IWD-YC2. The accumulation of filter cake for hauling off-site is designated as the sludge sampling point, IWD-YC3. The receiving water sampling point downstream of the Yuba City outfall is designated in the permit as R-1.

- Water Supply - For most of its sewered users, Yuba City provides surface water drawn from the Feather River and treated through its water treatment plant. Some sewered customers located outside of the city limits receive untreated ground water from the former Hillcrest Water Company system. According to the City's Urban Water Management Plan, an estimated 1,000 of the 9,020 water users receive the more mineralized ground water. For the purposes of this report, a ratio of 1:9 ground to surface water was used in estimating the flow-weighted average concentrations for the water supply.

- Receiving Water Hardness - The USGS maintains a station on the Feather River at Nicolaus, approximately 13 miles downstream from the Yuba City outfall. This station and six others in Sacramento River basin were extensively sampled under a full range of conditions for conventional, toxic, and pesticide-related pollutants, as part of the 1995-1998 National Water Quality Assessment Program. The calculated 99th% minimum hardness and the minimum sample result for the Feather River station was 22.6 mg/l and 22 mg/l as CaCO3. The lowest minimum sample result recorded for all seven stations both upstream and downstream of the Feather River station was 16 mg/l. For the purposes of this report, a hardness of 22.6 mg/l is used in the calculations of the permit limits for metals to be in effect in 2007. By then, Yuba City will have a better data set of hardness values for the Feather River near the outfall, as required by the NPDES permit.

1.2 Sewer Service Area

The Yuba City sewer service area comprises the incorporated area of the city that receives city supplied surface water as well as the unincorporated county lands southwest of the city limits that receive ground water. The WWTP also serves as a regional disposal point for septage collected from septic tanks in unsewered areas within both the city limits and in the outlying county land. According to the City's Urban Water Management Plant, the service area has a population in 2004 estimated to be 60,000, and 950 commercial and four industrial users, who together contribute 35-40% of the sewered wastewater. The inventory of industrial users includes at least seven considered to be significant industrial users who together discharged an average of 930,000 gallons per day into the sewers in 2003 (14% of total flows).

1.3 Discharge Requirements

Yuba City is authorized by the June 6, 2003 RWQCB Waste Discharge Requirements, Order R5-2003-0085, ("WDRs"), and a concurrent Cease and Desist Order, Order No. R5-2003-0086, ("CDO"), to discharge treated sewage from the Yuba City WWTP either to the Feather River or to percolation ponds sited along the river or from the percolation ponds to the Feather River. The WDRs also function as National Pollutant Discharge Elimination System ("NPDES") permit CA0079260. The WDRs contain narrative prohibitions, effluent limits that implement the California Toxics Rule, receiving water limitations, monitoring requirements, pretreatment provisions, and sludge disposal requirements. In essence, the WDRs and CDO together require Yuba City to comply with effluent limits for conventional pollutants, disinfection, and pH upon issuance of the permit and for pesticides, metals, surfactants, toxic organics, ammonia, and nitrates by November 2007.

The effluent limitations for a discharge to the Feather River are for conventional pollutants, total coliform, ammonia based on temperature and pH, nitrites and nitrates, surfactants, residual chlorine, pH, acute biotoxicity, and various pesticides, metals, and toxic organics. The effluent limits that take effect on November 1, 2007 are for additional metals based on

the hardness in the river, and for additional toxic organics. The CDO required the completion of the corrective steps necessary to meet the WDRs for organochlorine pesticides, thiobencarb, aluminum, ammonia, arsenic, chloroform, diazinon, cis-1,2-dichloroethene, ethion, iron, manganese, MTBE, surfactants, molybdenum, and nitrates also by November 1, 2007.

The limitations for a discharge to percolation ponds are limited to narrative prohibitions against public contact, objectionable odors, anoxic conditions, the proliferation of mosquitoes, inadequate freeboard, degraded ground waters, and exceeding numerical limitations for pH. The receiving water limitations include narrative provisions against causing a visible film, discoloration, objectionable growths, nuisance conditions, the bioaccumulation of toxics, bad tasting fish, increased temperatures over 5°F, increased turbidity, increased specific conductivity, high or low pH's, and any adverse effect on the beneficial uses of the receiving waters.

1.4 Legal Authorities

Yuba City obtained approval of its pretreatment program in 1982. Yuba City operates under the authority of Public Works Title 6, Wastewater Collection and Treatment Chapter 5 of its municipal code as adopted in 1976. Yuba City began the process of revising its ordinance to be in accord-ance with the requirements of 40 CFR 403 in the late 1980's and submitted a draft ordinance for review in 1990. EPA and the RWQCB provided numerous and extensive reviews of the ordinance culminating in an approval letter from the RWQCB issued on November 29, 1995. Yuba City has not readopted the revised ordinance. As a result, the local limits and the regulatory provisions in effect are those in the 1976 ordinance. The WDRs since 1990 have imposed pretreatment provisions that require implementation of the regulatory controls necessary to enact all of 40 CFR 403. The current WDRs issued in June 2003, require Yuba City to resubmit pretreatment program for approval. Requirements to obtain and implement an approved pretreatment program would include the following:

- The implementation of the general and specific national prohibitions in 40 CFR 403.5 for industrial users against the introduction of incompatible wastewaters;
- The requirement in 40 CFR 403.5 to develop locally-determined limits necessary to protect the treatment works from potential adverse impacts, such as operational interference, worker health and safety risks, the pass-through of pollutants to the receiving waters, and sludge contamination;
- The performance of the program functions set forth in 40 CFR 403.8, such as identifying industrial users, issuing permits, inspecting and sampling industrial users, providing adequate funding, and enforcing against violators;
- The implementation of an industrial users self-monitoring program under 40 CFR 403.12;
- The implementation of Federal categorical standards under 40 CFR 403.6; and
- The enacting of the local legal authorities necessary to operate an approved pretreatment program under 40 CFR 403.8.

Section 1 – Introduction and Background

This evaluation did not involve a review of the 1976 ordinance because the proposed 1990 revised ordinance has not been adopted. As a result, the administrative record since the late 1980's stands as the determination that Yuba City does not have the legal authority to implement all aspects of an approved pretreatment program.

Section 2

Wastewater Treatment Plant Performance

The Yuba City WWTP must meet permit effluent limits for conventional pollutants, nutrients, pesticides, metals, toxic organics, pH, surfactants, and biotoxicity. 40 CFR 403.5(a,b,c) and 403.6.

Non-domestic wastewaters may not result in unpermitted releases, hazardous or explosive conditions with the sewers, or operational interferences in the collection system. 40 CFR 403.5(b).

2.0 Summary

The WWTP has the capacity and capability to handle the domestic wastewaters in the Yuba City service area as well as the high-strength wastes generated by Sunsweet. However, without a change in the influent loadings, removal rates, or disinfection methods, the WWTP is expected to experience the pass-through of a number of metals, chlorination byproducts, toxic organics, and pesticides once their NPDES permit limits take full effect in 2007. Moreover, without nitrification and denitrification, the WWTP is also expected to experience the pass-through of ammonia and the toxicity associated with ammonia. Finally, the nutrient-poor nature of Sunsweet's contributions caused operational interferences related to WWTP responses, however, better metering has lessened those risks.

See Tables 1 - 3 for wastewater and sludge summaries, Table 4 for statistical probabilities of violation, Table 5 for a comparison of Yuba City with representative Central Valley sewer districts, Table 6 for the EPA sampling results, and Table 8 for the definitions of 'pass-through' and 'interference'.

Requirements

- The domestic, non-domestic, and water supply sources of aluminum, arsenic, copper, iron, manganese, molybdenum, and zinc must be identified and quantified.

Recommendations

- The wastewater treatment plant influent should be monitored for aluminum, arsenic, copper, iron, manganese, mercury, molybdenum, selenium, and zinc.
- The receiving waters should be monitored for hardness, pH, and temperature.
- The cause of the instances of low pH in the influent should be determined.

Section 2 – Wastewater Treatment Plant Performance

Recommendations – continued

- Corrosion controls of the water delivery system should be implemented in order to reduce the leaching of copper, thereby reducing the copper discharged from the treatment plant.
- Sunsweet and septage deliveries should be monitored for the farm-related contaminants such as arsenic and selenium.
- Sunsweet and the power plants should be monitored for the corrosion-related contaminants associated with circulating water systems such as iron, molybdenum, and zinc.
- A specific prohibition against abrupt changes in organic loads, such as a restriction in the percentage change in mass loads per day, should be considered for Sunsweet.
- The water service newsletter should be supplemented to also inform rate payers of the wastewater compliance status and the on-going need to fund the capital improvements, pretreatment, and operations to protect and maintain the public wastewater investment.

2.1 Conventional Pollutants

The WWTP produces high-quality secondary-treated wastewaters. As a result, it consistently complies with its permit limits for conventional pollutants. The average and calculated 99th% peaks are less than 11 and 22 mg/l BOD and 9 and 16 mg/l TSS even through Sunsweet's contributions elevate the average influent BOD to 339 mg/l. The WWTP discharged to the percolation basins May 1 through October 31, and to the river otherwise.

There were four instances of the effluent pH below the lower 6.5 limit and one above the upper 8.5 limit. There were also two unrelated instances of low influent pH, (2.62 on 11/14/03 and 4.99 on 11/22/03). The national prohibitions not only prohibit discharges that cause structural damage to the sewerage works but also specifically prohibit discharges below 5.0 s.u. because pHs below that level are known to cause concrete degradation.

2.2 Ammonia Toxicity

The permit sets sliding-scale effluent limits for ammonia which are most stringent when pH and temperature are high. During the winter wet-season when the WWTP discharges to the Feather River, the monthly-average and sample-maximum ammonia limits bottom out at 3.56 and 19.7 mg/l based on and assumed maximums for pH and temperature of 7.2 s.u and 70ºF. Sampling required by the permit would result in actual values for maximum pH and temperature in the Feather River and better establish the ammonia limits. Against these preliminary sliding-scale ammonia limits, the WWTP inconsistently complies when it discharges to the river, with the average and calculated 99th% peak ammonia concentrations

of 12.9 and 36.9 mg/l. As a result, there is a >20% chance of violating the lowest expected maximum limit and 99%+ chance of violating the lowest expected monthly-average limit.

2.3 Nitrates Plus Nitrites

The WWTP complies with the permit limits for nitrite plus nitrate of 10 mg/l primarily because it does not nitrify by design. The WWTP would be expected to comply with the permit limits upon the 2007 compliance deadline only upon completion of upgrades for both full nitrification and denitrification.

2.4 Salts

The permit does not limit salts but requires monitoring for total dissolved solids, hardness, and electrical conductivity. The monitoring results for salts are all well below what could adversely impact reuse, or in the case of sulfate, impart an acute toxicity.

2.5 Toxic Metals

Without decreased loadings, corrosion controls, or increased removals, the WWTP would be expected to exceed the permit limits for aluminum, arsenic, copper, iron, lead, manganese, molybdenum, and zinc. See Table 2 for a summary of toxics in the influent, effluent, and water supply, Table 4 for statistical probabilities of exceeding limits, and Table 5 for comparisons with representative of Central Valley sewer districts with industrial contributions. (The sewer districts selected for comparison were Deer Creek, El Dorado Hills, Grass Valley, Nevada City, Placer County No.1, Red Bluff, and Stockton.)

For most metals, the effluent concentration averages for Yuba City exceed the averages for sewer districts representative of the industrialized Central Valley. Elevated levels for Yuba City are partly explained by the water supply (*arsenic, barium*), water delivery (*copper*), and the fact that the other districts perform advanced treatment of some sort, either nutrient removal or tertiary filtration, and thus have higher removal rates (*chromium, manganese, iron, silver*). Nevertheless, for a number of metals, unidentified non-domestic contributions appear to be the primary or at least a significant cause of the elevated levels in the Yuba City effluent *(aluminum, iron, manganese, mercury, molybdenum, selenium, zinc*).

Aluminum - Influent concentrations are significantly higher than can be explained by the water supply or known non-domestic sources. In fact, the influent levels are so high, up to 6,225 µg/l, that the sources are likely limited to utilities' use of alum for water, wastewater, or sludge conditioning or water conditioning at industries that discharge the generated sludges or backwashes. A sample of 3,600 µg/l from Greenleaf Unit 2 partly bears this out. Since the 85%+ removal rate is typical for secondary wastewater treatment, not only the influent but also effluent concentrations far exceed the averages for representative Central

Section 2 – Wastewater Treatment Plant Performance

Valley sewer districts. The effluent average and calculated 99th% peaks are 256 and 571 µg/l resulting in a >80% chance of a sample violating the 120 µg/l maximum limit.

Arsenic - Influent concentrations are higher than can be explained by known sources. The ground water used in part of the city accounts for nearly half of the elevated influent levels. However, for the remainder, arsenic in fruit pesticides makes it possible that fruit washing at Sunsweet and farm-related run-off or septage are likely sources that account for the increases from 2.5 µg/l in the water supply to 6.1 µg/l in the influent. Both the average influent and effluent concentrations are >400% higher for Yuba City than for representative Central Valley sewer districts. The effluent average and calculated 99% peaks are 7.8 and 33.5 µg/l which result in a >40% chance of samples violating the 10 µg/l monthly limit.

Barium - The permit does not set effluent limits for barium. Average effluent concentrations are >400% higher than representative Central Valley sewer districts, and ground water may account for nearly half of the elevated levels. Potential non-domestic sources might include the removal of barium sulfate deposits from circulating cooling water circuits.

Cadmium - The industrial discharge from Custom Chrome is the likely source of the small concentrations of cadmium found in the influent and effluent. No cadmium was detected in the water supply and the WWTP levels are consistent with those for representative Central Valley sewer districts. The effluent average and calculated 99% peaks are 0.17 and 0.31 µg/l which result in far less than a 1% chance of a sample exceeding the calculated 0.85 µg/l maximum limit.

Chromium - The industrial discharge from Custom Chrome is the likely source of the small concentrations of chromium found in the influent and effluent. No chromium was detected in the water supply and the WWTP levels are consistent with those for representative Central Valley sewer districts. The effluent average and calculated 99% peaks are 0.94 and 1.14 µg/l which result in far less than a 1% chance of a sample exceeding the calculated 106 µg/l maximum limit.

Copper – Corrosion of household plumbing appears to be the principal source. Surveys conducted by Yuba City found 10% of the households with copper concentrations at their taps over 199 µg/l if served by surface water and 459 µg/l if served by ground water. These concentrations are high enough to account for the significant increases from 1.3 µg/l in the surface water supply to 50.1 µg/l in the WWTP influent. The removal rate of 80%+ is in the typical range for secondary wastewater treatment. As a result, the effluent average and calculated 99th% peaks are 8.5 and 18.7 µg/l which result in a >90% chance of a sample violating the 2.65 µg/l maximum limit. This means Yuba City is likely to nearly always exceed permit limits without preconditioning the water supply to inhibit corrosion.

Section 2 – Wastewater Treatment Plant Performance

The principal corrosion control methods in use by other water suppliers include the following:

- carbonate passivation of copper pipes through the increase of both pH and alkalinity,
- silicate passivation of copper pipes through the application of sodium silicates and sodium carbonate, and
- precipitation of scale within the pipes through the supersaturation of calcium.

(EPA publication EPA-811-B-92-002, September 1992, "Lead and Copper Rule Guidance Manual, Vol. II: Corrosion Control Treatment).

Iron - Lone samples of 15,000 and 9,800 µg/l from Sunsweet and Greenleaf Unit 2, respectively, could easily account for the significant increase between the flow-weighted average of 25.3 µg/l for the water supply and the average WWTP influent of 960 µg/l. The removal rate of 80%+ is typical for secondary wastewater treatment. The effluent concentrations exceed the averages for repre-sentative Central Valley sewer districts. The effluent average and calculated 99th% peaks are 164 and 309 µg/l which result in a slight >1% chance of a sample violating the 300 µg/l maximum limit.

Lead - There is not enough data to make conclusions regarding future compliance with the 0.83 µg/l maximum or 0.38 µg/l monthly-average limits. All water supply samples were below detection, but the 1 µg/l detection limit is over the limits.

Manganese - Effluent concentrations are far higher than typical for representative Central Valley sewer districts because treatment plant removals are essentially 0% in Yuba City but between 60% and 97% at the representative Central Valley sewer districts. The effluent average and calculated 99th% peaks are 53 and 156 µg/l which result in a >50% chance of a sample violating the 50 µg/l maximum limit. Influent concentrations are typical for representative sewer districts, although there are no sources identified at this time that could account for the increase between the flow-weighted average for the water supply of 11.5 µg/l and the WWTP influent of 49.8 µg/l.

Mercury – There is a negligible chance of even a single sample violating the 0.05 µg/l monthly-average limit, even though both influent and effluent concentrations exceed the averages for representative Central Valley sewer districts. The removal rate of 95%+ is typical for secondary wastewater treatment. Effluent average and calculated 99th% peaks are 0.017 and 0.048 µg/l.

Molybdenum - Molybdate is a corrosion inhibitor in widespread use in circulating cooling water circuits, which account for a significant fraction of the non-domestic contributions into the Yuba City sewers. As a result, circulated cooling at Sunsweet and the power plants are likely sources of the significant increase in the average concentration from less than 1.0 µg/l in the water supply to 10.3 µg/l in the influent. Both influent and effluent concentrations exceed the averages for the representative Central Valley sewer district with molybdenum

samples. The effluent average and calculated 99th% peaks for Yuba City are 11.0 and 31.6 µg/l which result in a >50% chance of a sample violating the 10 µg/l maximum limit.

Nickel - The industrial discharge from Custom Chrome is the likely source of the small concentrations of nickel found in the influent and effluent. No nickel was detected in the water supply and the WWTP levels are consistent with representative Central Valley sewer districts. The effluent average and calculated 99th% peak concentrations are 1.78 and 3.96 µg/l, which result in less than a 1% chance of a sample violating the 23.6 µg/l maximum limits.

Selenium - The permit does not set effluent limits. Selenium has farm-related uses in veterinary medicine, fungicides, and insecticides. As a result, fruit washing at Sunsweet and farm related run-off or septage are likely sources of the increase in the average concentration from less than 1.0 µg/l in the water supply to 7.1 µg/l in the influent. Both influent and effluent concentrations far exceed the averages for the representative Central Valley sewer district. The effluent average and calculated 99th% peaks for Yuba City are 7.1 and 44.7 µg/l.

Silver - There is not enough data to make conclusions regarding future compliance with the 0.31 µg/l maximum limits, even though the single effluent sample exceeded the limit. All water supply samples were below detection, but the 1 µg/l detection limit is over the limit.

Zinc - Zinc phosphates are corrosion inhibitors in widespread use in circulating cooling water circuits, which account for a significant fraction of the non-domestic contributions into the Yuba City sewers. As a result, the circulated cooling at Sunsweet and the power plants are likely sources of the huge increase in the average concentration from less than 1.0 µg/l in the water supply to 157 µg/l in the influent. The influent and effluent concentrations are within the ranges at the representative Central Valley sewer districts. The effluent average and calculated 99th% peaks for Yuba City are 51.8 and 86.7 µg/l which result in a >80% chance of a sample violating the 34.0 µg/l maximum limit.

2.6 Toxic Organics and Pesticides

A number of other toxic pollutants were detected but most of them did not or will not exceed the permit limits. Those detected but not exceeding permit limits include MTBE (*methyl-tert-butyl ether*). The principle exceptions were the permit limits for two chlorination byproducts (*dichloro-bromomethane, dibromochromomethane*), a pesticide (*diazinon*), and two chlorinated solvents (*chloroform, tetrachloroethylene*). However, no definitive conclusions regarding any of these pollutants can be made at this time because there are only three samples for each and the permit limits are not much higher than the detection limits.

Section 2 – Wastewater Treatment Plant Performance

2.7 Federal Sludge Limits

The WWTP sludges consistently comply with the Federal sludge limits for disposal as landfill cover. The WWTP sludges also would likely consistently comply with the Federal clean sludge limits suitable for any reuse in Table 3 of 40 CFR 503.13 although the more stringent limits do not apply as long as the Yuba City disposes of sludge as landfill cover.

2.8 WWTP Interference

Sunsweet poses two operational risks to the Yuba City treatment works. First, sharp drops in loadings have in the past resulted in operational interferences at the WWTP related to the treatability of the nutrient-deficient discharges from Sunsweet and the responsive dosing of nutrients by Yuba City. Second, the high-strength organic discharges could cause sulfide degradation of concrete sewers if they become anoxic.

Yuba City has instituted permit requirements to Sunsweet to keep the pH above 8.5 and to provide 48-hour prior notification for impending shutdowns of more than 24 hours. Yuba City also has real-time probes with automatic alarms for dissolved oxygen, solids, and redox potential at various locations in the WWTP. Nevertheless, within the permit requirements, the variabilities in the organics, suspended solids, and hydraulic loadings from Sunsweet still have the potential to be large enough to adversely effect the operation of the WWTP because the mitigating actions rely solely on operators and procedures. It would be better for the City if Sunsweet installed some form of built-in load equalization that does not rely on operating procedures. See the February 20, 2004 EPA report of the inspection of Sunsweet and Sunsweet's May 26, 2004 response for a larger discussion.

Section 3

Local Limits

Pretreatment programs are required to develop local limits to prevent pass-through, interference, sludge contamination or other adverse effects upon the treatment works. 40 CFR 403.5(c).

3.0 Summary

Yuba City has an ordinance to prohibit discharges that exceed local limits or could harm the treatment works. However, the technical basis of the local limits is questionable since they are not based on the current conditions or permit. Furthermore, Yuba City did not adopt an updated sewer ordinance reviewed by EPA and approved by the RWQCB to reflect changes in the Federal pretreatment rule promulgated after 1982. Sampling has indicated that without a change in the influent loadings, or removal rates, the WWTP would be expected to experience the pass-through of a number of metals, toxic organics, and pesticides once the permit limits take full effect in 2007. See Table 7 for a definition of 'local limits'. Also see Item 1.4 of this report for more detail regarding Yuba City's legal authority.

Requirements

- Yuba City must determine the maximum allowable headworks loadings for aluminum, arsenic, copper, iron, manganese, molybdenum, and zinc, and enact new local limits, prohibitions or control strategies.
- The sewer use ordinance must be updated to reflect the changes in the Federal rules.

Recommendations

- The WWTP influent and effluent should be sampled to determine whether diazinon, chloroform, tetrachloroethylene are pollutants of concern present at levels above their detection limits.

3.1 Sewer Use Ordinance

This pretreatment program evaluation did not include a new review of the sewer use ordinance. However, the ordinance has not be updated to reflect the changes in the Federal pretreatment rules in the ways outlined in the reviews by EPA of the ordinance and culminating in the approval letter issued by the RWQCB on November 29, 1985.

Section 3 – Local Limits

3.2 National Prohibitions

The national prohibitions apply to every non-domestic discharge into the sewers nationwide to prevent harm to the treatment works. They consist of the general prohibitions in 40 CFR 403.5(a) against harm and the specific prohibitions in 40 CFR 403.5(b). In practice, local limits, covering a range of pollutants, and developed in accordance with 40 CFR 403.5(c), replace most of the effective span of the national prohibitions.

3.3 Pollutants of Concern

The pollutants of concern are those related to non-domestic sources with a statistical chance of over 1% to cause a violation of the WDRs or the Federal sludge limits. The pollutants with a statistical chance over 1% are aluminum, ammonia, arsenic, chloroform, copper, diazinon, dibromochloro-methane, dichlorobromomethane, iron, lead, manganese, molybdenum, tetrachloroethylene, and zinc. Of these, dibromochloromethane and dichromobromomethane would not be pollutants of concern because they are chlorination by-product unrelated to influent quality. Ammonia and nitrates also would not be pollutants of concern because their effluent concentrations are a function of the treatment plant operations. It cannot be determined without further monitoring of both the influent and effluent whether diazinon, chloroform, and tetrachloroethylene are pollutants of concern.

A number of other pollutants with a statistical chance below 1% to cause a violation, nevertheless, should be pollutants of concern because of discernible sources. Cadmium, chromium, and nickel are entrained in solution and rinse tanks at metal finishers (*Custom Chrome*). Selenium is associated with farm-related uses (*Sunsweet, septage*). Lead and barium are scoured from boilers (*Sunsweet, power plant*). Mercury has non-domestic commercial sources (*dentists*). MTBE at aquifer clean-up sites are pollutants of site-specific concern. And oil & grease is a concern in every sewer district.

3.4 Maximum Allowable Headworks Loadings

Every sewer district must determine the maximum loading of pollutants it can accept and still comply with the permit requirements and Federal sludge limits. The maximum allowable headworks loadings ("MAHLs") form the technical basis for determining local limits. All this requires influent, effluent, and sludge monitoring under the range of conditions expected during the year, in order to determine the WWTP removal efficiencies. EPA has a free spread sheet program called Prelim to assist in the calculations. WEF also has a fate and transport model available for purchase on its web-site.

Section 3 – Local Limits

3.5 Allocation Method

The MAHLs for each of the pollutants of concern must be allocated between uncontrollable and controllable sources. The uncontrollable sources comprise domestic sewage, and infiltration and inflow. The controllable sources are those that could be regulated under permits or best-management practices. This will require background monitoring of domestic sewage, and infiltration and inflow, in order to determine the pollutant loadings that cannot be allocated to the controllable sources. The remaining loadings can then be allocated in any fashion to the individual industrial and commercial sources. For example, Yuba City could set different local limits by individual industrial discharge, or by flow-weighted average, or uniformily across the entire service area for some pollutants but differentially set for others. The allocation method does not matter as long as the total allocation out to the domestic and non-domestic users does not exceed the calculated MAHLs.

It is possible that the main sources of certain pollutants are domestic in nature and largely uncontrollable by ordinance through permitting or best-management practices. For example, significant loadings of copper likely come from the delivery pipes and pesticides may come primarily from infiltration and inflow off of nearby fields, or household use. In these cases, Yuba City would have to redetermine the MAHLs after the sources are mitigated through some other means.

3.6 Industrial User Compliance with Local Limits

The Federal regulations do not define how to determine regulatory success. Moreover, any conclusion regarding industrial user compliance with the local limits would be premature since they are not technically-based to protect the Yuba City treatment works from adverse impacts, and the sources of the pollutants of concern are not yet identified. Once the local limits are sound and implemented through industrial user permits, however, the following performance measures determine regulatory success in achieving industrial user compliance.

- Treatment Plant Performance - EPA Region 9 bases its primary determinations on the purpose of local limits and the national prohibitions to prevent pass-through, interference, sludge con-tamination, or potential worker safety risks. As a result, the best measure of a program's effectiveness is consistent compliance with the NPDES permit and sludge limits. By this measure, Yuba City would not be successful if the pass-through of aluminum, arsenic, chloro-form, copper, diazinon, iron, lead, manganese, molybdenum, tetrechloroethylene, and zinc continues to persist.

- Cost Effective On-Site Treatment - Conventional pollutants can be treated at the sources and the sewage treatment plant. In general, primary treatment for solids and organics, pH adjustment, and gravity oil-water separation, are cost effective at the sources, while secondary treatment for dissolved organics, nitrification and denitrification are much more cost effective at the sewage treatment plant. On the other hand, toxics must be entirely controlled by the sources since sewage treatment plants are not designed to for

Section 3 – Local Limits

toxics. By this measure, Yuba City would not be successful in ensuring all non-domestic dischargers of acidic and alkaline wastewaters provide final pH adjustment.

- Significant Non-Compliance - Significant non-compliance will be based on industrial user compliance rates once the local limits are re-developed and implemented into the permits.

Section 4

Industrial User Compliance with Federal Standards

Pretreatment programs are required to be administered to ensure industrial user compliance with Federal categorical pretreatment standards. 40 CFR 403.8(b).

4.0 Summary

Best-available-technology ("BAT") treatment or its equivalent was not applied and in place at the identified Federally-regulated industrial process within the Yuba City service area.

Requirements

- Compliance sampling points, monitoring requirements, and on-demand rinsing practices must be established and implemented in order to determine whether treatment is necessary at Custom Chrome.

Recommendations

- The operational and disposal procedures to ensure compliance with Federal categorical pretreatment standards through the achievement of zero-discharge should be determined.

4.1 Treatment In-Place

EPA Region 9 uses two performance measures that together reflect the purpose of the various Federal categorical pretreatment standards to bring about the nationwide use of model BAT treat-ment. The first measure is BAT treatment across the industrial inventory. The Federal standards for each Federally-regulated industrial category were based on the statistical performance of model BAT treatment as it is separately defined for each category. For job-shop electroplating, BAT treatment is metals precipitation, settling and solids removal, and if necessary, cyanide destruction and chromium reduction.

The lone industrial user identified during this evaluation by EPA as a Federally-regulated user, was not found to comply with its Federal standards either through BAT treatment or through facility configurations and practices to keep from discharging to the sewers.

Custom Chrome - This metal finishing job-shop is required to comply with either the expanded list of pollutants in the Federal job-shop electroplating for dischargers over 10,000 gpd, or the abbreviated list of standards for dischargers under 10,000 gpd. Compliance cannot be determined at this time with either set of standards because the rinses discharge continuously irrespective metal finishing work and the spent solutions

are not specifically monitored. This constitutes "dilution as a substitute for treatment" since the Federally-regulated wastewaters discharge without treatment for metals or cyanide. None of the previous samples are usable for the determination of compliance.

- Power Plants - No Federal categorical standards apply (*Calpine Greenleaf Unit 2, Calpine Feather River Energy Center, Calpine Yuba City Energy Center, and Yuba City Cogeneration*).

4.2 Comparison with Model IU Performance

The second measure, derived from statistical comparisons with the performance of model categorical industrial users, only applies to larger industrial user inventories.

Section 5

Industrial User Inventory

Pretreatment programs are required to develop a complete inventory of industrial users, as part of ensuring industrial user compliance. 40 CFR 403.8(b,f1iii,f2i).

5.0 Summary

Yuba City has identified for regulation its significant industrial users ("SIUs"). However it has misclassified the SIUs qualifying as either categorical industrial users. Yuba City does not have a current inventory of non-significant industrial users nor of any zero-discharge categorical industrial users who would be subject to Federal standards if they discharged. Yuba City does have an unverified business list. See Table 7 for a list of identified SIUs and Table 8 for a definition of SIU.

Requirements

- Yuba City must field verify its industrial user inventory and institute formal documented procedures to continually identify additions, deletions and changes.
- Yuba City must re-identify the SIUs in its inventory as categorical, non-categorical, and zero-discharging categorical.

Recommendations

- Yuba City should maintain its industrial user inventory by non-domestic wastewater discharge point, with each discharge point characterized by Federal point source category, annual average flow rate, type of wastewater, and owner or operator.

5.1 Inventory Completeness

Yuba City has identified SIUs but has not identified, visited, or permitted all of its commercial and industrial users in its sewer service area. As a result, EPA could not produce a completed inventory during this performance evaluation and cannot verify that all SIUs are identified. The following four characteristics would be considered by EPA as good indications of a complete inventory. First, the inventory should include commercial sources, such as dentist, supermarkets, restaurants, and automobile repair shops, none of which would be expected to pose a significant risk to the treatment works. Second, the inventory should include commercial and industrial dischargers of less than 25,000 gpd designated by SIC code. Third, the inventory should include "zero-dischargers" that would be categorical if they discharged. Fourth, the industrial users with multiple non-domestic discharges to the

sewers should be identified and permitted by separate discharge points. All of these modifications to the basic definition in 40 CFR 403.3(t) of an SIU are good indications of the successful identification of the potential threats to its treatment works. EPA found none of these modifications to the basic definitions in effect in Yuba City, however, the inventory would include two non-categorical power plants with discharges averaging less than 25,000 gpd once they are reclassified.

5.2 Inventory Classifications

The Yuba City must re-determine which industries qualify as SIUs and re-classify the five of SIUs identified by Yuba City that were found to be misclassified.

- Custom Chrome - Job-shop electroplaters subject to the Federal standards in 40 CFR 413 qualify for regulation under either a full set of regulated pollutants or an abbreviated set depending on the discharge flow rate. If every day of discharge to the sewers is under 10,000 gpd, then the abbreviated set of standards apply for cadmium, lead, cyanide, and toxic organics. If any one day exceeds 10,000 gpd, then the full set of standards apply for cadmium, lead, cyanide, and toxic organics, as well as chromium copper, nickel, silver, and zinc. Yuba City classified Custom Chrome as a job-shop electroplater discharging more than 10,000 gpd. Custom Chrome has show that its average discharges are less than 10,000 gpd. It is not clear that there is not any one day exceeding 10,000 gpd. EPA expects Custom Chrome to qualify as a job-shop electroplater that always discharges less than 10,000 gpd once it documents its daily discharges and reduces flow by instituting on-demand rinsing in response to an EPA Order.

- Calpine Greenleaf Unit 2 - This industry qualifies as an SIU because the highly mineralized nature of its wastewater discharges poses the risks of sewer line disintegration and the pass-through of toxics. Furthermore, its discharges average more than 25,000 gpd. It was misclassified as a steam electric power generating station subject to the Federal standards in 40 CFR 423. It does not qualify because it does not generate any power through steam-driven turbines. The steam electric rule would cover combined-cycle cogeneration plants that use steam-driven turbines to generate power from exhaust heat.

- Calpine Feather River Energy Center - This industry qualifies as an SIU and was misclassified as a steam electric power generating station for the same reasons stated above for Calpine Greenleaf Unit 2.

- Calpine Yuba City Energy Center - This industry qualifies as an SIU and was misclassified as a steam electric power generating station for the same reasons stated above for Calpine Greenleaf Unit 2, except its discharges do not average more than 25,000 gpd.

Section 5 – Industrial User Inventory

- Yuba City Cogeneration - This industry qualifies as an SIU and was misclassified as a steam electric power generating station for the same reasons stated above for Calpine Greenleaf Unit 2, except its discharges do not average more than 25,000 gpd.

- Sunsweet and Franklin Circle K - These are properly classified as non-categorical SIUs.

- Metal-Bearing Discharges - These might include glass polishers, metal finishers, metals formers, radiator shops, water purification facilities, and agricultural-chemical sources. See the discussion in item 2.5 of this report for sources of aluminum, arsenic, copper, iron, manganese, molybdenum, and zinc. Possibles: Chipco Mfg., Transitional Systems Mfg., Cal Classic Custom Trim.

- Other Possibles - These would include any other large dischargers, categoricals, or toxic loaders. Possibles: Paperboard Packaging Corp.

5.3 Zero-Discharging Categorical Industrial Users

Yuba City should institute the good practice of identifying and permitting industrial users that would qualify as categoricals if they discharged their Federally-regulated process-related wastewaters to the sewers. In essence these are the industrial users that comply with their Federal standards by maintaining the steps necessary to prevent the discharge of process-related wastewaters to the sewers. Including zero-discharging CIUs in the inventory ensures the local regulatory control over industrial users who would violate their Clean Water Act requirements and could endanger the operations of the treatment works if they discharged to the sewers.

Section 6

Industrial User Permits

Pretreatment programs are required to issue permits with standards and limits, sampling locations, self-monitoring requirements, and a 5-year or less expiration, as part of ensuring industrial user compliance. 40 CFR 403.8(b,f1iii,f2i).

6.0 Summary

Yuba City has a good permit program and has successfully issued valid permits to all of its identified SIUs. The permits all have standards and limits, self-monitoring requirements, and a 2-year expira-tion, but they do not specify sampling locations nor define what constitutes representative sampling. Permits will have to be re-issued once the local limits are re-determined, the SIU inventory is re-determined, and the Federal standards are re-applied. See item 7.0 for this report for a discussion on representative sampling.

Requirements

- Each permit issued to an SIU must explicitly state all applicable Federal standards, national prohibitions, and local limits, as well as the self-monitoring and reporting requirements, and sampling locations.

Recommendations

- Permits should be issued with the applicable Federal standards and national prohibitions, and then reissued to include the local limits once they are re-determined.
- Each permit issued to an SIU should list all standards, limits, self-monitoring and analytical requirements on one page, and the sampling location(s) on a site map.
- The information in the permit applications as well as any other information gathered to issue the permits, such as statistical analyses of sample representativeness, should be field verified and documented in fact sheets prepared for each SIU.

6.1 Permit Accuracy and Fact Sheets

Yuba City will have to reissue permits with the applicable Federal standards and national prohibit-tions to all of its SIUs, and then reissue them again with local limits once they are re-determined. Fact sheets should be prepared to document the information and decisions behind the permit provisions, such as Federal category, sample point, pollutants of concern, representative sampling, and self-certifications in lieu of self-monitoring.

Section 6 – Industrial User Permits

- Sunsweet - A permit must be reissued to apply the national prohibitions and the local limits, once they are re-determined. The permit should require self-monitoring for all of the local limits as well as any other toxics that identified by Sunsweet under the EPA Order, with a provision to re-open the self-monitoring requirements depending on the results. The national prohibitions should be restated to explicitly prohibit the identified discharges and conditions from Sunsweet that have or could have adversely effected the sewers or the WWTP. See items 2.0 and 2.8 of this report. Sampling protocols set in the permit should reflect the variabilities from plant operations and treatment associated with the defined sample point not only over the sampling day but also over the reporting period.

- Power Plants - The permits for the power plants must be reissued to apply the national prohibitions, to remove the Federal standards for steam electric power stations, and add the local limits, once they are re-determined. The permits should require self-monitoring for all of the local limits, with a provision to re-open the self-monitoring requirements depending on the results. The national prohibitions should be restated to explicitly prohibit the discharges and conditions that could adversely affect the sewers or the WWTP. Sampling protocols set in the permit should reflect the variabilities from plant operations and treatment associated with the defined sample points not only over the sampling day but also over the reporting period. In particular, the permit should address the entire schedule of batch, slug, blowdown, or continuous discharges through the sample point.

- Zero-Discharging CIUs - Zero-discharge permits should be issued to any industries found to comply with Federal categorical pretreatment standards by not discharging Federally-regulated process-related wastewaters. A zero-discharge permit should explicitly prohibit the discharge of the Federally-regulated wastewaters and require the industry to certify every six months to not discharging in lieu of self-monitoring. A zero-discharge permit would strengthen enforcement efforts against the illegal dumping to the sewer because the establishment of violation depends only on whether a discharge occurred and not on surveillance sampling and the difficult arguments surround the representativeness of sampling.

6.2 Permit Clarity

All of the permits issued to the SIUs should clearly communicate the applicable Federal standards, national prohibitions, local limits, sample type, sampling frequency, self-certifications in lieu of self-monitoring, analytical test methods and the associated detection limits, and, if necessary, the flow and production rates behind the Federal standards. All of this information can be presented in table form on a single page of the permit with one line per pollutant. The compliance sampling locations also could be clearly delineated on a site map annotated with a description of the location. Each permit should clearly state the effective duration and the procedures for re-applying.

Section 7

Monitoring, Self-Monitoring and Inspections

Pretreatment programs, as part of ensuring industrial user compliance [40 CFR 403.8(b)], are required to:

- Cause industrial users to self-monitoring at least twice per year unless the program samples for them [40 CFR 403.8(f1iii), 403.12(e1,g10)];
- Inspect industrial users at least once per year;
- Sample industrial users at least once per year if they self-monitor or twice per year if they are not required to self-monitor [40 CFR 403.8(f2v), 403.12(i2,e1,g10)];
- Ensure that all sampling and self-monitoring is representative of the reporting period [40 CFR 403.12(g3)].

7.0 Summary

For the most part, Yuba City successfully obtains self-monitoring as well as performs the inspections and city sampling necessary to determine compliance independent of the information submitted by the SIUs. However, the self-monitoring is not representative over the reporting periods and the sample records do not cover all of the pollutants of concern.

Requirements

- The self-monitoring records for each SIU must be complete in the number and type of

- Yuba City must sample each SIU, including Franklin Circle K, at least once per year.

Recommendations

- Inspection reports should include an analysis that the sampling is representative of both the sampling day and reporting period.

- Inspection reports should document the findings that establish the sewer discharge permit conditions and prompt any necessary revisions or enforcement actions.

- All self-certifications in lieu of self-monitoring should be explicitly stated in the permit.

Section 7 – Monitoring, Self-Monitoring and Inspections

7.1 City Inspections and Sampling

Yuba City performs routine inspections of each SIU once per year and samples them at least once per year since its permits require self-monitoring. Sunsweet is sampled each weekday and the power plants are sampled once per week. The one exception is the contaminated groundwater clean-up site, Franklin Circle K, which is not sampled by the City.

7.2 Self-Monitoring

Frequency and Coverage - The permits require daily self-monitoring for Sunsweet and quarterly self-monitoring for the others. However, the self-monitoring and city monitoring do not cover all of the pollutants of concern (aluminum, arsenic, chloroform, copper, diazinon, iron, lead, manganese, molybdenum, tetrachloroethylene, and zinc), nor the potential pollutants of concern (barium, cadmium, chromium, mercury, nickel, oil & grease, selenium, and MTBE).

Sampling Representativeness - Representative sampling points have been established and known even though they are not specified in the permits. However, the self-monitoring frequencies do not ensure representative sampling over the reporting period because the significant slug, batch and variable discharges, such as spent solutions, blowdowns and regenerants, are not specifically required by the permits to be self-monitored. Both of these findings regarding the representative-ness of sampling were illustrated at each of the SIUs inspected during this inspection.

7.3 Self-Certifications

Self-certifications in lieu of any required self-monitoring for Federal standards or local limits should be explicitly stated in the permits. In particular, the Custom Chrome permit should explicitly state which toxic organic pollutants do not have to be self-monitored if Custom Chrome self-certifies to following a previously submitted and approved toxic organics management plan, as allowed under the Federal job-shop electroplating standards in 40 CFR 413.

Section 8

Enforcement and Compliance Assistance

Pretreatment programs, as part of ensuring industrial user compliance are required to enforce their permits following an enforcement response plan, and to publish annual significant non-compliance lists [40 CFR 403.8(b,f1ii,f2vii,f5)].

8.0 Summary

The Federal regulations do not define how to determine a program's success in enforcing permit limits. However, an evaluation of enforcement and the City's enforcement response plan is premature since the SIU permits need to be revised to include updated local limits, result in representative sampling records, and apply the proper Federal standards.

Requirements

- Approved pretreatment programs are required to develop and follow an enforcement response plan that specifies the actions, and their time frames, that the City will take in response to each type of industrial user permit.

Recommendations

- None.

Figure 1

Yuba City Water Pollution Control Facility
Schematic of the Wastewater Treatment

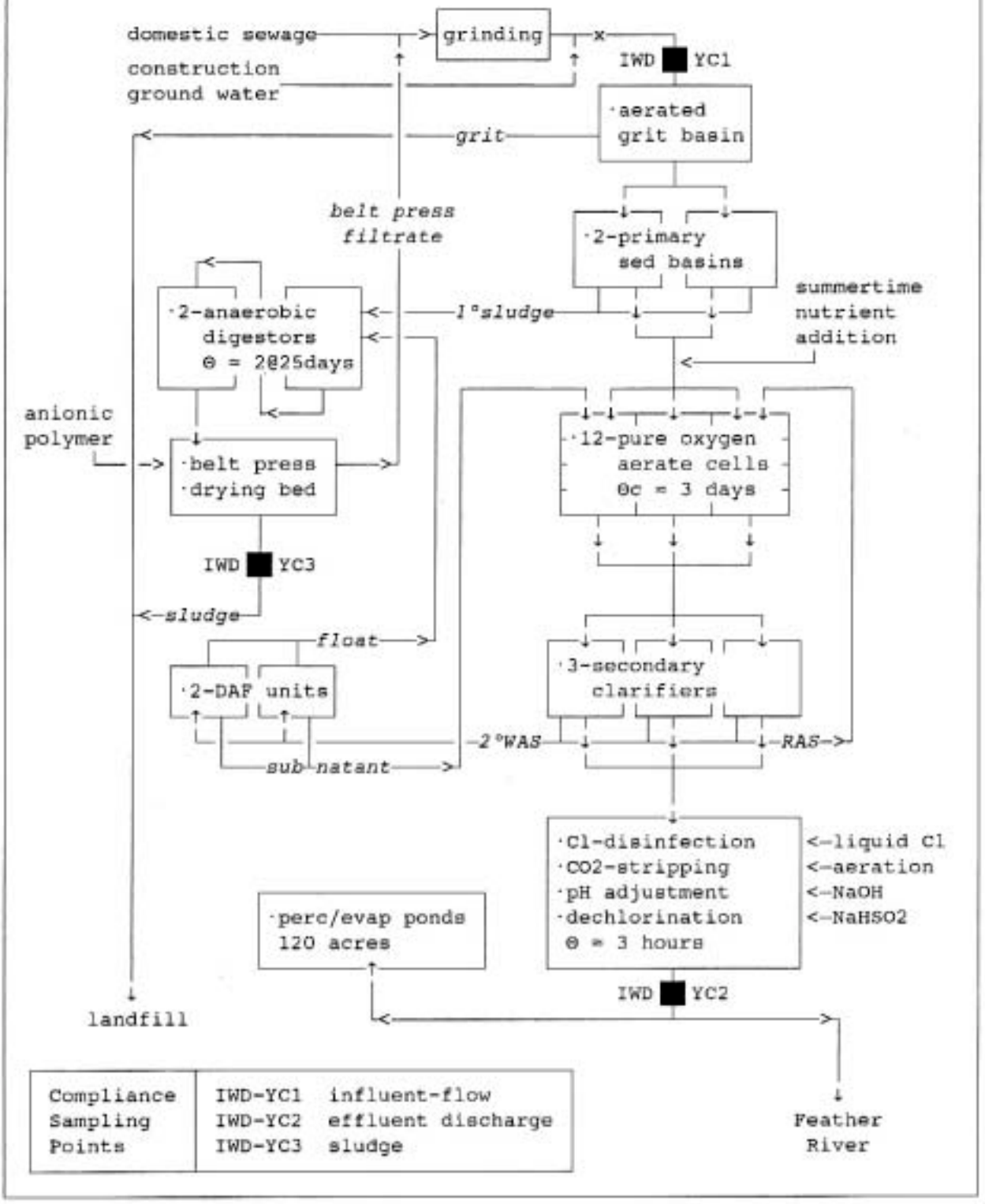

Table 1

Yuba City WWTP Wastewater Quality
Conventionals Pollutants, Nutrients, Other Non-Toxics
Jan-2003 to Jan-2004

Pollutants (mg/l)	influent mean	5th%	99th%	effluent mean	99th%	sample viol rate d-max	avgs	count
flow (mgd)	6.60	5.57	8.05	5.98	-	nr	nr	365
BOD	339.	182.	560.	10.5	21.6	0/101	0/12	101
TSS	190.	103.	312.	8.7	15.4	0/261	0/12	261
*ammonia-N	28.8	12.3	52.1	12.9	36.9	8/34 b/	3/3	34
*nitrates-N	0.28		0.51	0.77	2.00	0/11	nr	11
*phosphates-P	4.73		14.6	3.03	5.02	nr	nr	5
MBAS-surfactants			-	0.25	0.45	0/3	nr	3
TDS			465.	370.	457.	nr	nr	11
alkalinity			-	145.	164.	nr	nr	3
*hardness			92.	119.	78.	nr	nr	7
*hardness @ R-1				15.2	8.78	nr	nr	5
hardness @ FR c/				34.9	22.6	nr	nr	27
*sulfates			15.	22.	44.	nr	nr	4
*chlorides			66.	82.	116.	nr	nr	4
sodium			61.		76.	nr	nr	1
EC (µmhos/cm2)			600.	728.	827.	nr	nr	10

Stat Measures	Median	95%th	99th%	Max	maxs	avgs	count
acute toxicity	pass	pass	pass	pass	0/12	nr	12
pH-min (s.u.)	<6.5 at least 4 times			5.8	≥4	-	cont
pH-max (s.u.)	>8.5 at least once			9.0	≥1	-	cont

* effluent results for salts/nutrients include data from 2000-2002 DMRs
b/ minimum ammonia based on maximum pH of discharges to the river of 7.2 and average temperature during the wet-season of 70°F.
c/ USGS Feather River station at Nicolaus from the 1996-1998 National Water Quality Assessment Program - Sacramento River Basin Study (single sample minimum hardness in entire basin was 18.0 mg/l)
nr no required permit limits
cont continuous pH meter reading

Table 2

Yuba City WWTP Wastewater Quality
Inorganic Toxic Pollutants, Toxic Organics, and Pesticides - Compliance Deadlines Nov 2007
Jan-2000 to Jan-2004

Pollutants (µg/l)	surface a/ mean	99th%	grnd mean	est avgs	influent mean	99th%	effluent b/ mean	99th%	remo vals	sampl viol rate d-max	avgs	count
aluminum	11.6	38.3		11.6	1965	6225	256.	571.	87%	4/4 c/	4/4	10 d/
arsenic	<1.0	<1.0	15.8	2.5	6.1	34.0	7.8	33.5	~0%	-	0/4	14
barium	13.7	18.2	292.	41.5	98.6	257.	19.5	24.1	80%	-	-	6
beryllium	<1.0	<1.0		<1.0	0.3	1.5	0.4	1.7	~0%	-	-	10
cadmium	<1.0	<1.0		<1.0	0.5	1.7	0.2	0.3	68%	0/3 c/	0/3	10
chromium	<1.0	1.1		<1.0	1.2	3.1	0.9	1.1	-	0/1 c/	0/1	11
copper	1.1	2.2		1.1	50.1	90.2	8.5	18.7	83%	4/4 c/	4/4	14 d/
iron	23.6	63.1	40.8	25.3	960.	1476	164.	309.	83%	0/4	-	10 d/
lead	<1.0	<1.0	4.7	1.4		2.7		0.75	-	1/1 c/	1/1	1 d/
manganese	4.8	13.4	71.5	11.5	49.8	130.	53.0	135.4	~0%	3/4	-	5 d/
mercury	0.008	0.030		0.008	0.50	1.37	0.017	0.048	96%	0/4	-	10
molybdenum	<1.0	<1.0		<1.0	10.3	30.8	11.0	31.6	~0%	0/3	-	13 d/
nickel	<1.0	1.0		<1.0	3.7	10.3	1.8	4.0	51%	0/1 c/	0/1	7
selenium	<1.0	<1.0		<1.0	7.2	45.1	7.1	44.7	~0%	-	-	11
silver	<1.0	<1.0		<1.0		0.90		0.32	-	0/1 c/	nr	1
zinc	<1.0	1.9		<1.0	157.	329.	51.8	86.7	67%	4/4 c/	4/4	14 d/
chloroform					9.7	18.5	3.7	18.5	-	1/3	-	3 d/
diazinon							0.12	0.57		1/3	1/3	3 d/
dibromochlorometh							0.21	1.02		0/3	1/3	3 d/
dichlorobromometh							1.62	6.22		1/3	1/3	3 d/
MTBE							0.32	1.24		0/3	-	7
tetrachloroethyle							0.64	1.00		0/3	0/3	3 d/
other tox organx							<0.02	<0.02		0/4	0/4	4

a/ Surface water supply data from USGS Feather River station at Nicolaus - 13 miles downstream.
Ground water supply data from Yuba City water quality report for Hillcrest water users.
Estimated water supply flow-weighted averages based on estimated mix of 1:9 ground to surface water.
b/ Effluent results for toxics include data from 2000-2002 DMRs.
c/ Metals limits based on a calculated 22.6 mg/l minimum hardness at Feather River station at Nicolaus.
d/ See Table 4 for computed statistical probabilities of exceeding limits - otherwise viols no expected.

Table 3

Yuba City WWTP Sludge Quality
Jan-2000 to Jan-2004

Pollutants (mg/kg)	Federal Standards ceiling	reuse	landfill	sample results mean a/b/ 99th%	sample viol d-max	count
arsenic	75	41	73	14.0	nr	1
cadmium	85	39	-	<10.9	nr	2
chromium	-	-	600	28.5	nr	2
copper	4300	1500	-	237.7	nr	2
lead	840	300	-	31.0	nr	1
mercury	57	17	-	1.4	nr	2
molybdenum	75	-	-	<77.0	nr	1
nickel	420	420	420	<59.6	nr	2
selenium	100	100	-	<15.0	nr	1
silver	-	-	-	8.5	nr	2
zinc	7500	2800	-	507.9	nr	2
total toxic metals				829.0		

a/ self-monitoring in 2000-2002 not reported in mg/kg dry-weight nor with moisture content
b/ detection limits in 2003 for arsenic and selenium over standards
nr no requirements because sludge is not land applied or monofilled

Table 4

Yuba City WWTP Wastewater Quality
Computed Statisitcal Probabilties of Exceeding Limits
Jan 2004

daily-max limits (µg/l)	mean	std dev	probability		percent
aluminum	µ = 256.2	σ = 135.1	α(120)	= 0.8433	84%
ammonia (mg/l)	µ = 12.87	σ = 10.32	α(19.7)	= 0.2231	22%
chloroform	µ = 3.670	σ = 6.355	α(1.1)	= 0.6569	66%
#copper	µ = 8.486	σ = 4.395	α(2.65)	= 0.9078	91%
diazinon	µ = 0.120	σ = 0.191	α(0.08)	= 0.5829	58%
#dibromochloromethane	µ = 0.210	σ = 0.347	α(1.1)	= 0.0051	<1%
#dichromobromomethane	µ = 1.620	σ = 1.976	α(1.5)	= 0.5242	52%
iron	µ = 163.8	σ = 62.37	α(300)	= 0.0145	1%
#lead	µ = na	σ = na	α(0.375)	> 0.5000	>50%
manganese	µ = 53.01	σ = 35.36	α(50)	= 0.5339	53%
molybdenum	µ = 11.05	σ = 8.816	α(10)	= 0.5474	55%
pH-lower limit (su.)	µ = na	σ = na	α(6.5)	= 0.0110	1%
pH-upper limit (su.)	µ = na	σ = na	α(8.5)	= 0.0027	<1%
#zinc	µ = 51.77	σ = 14.97	α(34.0)	= 0.8683	87%

month-avg limits (µg/l)	mean	std dev	probability		percent
aluminum	µ = 205.0	σ = 58.02	α(78)	= 0.9857	99%
ammonia (mg/l)	µ = 13.07	σ = 3.912	α(3.56)	= 0.9925	99%
arsenic	µ = 8.870	σ = 9.002	α(10)	= 0.4540	45%
#copper	µ = 7.900	σ = 2.252	α(1.38)	= 0.9980	>99%
diazinon	µ = 0.120	σ = 0.191	α(0.04)	= 0.6623	66%
#dibromochloromethane	µ = 0.210	σ = 0.347	α(0.41)	= 0.2816	28%
#dichromobromomethane	µ = 1.620	σ = 1.976	α(0.56)	= 0.7041	70%
#lead	µ = na	σ = na	α(0.829)	< 0.5000	<50%
#tetrachloroethylene	µ = 0.640	σ = 0.155	α(0.8)	= 0.1510	15%
#zinc	µ = 40.50	σ = 3.786	α(22.3)	= 0.9999	>99%

expected permit limits to be in effect in Nov 2007
minimum hardness of 22.6 mg/l CaCO3 used in metals limits calculations

Table 5

Comparison of Wastewater Quality
Average Concentrations of Toxics Jan-00 to Jan-2004

Influent (µg/l)	Yuba City	Deer Creek	ElDor Hills	Grass Vally	Nevad City	Placr Co#1	Red Bluff	Stock -ton	norm a/
aluminum	**1965**					820.			+0.7
arsenic	**6.1**	<1.0	1.4	<1.0	1.1	<1.0	1.33	4.4	+2.0
barium	98.6								
beryllium	0.3							<0.5	
cadmium	**0.5**	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.4	
chromium	1.2	<5.0	5.5	<1.0	<5.0	<5.0	7.6	**8.0**	-1.4
copper	50.1	83.0	**110.**	45.5	20.0	22.5	26.0	39.0	+0.0
iron	960.	430.	**1600**	510.	1500	1425			-0.2
lead	2.7	<5.0	<5.0	<5.0	5.8	10.4	<5.0	**10.9**	-0.6
manganese	49.8	24.0	**200.**	98.0	46.0	87.0			-0.5
mercury	**0.50**	0.26	0.43	0.26	0.21	<0.2	<0.2	0.30	+1.7
molybdenum	**10.3**							4.6	+0.7
nickel	3.7	3.3	5.5	4.6	3.1	5.1	5.0	**9.1**	-0.6
selenium	**7.2**	1.1	1.4	<1.0	<1.0	<1.0	<1.0	<0.5	+2.4
silver	0.90	1.1	2.5	**3.7**	1.0	1.3	2.86	1.8	-1.0
zinc	157.	120.	160.	**225.**	91.0	110.	77.5	138.	+0.5

Effluent (µg/l)	Yuba City	Deer Creek	ElDora Hills	Grass Valley	Nevada City	Placer Co#1	Red Bluff	Stock -ton	norm a/
aluminum	**256.**	39.0	36.4	26.8	47.1	101.			+2.0
arsenic	**7.75**	0.4	0.50	1.29	1.5	0.43	1.44	3.6	+2.3
barium	**19.5**	4.05	2.02	4.04	9.2	4.82			+1.9
beryllium	**0.44**	0.022	<0.003	<0.1	<0.1	<0.02	<1.0	<0.5	+2.1
cadmium	0.17	<1.0	0.071	0.05	<1.0	0.05	**0.39**	<0.1	+0.2
chromium	0.94	0.34	0.48	0.30	0.30	0.25	1.13	**1.6**	+0.6
copper	8.49	**20.4**	13.7	4.03	2.4	2.00	7.62	5.6	+0.1
iron	**164.**	31.4	8.40	87.1	44.0	79.2			+1.7
lead	**0.75**	0.50	0.061	0.41	0.33	0.73	0.45	<1.0	+0.9
manganese	**53.0**	1.58	2.57	35.9	10.8	34.7			+1.4
mercury	**0.017**	<2.0	0.002	0.005	0.013	0.004	<0.2	<0.2	+1.4
molybdenum	**10.5**							5.1	+0.7
nickel	1.78	**24.0**	3.28	4.15	1.8	2.62	1.55	7.1	-0.5
selenium	**7.10**	<1.0	0.28	0.45	0.3	0.15	0.57	<0.5	+2.5
silver	**0.76**	<1.0	0.006	<0.08	<1.0	0.07	0.34	<0.4	+1.7
zinc	51.8	36.5	22.9	**60.7**	34.5	27.3	53.0	14.8	+0.9

Flow (mgd)	6.60	2.94	1.94	1.75	0.42	1.95	1.35	32.4	

bold highest sampling averages highlighted in bold

a/ calculated norm for Yuba City versus 8-city averages

$$\text{norm} = \frac{(x - \mu)}{\sigma}$$

x = Yuba City average
μ = 8-city averages
σ = 8-city std deviation

Table 6

Sampling Results
City of Yuba City Wastewater Treatment Plant

Sample Number	YC001	YC002	YC003	YC009	YC004
Date	08/27/03	08/27/03	08/27/03	08/27/03	08/27/03
Type	24-hr	24-hr	24-hr	grab	grab
Location	WWTP	WWTP	WWTP	Field	WWTP
Point	Influent	Influent	Effluent	Blank	Sludge
Units	mg/l	mg/l	mg/l	mg/l	mg/kg *
aluminum	1.40	1.40	0.240	<0.010	13000
arsenic	0.0026	0.0028	0.0026	<0.0005	14
cadmium	<0.0010	<0.0010	<0.0010	<0.0010	<7.7
chromium	0.0041	0.0034	0.0012	<0.0010	38
copper	0.028	0.024	0.0056	<0.0020	320
cyanide-total	<0.010	0.020	<0.010	<0.010	
iron	0.76	0.73	0.18	<0.10	8200
lead	0.0026	0.0028	0.0008	<0.0010	31
manganese	0.024	0.023	0.068	<0.0010	940
mercury	0.00032	0.00041	0.00004	<0.00003	2.0
molybdenum	0.010	0.010	0.018	<0.0005	<77
nickel	0.0039	0.0036	0.0039	<0.0010	<77
selenium	0.0007	0.0007	0.0006	<0.0010	<15
silver	0.0009	0.0009	0.0003	<0.0005	12
zinc	0.095	0.094	0.046	<0.005	700
ammonia-N	10	10	5.30	<0.30	
boron	0.170	0.170	0.180	<0.100	
chloride	66	65	99	<1.0	
hardness	92	92	110	<2.3	
nitrate-N	0.51	0.28	1.6	<0.10	
total phosphate-P	3.5 o/	3.5 o/	1.4 o/	<1.0 o/	
sodium	61	61	76	<0.5	
sulfate	14	15	21	<0.5	
TDS	470	460	360	<20	
EC (umohs/cm)	610	590	630	3	
moisture (%)					87%

All samples collected, kept in custody, and delivered to the laboratory by Greg V. Arthur. Samples analyzed by EPA's Richmond Laboratory. Documentation including chain of custody and quality control results are attached.

* dry-weight o/ ortho-phosphate as P

Table 6 (continued)

Sampling Results
City of Yuba City Wastewater Treatment Plant

Sample Number	YC005	YC006	YC008	YC007	
Date	08/20/03	08/20/03	08/20/03	08/21/03	
Type	grab	grab	24-hr	grab	
Location	CustChrm	CustChrm	Greenleaf	Field	
Point	Tank-3	Tank-26	Unit2	Blank	
Units	mg/l	mg/l	mg/l	mg/l	
aluminum	0.032	0.130	3.60	<0.010	
arsenic	0.0003	0.0006	0.0087	<0.0005	
cadmium	<0.0010	0.033	0.0016	<0.0010	
chromium	0.032	0.019	0.047	<0.0010	
copper	0.057	0.063	0.300	<0.0020	
cyanide-total	<0.010	<0.010		<0.010	
iron	0.72	1.70	9.80	<0.100	
lead	0.0006	0.021	0.0044	<0.0010	
manganese	0.001	0.009	0.190	0.0018	
mercury	<0.00003	<0.00003	0.00006	<0.00002	
molybdenum	0.0003	0.0004	2.00	<0.0005	
nickel	2.70	0.080	0.064	<0.0010	
selenium	<0.0010	<0.0010	0.0070	<0.0010	
silver	<0.0005	<0.0005	<0.0005	<0.0005	
zinc	0.023	0.140	0.870	<0.0050	
ammonia-N	<0.30	<0.30	<0.30	<0.30	
boron	0.240	<0.100	0.098	<0.100	
chloride	4.0	5.7		<1.0	
hardness	46	46		<2.3	
nitrate-N	<0.10	0.06		<0.10	
ortho phosphate-P	<1.0 o/	<1.0 o/		<1.0 o/	
sodium	6.9	9.9	1700	<0.500	
sulfate	19	7.9		<0.50	
TDS	93	85		<20	
EC (umohs/cm)	150	140		3	

All samples collected, kept in custody, and delivered to the laboratory by Greg V. Arthur. Samples analyzed by EPA's Richmond Laboratory. Documentation including chain of custody and quality control results are attached.

() invalid result o/ ortho-phosphate as P

Table 7

City of Yuba City Service Area 2004 Inventory
(based solely on EPA observations)

SIGNIFICANT INDUSTRIAL USERS ("SIUs")	FLOW in gpd	PRETREATMENT-IN-PLACE	FEDERAL CATEGORY	BAT
Sunsweet Growers	764485	SCRN PH	non-cat	n/a
Custom Chrome & Bumper	15000	-	413	BAT-
Calpine-Greenleaf #2	47600	PH	non-cat	n/a
Calpine-Feather River EC	50000	PH	non-cat	n/a
Calpine-Yuba City EC	20000	PH	non-cat	n/a
Calpine-Yuba City Cogen	5000	PH	non-cat	n/a
Franklin Circle K	25000	CARBON	non-cat	n/a

Federal Category and Best Available Technology

413	Job-shop Electroplating >10,000 gpd
non-cat	Non-Categorical SIU
BAT	Best-Available-Technology treatment (equivalent to the model treatment used in setting the Federal standards)
BAT+	Exceeds BAT treatment
BAT-	Falls short of BAT treatment
n/a	No applicable Fed standards that are that are based on model treatment

Treatment-In-Place

CARBON	Activated Carbon
PH	pH Adjustment
SCRN	Screening

Table 8

Pretreatment Program Definitions

Pass-Through: A non-domestic discharge which exits the treatment works in quantities or concentrations which, alone or in conjunction with other non-domestic discharges, *is a cause of violation* of any requirement of the NPDES permit, 40 CFR 403.3(n).

Interference: A non-domestic discharge, including excessive or slug loads of conventional pollutants, which inhibits or disrupts the treatment with other non-domestic discharges, inhibits or disrupts the treatment works, its treatment processes or operations, or its sludge processes, use or disposal, *thereby causing a violation* of any requirement of the NPDES permit or any Federal, state or local sludge regulation, 40 CFR 403.3(i).

Local Limits: Specific limits developed and enacted by the local authority, designed to prevent pass-through, interference, sludge contamination, and potential threats to worker health and safety, and to ensure renewed and continued compliance with the NPDES permit or sludge use or disposal practices, 40 CFR 403.5(c).

Significant Industrial User: A non-domestic source that either (1) is subject to Federal categorical pretreatment standards, or (2) discharges an average of more than 25,000 gpd of process wastewater, or (3) makes up more than 5% of the flow or organic capacity of the treatment plant, or (4) is determined by the local authority or State to have a reasonable potential to adversely effect the treatment works, 40 CFR 403.3(t).

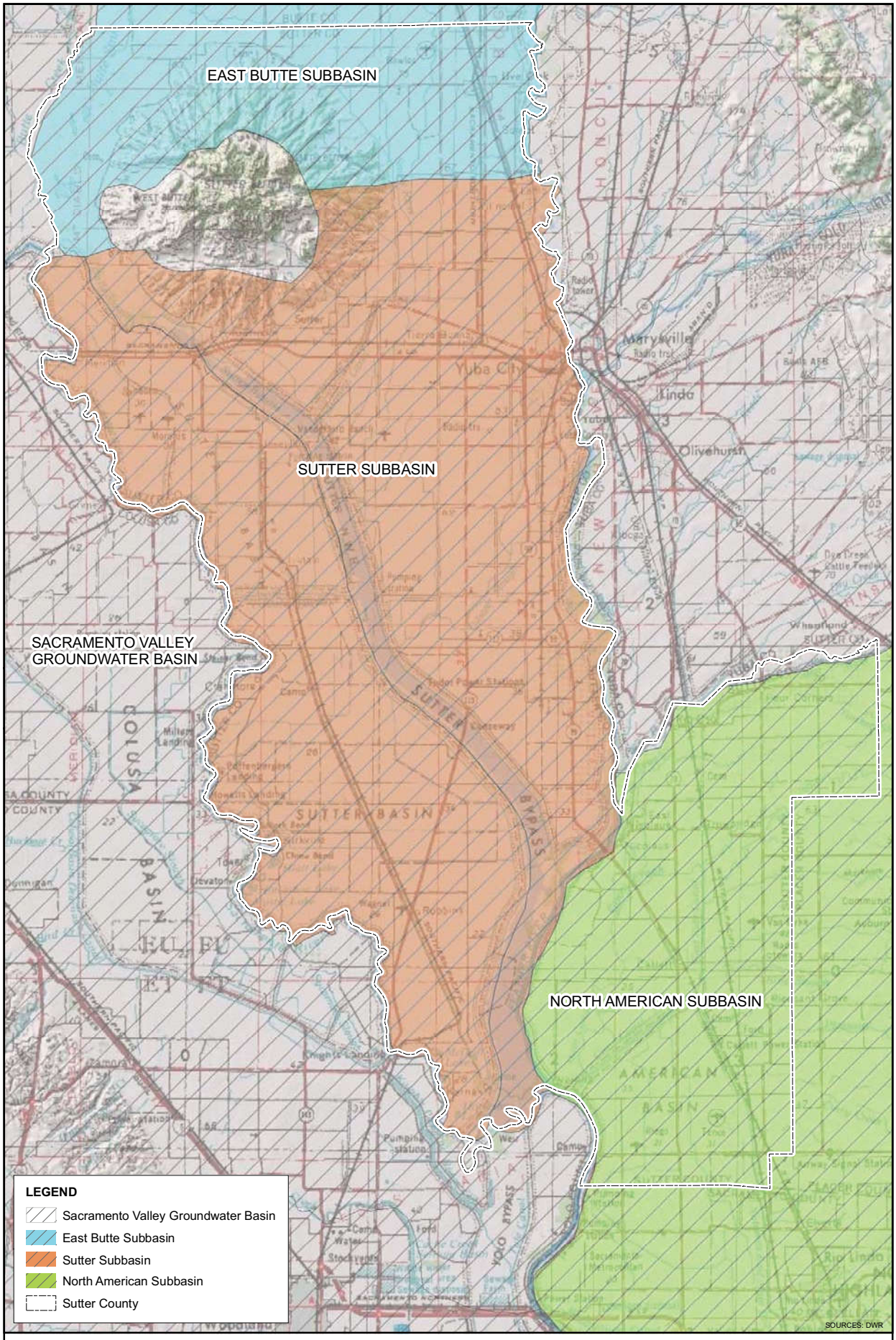

FIGURE 1
GROUNDWATER BASIN AND SUBBASINS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120201 Final Draft Figure Comments\Figure 1 Groundwater Subbasins.mxd 2/7/2012 12:50:01 PM bdemucha

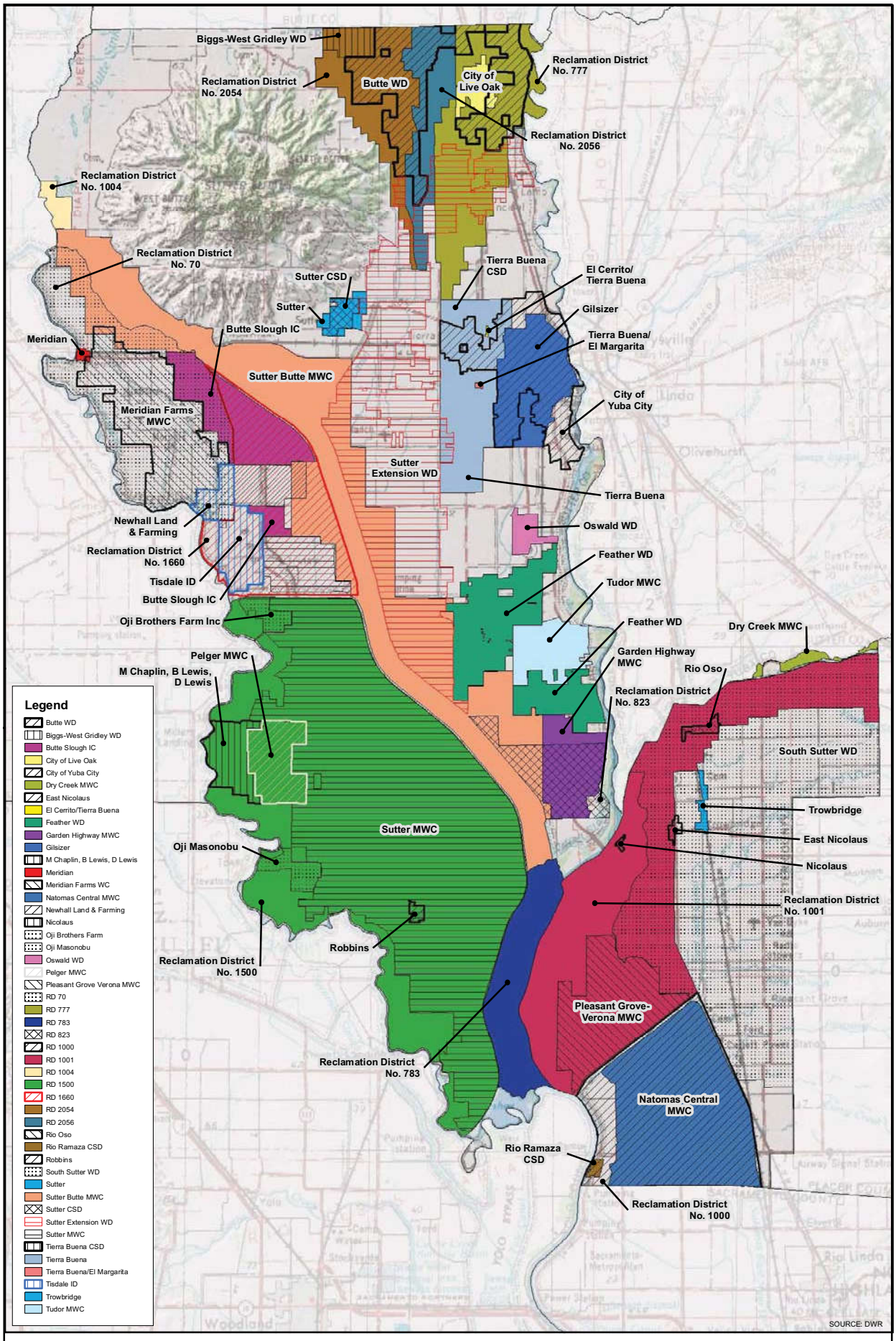

FIGURE 2
WATER DISTRICTS, PURVEYORS, AND WATER COMPANIES
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
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MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 2 Water_District_Poster.mxd 2/7/2012 12:39:44 PM bdemucha

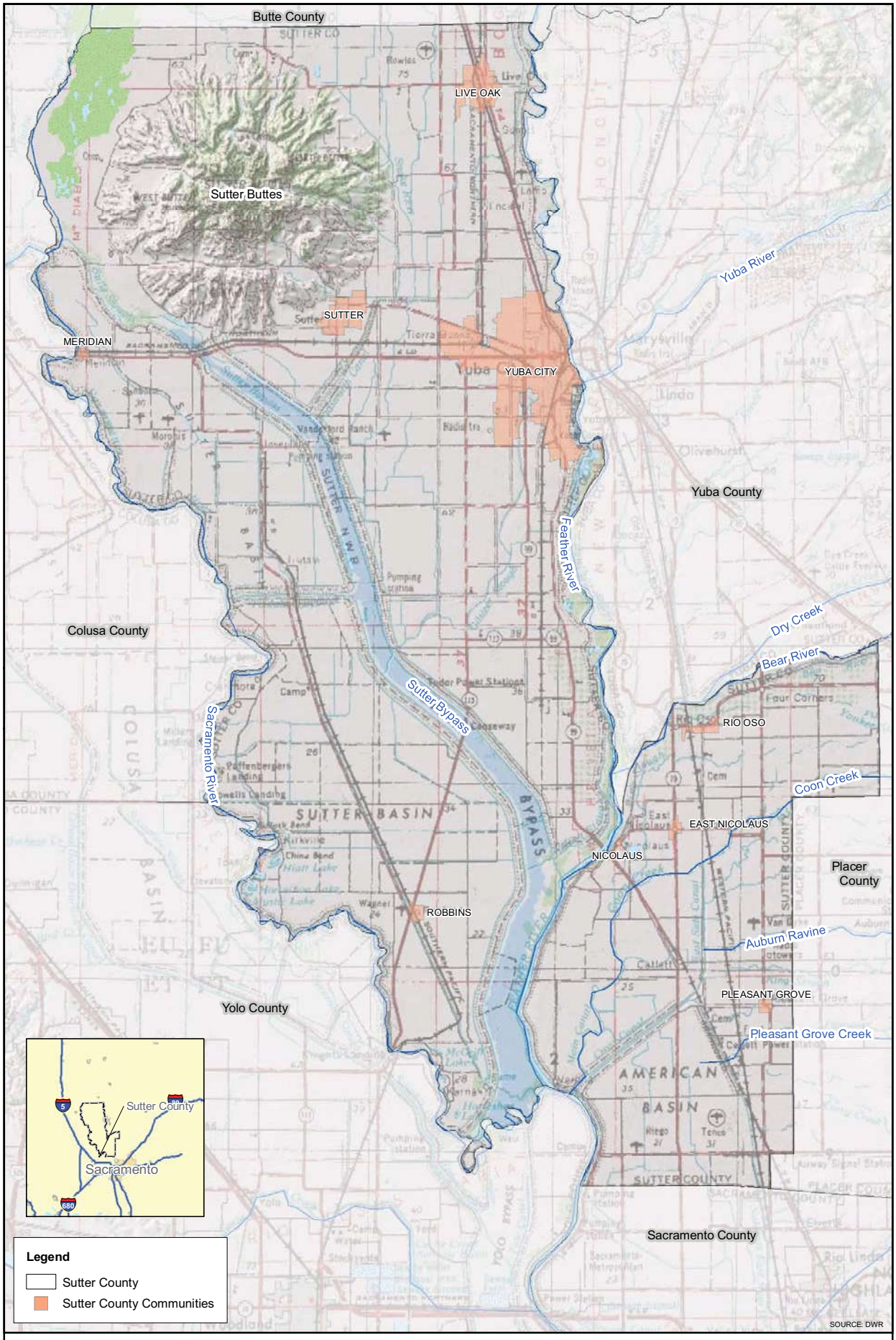

FIGURE 5
PHYSICAL FEATURES
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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NORTH
0 1.5 3
MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 5 Sutter County Physical Features.mxd 2/7/2012 12:47:54 PM bdemucha

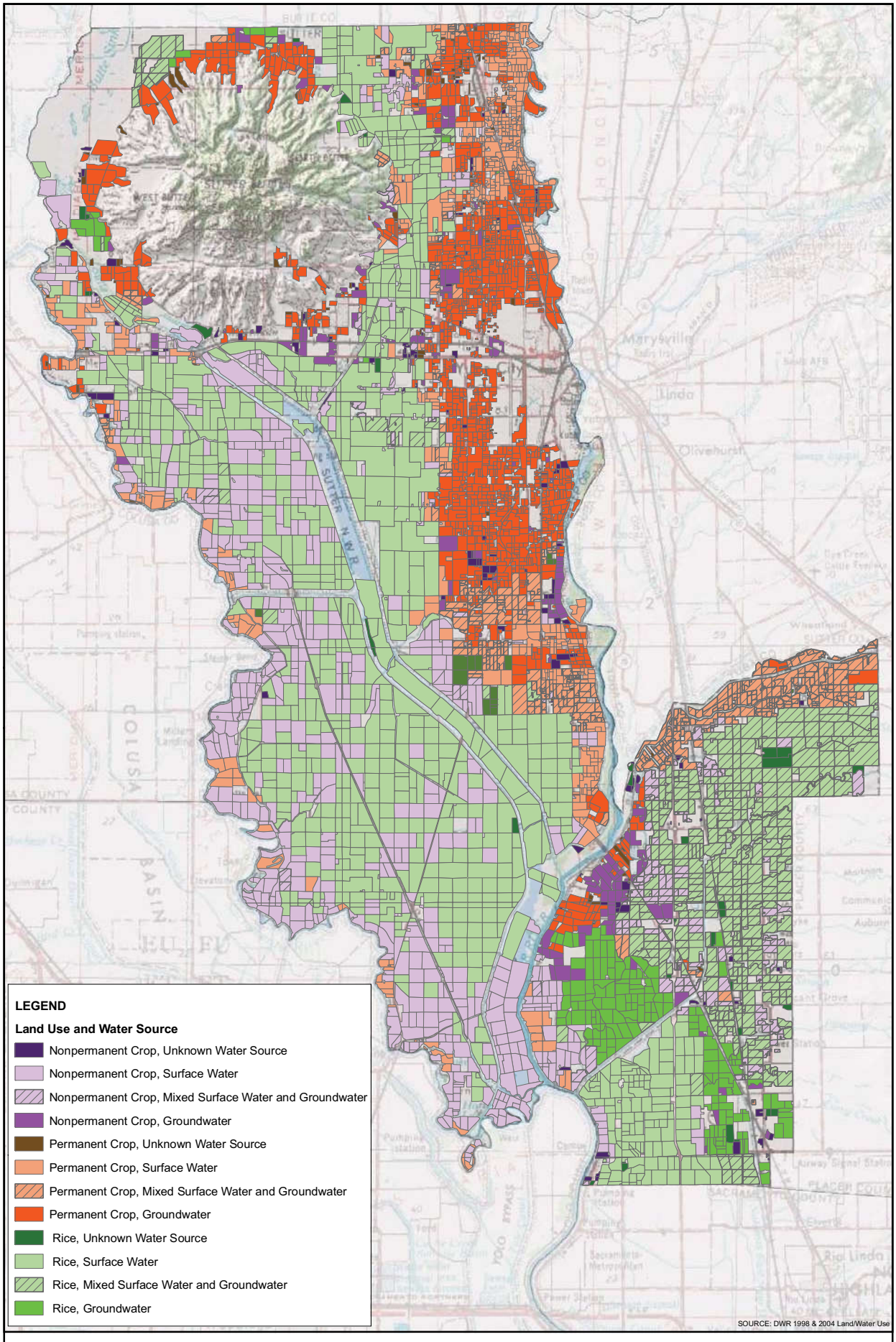

FIGURE 6
WATER SOURCES FOR IRRIGATED CROPS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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NORTH
0 1.5 3
MILES

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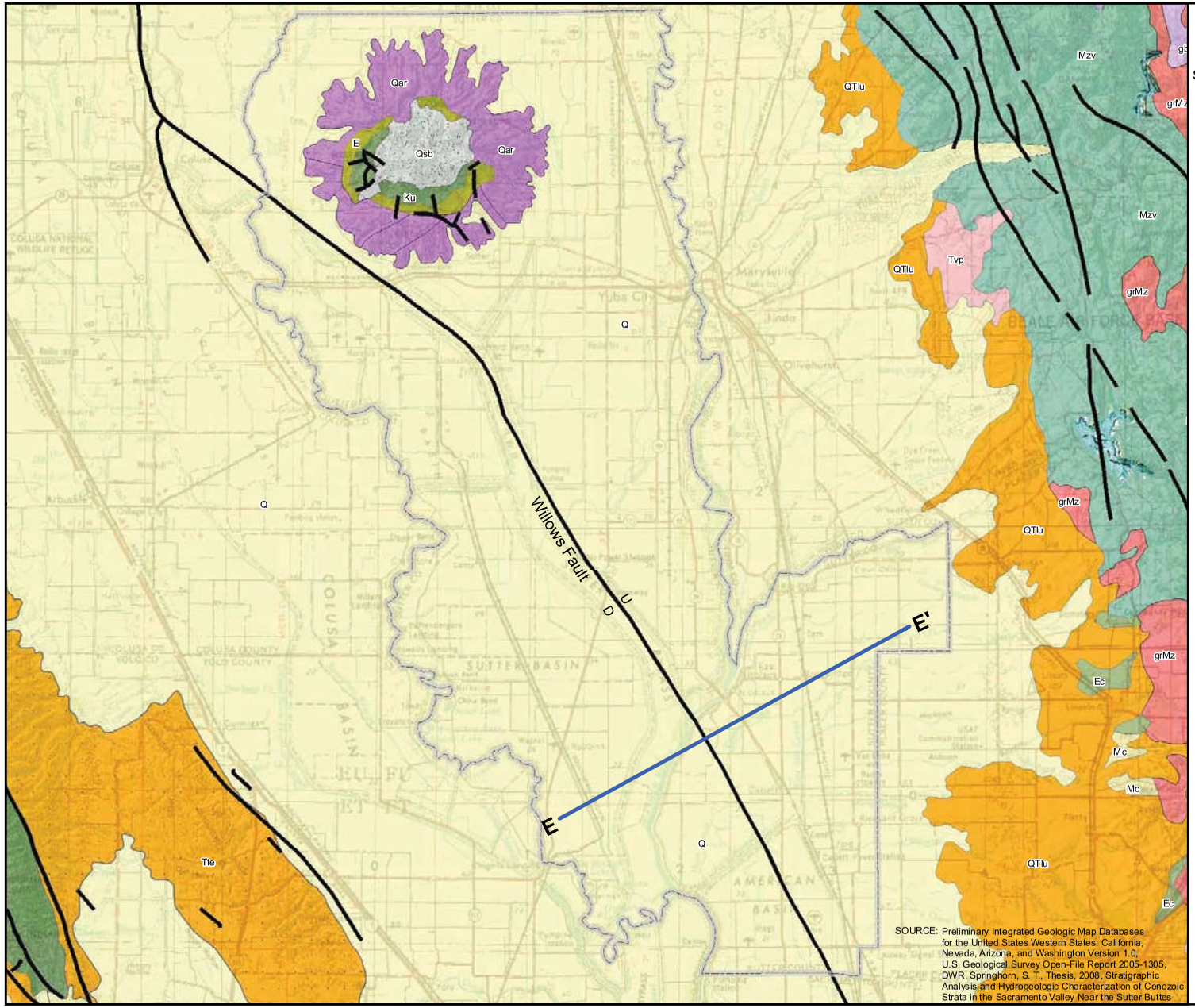
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 6 Water_Source_IRR_Crops_.mxd 2/7/2012 12:52:19 PM bdemucha

FIGURE 7
SIMPLIFIED SURFACE GEOLOGY AND FAULTS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012



NORTH

0 2 4
MILES

LEGEND

- Q - Recent Deposits
  - Qb - Basin Deposits
  - Qm - Modesto Formation
  - Qr - Riverbank Formation
- Qsb - Sutter Buttes Igneous Rocks
- Qar - Sutter Buttes Andesitic Rampart
- QTlu - Laguna Formation
- Tte - Tehama Formation
- Tvp - Andesite, Rhyolite
- Mc - Sandstone, Conglomerate
- Ec - Conglomerate, Sandstone
- E - Mudstone, Sandstone
- Ku - Sandstone, Mudstone
- J - Mudstone, Sandstone, & Slate
- um - Serpentinite
- Mzv - Volcanic, Metavolcanic
- gb - Gabbro, Diorite
- grMz - Granodiorite
- Fault
- Fault Displacement - U, upthrown side; D, downthrown side
- Counties
- Simplified Conceptual Geologic Cross Section Line (See Figure 8)

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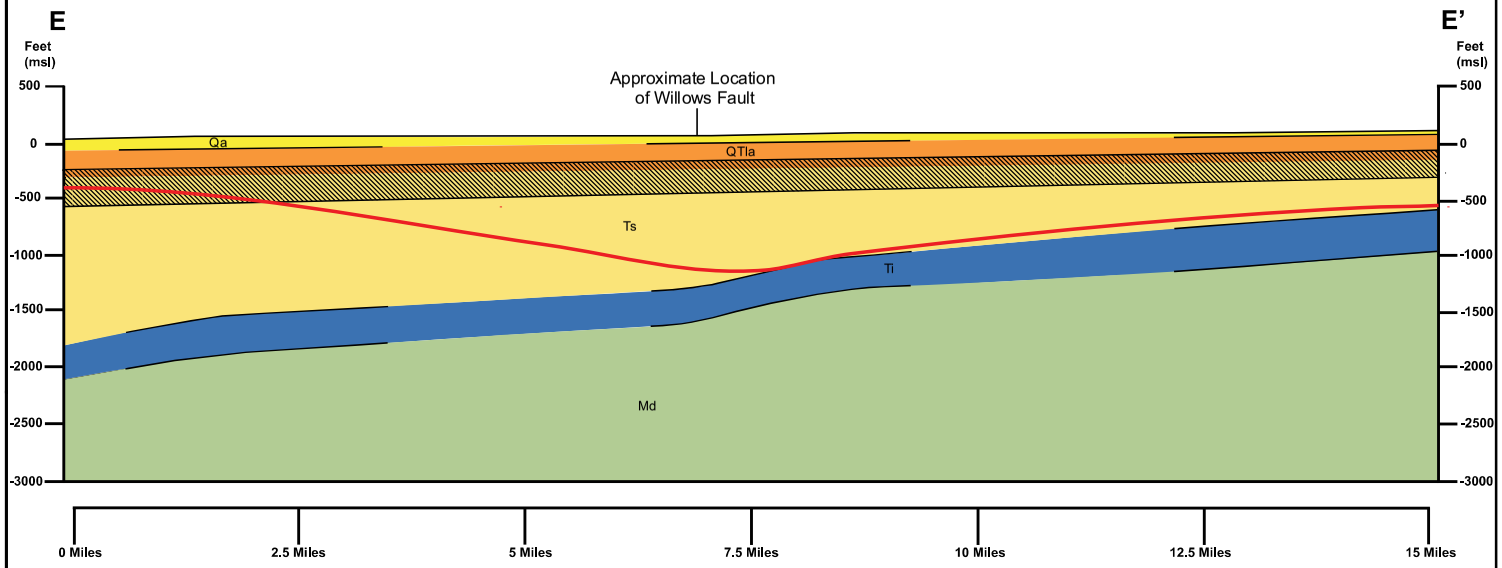
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 7 Simplified Surface Geology and Faults.mxd 2/7/2012 12:54:14 PM bdemucha

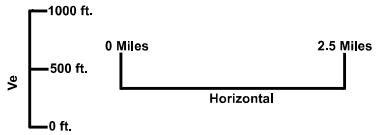
FIGURE 8
SIMPLIFIED CONCEPTUAL GEOLOGIC CROSS SECTION
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012



Explanation

- Qa — Alluvial Deposits
- QTla — Laguna Formation
- Laguna and Sutter Formation Transition (approximate depth)
- Ts — Sutter Formation (map unit, Williams and Curtis, 1977; Helley and Harwood, 1985)
  - Tt — Tuscan Formation (map unit, Helley and Harwood, 1985)
  - Tm — Mehrten Formation (map unit, Helley and Harwood, 1985)
- Ti — Ione Formation (map unit, Helley and Harwood, 1985)
- Md — Marine Deposits
- Inferred Geologic Contact
- Approximate Base of Fresh Water. Line represent depths at which Specific Conductance levels exceed approximately 3,000 umhos/cm

Cross Section Scale



SOURCES: DOGGR; DWR; Springhorn, S. T., Thesis, 2008, Stratigraphic Analysis and Hydrogeologic Characterization of Cenozoic Strata in the Sacramento Valley Near the Sutter Buttes; Berkstresser, C.F. Jr. 1973. Base of Fresh Ground-Water -- Approximately 3,000 micromhos in the Sacramento Valley and Sacramento-San Joaquin Delta, California. U.S. Geological Survey Water-Resource Inv. 40-73; Helley, E. J. and Harwood, D. S., 1985, Geologic Map of Late Cenozoic Deposits of the Sacramento Valley and Northern Sierran Foothills, California.

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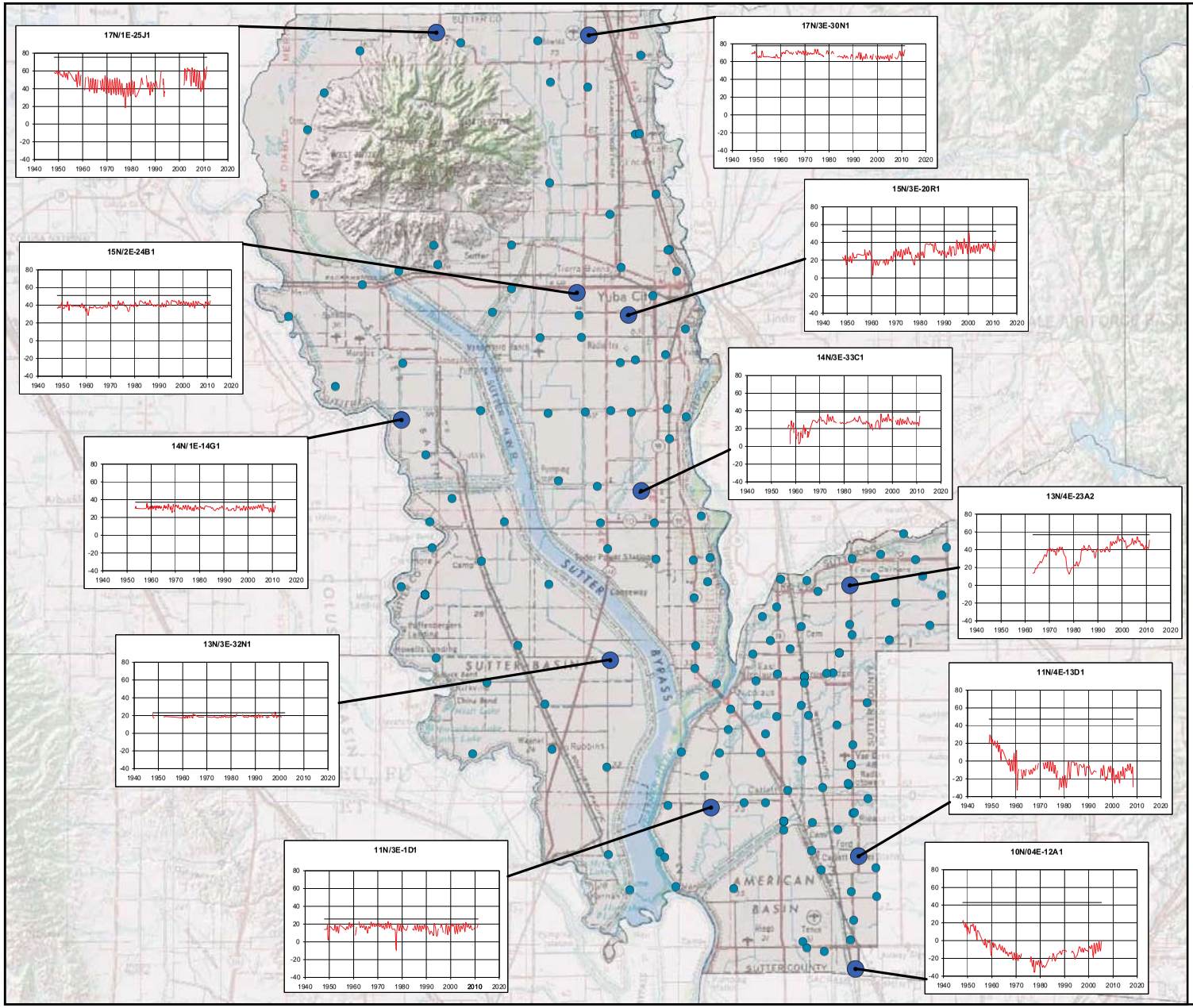


FIGURE 9
HISTORIC GROUNDWATER ELEVATIONS IN SUTTER COUNTY
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH

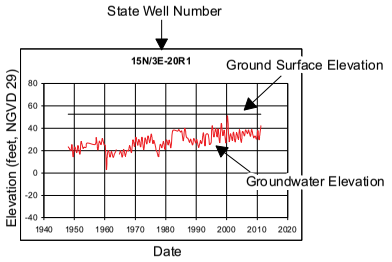
0 2 4
MILES

Legend

- Well with Hydrograph Shown
- Well with Water Level Measurement since 2004

Note: This figure represents wells with historic water level and current measurements either submitted to or obtained by the California Department of Water Resources and may not represent current monitoring activities. Groundwater elevations are in feet above mean sea level.

SOURCE: DWR



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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 9 Historic Groundwater Elevations in Sutter County .mxd 2/7/2012 12:59:56 PM bdemucha

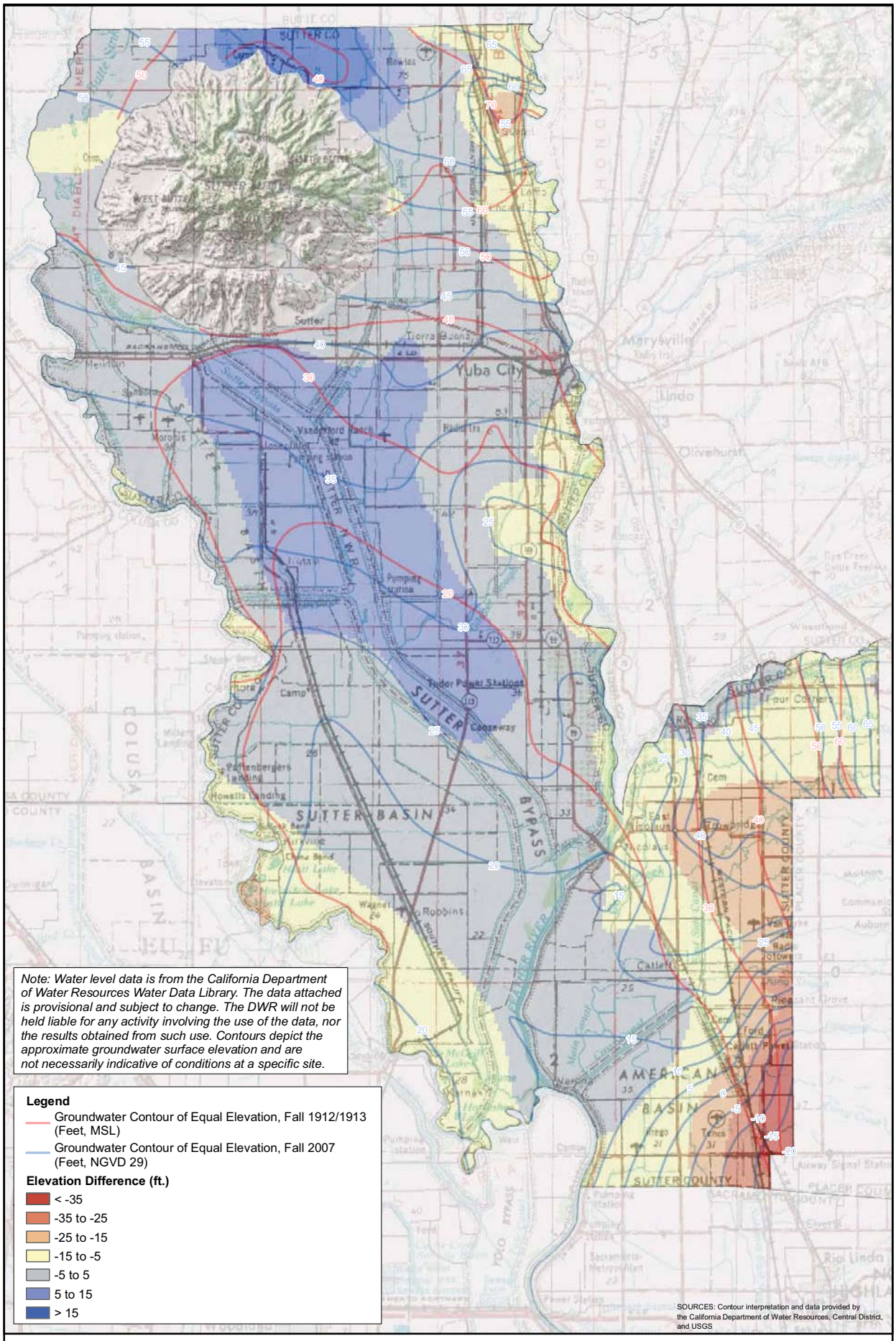

FIGURE 10
GROUNDWATER LEVEL CHANGE MAP
FALL 2007 AND FALL 1912/1913
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120201 Final Draft Figure Comments\Figure 10 Groundwater_elevation_change_map.mxd 2/7/2012 5:35:33 PM bdemucha

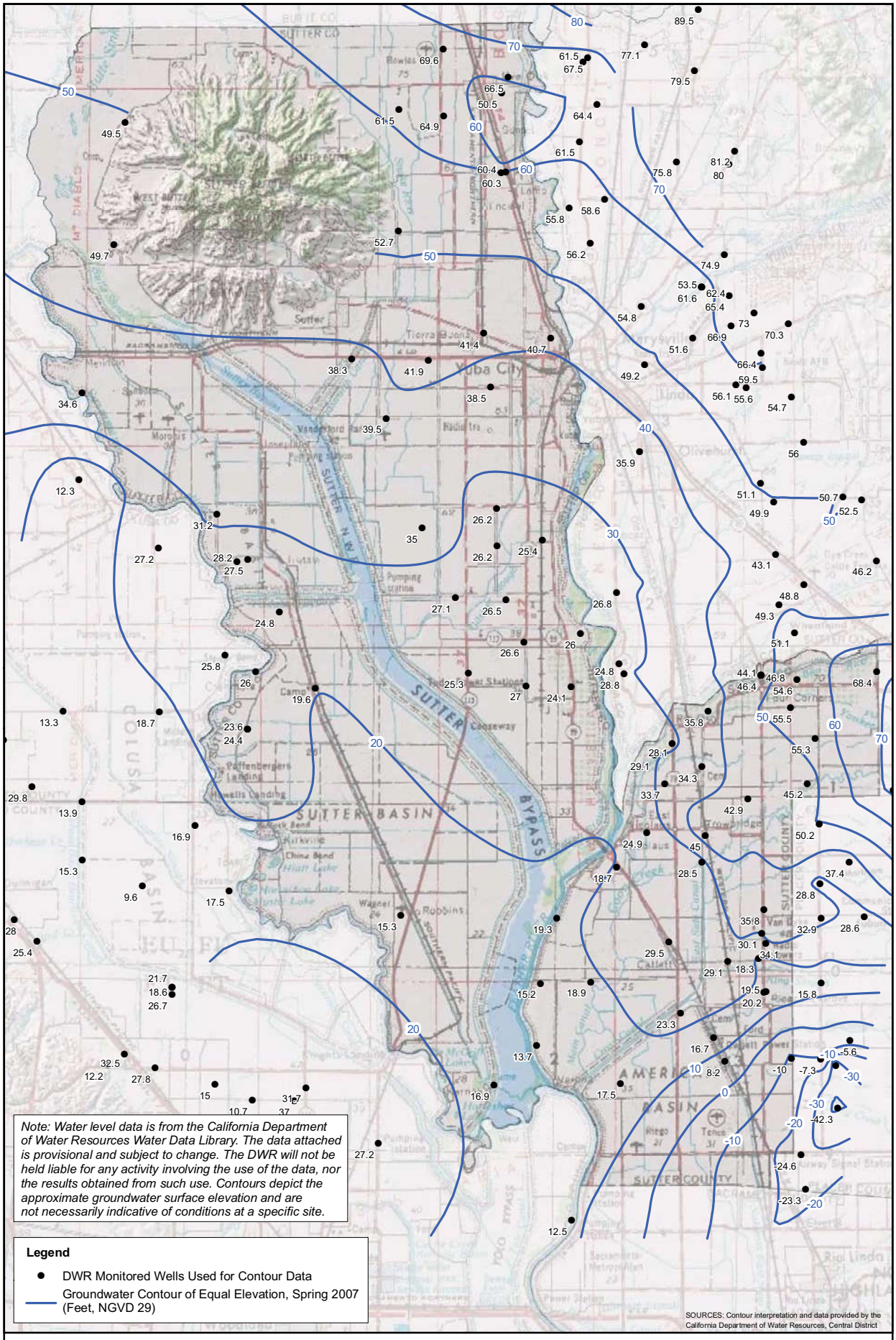

FIGURE 11
GROUNDWATER ELEVATION CONTOUR MAP
SPRING, 2007
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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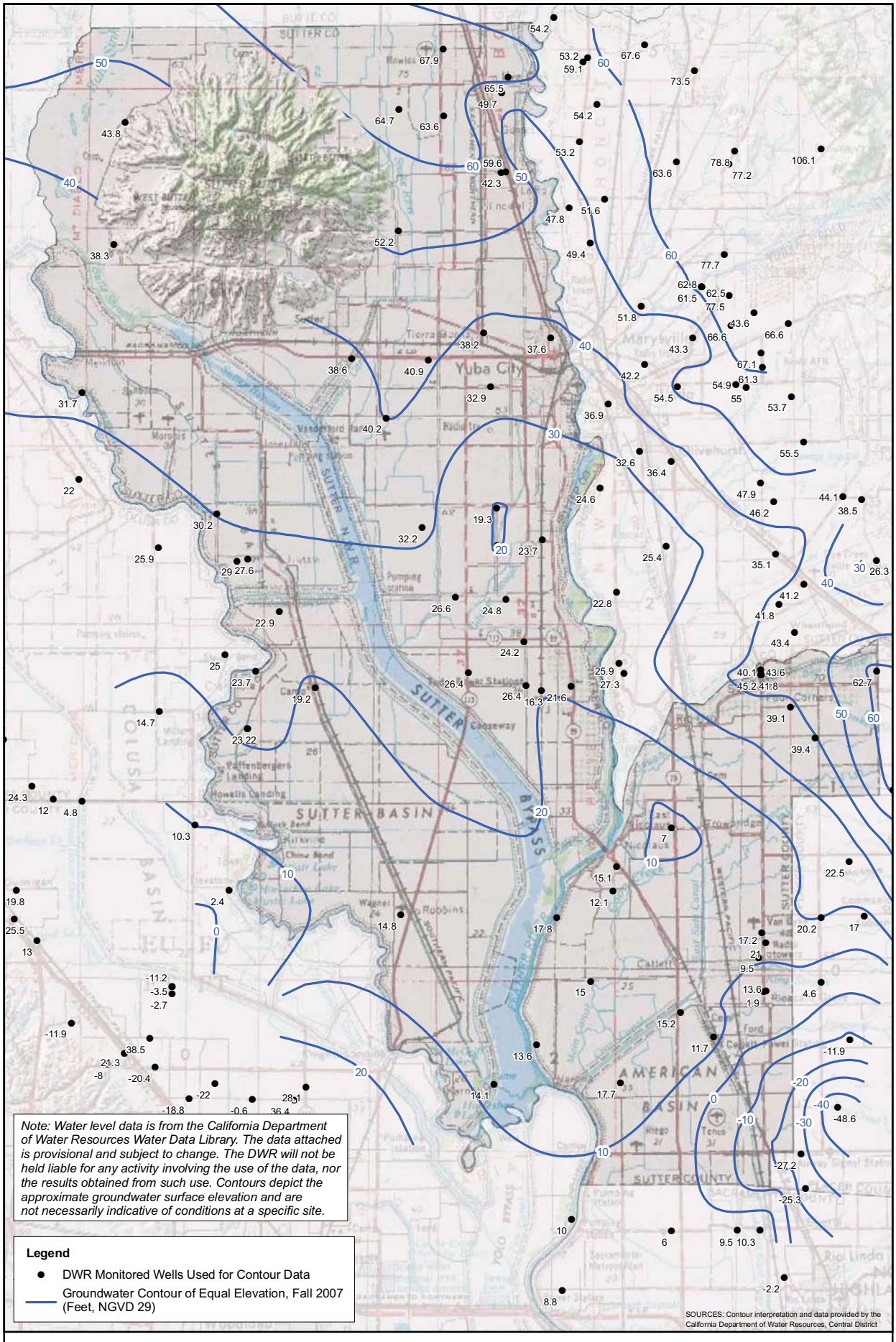

FIGURE 12
GROUNDWATER ELEVATION CONTOUR MAP
FALL, 2007
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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NORTH
0 1.5 3
MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 12 Groundwater Elevation Contour Map Fall 2007.mxd 2/7/2012 6:07:59 PM bdemucha

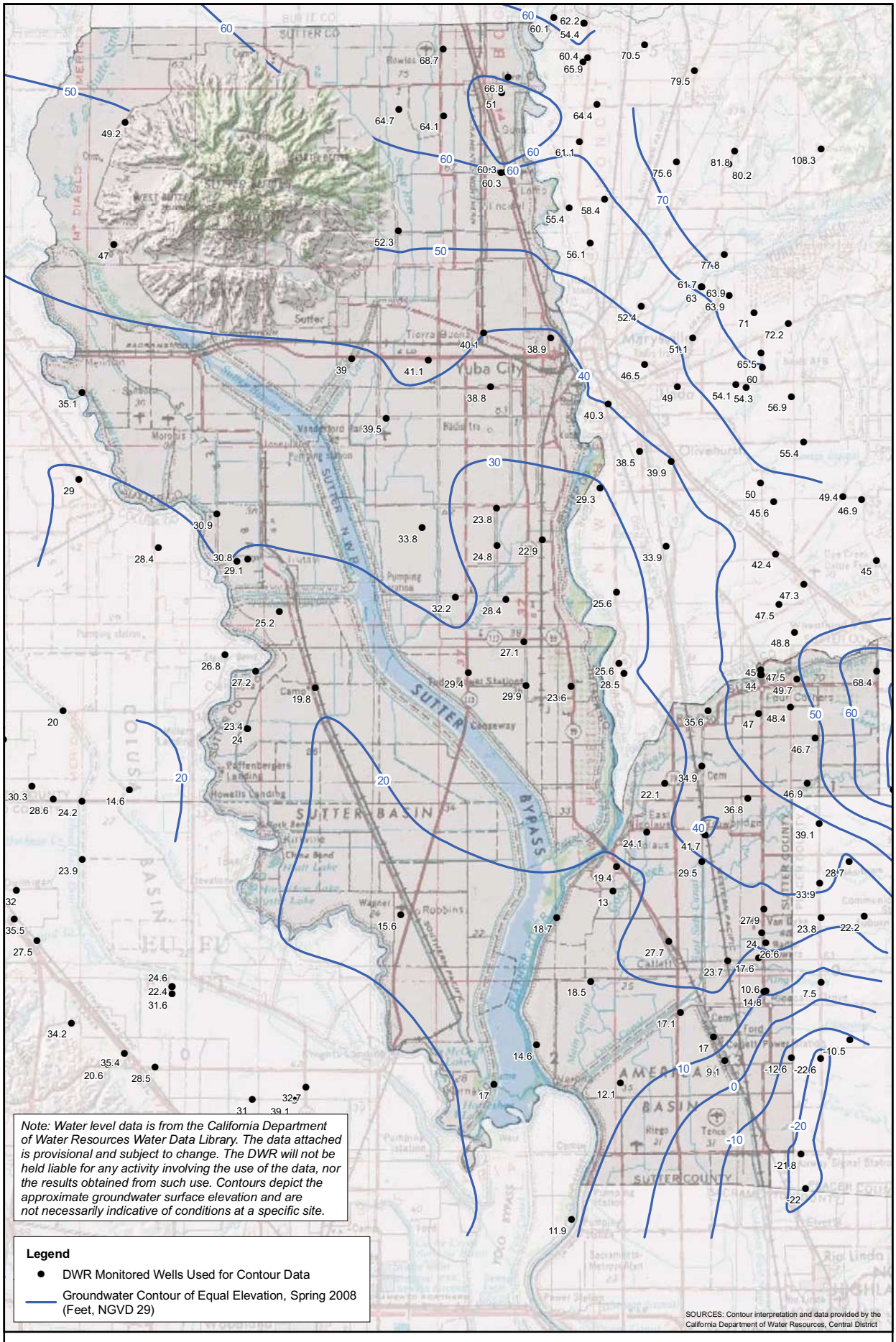

FIGURE 13
GROUNDWATER ELEVATION CONTOUR MAP
SPRING, 2008
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 13 Groundwater Elevation Contour Map Spring 2008.mxd 2/7/2012 6:20:59 PM bdemucha

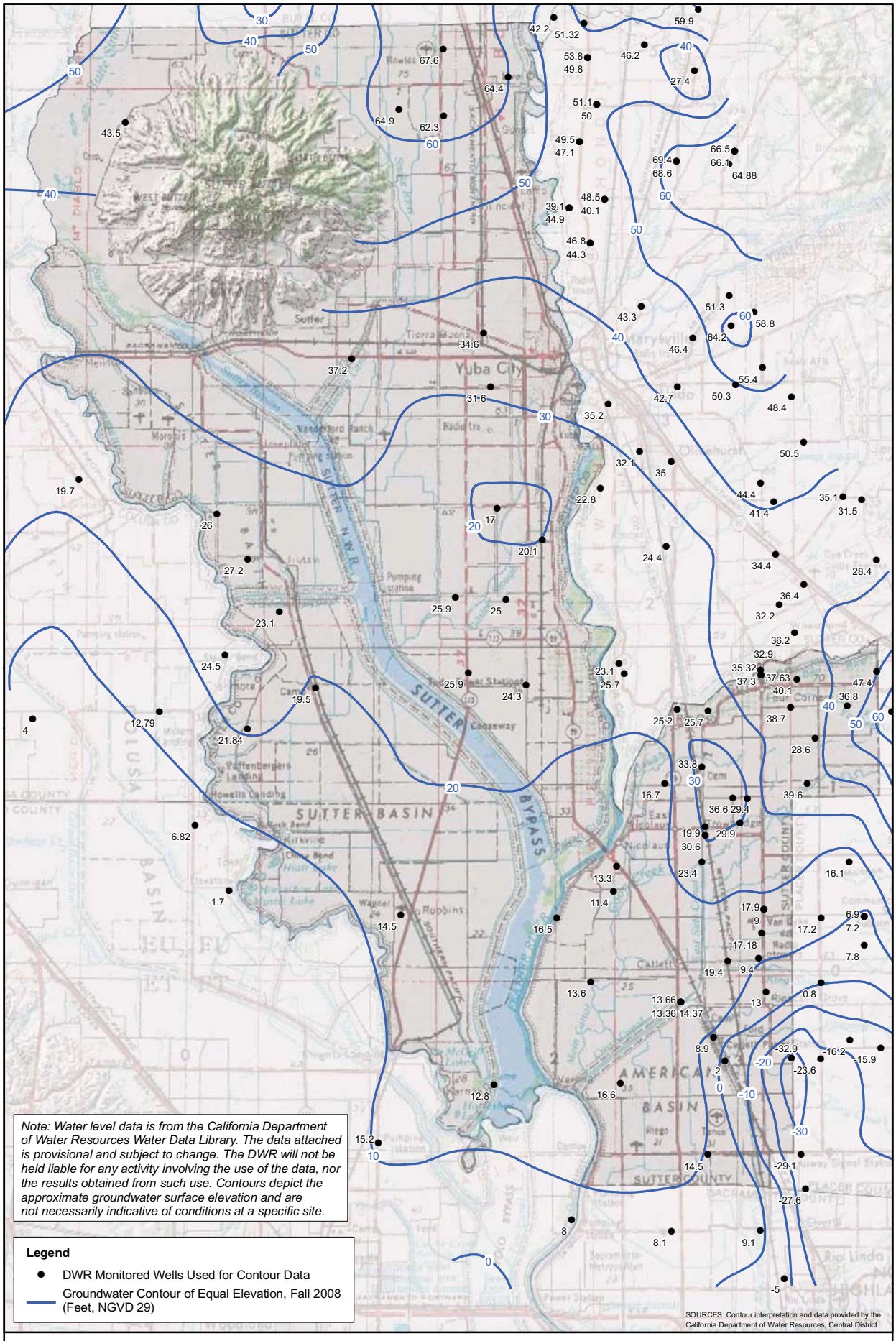

FIGURE 14
GROUNDWATER ELEVATION CONTOUR MAP
FALL, 2008
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

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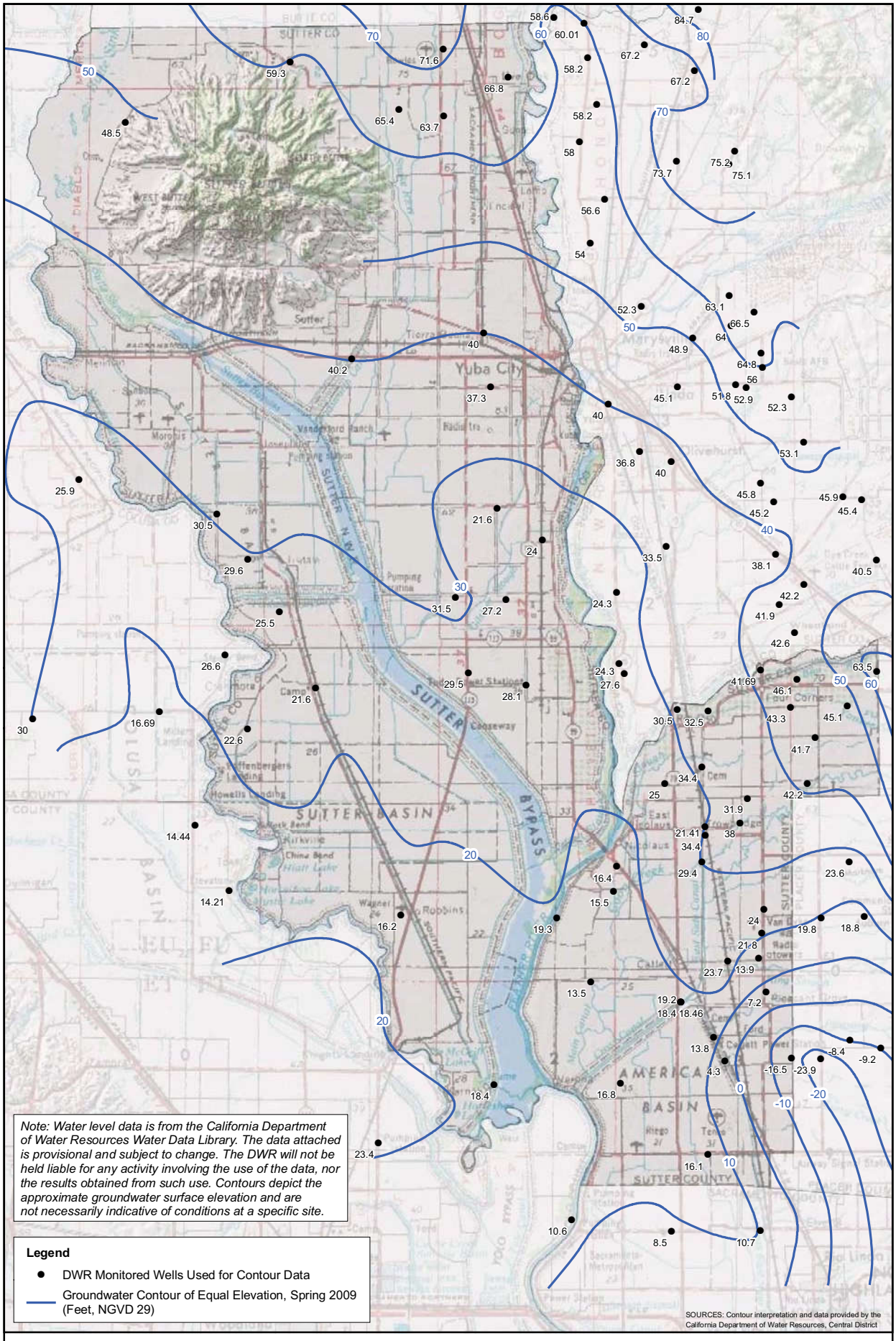
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 14 Groundwater Elevation Contour Map Fall 2008.mxd 2/8/2012 9:20:28 AM bdemucha



Note: Water level data is from the California Department of Water Resources Water Data Library. The data attached is provisional and subject to change. The DWR will not be held liable for any activity involving the use of the data, nor the results obtained from such use. Contours depict the approximate groundwater surface elevation and are not necessarily indicative of conditions at a specific site.

Legend

- DWR Monitored Wells Used for Contour Data
- Groundwater Contour of Equal Elevation, Spring 2009 (Feet, NGVD 29)

SOURCES: Contour interpretation and data provided by the California Department of Water Resources, Central District

FIGURE 15
GROUNDWATER ELEVATION CONTOUR MAP
SPRING, 2009
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

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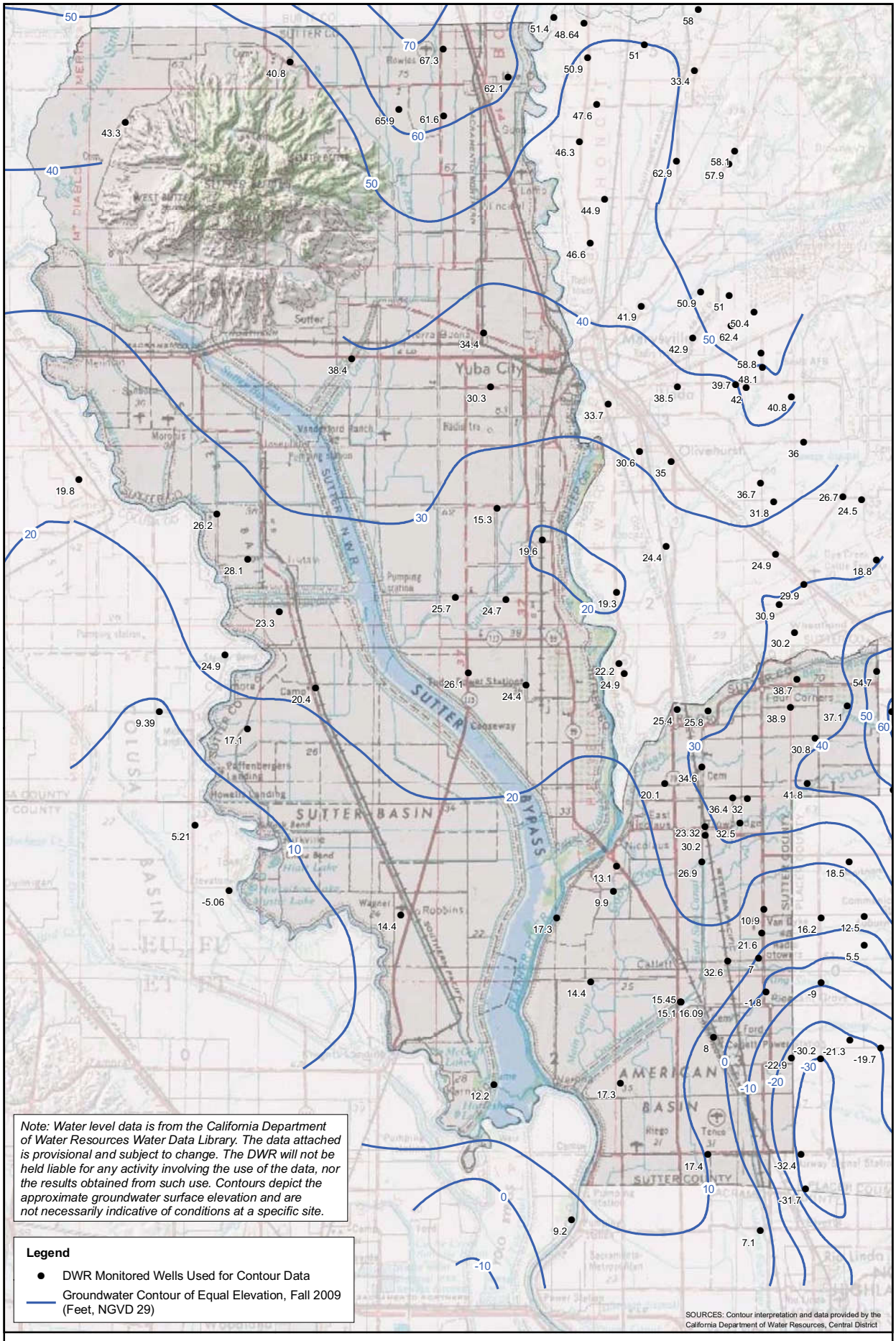

FIGURE 16
GROUNDWATER ELEVATION CONTOUR MAP
FALL, 2009
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

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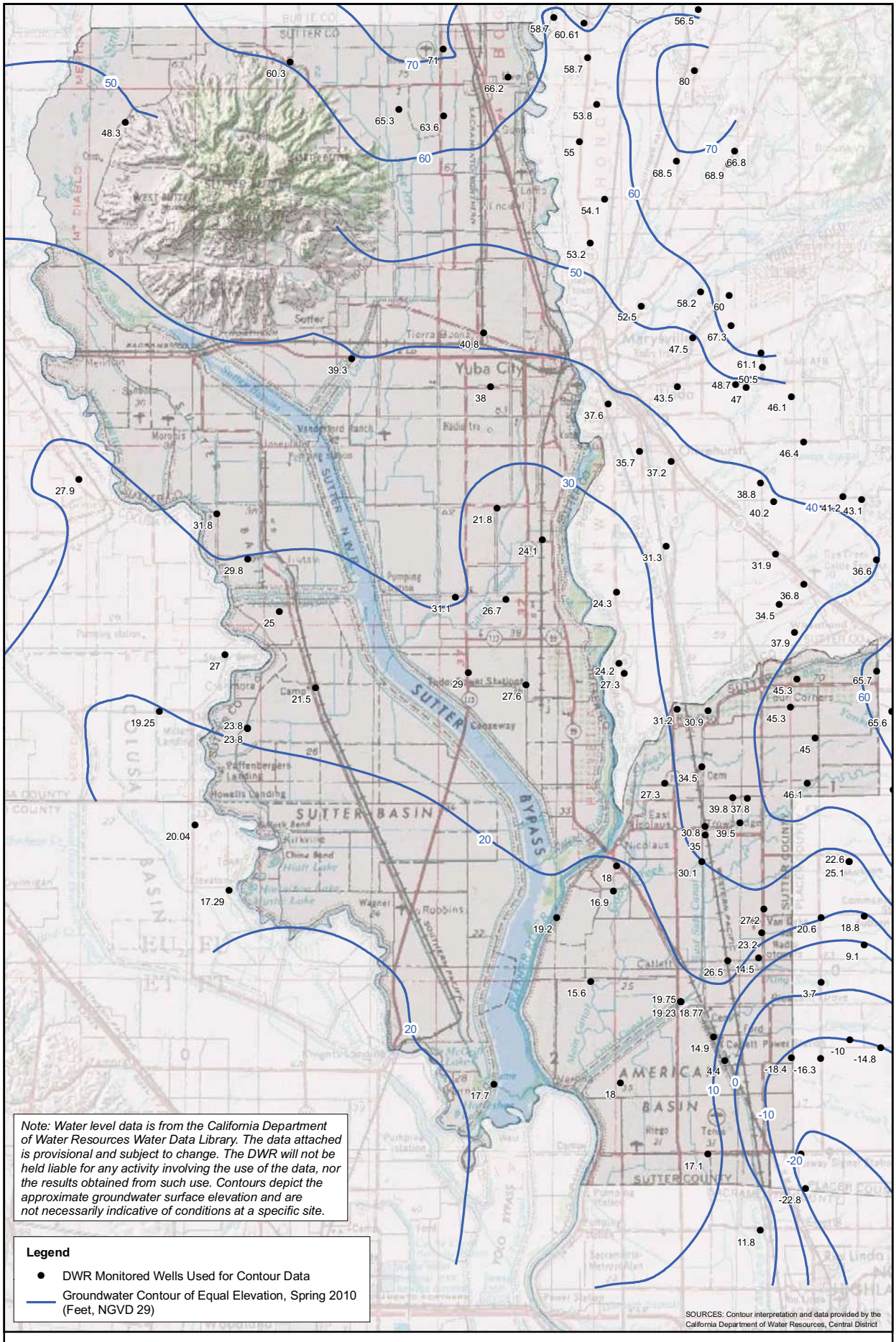
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 16 Groundwater Elevation Contour Map Fall 2009.mxd 2/8/2012 9:44:53 AM bdemucha



Note: Water level data is from the California Department of Water Resources Water Data Library. The data attached is provisional and subject to change. The DWR will not be held liable for any activity involving the use of the data, nor the results obtained from such use. Contours depict the approximate groundwater surface elevation and are not necessarily indicative of conditions at a specific site.

Legend

- DWR Monitored Wells Used for Contour Data
- Groundwater Contour of Equal Elevation, Spring 2010 (Feet, NGVD 29)

SOURCES: Contour interpretation and data provided by the California Department of Water Resources, Central District

FIGURE 17
GROUNDWATER ELEVATION CONTOUR MAP
SPRING, 2010
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

SUTTER COUNTY CALIFORNIA

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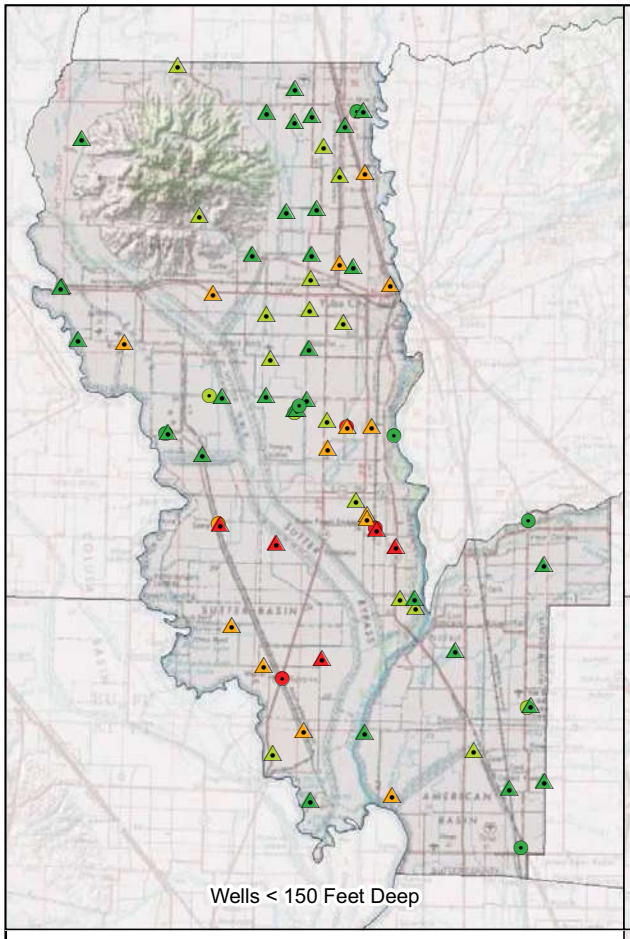
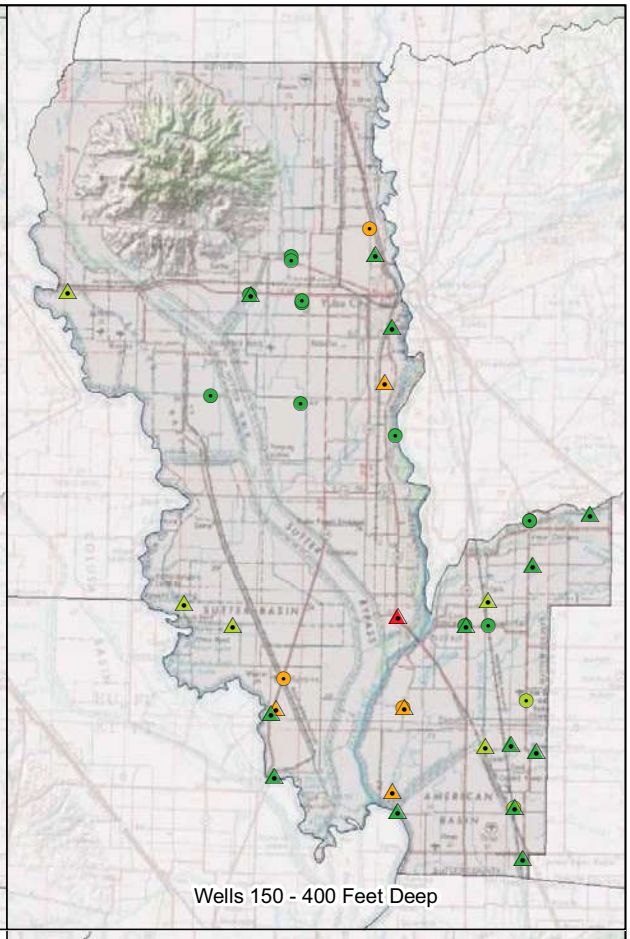




EC in DWR Wells (µmhos/cm)

- < 600
- 600 - 900
- 900 - 1600
- > 1600

EC in USGS Wells (µmhos/cm)

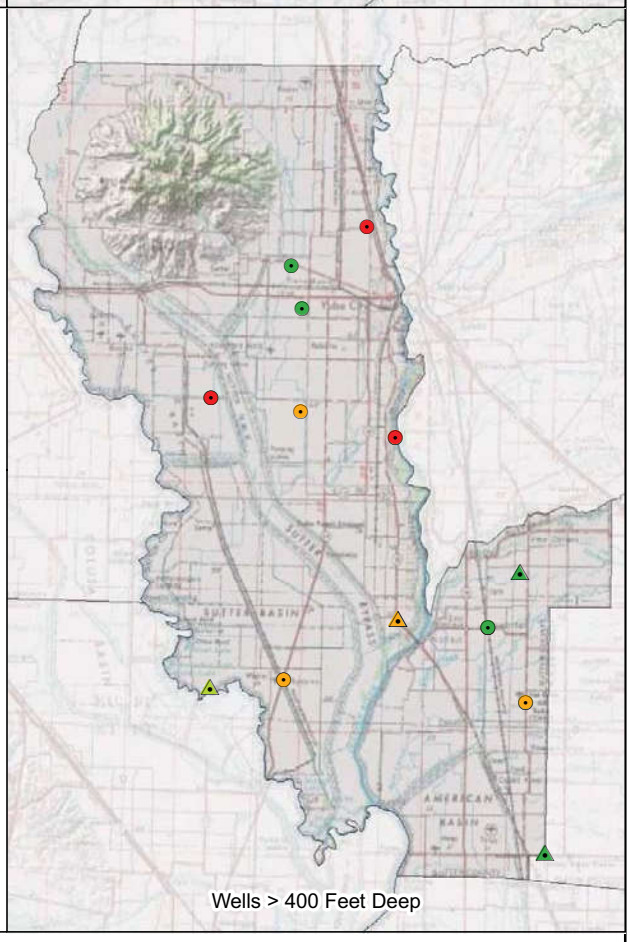
- < 600
- 600 - 900
- 900 - 1600
- > 1600

Note:
"EC" is an abbreviation for specific conductance, which is related to the salt content of a water sample.

For public drinking water systems, the secondary (aesthetic) maximum contaminant levels for EC are 900 micromhos/centimeter (µmhos/cm) (recommended), 1600 µmhos/cm (upper), and 2200 µmhos/cm (short-term).

For irrigation, crop yields decrease above a threshold EC value, which is crop-dependent. Crop yield potential decreases above these threshold levels:

Almonds - 1000 µmhos/cm
Beans - 700 µmhos/cm
Rice - 2000 µmhos/cm
Squash - 2100-3100 µmhos/cm
Tomatoes - 1700 µmhos/cm
Wheat - 4000 µmhos/cm



SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA

FIGURE 18
SPECIFIC CONDUCTANCE BY WELL DEPTH
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 3 6
MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 18 EC_Well Depth.mxd 2/8/2012 10:00:29 AM bdemucha

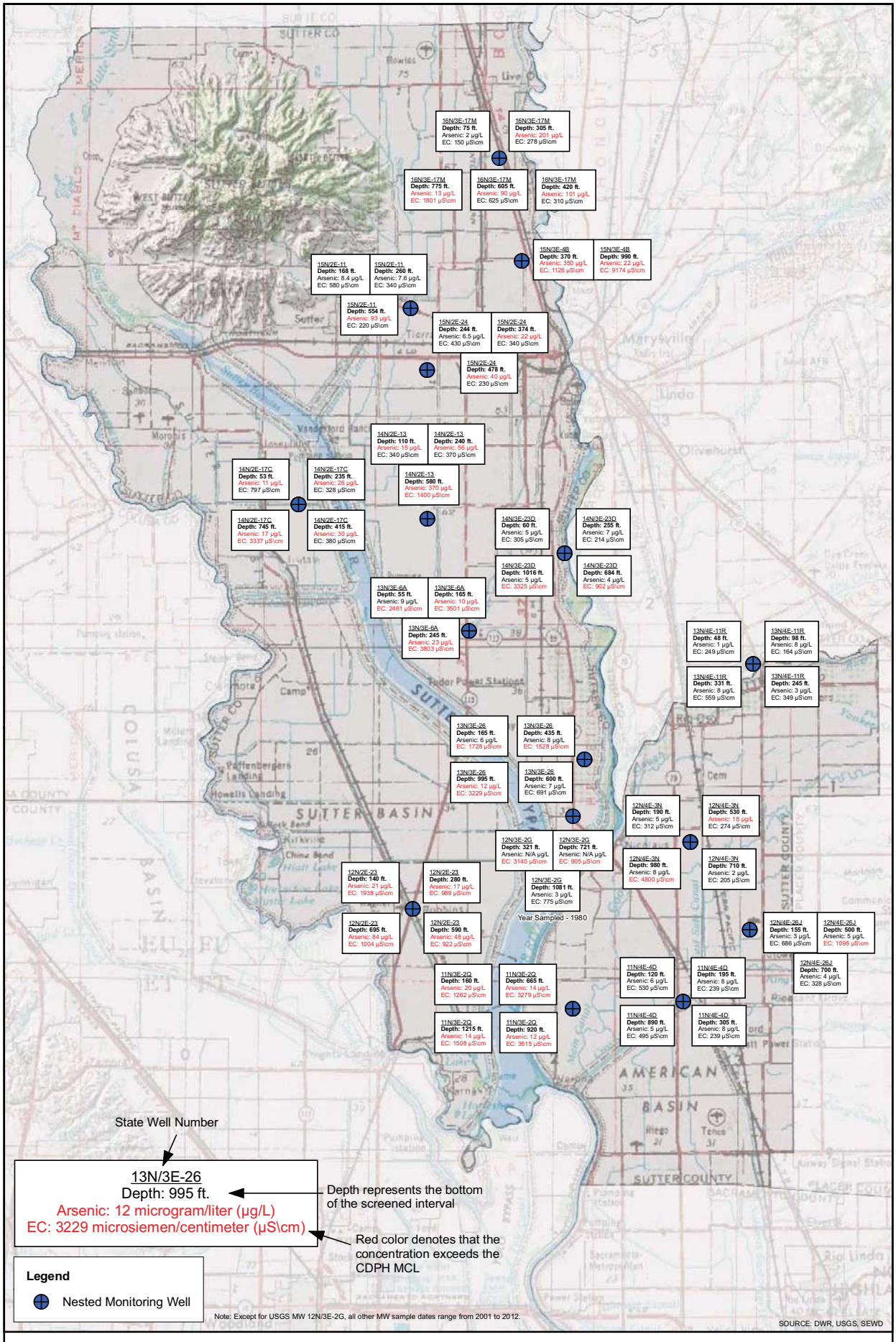

FIGURE 19
DEPTH SPECIFIC ARSENIC AND SPECIFIC CONDUCTANCE CONCENTRATIONS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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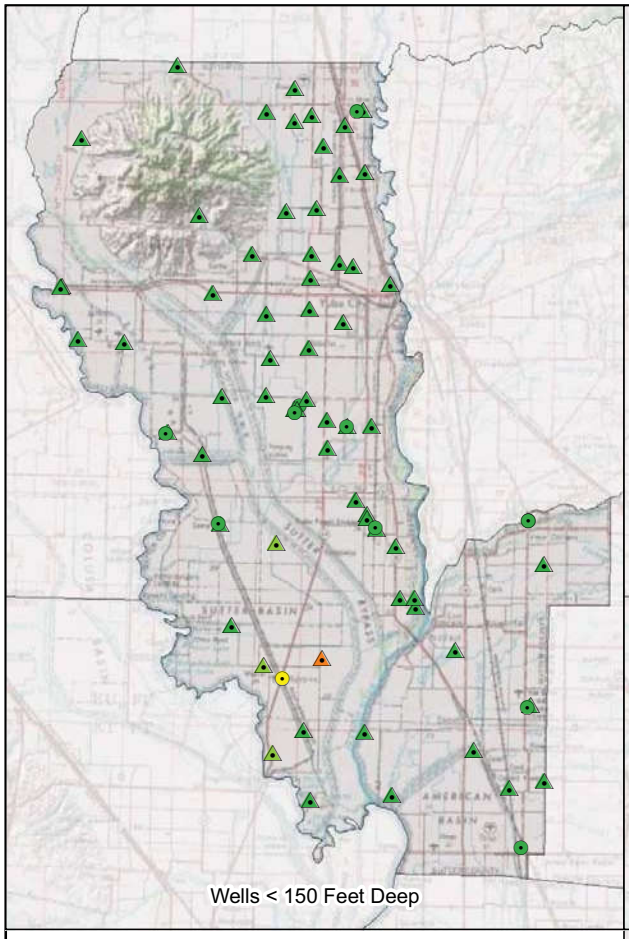
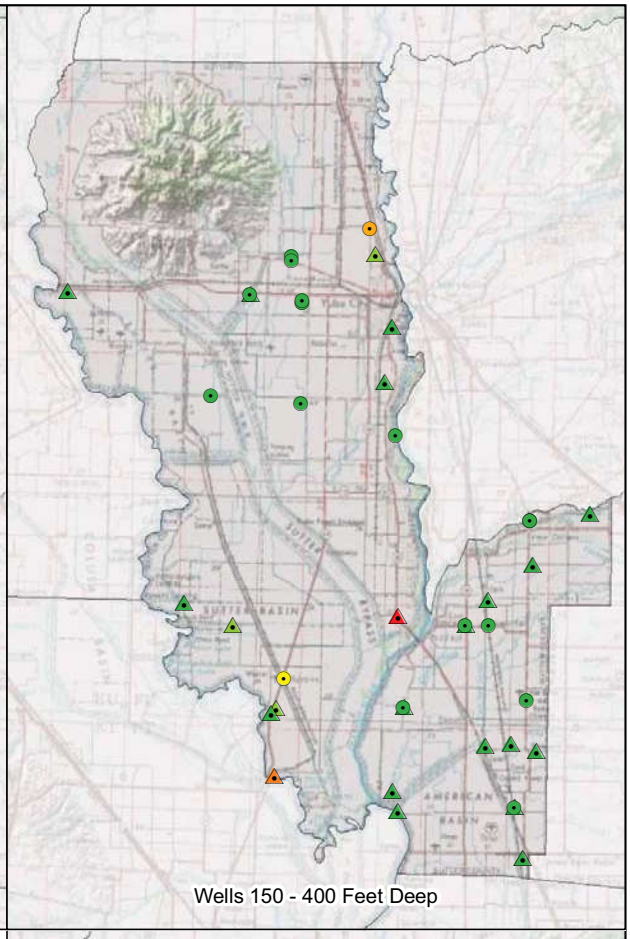
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120201 Final Draft Figure Comments\Figure 19 Depth Specific Arsenic and Specific Conductance.mxd 2/8/2012 11:34:41 AM bdemucha



Wells < 150 Feet Deep



Wells 150 - 400 Feet Deep

Boron in DWR Wells (µg/L)

- < 500
- 500 - 750
- 750 - 1000
- 1000 - 2000
- > 2000

Boron in USGS Wells (µg/L)

- < 500
- 500 - 750
- 750 - 1000
- 1000 - 2000
- > 2000

Note:
Boron is naturally occurring and leaches from aquifer materials into groundwater.

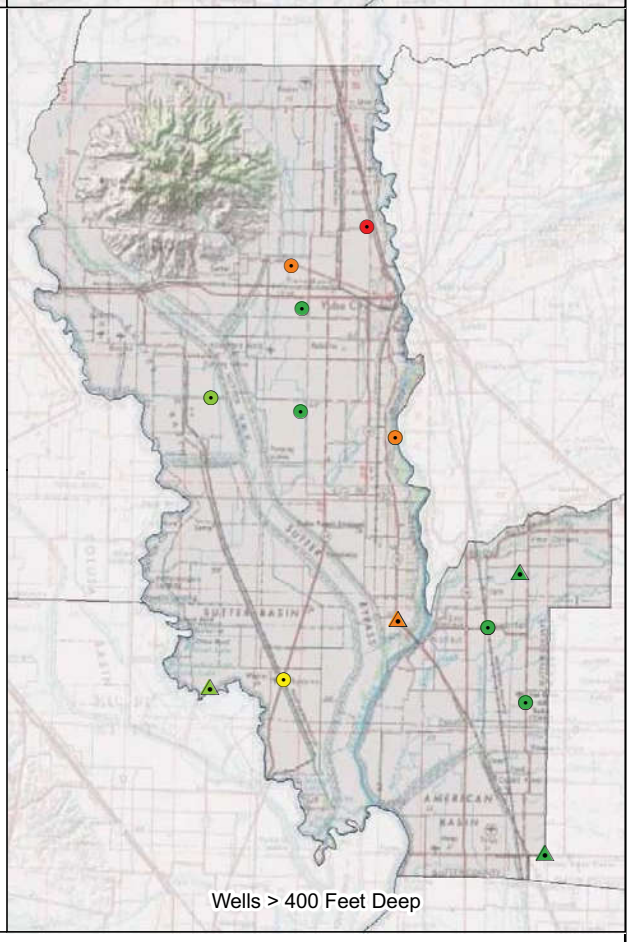
For public drinking water systems, there is a notification level for boron of 1000 micrograms/liter (µg/L).

For irrigation, boron is necessary for crop growth but becomes toxic to the point that yields may decrease above these threshold levels:

Beans - 750 - 1000 µg/L
Grapes - 500 - 750 µg/L
Squash - 2000 - 4000 µg/L
Tomatoes - 4000 - 6000 µg/L
Walnuts - 500 - 750 µg/L
Wheat - 750 - 1000 µg/L

Many other trees are vulnerable to boron toxicity above 500 - 750 µg/L.

SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA



Wells > 400 Feet Deep

FIGURE 20
BORON BY WELL DEPTHS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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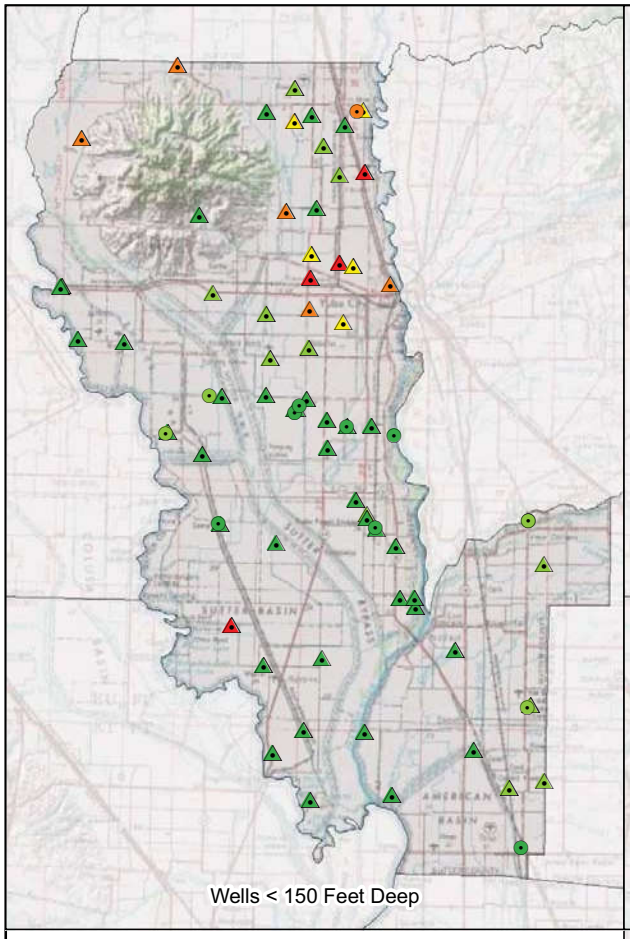
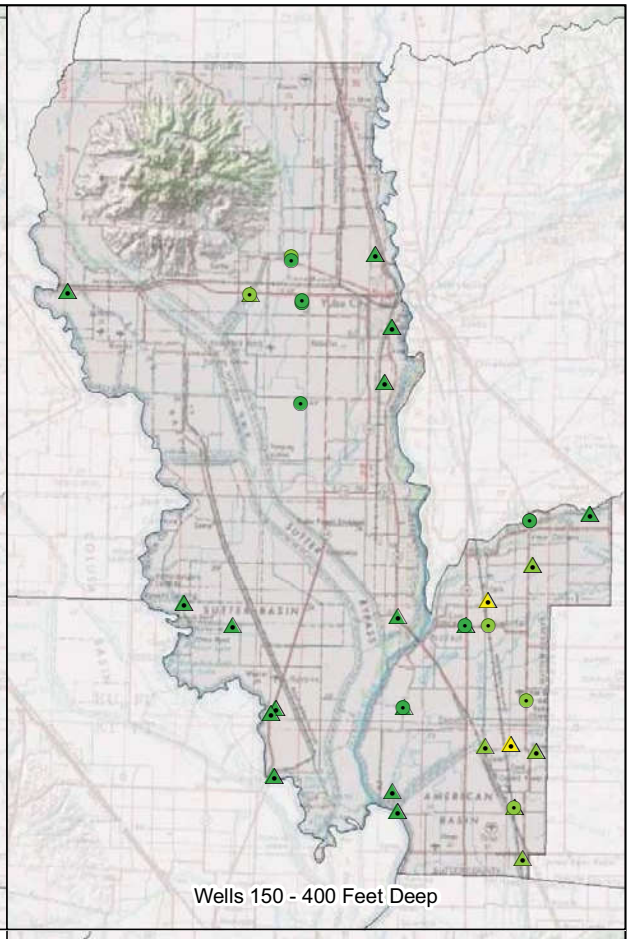




Nitrate in DWR Wells (mg/L)

- < 5
- 5 - 15
- 15 - 30
- 30 - 45
- > 45

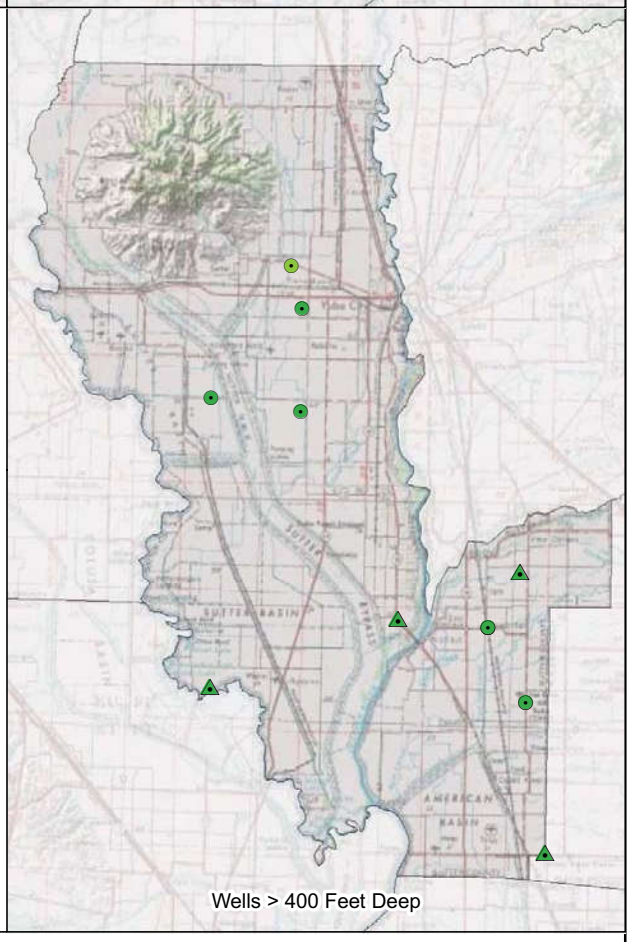
Nitrate in USGS Wells (mg/L)

- < 15
- 5 - 15
- 15 - 30
- 30 - 45
- > 45

Note:
Nitrate is generally introduced into groundwater by septic systems, fertilizers, or confined animal operations.

For public drinking water systems, the primary (health-based) maximum contaminant level for nitrate as NO3 is 45 milligrams/liter (mg/L).

At concentrations exceeding the maximum contaminant level, nitrate can interfere with the blood's ability to carry oxygen. This effect can be especially pronounced in infants, where it is known as "blue baby syndrome".



SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA

FIGURE 21
NITRATE BY WELL DEPTH
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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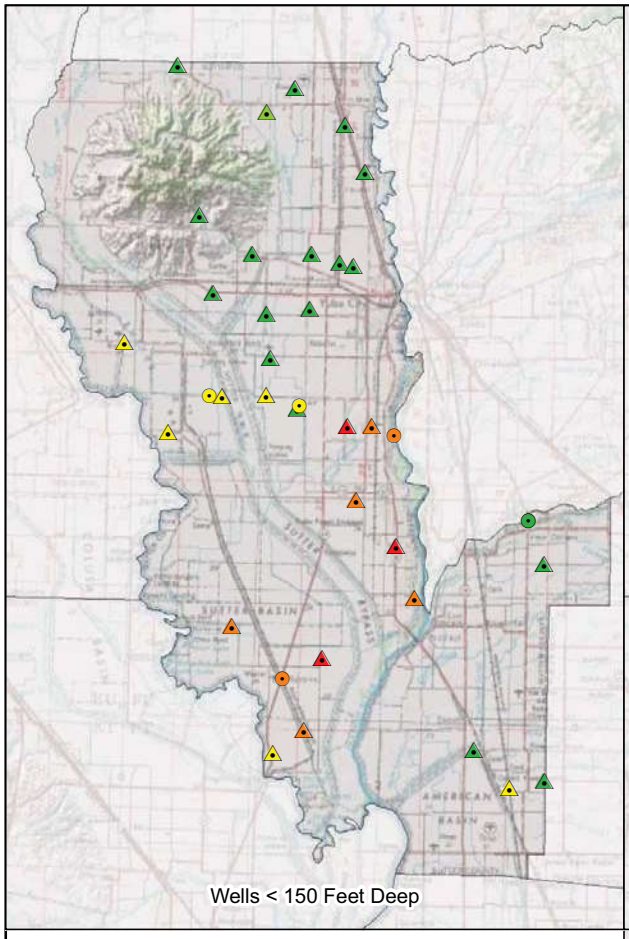
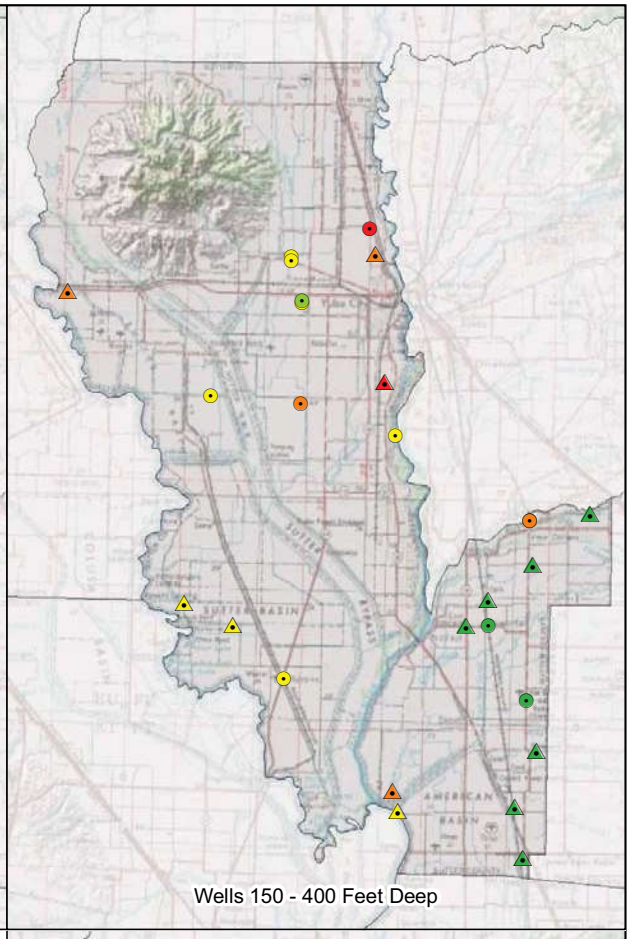
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 21 Nitrates_Well Depth.mxd 2/8/2012 2:10:46 PM bdemucha





Manganese in DWR Wells (µg/L)

- < 25
- 25 - 50
- 50 - 150
- 150 - 500
- > 500

Manganese in USGS Wells (µg/L)

- < 25
- 25 - 50
- 50 - 150
- 150 - 500
- > 500

Note:
Manganese is naturally occurring and leaches from aquifer materials into groundwater.

For public drinking water systems, the secondary (aesthetic) maximum contaminant level for manganese is 50 micrograms/liter (µg/L). There is also a notification level for manganese of 500 µg/L. Notification levels are health-based advisory levels for chemicals that do not have primary maximum contaminant levels.

Manganese can cause staining of plumbing and fixtures, and can contribute a metallic odor to water. At very high concentrations (above the notification level) manganese may cause neurologic problems.

Analysis for manganese is very sensitive to turbidity of samples - turbid samples will often have artificially high results for manganese.

SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA

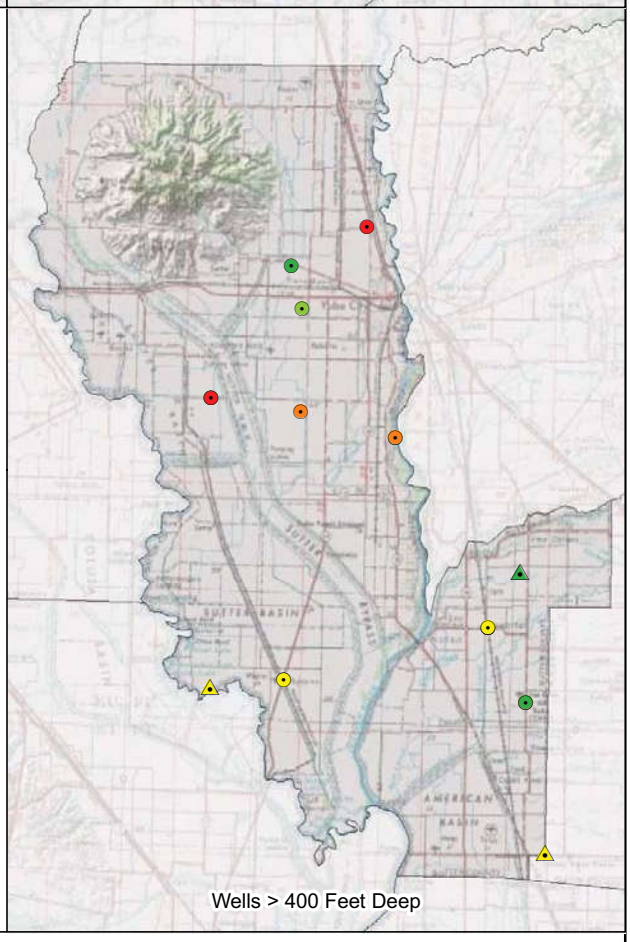


FIGURE 22
MANGANESE BY WELL DEPTHS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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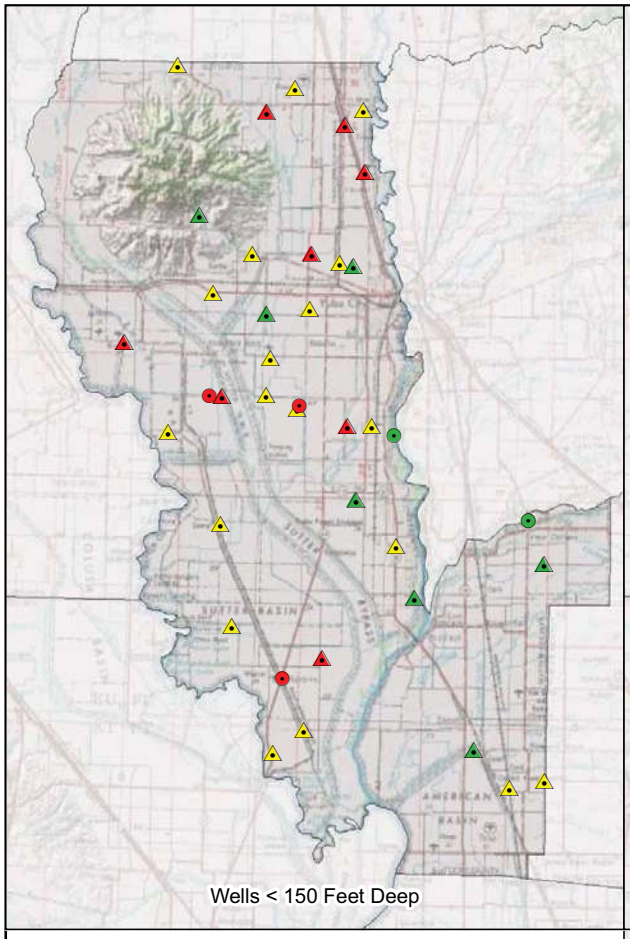
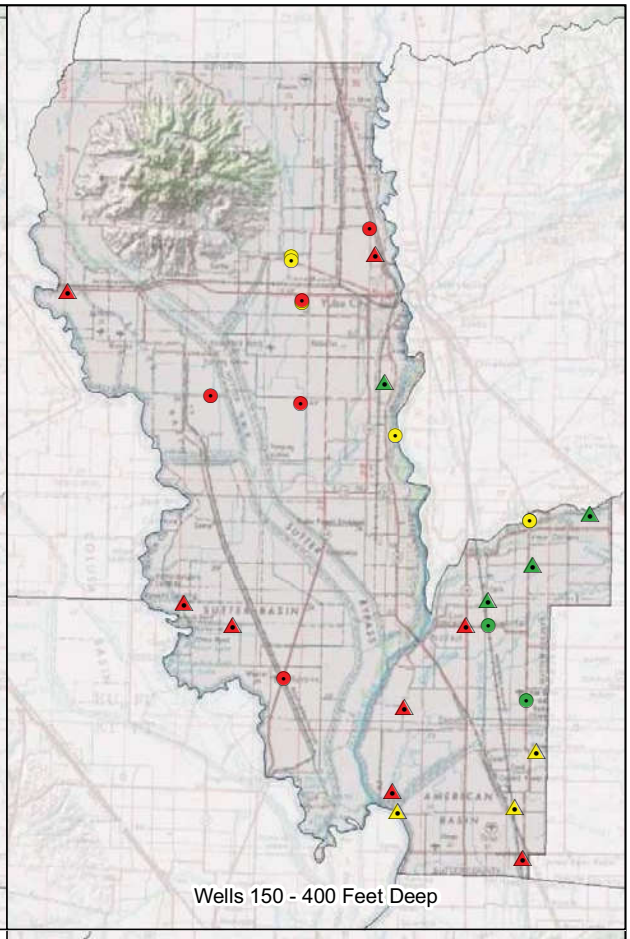




Arsenic in DWR Wells (µg/L)

- < 5
- 5 - 10
- > 10

Arsenic in USGS Wells (µg/L)

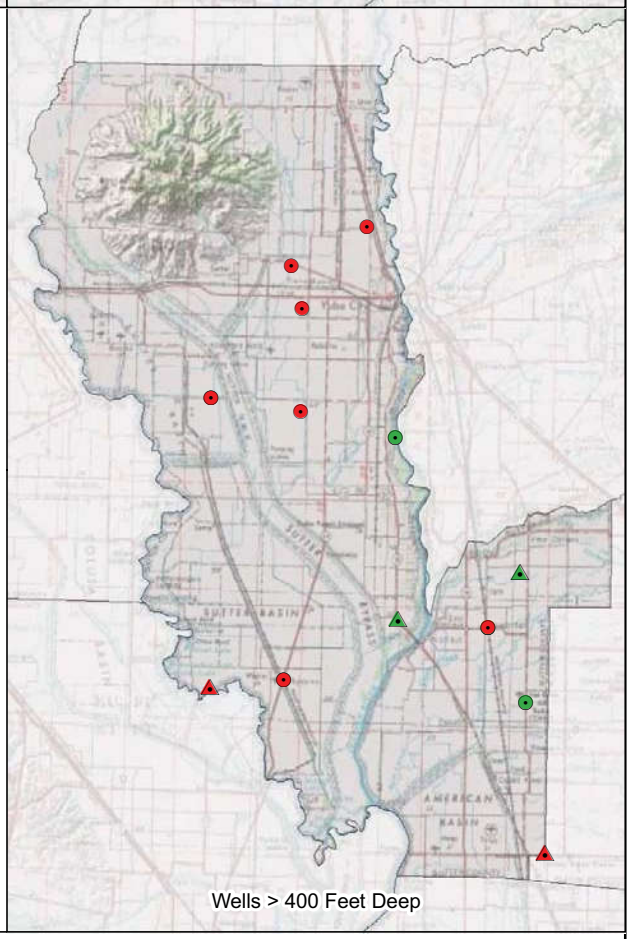
- < 5
- 5 - 10
- > 10

Note:
Arsenic is naturally occurring and leaches from aquifer materials into groundwater.

For public drinking water systems, the primary maximum contaminant level for arsenic is 10 micrograms/liter (µg/L).

Exposure to arsenic can cause both short and long term health effects. Long term exposure to arsenic has been linked to cancer of the bladder, lungs, skin, kidneys, nasal passages, liver and prostate. Short term exposure to high doses of arsenic can cause other adverse health effects.

Analysis for arsenic is very sensitive to turbidity of samples - turbid samples will often have artificially high results for arsenic.



SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA

FIGURE 23
ARSENIC BY WELL DEPTHS
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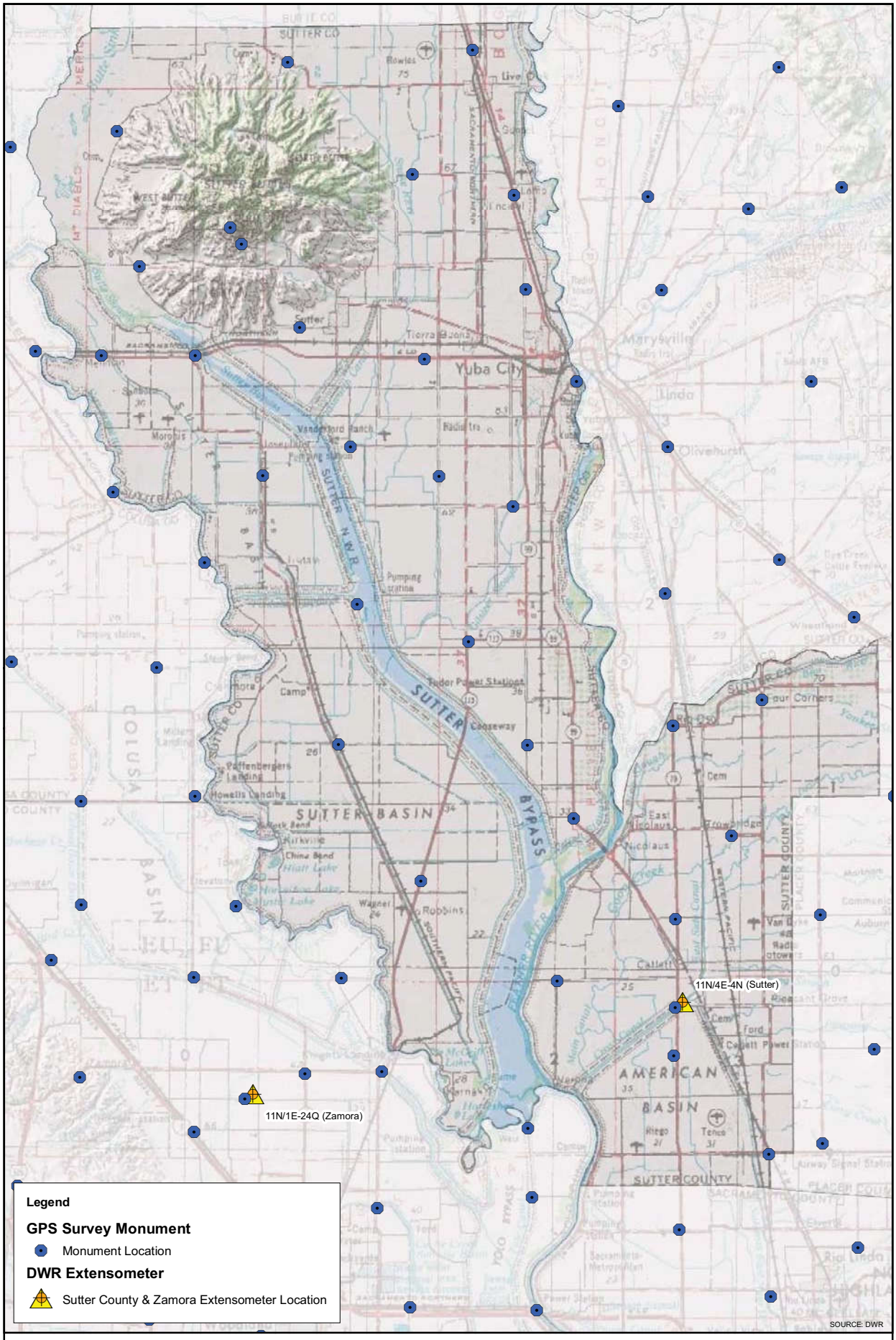

FIGURE 24
LAND SUBSIDENCE NETWORK
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 24 Land Subsidence Network.mxd 2/8/2012 2:43:42 PM bdemucha

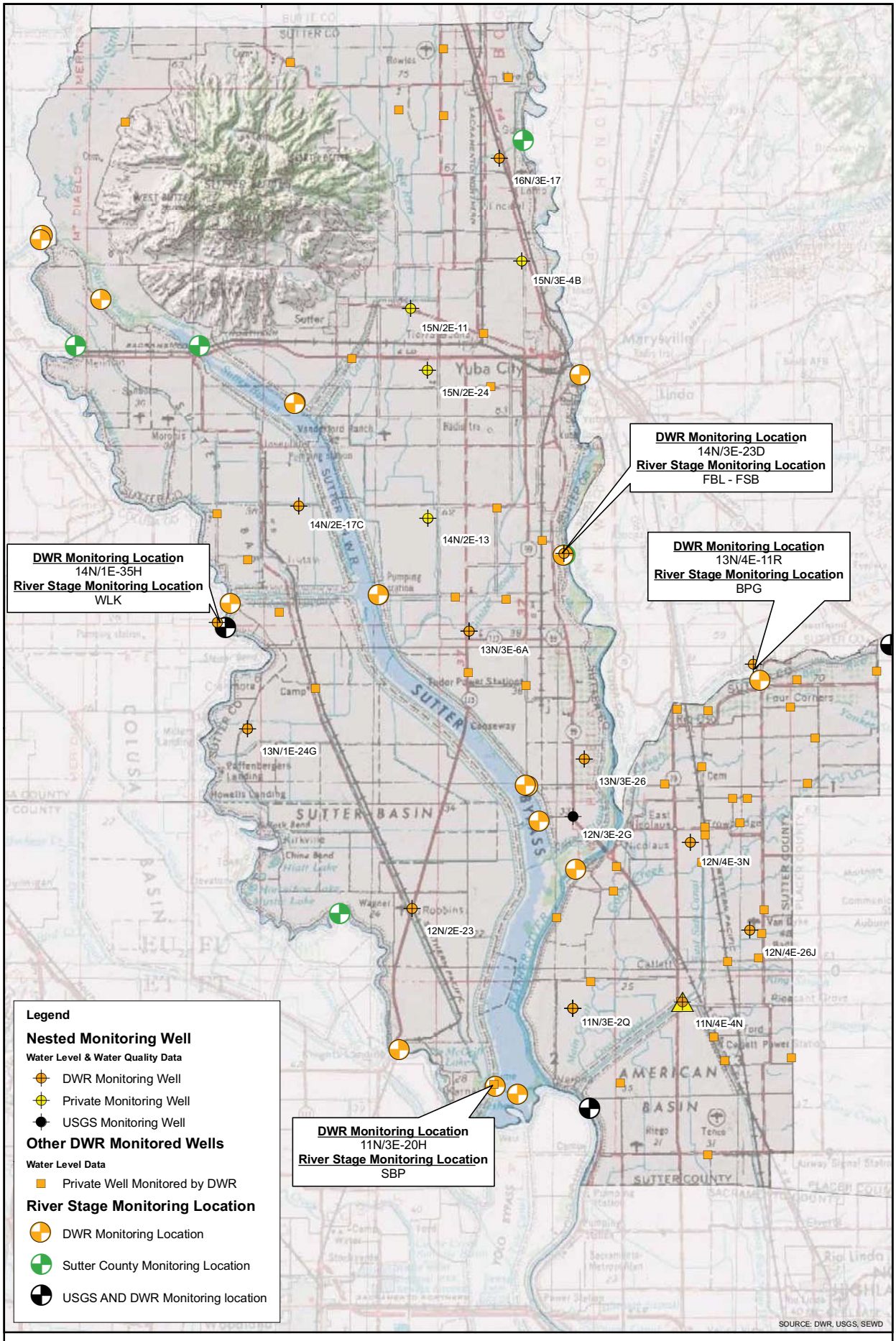

FIGURE 25
GROUNDWATER AND RIVER STAGE MONITORING LOCATIONS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 25 Groundwater and River Stage Monitoring Locations.mxd 2/8/2012 2:46:51 PM bdemucha

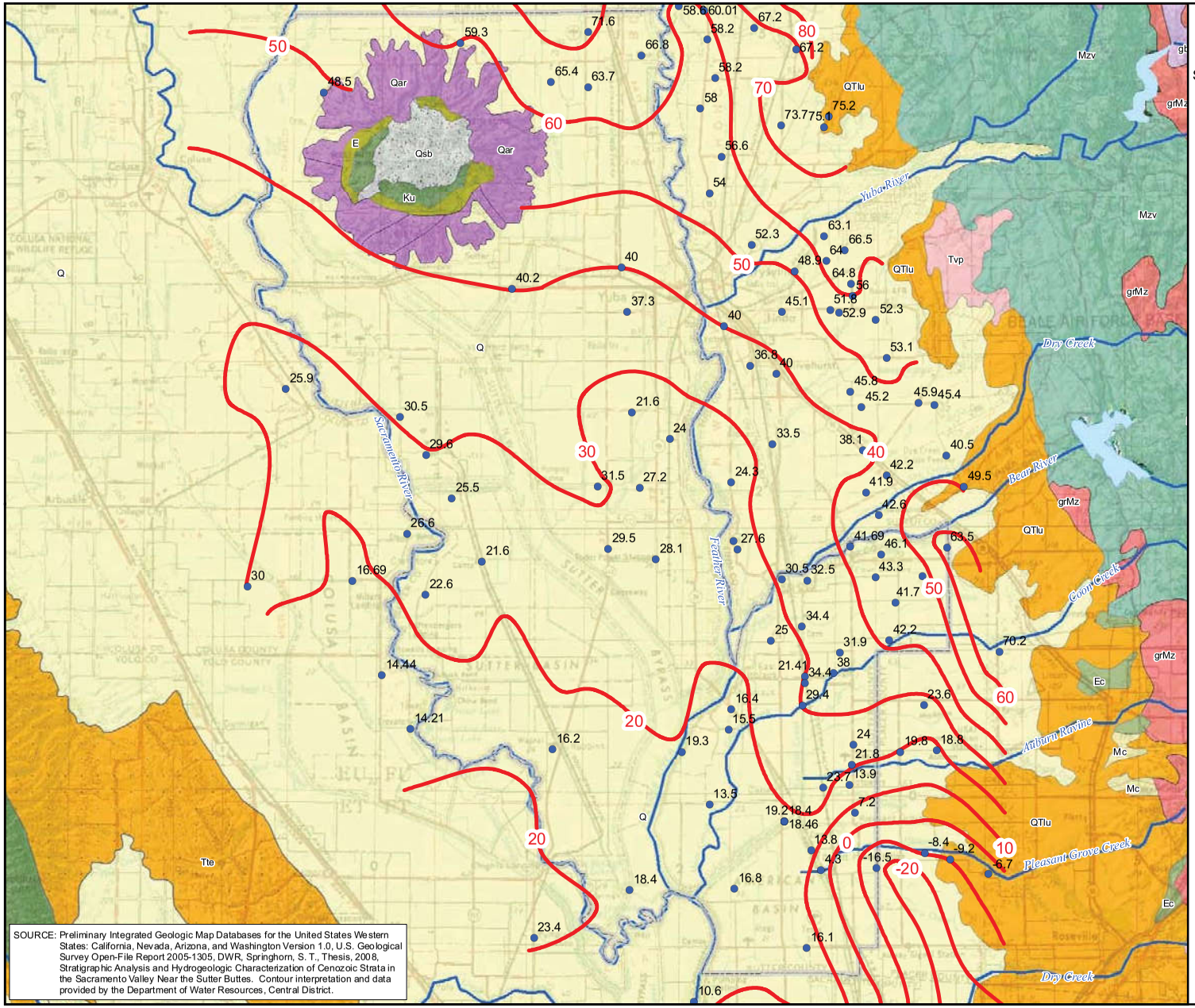

FIGURE 26

RECHARGE AND GROUNDWATER ELEVATION CONTOUR MAP SPRING, 2009

SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN

FEBRUARY 2012

NORTH

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MILES

- Q - Recent Deposits
  - Qb - Basin Deposits
  - Qm - Modesto Formation
  - Qr - Riverbank Formation
- Qsb - Sutter Buttes Igneous Rocks
- Qar - Sutter Buttes Andesitic Rampart
- QTlu - Laguna Formation
- Tte - Tehama Formation
- Tvp - Andesite, Rhyolite
- Mc - Sandstone, Conglomerate
- Ec - Conglomerate, Sandstone
- E - Mudstone, Sandstone
- Ku - Sandstone, Mudstone
- J - Mudstone, Sandstone, & Slate
- um - Serpentinite
- Mzv - Volcanic, Metavolcanic
- gb - Gabbro, Diorite
- grMz - Granodiorite
- Sutter County
- DWR Monitored Wells Used for Contours
- Groundwater Contour of Equal Elevation (Feet, NGVD 29)

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 26 Recharge and Groundwater Elevation Contour Map Spring, 2009.mxd 2/8/2012 3:11:15 PM bdemucha

Figure 27
Sutter County
Well Construction By Year

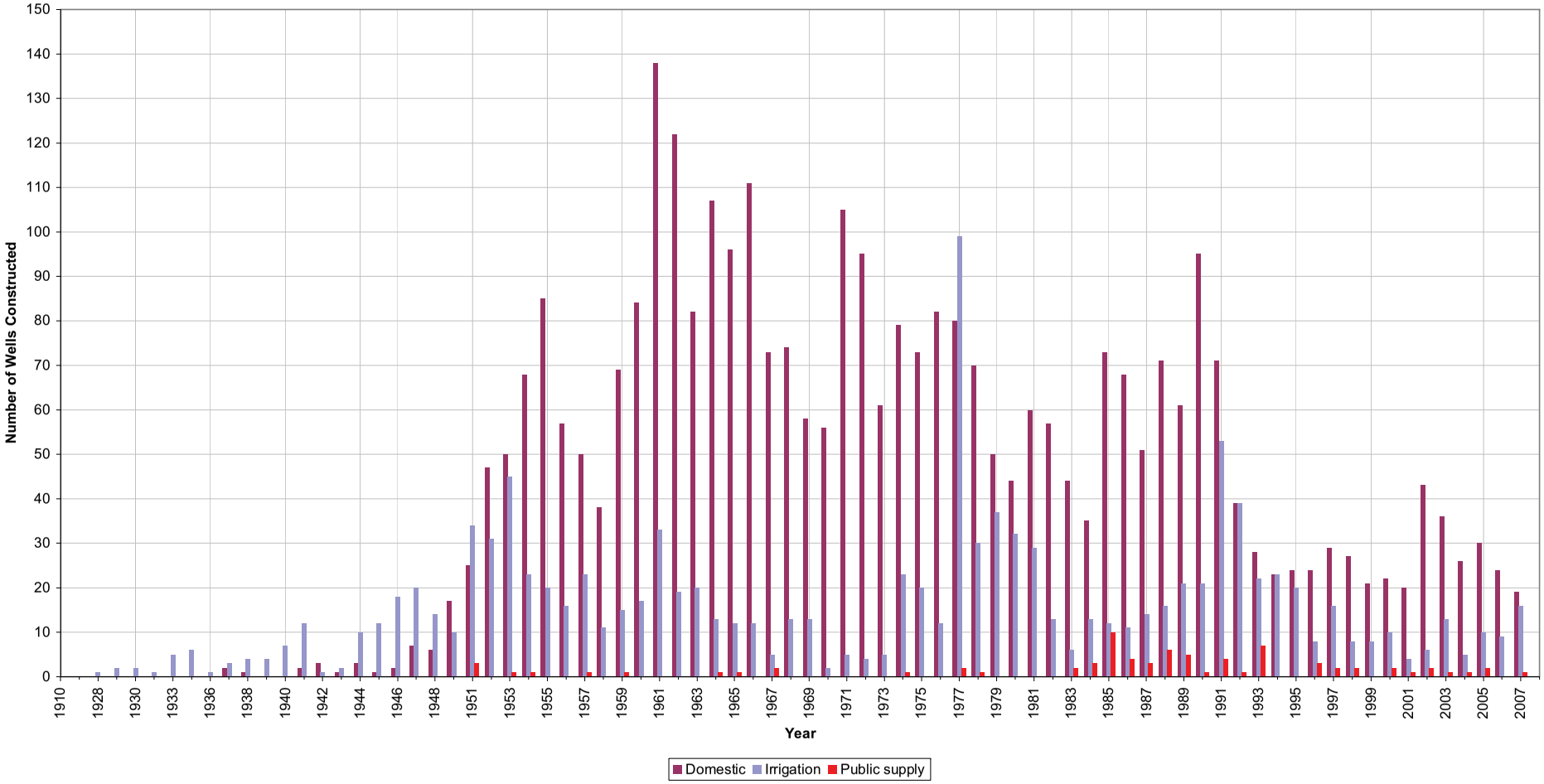
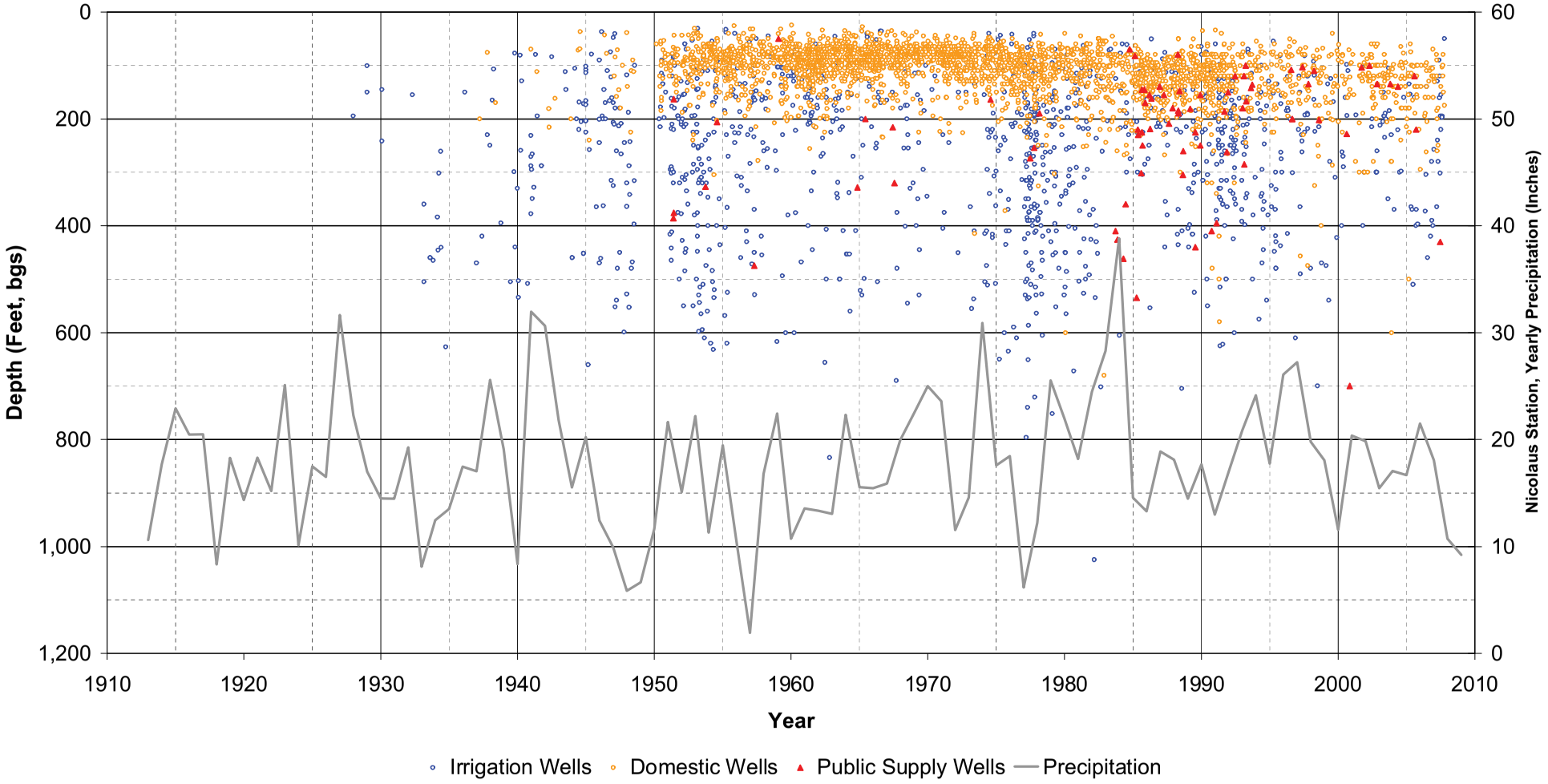


Figure 28
Sutter County
Historic Well Construction by Depth and Annual Precipitation

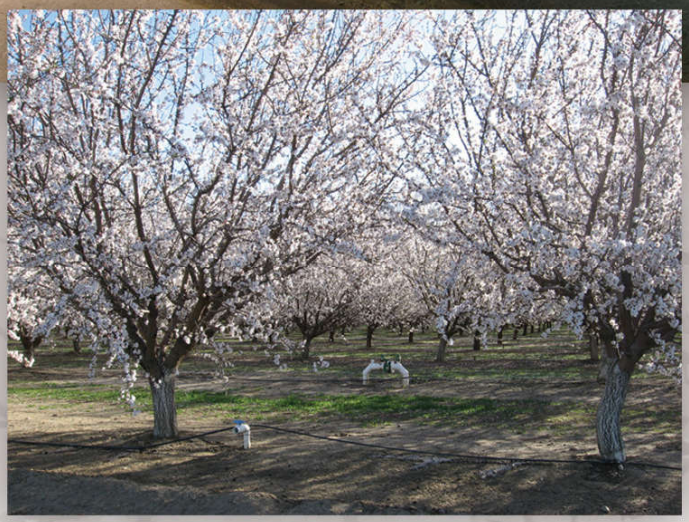


Sutter County

Groundwater Management Plan







March 2012

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Sutter County Groundwater Management Plan

Certificate and Seals

This report and analysis was prepared by Wood Rodgers, Inc. with data and technical assistance provided by the Sutter County Public Works Department - Water Resources Division and the California Department of Water Resources - North Central Region.

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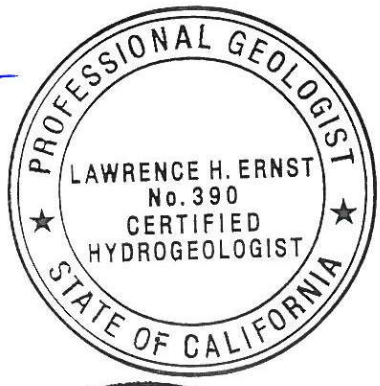

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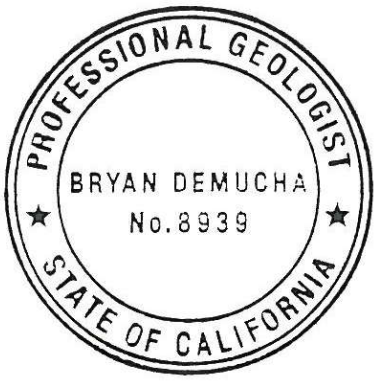

Kimberly B. Venton Date: 3/19/12

Kimberly B. Venton
Associate Hydrogeologist

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1. INTRODUCTION

1.1. Purpose of Groundwater Management Plan

Sutter County (County) has prepared this Groundwater Management Plan (GMP) with input and direction from County stakeholders, and with financial and technical assistance from the California Department of Water Resources (DWR). Preparing this GMP is one step Sutter County is taking to promote and encourage groundwater users in the County to be responsible stewards of the water resources.

Sutter County's purposes for preparing this GMP are to:

- Summarize the current understanding of the groundwater underlying Sutter County and its role in the County's overall water supply, and make that information publicly available.
- Formulate goals and objectives that can be used as guidelines to help manage groundwater resources to meet current and future demands in Sutter County.
- Establish a plan for the County's involvement in ongoing monitoring and management of groundwater to promote those goals and objectives.
- Maintain eligibility for grant funding administered by the California Department of Water Resources to increase the understanding of the groundwater basins underlying Sutter County.

1.2. Sutter County's Role in Groundwater Management

Sutter County has the authority to adopt and implement this GMP under California Water Code §10750 et seq., which states that a local agency that overlies part of a groundwater basin can "by ordinance, or by resolution…adopt and implement a groundwater management plan…within all or part of its service area," so long as the area is:

- Not served by another local agency, a water corporation regulated by the Public Utilities Commission, or a mutual water company.
- Served by a local agency, when the majority of the agency's governing body declines to exercise its authority to manage groundwater and enters into an agreement with the local agency developing the GMP.

Sutter County's intended role in groundwater management, as discussed in this GMP, is to help coordinate the various groundwater users in the County, and encourage them to be

responsible stewards of the water resources. The County does not have the budget or staff to act as an "enforcer" with regards to groundwater use, and does not intend to do so.

1.3. Plan Area

Sutter County intends this GMP to be relevant for the entire County. Sutter County overlies the south central part of the Sacramento Valley Groundwater Basin, and specifically the Sutter Subbasin and portions of the East Butte and North American Subbasins, as shown in Figure 1. The majority of the County is serviced by water and irrigation districts, reclamation districts, cities, and public utility districts (Figure 2), which have the authority to manage groundwater in their service areas. Unless those entities decline to manage groundwater on their own, and instead enter into agreements with the County, this GMP does not formally apply to those areas. If those entities choose not to adopt their own GMPs, they have the option of taking formal action to adopt the Sutter County GMP for their areas. By doing so, they will fulfill the requirements of the groundwater management provisions of the California Water Code.

Some of the water purveyors in the County have prepared groundwater management plans established under provisions of Sections 10750-10756 of the California Water Code (Assembly Bill 3030). Four of these plans have been submitted to DWR for final adoption.

1.4. Public Involvement in Plan Development

Throughout the development of this GMP, Sutter County solicited public input to help guide the direction and content. Aside from the required public notices and hearings related to the GMP development, Sutter County undertook an extensive public outreach program to encourage public involvement in the GMP development and to solicit public input for the GMP. To help guide the development of the GMP, a Plan Advisory Group (PAG) was formed that included representatives of water purveyors, cities, and the general public (attendance sheets provided in Appendix A)

The Sutter County Water Resource Department and the Board of Supervisors approved a Public Outreach Plan (Appendix B) for the GMP process. The Public Outreach Plan established the following objectives:

- Establish an open process to facilitate stakeholder input.
- Provide information to facilitate stakeholder education on material forming the basis of the GMP.

- Provide a framework by which stakeholders are kept informed of the process, issues, and potential solutions.
- Incorporate public comments throughout the decision-making process.

Various entities – including the Board of Supervisors, Plan Advisory Group, and the general public – were involved in the development, approval, and adoption of the GMP.

While developing the GMP, eleven public meetings were held. The location and time for each of the PAG meetings were advertised in local media. Attendance at each PAG meeting was recorded and a mailing list was created to disseminate meeting times and important information regarding the GMP progress. Participation in the PAG was voluntary and the public was invited to attend and comment at public workshops held in Yuba City. At each of the public workshops, Wood Rodgers, Inc. presented a PowerPoint® presentation of the purpose, scope, and schedule for preparing the GMP, along with educational information related to groundwater, geology, wells, and information about the hydrogeology within the County. The PAG meetings were held in 2008 on June 10, August 14, October 17, and December 9; in 2009 on February 10; in 2010 on June 17, August 19, October 28, and December 15; and in 2011 on April 14[1] and October 20. The Sutter County Water Resources Department hosted a website for the GMP at:

http://www.co.sutter.ca.us/doc/government/depts/pw/wr/gmp/gmphome

All of the presentations and applicable meeting information were posted on the GMP website. Presentations, attendance sheets, and a summary of public comments from the workshops are included in Appendix B.

1.4.1. GMP Survey

The County circulated a voluntary Public Opinion Survey to obtain participation and feedback from stakeholders. The surveys were distributed to interested individuals at the PAG meetings and were also made available for download on the County's website. In order to differentiate between individual well owner concerns and water district concerns, two surveys were distributed. Unfortunately, due to the limited returns, the surveys were not beneficial in identifying countywide concerns related to groundwater.

[1] The reason the meetings extended over four years is that DWR issued a stop work order in 2009 due to uncertainties with the State of California budget. Consequently, the GMP process was temporarily delayed from February 2009 to May 2010. Resumption of the GMP process required approval of a new Notice of Intent and a contract amendment with DWR.

1.5. Issues of Concern

A variety of issues and/or concerns with regard to groundwater and groundwater management have been raised by residents of the County during the development of this GMP. These issues and concerns include the following.

1.5.1. Protect private groundwater rights.

The development of the GMP has raised concerns about how individual groundwater rights will be affected. California State Water Law gives property owners the right to make reasonable and beneficial use of the groundwater resource underlying their property. The GMP does not encroach upon or place any restrictions on groundwater rights. Furthermore, the County does not have the budget or staff to act as an "enforcer" with regards to groundwater use, and does not intend to do so.

1.5.2. Is there enough groundwater to sustain a drought?

Water districts within the County have been able to provide groundwater when surface water supplies were reduced during past droughts. Conversely, the use of groundwater when surface water is in short supply allows the aquifer(s) to recharge when surface water is available and is known as conjunctive use.

Increased use of groundwater in some areas is perceived to be taxing the available supply, and there is concern that wells will go dry during a drought. A related concern is that existing wells may be damaged by increased pumping. This concern is particularly widespread in the southeastern portion of the County, where groundwater is used extensively for irrigation. Additionally, changes in cropping trends to more permanent crops have raised concerns about the ability to reduce groundwater use during drought periods without sustaining substantial economic losses in areas that do not use groundwater conjunctively with surface water.

This concern is understandable given the history of significant groundwater level fluctuations in the southeastern portion of the County during past drought periods. Data also indicate that during wetter periods, or when pumping is reduced, groundwater levels have started to recover. The need for water supply reliability to support water users in the County can be addressed through the conjunctive use/management of available surface water, groundwater, and recycled water supplies. Together, these water sources comprise the irrigation water supply for the County, and can be used in fluctuating proportions to meet demands during different hydrologic (including climatic) and economic conditions. Successful management will also require better coordination among water users, and water users will need to work together to develop strategies for curtailing water use

during drought periods. If intra-county water transfers (transfers from one party to another within Sutter County) are possible, they can become an important water management tool and consideration during these periods.

1.5.3. Are there plans to "export" water out of Sutter County?

There is general concern that projects related to groundwater studies and groundwater management (including this GMP) are somehow related to the desire to "export" water from the County. Those who express this concern feel that the State (and other parties within and outside of the County) cannot be trusted to protect the interests of the community within the County. Currently, under state law, groundwater substitution water transfers are allowed. A groundwater substitution water transfers occurs when an entity with surface water rights makes an agreement to transfer some or all of its surface water to downstream users (by not diverting it), and then pumps groundwater to make up for the "lost source supply" that results from the transfer.

This concern can be somewhat allayed by maintaining local water district control of water management decisions. Also, establishing an open process for discussing groundwater conditions and making management decisions will help the stakeholders within the County have a better understanding of the resources and issues and to voice their concerns and have them addressed.

1.5.3.1. Sutter County Conjunctive Water Use Success (Case Study)

The Department of Water Resources provided the following case study for inclusion in this GMP to demonstrate the effectiveness of conjunctive water use.

"An example of a successful conjunctive use program was implemented by the South Sutter Water District (SSWD or District). The SSWD is located in southern Sutter and western Placer counties, with the Bear River as the northern boundary and stretching southwest between Highway 65 and Highway 70 to Pleasant Grove and Curry Creeks. The District was formed in 1954 to develop, store and distribute surface water supplies and to augment and replenish over-drafted groundwater supplies. Figures 3 and 4 are groundwater level hydrographs illustrating the recovery of groundwater levels after the implementation of the

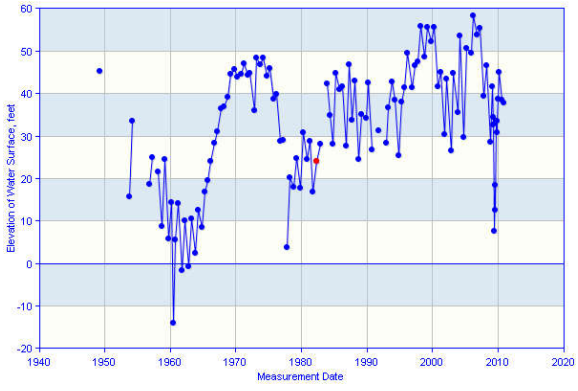

Figure 3 - Hydrograph for Well 13N/5E-30A1M

conjunctive use program. Today SSWD encompasses a total gross area of nearly 64,000 acres, including 57,012 acres that are authorized to receive surface water. According to the District,41,946 acres have actually been irrigated in recent years using a combination of surface and groundwater supplies. By far the majority of those acres grow rice (roughly 34,834 acres, or 83%), while the balance is apportioned between orchards (2,881 acres, or 5%), irrigated pasture (2,088 acres, or 5%), row and field crops (1,742 acres, or 4%) and the remaining 3%, which is fallowed in certain years.

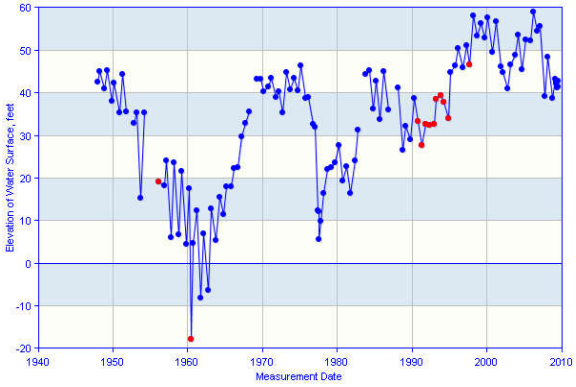

Figure 4 - Hydrograph for Well 13N/4E-13R1M

The enlarged New Camp Far West (NCFW) Reservoir was completed in 1964 with a storage capacity of 104,400 acre-feet (AF). SSWD and Camp Far West Irrigation District (CFWID), formed in 1924, holds the water rights for operating the reservoir. Surface supplies are managed conjunctively with groundwater supplies. The seven (7) megawatts of power generated by the NCFW powerhouse is wholesaled to Sacramento Municipal Utility District. The Federal Energy Commission (FERC) license for NCFW was issued on July 2, 1981.

One and a quarter miles downstream of NCFW Dam (and about 15 miles above the confluence with the Feather River), water is diverted by a diversion dam designed to move 30 cubic feet per second (cfs) north into the CFWID and 380 cfs south into the SSWD. In 1994, SSWD, CFWID, and the Department of Water Resources entered into a settlement agreement to meet the District's obligations under the State Water Resources Control Board's (SWRCB) Water Quality Control Plan for the Bay-Delta. Under the agreement, SSWD agreed to release up to 4,400 AF of water from NCFW, when requested by DWR, in all dry and critical year types. The present water rights require minimum in stream flows below the diversion works of 25 cfs from April 1 through June 30 and 10 cfs from July 1 through March 30. Under the new agreement, SSWD would increase the flow releases to the lower Bear up to 37 cfs in dry and critical years for up to sixty days in July through September.

SSWD receives anywhere from 5,000-20,000 AF of surplus water from Nevada Irrigation District (NID) annually. That water is currently conveyed to SSWD from Rollins Reservoir via the Bear River/Wise Canal system. When completed, SSWD's Canal Expansion project, including related conveyance system improvements, could

well provide previously-unforeseen opportunities for delivering a portion of surplus NID supplies to SSWD directly via the Bear River and NCFW Reservoir."

1.5.4. Will there be taxes or fees for groundwater use?

Concerns have been expressed about the sources of funding for the GMP and other groundwater programs in the County. Funding would be necessary should staff be required to perform new monitoring and evaluation activities or to undertake groundwater investigations. Funding for the latter may be available from DWR and other grant programs, under which this GMP maintains eligibility for the County. Currently, the County assesses fees only for exploratory drilling, well construction, and well destructions, as shown in the following table (Table 1).

Table 1
***Current* Sutter County Fee Assessments (as of January 1, 2012)**

Well Permit	***Fee***
Well Construction	$470.00
Well Destruction	$376.00
Water Exploration and Test Holes	$376.00
Permit Extension (1 year)	$47.00

There is concern about the potential for taxes and fees on groundwater use, and metering of pumps. This GMP does not contain any recommendation to meter groundwater pumping or to enact use-based fees or taxes, although they are considerations and are used in other areas. State law affords property owners the right to make beneficial use of groundwater on their land.

1.5.5. How can we obtain good quality water?

Water quality problems are significant within the County and concerns have been expressed about water quality with regard to salinity, arsenic, and manganese. The hydrogeology of the County as it relates to water quality is not well-understood, and further study will be necessary to develop guidelines for how to obtain good-quality water in different areas of the County, and to determine how to manage groundwater without causing water quality deterioration in areas with otherwise good quality water. As discussed in Section 4.4, this GMP illustrates water quality in different areas of the

County, and shows the geographic areas (and depths) where poorer quality groundwater can be anticipated. As more data becomes available, the County will be able to incorporate it into the existing understanding of the groundwater subbasins.

1.5.6. Is this going to generate new regulations on groundwater?

Concern has been expressed about the potential for additional layers of bureaucracy and regulations on groundwater use. In general, stakeholders recognize a need to better understand and manage groundwater in the County, but have expressed a desire for a "balance" between achieving this objective and minimizing bureaucracy and regulations.

To implement the GMP, an institutional framework (not yet determined) will be needed; however, the intent of this GMP is to minimize the bureaucracy and regulations needed to achieve the goals and objectives of the GMP. The GMP provides a framework and a forum for studying, discussing, and managing groundwater within the County. Ideally, management will be accomplished cooperatively amongst the groundwater users in the County.

2. THE COUNTY

2.1. Physical Setting

Sutter County encompasses approximately 607 square miles (389,443 acres) in the central portion of the Sacramento Valley. As shown in Figure 5, Sutter County is bound by Butte County to the north, Colusa and Yolo Counties to the west, Yuba and Placer Counties to the east, and Sacramento County to the south. The County seat, Yuba City, is located approximately 50 miles north of Sacramento. The 2010 U.S. Census reported that the population of the County in 2010 was 94,737, with the majority of the population residing in Yuba City and Live Oak, and about 25 percent of the population in the rural communities. Land use within the County is principally agricultural, with approximately 318,701 acres in production (Sutter 2010a).

The two main population centers in the County are Yuba City, with 67 percent of the population, and the City of Live Oak, approximately 10 percent of the population (U.S. Census 2010). The remaining County residents live within the small communities of Tierra Buena, Meridian, Rio Oso, Trowbridge, Sutter, Pleasant Grove, Nicolaus, East Nicolaus, Riego, Robbins, or in the vast rural agricultural areas which make up Sutter County. Future major growth areas planned for Sutter County include Sutter Pointe (Measure M). The Sutter Pointe Specific Plan details a large-scale development project that is currently on file with and being processed by Sutter County. This plan area is located in the southern most portion of the County adjacent to the Sacramento County border and a portion of the Placer County border. The plan area includes the development of approximately 7,500 acres into mixed use and residential properties and has been structured to facilitate future incorporation as an independent city (Sutter 2010).

The main transportation routes connecting the County with the region are Highway 99, which runs north-south through the County, California State Route 20, which runs east-west through the County and Highway 113, which runs from the south-west portion of the County and terminates at Highway 99 (connecting Woodland with the County).

Land elevations range between 80 and 20 feet above sea level throughout the County with the exception of the Sutter Buttes, where elevations are more than 2,100 feet above sea level. The lowest land elevations are located towards the southern portion of the County.

Sutter County has abundant surface water, including the Sacramento, Feather, and Bear Rivers, as shown in Figure 5. A number of the water districts in the County (Figure 2) divert and transfer surface water.

2.2. Water Purveyors and Users

Water resources in the County are managed by water purveyors and individual water users who have "hands on" control of both surface water and groundwater for agricultural, urban, environmental, and domestic uses. These water managers represent a complex mix of organized water purveyors, non-organized areas, and areas within National Wildlife Refuges. A brief discussion of each category is presented below.

2.2.1. Water Purveyors

There are 48 water purveyors in Sutter County which provide water service to their customers (Figure 2). These water purveyors include water districts, irrigation districts, reclamation districts, mutual water companies, public utilities districts, and incorporated cities. Additionally, there are many private water users including community service districts (CSD's) and farming interests.

Six water purveyors provide water service not only in Sutter County, but in the counties that share borders with Sutter. They are:

- Reclamation District No. 1004 (Colusa County)
- Biggs-West Gridley Water District (Butte County)
- Butte Water District (Butte County)
- Dry Creek Mutual Water Company (Yuba County)
- South Sutter Water District (Placer County)
- Natomas Central Mutual Water Company (Sacramento County)

2.2.2. Non-Organized Areas

The non-organized areas within the County are not within the boundaries or service area of established water purveyors.

2.2.3. National Wildlife Refuges

The Sacramento National Wildlife Refuge Complex consists of five national wildlife refuges and three wildlife management areas. Portions of Sutter County have been dedicated, both through public and private efforts, as wildlife refuges. Exclusively in Sutter County, the Sutter National Wildlife Refuge has 2,591 total acres, with the majority (83%) located inside the Sutter Bypass. According to U.S. Fish and Wildlife

Service, the refuge "consists of approximately 1,881 acres of seasonal and summer wetlands and approximately 674 acres of unmanaged wetlands, grasslands, and riparian habitats" (USFW 2009).

The Natomas Basin Conservancy also owns nearly 1,000 acres of wildlife habitat/mitigation lands within the southern portion of the County.

2.3. Land Use

The predominant land use within the County is agriculture. The 2008 Sutter County General Plan Technical Background Report estimates that 322,240 acres (83%) of Sutter County is agricultural land. An estimated 44,581 acres (11%) is designated as open space. The remaining 6% of the County is designated as residential, public and vacant, commercial, industrial, and transportation and utilities. As stated above, agriculture dominates land uses within Sutter County. Figure 6 shows the distribution of land uses, with regard to crop type and water source, for the entire County. It is apparent that permanent crops dominate the eastern portion of the County, along the Feather River, while rice and other non-permanent crops dominate the central and western portion of the County.

2.4. Water Use

The amount of water applied for agricultural production and urban or community use has been estimated using information from DWR with respect to unit crop, consumptive use, and applied water, with corresponding losses included and accounted for. Water use within cities and communities was estimated using limited production data from some water purveyors from 2008 to 2010.

2.4.1. Agricultural Water Use

Water use during the 2009 growing season was calculated based on the Sutter County 2009 Crop Report. Estimates of applied water for irrigated agriculture are 1,122,018 AF.

Sutter County's agricultural water usage is approximately 60 percent surface water, 20 percent groundwater, and 20 percent that is irrigated by both surface water and groundwater. Figure 6 illustrates the source of water for crops grown in the County. The predominant source of water for permanent crops is groundwater.

2.4.2. Urban/Community Water Use

Water for urban and community use is from groundwater and surface water. From available DWR records, the minimum urban water use was 1,770 AF in 2010 (records for

all urban water suppliers was not available). Yuba City provides mostly surface water (15,682 AF in 2008) while smaller communities rely exclusively on groundwater.

3. HYDROLOGY AND SURFACE WATER

3.1. Seasonal and Long-Term Hydrology

Annual fluctuations in northern California precipitation directly influence the volume of water flowing in the Sacramento River. Precipitation and climate data from the Western Regional Climate Center (WRCC) suggest the average annual precipitation for the west side of the County (Colusa Station) is 16.40 inches per year and on the east side of the County (Marysville Station), it is 20.96 inches per year. In Nicolaus, the average annual precipitation is 18.27 inches per year. Collectively, average annual precipitation is 18.54 inches per year. Snow-fall within Sutter County is rare, measuring on average 0.01 inches per year. Precipitation is highly variable throughout the State, from year to year. Precipitation usually takes place from October to May and on average no precipitation occurs from June to September. The water year, defined as starting on October 1 and ending September 30, is classified as one of five water year types: critical, dry, below normal, above normal, or wet[2]. Within the past ten years, only two water years were classified as wet and one year was classified above normal. The remaining years were either dry, critical, or below normal. The average annual temperature is approximately 62° F, with an average high of 95.7° F in July and an average low of 37.4° F in January.

Precipitation in the Sierra Nevada, Coast Range, Klamath, and Cascade Mountains contribute to surface water flow and groundwater recharge in the Sacramento River Basin. The general direction of surface water flow is toward the center of the valley, flowing south. Water diversions, evaporation, and groundwater recharge reduce flows as the Sacramento River approaches the Delta.

3.2. Surface Water

Sutter County is located in the Sacramento River Basin, with the Sacramento River on the west and the Feather River on the east. The Sacramento River is the largest river in northern California and drains the northern central part of California. The watershed for the Sacramento River includes tributaries originating in the Sierra Nevada, the Coast Range, and the Cascade Mountains. The main tributaries in Sutter County include the Feather River, Bear River, Dry Creek, Pleasant Grove Creek, Auburn Ravine, and Coon Creek.

During periods of heavy precipitation and runoff, a portion of the flow within the Sacramento River is diverted through the Sutter Bypass. The Sutter Bypass is a man-made feature in Sutter County and was designed to alleviate the flood control system along the Sacramento

[2] http://cdec.water.ca.gov/cgi-progs/iodir/wsihist

River. Aside from the major rivers and tributaries within Sutter County, there are no significant surface water storage reservoirs within Sutter County.

It is important to note that flows in all the major rivers in northern California are managed by dams, e.g. the Feather River by Lake Oroville and the Sacramento River by Lake Shasta. The reservoirs are managed to provide flood protection while collecting runoff from the watershed. Releases from the reservoirs occur from spring through summer to provide irrigation water for agriculture as well as to provide drinking water downstream.

The following discussion provides information on the location, ownership, infrastructure, and an overview of the operational practices of the major water bodies that relate to or are within Sutter County.

3.2.1. The Sacramento River

The Sacramento River is the major surface water feature in Sutter County. Running north-south along the western part of the County, the Sacramento River is the main drainage for the Sacramento Valley Basin on its way to the Delta and the San Francisco Bay. The Sacramento River supports many beneficial uses including recreational, agricultural, and wildlife. The river is currently not used for municipal or domestic water supplies in the County. There are, however, future plans to utilize the Sacramento River, in conjunction with groundwater, to provide municipal water supply to the Measure M Sutter Pointe development (Sutter 2011).

Many tributary streams flow from the mountains on both sides of the valley into the Sacramento River. According to a 2005 report by the Glenn County Department of Agriculture (GCDA), flows in the Sacramento River near Grimes in Southern Colusa County range from 6,500 cfs to 16,900 cfs for the period of record of 1946-2003 (GCDA 2005).

3.2.2. The Feather River

The Feather River is a major tributary of the Sacramento River and outlines a major portion of Sutter County's eastern boundary. The river trends north-south along the northern and central portions of the County to the convergence with the Bear River, where it changes course and flows southwest through the south-central portion of the County until it intersects the Sutter Bypass and the Sacramento River. Like the Sacramento River, the Feather River provides beneficial uses including recreation, agricultural, and wildlife. Yuba City obtains a large portion of its annual water supplies for municipal and domestic use from the Feather River.

3.2.3. The Bear River

The Bear River is a tributary of the Feather River and enters Sutter County from Placer County near the City of Wheatland in Yuba County. It forms the boundary between Sutter and Yuba Counties up to the convergence with the Feather River. The Bear River generally flows west until it converges with the Feather River, approximately one mile upstream from the rural community of Nicolaus. Although smaller than the Sacramento and Feather Rivers, the Bear River also provides beneficial uses that include recreation, agricultural, and wildlife. Discharges within the river are partially controlled by several upstream reservoirs. The Camp Far West Reservoir (located in the counties of Yuba, Placer and Nevada) is the last downstream reservoir on the river and subsequently regulates surface water discharges to downstream users, which has been the source of surface water for a very successful conjunctive water use program for the South Sutter Water District.

3.2.4. The Sutter Bypass

The Sutter Bypass (Bypass) is an artificial flood corridor constructed in the 1930's. As described by the Army Corp of Engineers, "the Sutter Bypass, which began operation in the 1930's, is a leveed portion of the natural floodway in the Sutter Basin. The bypass is south of the Sutter Buttes from Colusa to Verona between the Sacramento and Feather rivers. Flows enter the Sutter Bypass from the Butte Basin at its upper end near Colusa at the Butte Slough. Other flows enter from Wadsworth Canal, interior drainage from pumping plants, and the Sacramento River by way of the Tisdale Weir and Bypass. Flows exit the Sutter Bypass and combine with the Sacramento River, Feather River, Natomas Cross Canal, and Yolo Bypass upstream from the Fremont Weir near the town of Verona"(USACE).

3.3. Seasonal and Long-Term Water Quality

Under the USGS National Water Quality Assessment (NAWQA) Program, the USGS conducted an intensive study of the Sacramento River Basin and collected data between 1995 and 1998. Through the sampling process, the USGS selected indicator streams that were based upon the characterization that "they drain small to intermediate sized watersheds with relatively homogeneous land use and geology" (USGS 1998). The Colusa Basin Drain is located entirely in the Sacramento Valley and was chosen as an indicator stream to determine the impacts of agriculture on stream-water quality (USGS 1998). At the indicator water quality station, Colusa Basin Drain at Road 99E near Knights Landing, it was determined that pH levels were generally on the higher end, with declining suspended sediment concentrations over the two-year sampling period. The higher concentrations of mercury

correlate with suspended sediment because much of the load of total mercury is transported with the suspended material.

The findings of the USGS study also indicated that the water of the Sacramento River and its major tributaries is generally of good quality. As stated in the U.S. Geological Survey Circular 1215:

> "the amount of dissolved solids in the Sacramento River and its major tributaries (Yuba, Feather, and American rivers) was low at all of the sampled locations. Higher median concentrations of dissolved solids occurred at agricultural sites such as the Sacramento Slough and Colusa Basin Drain, but those are diluted upon mixing with Sacramento River water. Nutrient concentrations such as nitrate also were low throughout the Sacramento River Basin, and drinking-water standards for nitrate were not exceeded during the course of this study. The concentrations of Molinate and other pesticides (used in rice farming) measured during this study in the Colusa Basin Drain or in the Sacramento River, represent a significant improvement over concentrations measured in previous years".

3.4. Surface Water Supply Contracts

3.4.1. Settlement Contracts

USBR currently contracts with approximately 145 water districts, water purveyors, or private users for water rights to the Sacramento River. The total amount of water under the settlement contracts is approximately 2.2 million acre-feet and cover a total of almost 440,000 acres of land bordering the Sacramento River and its tributaries between Redding and Sacramento. The Settlement Contracts were originally executed in 1964 with a term not to exceed 40 years. New contracts have been executed with approximately 145 existing Sacramento River Settlement Contracts.

The Settlement Contracts include a Base Supply and Project Water. The Base Supply is the amount that reflects the agreed-upon water right of the respective entity. This is generally regarded as pre-1914 water rights and also water rights perfected after 1914 and reflect water that would be available to the respective entities under "natural" conditions. Project Water represents the amount of water the Bureau of Reclamation agrees to provide from its Central Valley Project (CVP) yield. Under the provisions of the Settlement Contracts both the Base Supply and Project Supply could be reduced by 25 percent of the total contract amount, but only in certain water year types.

3.4.2. Long-Term Renewal Contracts

In accordance with the CVP Improvement Act (CVPIA), the USBR negotiated long-term water service contracts in 2007. According to Section 3404c of the CVPIA, Renewal of Existing Long-Term Contracts requires the USBR to renew any existing long-term repayment or water service contract for the delivery of water from the CVP for a period of 25 years and may renew such contracts for successive periods of up to 25 years each. The USBR anticipates that, "as many as 113 CVP water service contracts, located within the Central Valley of California, may be renewed during this negotiation process" (USBR 2007a).

The long-term renewal contracts, unlike the Settlement Contracts, have no specified reduction in delivery; during critically dry or water-short years, the water supply available from the Project will be allocated among the contractors.

Also, the long-term renewal contracts contain a tiered pricing provision. The Base Supply is 80 percent of the total contract amount, and Tier 1 and Tier 2 supplies represent 10 percent each of the remaining contract amount. Each tier has an incrementally higher water cost. The Tier 1 and Tier 2 water, which is available in most years, is not used due to the incremental higher cost of water.

4. GROUNDWATER

4.1. Groundwater Basins and Subbasins

Sutter County is underlain by the Sacramento Valley Groundwater Basin. The Sacramento Valley Groundwater Basin covers a vast area and encompasses the alluvial deposits under the valley floor from the Sierra Nevada Mountains to the east, the Coast Range mountains to the west, the Sacramento-San Joaquin Delta to the south, and the Klamath and Cascade Ranges to the north. The Sacramento Valley Groundwater Basin covers over 5,900 square miles and 10 counties, and has been divided into 18 subbasins. The GMP area is underlain by three groundwater subbasins (Figure 1) as defined by the California Department of Water Resources (DWR) in "California's Groundwater, Bulletin 118 – Update 2003". These subbasins are: the East Butte Subbasin, the Sutter Subbasin, and the North American Subbasin. According to DWR,

"A groundwater basin is defined as an alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined […] features that significantly impede groundwater flow such as rock or sediments with very low permeability or a geologic structure such as a fault. […]

"A subbasin is created by dividing a groundwater basin into smaller units using geologic and hydrologic barriers or, more commonly, institutional boundaries […]. These subbasins are created for the purpose of collecting and analyzing data, managing water resources, and managing adjudicated basins."

4.2. Hydrogeology

4.2.1. Overview of Groundwater and Geology

Groundwater is water that is underground and below the water table (saturated zone), as opposed to surface water, which flows across the ground surface. There are three main types of subsurface geology where groundwater can exist:

- Hard Rock – Groundwater can be present in cracks or fractures in the rocks.
- Underground Caverns – Groundwater can fill these underground voids.
- Porous Sediments – Groundwater can fill the pore spaces between grains of sand and gravel.

In Sutter County, groundwater exists in porous sediments, alluvial aquifers, or fractured volcanic rock such as in the vicinity of the Sutter Buttes. Figure 7 shows a simplified surface geologic map with the major faults in the County. Sutter County is situated along

the axial portion of the Sacramento Valley Groundwater Basin. The subsurface aquifers consist generally of layers of gravel, sand, clay, and in some cases volcanic ash. The characteristics of different aquifers, and zones within each aquifer, are related to the aquifer materials (sands, gravels, clays, etc.). Within a single aquifer zone, nearby wells with similar construction can have very similar well yields and water quality. It should be noted that many of the geologic formations that make up the alluvial aquifers are continuous units that are also present in other counties as discussed.

In the northern portion of Sutter County, the geologic setting changes rapidly from the stratigraphic succession observed in the rest of the County. A thick sequence of volcaniclastic sediments derived from the Sutter Buttes volcanic epoch form a volcanic fan apron of alluvial deposits around its perimeter. These deposits have been characterized recently by DWR as consisting largely of gravel, sand, silt, and clay. These deposits are observed at ground surface around the Buttes, and may extend up to a 15 mile radius in the subsurface (Springhorn 2008). Sediments deposited under marine sedimentary processes are also observed at ground surface and at shallow depths in the subsurface around the Buttes. These deposits were elevated from depth to their current position during the emplacement of the volcanic intrusion which formed the Sutter Buttes. Water quality in these sediments is generally poor and deteriorates with depth.

There is a large amount of hydrogeologic data available in the Sacramento Valley which has been widely studied, and groundwater is continuous within specific aquifer zones (although discontinuous between different aquifer zones) over large areas within the Sacramento Valley.

4.2.2. Status of Understanding of Regional and Local Geology

The geology of the Sacramento Valley has been studied for at least 95 years, and much has been learned over this time. However, there are still many areas of active study and debate. In Sutter County, areas that are not well-understood and/or are actively being studied include:

- The connection between the Coast Range-sourced Tehama Formation and the analogous Sierra Nevada-sourced deposits, and where this interaction occurs.
- The possible existence of subsurface barriers to groundwater flow within the County.
- The source of poor water quality in parts of the County.

4.2.3. Regional Geology and Structure

The Sacramento Valley Groundwater Basin is a north-south trending structural trough which is filled with layers of sediments. The stratigraphic succession of the basin deposits, from oldest to youngest (deep to shallow), depict a regional change in depositional environment from one dominated by marine sedimentary processes to that of continental (alluvial) processes. The deepest portions of the basin generally consist of marine sedimentary rocks, ranging in age from Late Jurassic to early Miocene (160 million years ago to 24 million years ago). These marine deposits are overlain by younger alluvial and locally prominent volcanic rocks of early Miocene to Holocene age (Harwood and Helley 1987). Within the Basin, these deposits are disrupted by deformational stresses derived from east-west compressional forces associated with regional uplift along the western margin of the valley and extensional forces to the east, within the Basin and Range Provenance (Harwood and Helley 1987). Over time, these forces have applied great stresses and strain on valley deposits, creating complex and diversely-oriented fold and fault structures.

The prominent fault system that occurs in Sutter County is the Willows Fault. The Willows Fault is an active northwest-trending fault that dips steeply to the east and shows reverse displacement, meaning the ground east of the fault has moved up relative to the west side. The Willows Fault enters into the County from Colusa County southwest of the Sutter Buttes and extends to the southeast portion of the County towards Sacramento.

The most prominent and recognizable geologic feature in Sutter County are the Sutter Buttes. The Sutter Buttes are composed of late Cenozoic volcanic rocks that rise over 2,000 feet above the Sacramento Valley floor. The Sutter Buttes formed between 2.4 and 1.4 million years ago as magma at depth was injected into the overlying Cretaceous and Tertiary rocks, causing deformation in the form of faulting, folding, and uparching (Harwood and Helley 1987).

4.2.4. Regional Stratigraphy

The prominent non-marine, fresh water-bearing stratigraphic units found within the East Butte, Sutter, and North American Subbasins include (from youngest to oldest):

- Recent Alluvial Deposits (stream channel, basin, and flood plain);
- the Modesto Formation;
- the Riverbank Formation;

- the Sutter Buttes Rampart;
- the Victor Formation;
- the contiguous Laguna, Tuscan, and the Tehama Formations;
- the Mehrten Formation; and
- the informally named Sutter Formation (Springhorn 2008).

Except for the Sutter Formation, the stratigraphic descriptions presented herein are based upon the California Department of Water Resources "Bulletin 118 – California's Groundwater" and are shown in the geologic cross-sections (Figure 8). The location of the cross-section is shown in Figure 7.

Locally, the stratigraphic succession observed in each subbasin differs slightly; therefore, each subbasin and its associated geologic setting are described separately with regard to their relative positions and occurrences in the specific subbasin.

4.2.4.1. East Butte Subbasin (Basin Number 5-21.59)

The northern section of Sutter County is underlain by the East Butte Subbasin. The East Butte Subbasin is bounded by the Sutter Buttes to the south, Butte Creek to the west and northwest, the Cascade Mountain range to the northeast, and the Feather River to the southeast. The East Butte Subbasin aquifer system consists of late Tertiary to Quaternary aged deposits comprised of Sierra and Cascade sourced material, and in the southern portion of the subbasin around the Sutter Buttes, by volcanic and volcaniclastic rocks. The geologic formations that comprise the East Butte Subbasin are (from youngest to oldest):

- Recent Alluvial Deposits;
- the Pleistocene aged Modesto and Riverbank Formations;
- the Sutter Buttes Rampart; and
- the Tertiary aged Laguna and Tuscan Formations.

Recent Alluvial Deposits

Stream channel deposits are Holocene in age and were deposited between 11,000 years ago and present day. The stream channel deposits occur along the current and ancestral paths of streams and rivers in Sutter County. Where present, the stream channel deposits extend from ground surface up to a depth of 80 feet below ground surface (Helley and Harwood 1985). The stream channel deposits consist of unconsolidated gravels, sand, silt, and clay, derived from the erosion and reworking of the Modesto and Riverbank Formations (described below). This unit is moderately to highly permeable, but because of its shallow depth and limited thickness, it possesses limited water-bearing capacity.

Basin deposits are Holocene in age and, like the stream channel deposits, were deposited between 11,000 years ago and present day. Basin deposits occur where sediment-laden floodwaters breached natural stream and river levees and spread across lower-lying topography. Where present, the basin deposits extend from ground surface up to a depth of 150 feet. The basin deposits consist mainly of silt and clay. These units have low permeability and generally yield small quantities of water to wells.

The Modesto Formation

The Modesto Formation is Pleistocene in age and is a stream terrace deposit that was deposited between 12,000 to 50,000 years ago (Helley and Harwood, 1985). Within this subbasin, the Modesto Formation consists of poorly indurated gravel and cobbles, sand, and clay and is derived from the reworking and deposition of the Riverbank Formation, Laguna Formation, and Tuscan Formation (DWR 2004). The Modesto Formation was likely deposited by the same stream and river systems that flow today, because it generally borders existing channels (Blake et. al. 1999). This formation may extend across the entire subbasin and where present, may range in thicknesses from 50 to 150 feet (DWR 2000). The sediments of the Modesto Formation are moderately to highly permeable and can yield moderate quantities of water to wells.

The Riverbank Formation

The Riverbank Formation is Pleistocene in age and was deposited between 120,000 and 500,000 years ago (Helley and Harwood, 1985). The Riverbank Formation consists of gravel and small cobbles, and is interbedded with reddish-clay, sand and silt. Like the Modesto Formation, the Riverbank Formation is a stream terrace deposit. However, the Riverbank Formation is older than the Modesto Formation. The

Riverbank Formation may extend across the entire subbasin, underlying the Modesto Formation, with thicknesses ranging from 50 to 200 feet. The Riverbank Formation is poorly to highly permeable and can yield moderate quantities of water to wells.

Sutter Buttes Rampart

The Sutter Buttes Rampart was deposited during the Middle to Lower Pleistocene period and is encountered in the southern portion of the subbasin. This unit is up to 600 feet thick in the subsurface (DWR 2000). In several studies (William and Curtis 1977, Springhorn 2008) the Sutter Buttes Rampart has been separated into two distinct units: the Rhyolitic Rampart and the Andesitic Rampart. The Andesitic Rampart phase of volcanism was much larger than the Rhyolitic phase. All the large peaks of the Sutter Buttes are andesitic domes and comprise the majority of the Rampart on the surface and the subsurface. The Sutter Buttes Rampart consists largely of gravel, sand, silt, and clay sediments which were deposited circumferentially around the Buttes as a geologic apron. These sediments may extend up to 15 miles north of the Sutter Buttes and west beyond the Sacramento River. Certain zones within these units yield large quantities of water (DWR 2004).

Laguna Formation

The Laguna Formation is Plio-Pleistocene in age and was deposited between 4 million and 2 million years ago. The Laguna Formation is comprised of Sierra Nevada sourced sediments, consisting of consolidated alluvial gravel, sand, and silt, comprised of granitic, metamorphic, and volcanic material. Estimates of the thickness of the Laguna Formation range from 180 feet (Helley and Harwood 1985) to 1,000 feet (Olmstead and Davis 1961). The Laguna Formation is characterized as being moderately consolidated and poorly to moderately cemented. Because of this, the permeability of formation is generally low to moderate. Wells completed in this formation have been observed to yield only moderate quantities of water (DWR 2003).

Tuscan Formation

The Tuscan Formation has been the subject of much interest in recent years. The Tuscan Formation is a regional aquifer system wholly or in parts of Tehama, Butte, Glenn, Colusa, and Sutter County. Within Sutter County, there has been limited analysis done on the subsurface extent of the Tuscan Formation. It is likely that the Tuscan Formation is only present in the northern portion of the County and consequently is not a major water resource for the County.

The Tuscan Formation is Plio-Pleistocene in age and was deposited between 4 million and 2 million years ago. The Tuscan Formation was derived by alluvial deposition associated with the erosion of volcanic material derived from Cascade volcanism. The formation outcrops from Red Bluff, in the northern part of the Sacramento Valley, to Oroville, southeast of Chico, and has been recognized in the subsurface at a distance of about 15 miles west of the Sacramento River (DWR 2003a). The deposits of the Tuscan Formation thin from east to west, from about 1,600 feet thick in the foothills of the Sierra Nevada to about 300 feet thick in the subsurface of the Sacramento Valley (Lydon 1969). In surface outcrops, the exposures of the Tuscan Formation are described as four separate, but lithologically similar units: Units A through D (Helley and Harwood 1985). Units A, B, and C are found within the subsurface in the northern part of the subbasin and units A and B are found in the southern part of the subbasin (DWR 2004). All of the units of the Tuscan Formation contain stratigraphic sequences of volcanic mudflows, volcanic conglomerates, volcanic sandstones, siltstones, and tuff deposits. In the subsurface, the Tuscan Formation consists largely of black volcanic sand and gravel, with interbedded layers of tuff breccias and tuffaceous clays (Ferriz, H. 2001). Unit A is the oldest (deepest) water-bearing unit and is distinguished from Units B and C by the presence of metamorphic clasts. Unit B contains equal distributions of volcanic mudflows, conglomerates, and tuffaceous sandstones. Units A and B are referred to as the "Lower Tuscan Formation". Unit C is capped by massive volcanic mudflows with some interbedded conglomerates and sandstones. In the subsurface, the volcanic mudflows of Unit C act as a confining layer to groundwater flow, separating the more permeable deposits of the Lower Tuscan Formation (Helley and Harwood 1985).

4.2.4.2. Sutter Subbasin (Basin Number 5-21.62)

The Sutter Subbasin underlies the central portion of Sutter County and is wholly within the boundaries of the County. The subbasin is bound by the confluence of Butte Creek with the Sacramento River and the Sutter Buttes to the north, by the Feather River to the east, by the confluence of the Sutter Bypass and Sacramento River to the south, and by the Sacramento River to the west. The Sutter Subbasin aquifer system consists of late Tertiary to Quaternary aged deposits comprised of Sierra-sourced (Sierra Nevada) detritus and volcanic and clastic rocks in the northern portion of the subbasin around the Sutter Buttes. The identified geologic formations that comprise the Sutter Subbasin are (from youngest to oldest):

- Recent Alluvial Deposits;
- the Pleistocene aged Sutter Buttes Rampart and Victor Formation;
- the Pliocene Laguna Formation; and
- the informally named Sutter Formation.

Recent Alluvial Deposits

The Holocene aged stream channel and flood plain deposits occur along the current and ancestral paths of streams and rivers in Sutter County. The stream channel and flood plain deposits consist of unconsolidated gravel, sand, silt, and clay. Both thickness and grain size decrease as the distance increases from their source. Where present, the stream channel and flood plain deposits extend from ground surface to an estimated depth of 100 feet (Helley and Harwood 1985). These units are highly permeable and provide for large amounts of groundwater recharge within the subbasin. This unit is highly permeable, and yields significant quantities of water to wells (DWR 2000).

Sutter Buttes Rampart

The Sutter Buttes Rampart is Middle to Lower Pleistocene aged alluvial deposit that is encountered in the northern portion of the subbasin. This unit can be up to 600 feet thick in the subsurface (DWR 2000). In several studies (William and Curtis 1977, Springhorn 2008), the Sutter Buttes Rampart has been separated into two distinct units: The Sutter Buttes Rhyolitic Rampart and the Sutter Buttes Andesitic Rampart. The deposition and composition of Rhyolitic Rampart reflects the initial stages of volcanism and deposition around the Sutter Buttes, while the Andesitic Rampart reflects the later stages. These fan deposits form an apron around the Buttes and consist largely of gravel, sand, silt, and clay, and may extend up to 15 miles north of the Sutter Buttes and west beyond the Sacramento River. Certain zones within these units yield large quantities of water (DWR 2004).

Victor Formation

The Pleistocene aged Victor Formation is comprised of alluvial fan deposits composed of Sierra-sourced loosely consolidated gravel, sand, and silt. The Victor Formation has an estimated thickness of 100 feet (DWR 2004). This unit is observed to have an impermeable surface due to the presence of hardpan and clay pan soils (DWR 2003). At its base, the Victor Formation has been observed to have moderate

permeability and provides most of the groundwater for domestic and shallow irrigation wells in Sutter County (DWR 2003). Wells completed in this unit have been reported to have yields as high as 1,000 gpm.

Laguna Formation

The Laguna Formation is comprised of Sierra sourced, consolidated alluvial gravel, sand, and silt, which consist of granitic, metamorphic, and volcanic material. Estimates of the formations thickness range from 180 feet (Helley and Harwood 1985) to 1,000 feet (Olmstead and Davis 1961). The Laguna Formation is characterized as being moderately consolidated and being poorly-to-moderately cemented, because of this, the formation generally has a low to moderate permeability. Wells completed in this formation have been observed to yield only moderate quantities of water (DWR 2003).

Sutter Formation

The Mio-Pliocene aged Sutter Formation is an informally named stratigraphic unit that underlies the area around the Sutter Buttes and the central portion of Sutter County. The extent of the deposits have been characterized on a local to sub-regional scale and have been generally classified as volcanic and epiclastic[3] sediments derived from volcanic sources located to the east in the Sierra Nevada, western Nevada, and the southern Cascade Volcanic Province (Springhorn 2008). Due to the complexity of identifying distinguishable characteristics within these deposits, informal and formal stratigraphic units within this region have been grouped together. Some of the major regional stratigraphic units that have been included in the Sutter Formation (from youngest to oldest) are the Tuscan, Mehrten, and Princeton Valley fill deposits.

4.2.4.3. North American Subbasin (Basin Number 5-21.65)

A portion of the North American Subbasin underlies the southeastern section of Sutter County. The North American subbasin is bound by the Bear River to the north, the Feather River to the west, the Sacramento River to the south, and in the east by a north-south trending line that represents the approximate edge of the alluvial basin (DWR 2004). The North American Subbasin is dominated by late Tertiary to Quaternary aged deposits consisting of Sierra-sourced volcanic sediments and alluvial derived sediments. The identified geologic formations that comprise the North American Subbasin are (from youngest to oldest):

[3] Consisting of fragments of preexisting rocks

- Recent Alluvial Deposits;
- Older alluvial deposits (the Pleistocene aged Modesto, Riverbank, Victor, and Laguna Formations); and
- the Mio-Pliocene aged Mehrten Formation.

Recent Alluvial Deposits

Stream channel deposits are Holocene in age and were deposited between 11,000 years ago and present day. The stream channel deposits occur along the current and ancestral paths of streams and rivers in Sutter County. The stream channel deposits consist of unconsolidated gravels, sand, silt, and clay, derived from active stream deposition, overbank sedimentation, and the erosion and deposition of existing Quaternary stream terrace deposits such as the Modesto and Riverbank Formations. Where present, the stream channel deposits extend from ground surface to a depth of 100 feet (Helley and Harwood 1985). This unit is highly permeable, and yields significant quantities of water to wells (DWR 2000).

The flood plain deposits consist primarily of silt and clay size sediments, with intermittent lenses of stream channel deposits. These deposits are generally observed along the flanks of existing and ancestral stream and river systems. These deposits have an estimated thickness up to 100 feet. Being that this unit is primarily comprised of finer-grained material, permeability is generally poor and generally yields low quantities of water. Brackish water is commonly encountered within this unit (DWR 2000).

Older Alluvial Deposits

Within this subbasin, a number of geologic formations have been assigned to the category "older alluvium" including: the Modesto, Riverbank, Victor, and Laguna Formations (DWR 2004). These deposits generally underlie the Recent Alluvial Deposits and consist of loosely to moderately compacted gravel, sand, silt, and clay size sediments that were derived and deposited under alluvial conditions. The thickness of these units ranges from approximately 100 to 650 feet (DWR 2004).

Mehrten Formation

The Mehrten Formation is Mio-Pliocene in age and consists of a sequence of volcaniclastic and volcanic rocks. In the subsurface, the Mehrten Formation ranges in thickness from 200 feet to 1,000 feet along the axis of the Sacramento Valley (DWR

2003). The Mehrten Formation is comprised of two distinct geologic units. The first unit consists of sediments deposited under alluvial and fluvial conditions and are comprised of gravel, sand, silt, and clay size sediments. This unit is highly permeable and wells constructed within this unit have been observed to produce yields exceeding 1,000 gpm (DWR 2003). The second unit consists of dense volcanic flows of tuff breccias with some interbedded conglomerates and sandstones. This unit acts as a confining layer between sand intervals and has a thickness that ranges from 200 to 1,200 feet in the subsurface (DWR 2003).

4.2.5. Areas Outside a Designated Groundwater Basin

The only part of the County that is not within a designated groundwater basin is the area consisting of the Sutter Buttes. Groundwater is likely found in the subsurface in fractures of the volcanic rock; however, historic groundwater levels and water quality were not reviewed in the preparation of this GMP. There are no local entities, aside from private domestic water users, that utilize groundwater resources in this area.

4.3. Groundwater Levels

DWR does not currently consider any of the groundwater subbasins underlying the County to be in overdraft. Overdraft is characterized by a declining trend in groundwater levels over multiple years without recovery during recharge events. Historic groundwater level data were reviewed for each of the subbasins within the County. DWR maintains a publicly available on-line database, which includes groundwater level data for the County. The DWR Water Data Library (WDL) website can be found at http://www.wdl.water.ca.gov. Wells monitored by DWR and cooperating agencies are identified by the State Well Number (SWN). Data can be obtained for specific wells by means of a map interface, by groundwater basin, or by the assigned SWN.

A 79-year period of record for water level measurements in Sutter County depicts a groundwater system that has experienced changing conditions over time. A number of DWR monitored wells were selected throughout the County to represent these changes. The locations of these wells, along with their associated hydrographs illustrating the historic groundwater levels, are shown in Figure 9. Groundwater level data from well 10N/4E-12A1, a 290-foot-deep well located in the southeast portion of Sutter County, and well 13N/3E-32N1, a shallow (less than 100 feet deep) well located in the southern portion of the County show the groundwater levels typical of different areas of the County. Groundwater levels in well 10N/4E-12A1 are characteristic of areas of high groundwater use and differing water conditions. Water levels fluctuate, sometimes dramatically, in response to changes in groundwater use and hydrologic conditions. This well is located in an area where agricultural

demands are supplied entirely with groundwater. The Sacramento County Department of Water Resources website includes published groundwater elevation maps and indicates that this well is in close proximity to a large pumping depression in northern Sacramento County. Groundwater levels in well 13N/3E-32N1 are characteristic of areas with lower groundwater use and more stable water conditions, and as such, water levels have not exhibited significant fluctuations over times. This well is located in an area where agricultural demands have been met almost entirely with surface water and groundwater demands have consequently been small.

Groundwater levels in well 10N/4E-12A1 have varied from 20 to 80 feet below ground surface over time. The combination of high groundwater use, the close proximity to a pumping depression, and changing climatic conditions has led to significant declines in groundwater levels from the early 1950' through the late 1970's. In the middle to late 1970's, drought conditions increased the rate of decline of groundwater levels on an even larger scale. In the mid 1980's and early 1990's, private and municipal water agencies in a collaborative effort started to implement conjunctive water use programs. With the availability of surface water, and the decrease in groundwater pumpage, groundwater levels have been steadily recovering from the early 1980's through present. Groundwater levels in this well are currently about 35 to 40 feet higher than they were in the late 1970's.

Groundwater measurements in well 13N/3E-32N1 shows very stable groundwater levels since measurements began in 1942. Groundwater levels have remained virtually unchanged, with water levels within 5 to 6 feet of ground surface and seasonal fluctuations of less than 10 feet.

The direction of groundwater flow during the fall season within the County has not changed significantly from 1912-1913 (Bryan 1923) to 2007; with the exception of the southeastern portion of the County. Contours of equal groundwater levels from fall 1912-1913 and fall 2007 were compared to identify changes over the 95 year period. Figure 10 depicts changes in groundwater levels over the aforementioned period. In most areas within the County, groundwater levels were not dramatically different in 2007 than they were in 1912-1913. In the central portion of the County, an increase in groundwater levels is observed in the data, which may be likely due to applied surface water for irrigation. In the southeastern portion of the County, a significant decline in groundwater levels is observed, which can be related to the high usage of ground water for irrigation of crops, and the influence of the large pumping depression in the northern portion of Sacramento County.

Fall and spring contour maps of equal groundwater elevation for 2007, 2008, 2009, and spring 2010 were reviewed (Figures 11 through 17) to determine groundwater gradient and

flow direction. The fall 2009 and spring 2009 groundwater contours generally follow the topography of the County and indicate that groundwater flows from the Sierra Nevada toward the Sacramento Valley (east to west), and north to south within the Valley. The fall 2007 contour map of equal groundwater elevations indicates a few locations where small pumping depressions are present, but in general, suggests the same direction of groundwater flow as seen in the spring 2007 groundwater contour map. Differences in groundwater levels between fall and spring appear to be a result of normal fluctuations in groundwater conditions from seasonal pumping and from wet and dry climatic cycles.

Data from the nested monitoring well at the extensometer site in the southern portion of the County indicates that, for the 14 years of available data, the spring groundwater levels in the monitored aquifer zones have been very similar, within a few feet of one another; except for the deepest completion where groundwater levels are approximately 10 feet lower than the shallower completions.

4.4. Groundwater Quality

The quality of groundwater is a product of the material through which it flows, or that flows into it. Local variations in the quality of the County's groundwater can limit its use for either potable water supply and/or agricultural applications. Groundwater contamination is a result of naturally occurring, point source contamination, and/or regional contamination. Naturally occurring contaminants of concern include dissolved salts [as measured by the specific conductance or electrical conductance (EC)], boron, nitrate, manganese, arsenic, and mercury. Point source contamination typically involves solvent releases originating mostly from gas stations and dry cleaners. Regional sources of contamination include applied fertilizers, salts, and leaky septic systems (nitrate and salt loading).

Historic and current water quality data (collected by the DWR, USGS, and local water purveyors) for wells located within the County were analyzed to characterize spatial and depth dependent water quality trends within the County's groundwater subbasins. The data was separated by well depth into the following three categories: less than 150 feet deep, 150 to 400 feet deep and more than 400 feet deep, as shown in Figures 18 through 23. The categories were chosen based on the occurrence at which certain stratigraphic units are observed in the subsurface in Sutter County.

4.4.1. Specific Conductance

Specific conductance was selected as an indicator of overall water quality. Specific conductance is a property of groundwater that is relatively simple to collect in the field at the well head and can help identify and characterize the condition of the non-marine fresh water

bearing aquifer system. Specific conductance is a measure of how effectively water will conduct electricity and is reported in micro Siemens (µS/cm) per centimeter and provides for the indirect measurement of the amount of dissolved solids (salts) in the groundwater. Lower specific conductance generally indicates better water quality (fresh water) while higher specific conductance generally indicates poorer water quality (brackish to saline water).

Applied irrigation and fertilizers can add salts to the water that percolate into the hydrogeologic system, increasing the specific conductance of the groundwater. Increased specific conductance values of the groundwater can also be attributed to naturally occurring brackish or saline water, such as geologic formations (aquifers) which are, or have been in the past, directly connected to a salt water body or where geologic formations were deposited under marine (salt water) conditions and which have inherently high dissolved salt concentrations. As shown in Figures 18 and 19, specific conductance values within the County are generally acceptable for agricultural and domestic use east of Highway 99 and in the northern half of the County. Elevated values for specific conductance are near to and/or exceed the recommended maximum contaminant level (MCL)[4] for domestic use in the shallow aquifers near the Sacramento River and in the aquifers below 900 feet. The elevated specific conductance could potentially be problematic for agricultural use. It is unclear why there is elevated specific conductance in this area.

4.4.2. Boron

Boron is a naturally occurring element. As shown in Figure 20, boron concentrations in the County are generally acceptable. Some deeper wells, which likely encounter more marine sediments, do contain elevated boron concentrations. Boron is a necessary element for agriculture, but may become toxic to crops above 500 micrograms per liter (µg/L). For public drinking water systems, the California Department of Public Health (CDPH) has established a notification level of 1,000 µg/L for boron. Increased concentrations of boron are observed in wells greater than 400 feet as well as in the southwestern portion of the County.

4.4.3. Nitrate

Nitrate is a contaminant which does not naturally occur in the subsurface. Elevated concentrations of nitrate are widespread in the Sacramento Valley. As shown in Figure 21, concentrations of nitrate in the populated areas of Sutter County are near or above the MCL for nitrate (as NO_3). The CDPH has established a primary MCL of 45 milligrams per liter (mg/L) for nitrate (as NO_3). Near the Sutter Buttes and Yuba City, nitrate concentrations in several wells (less than 150 feet) exceed the MCL. Where present, elevated concentrations of

[4] Recommended CDPH MCL for Specific Conductance is 900 µS/cm; upper limit is 1,600 µS/cm; short term is 2,200 µS/cm

nitrate are likely a result of overlying land uses, such as septic systems, animal enclosures, or applied fertilizers.

4.4.4. Manganese

Manganese is a naturally occurring element found in rocks and minerals. Its presence in groundwater is a result of the dissolution of the naturally occurring element in sediments containing minerals composed of manganese. As illustrated in Figure 22, manganese concentrations are elevated in all portions of the County, at levels that may cause aesthetic problems (odor or staining) for domestic and municipal uses, but generally below levels that could represent a health risk. There are, however, a few locations where manganese concentrations are near or exceed the CDPH established Notification Level of 50 µg/L, and may pose a health risk.

4.4.5. Arsenic

Arsenic is a naturally occurring element commonly found in alluvial sediments. Its presence in groundwater is a result of the dissolution of the element in sediments containing minerals containing arsenic. The CDPH has established a primary MCL of 10 µg/L for arsenic. As illustrated in Figures 19 and 23, arsenic concentrations are near to or above the CDPH MCL throughout the County in each of the aquifer zones assessed; conversely, concentrations of arsenic below the CDPH MCL are also present throughout the County in each of the aquifer zones assessed. Countywide, arsenic concentrations do not appear to be isolated to any one specific aquifer zone in the subsurface. However, recent data analysis suggests a possible correlation between elevated arsenic concentrations and the presence of volcaniclastic material of the Sutter Buttes Rampart formation. Concentrations of arsenic in the stratigraphic units that occur above and below the Rampart are generally less than 10 µg/L, whereas concentrations of arsenic within the Rampart material are between 10 to 370 µg/L (Springhorn, 2008). Concentrations of arsenic tend to be under the CDPH MCL southeast of Highway 99 and in the shallow aquifers.

4.4.6. Mercury

Historic gold mining processes and operations introduced toxic mercury into the surface water system throughout Northern California in the late 1800's. Due to the proximity of these operations to Sutter County, the PAG requested an assessment of the concentrations of mercury in the groundwater. A limited number of wells have been sampled within Sutter County for mercury, and as such, concentrations of mercury in the groundwater within Sutter County can not be well characterized. The few wells that have been sampled for mercury

indicate that mercury concentrations were low. In most cases, the concentrations were below the analytical detection limit (not detectable by the laboratory method used at the time).

4.5. Land Subsidence

Land subsidence is the gradual or sudden lowering of the land surface due to compaction of the underlying sediments. Two types of land subsidence are observed within alluvial sediments: inelastic and elastic. Inelastic land subsidence is a result of the compression of geologic formations and is irreversible. Inelastic land subsidence can be caused by excessive extractions of groundwater, oil, or natural gas. In discussing land subsidence, it is important to note that elastic (reversible) land subsidence is a normal occurrence, whereas inelastic land subsidence has associated negative impacts.

Although there are several causes of inelastic land subsidence, the compression of clay as a result of groundwater extraction is considered the most likely cause of subsidence north of the Sacramento-San Joaquin Delta (Page 1998). Once water is removed (mined) from compressible clay, the clay compresses and cannot accept water again, thus resulting in the permanent lowering of the overlying land surface (inelastic land subsidence). Clay compression has occurred in several locations in California, including the San Joaquin Valley. Compressible clay, such as the Corcoran Clay member of the Tulare Lake Formation, has been mapped over much of the western side of the San Joaquin Valley and can be over 130 feet thick. The subsidence documented in the San Joaquin Valley extends over a very large area, with over 30 feet of subsidence recorded in some areas.

North of the Sacramento-San Joaquin Delta in the Sacramento Valley, inelastic land subsidence, which has been directly related to clay compression as a result of groundwater extraction, has occurred in portions of Solano, Yolo, and Colusa Counties (Page 1998). Recorded land subsidence of more than two feet, and possibly as much as five feet, has occurred in this area. Subsidence in the Sacramento Valley appears to extend from Davis to Arbuckle. The area of subsidence appears to follow a local geologic feature known as the Zamora Syncline. A syncline is a structural fold that is formed by compressional forces which cause the sedimentary layers to have a concave, or a bowl-like geometry. Lakebeds are often associated with structural lows such as synclines. Lakebed deposits typically consist of fine-grained, clayey sediments, which settle out to the bottom of standing bodies of water and of which can include large volumes of freshwater diatoms[5]. Along with sediments, the microscopic diatoms settle and collect on the bottom of a lakebed. In Yolo County, diatomaceous (diatom rich) clay sediments have been identified within the geologic formations of Zamora Syncline. These diatomaceous clay sediments were identified to be

[5] Diatoms are unicellular aquatic algae, typically 20 to 200 microns (Prothero, 1998)

highly compressible (Page 1998). Although diatomaceous clay has been identified in numerous boreholes drilled in Sutter County, there have not been any recorded land subsidence issues.

Elastic land subsidence is observed to be cyclical and does not result in permanent compaction of subsurface materials. One example of elastic land subsidence is seasonal fluctuations in ground surface elevations that coincide with fluctuations in groundwater levels (and associated aquifer pressure). In elastic land subsidence, the subsurface pressures acting on the aquifer do not decrease enough so that subsurface materials permanently compact.

The DWR, in cooperation with federal, state and local agencies, installed and surveyed Global Positioning System (GPS) monuments to be able to measure and monitor ground surface elevations over time in the Sacramento Valley. The project, titled "The Sacramento Height-Modernization Project", consists of 339 monuments, spaced approximately 7 kilometers apart, in 10 counties. There are 32 monuments located in Sutter County. The GPS monuments will augment the existing network of extensometers which DWR currently monitors for land subsidence. In total, there are 13 extensometers located in Glenn, Colusa, Butte, Yolo, and Sutter Counties. The land subsidence monitoring network is shown in Figure 24. Only one of these extensometers, State Well Number 11N/4E-04, is located within Sutter County. It is located in the south-central part of the County along Highway 99, and extends to a depth of 1,003 feet, extending over a large portion of the fresh-water formations. The extensometer is installed in a dedicated monitoring well and is designed to measure any change in distance between the bottom of the well and the ground surface. DWR reports the accuracy of the extensometer to be ±0.001 feet. The extensometer provides for ongoing, real-time data collection, of land surface elevation changes. The Sutter County extensometer has been recording data since early 1994. In the 14 years since it began recording, the extensometer in Sutter County has recorded seasonal (cyclic) elastic land subsidence of approximately 0.03 feet (approximately one-third inch). There has been no indication over the period of record that any inelastic subsidence has occurred.

4.6. Groundwater-Surface Water Interaction

Several clustered monitoring wells located throughout the county adjacent are used to monitor changes in surface flow or quality that directly affect the groundwater system (levels or quality), and/or to monitor changes in surface flow or quality that are caused by groundwater pumping. These monitoring wells are adjacent to surface water bodies, and have a river stage gage located in the immediate vicinity.

Several of the network wells are located along the banks of the Sacramento, Feather, and Bear Rivers, as shown in Figure 25. The relationship between the volume of water flowing in the major rivers/streams and the influence the surface water imparts on groundwater elevation are being monitored with a combination of nested monitoring wells and river stage gages. Four stations exist in the County for observing this interaction: on the Sacramento River below Wilkins Slough (WLK), on the Bear River at Pleasant Grove Road (BPG), on the Sutter Bypass at RD 1500 pump (SBP), and along the Feather River above Star Bend (FSB). Sutter County also monitors a river stage gage at Boyd's Landing (FBL). At stations BPG and FBL, observations of water surface/groundwater elevations trend closely during high flow/stage events in the rivers, suggesting a significant hydrologic connection between the groundwater in the shallow aquifers and the surface water.

4.7. Groundwater Recharge

Groundwater recharge is the process in which groundwater is replenished. The geologic formations that comprise the aquifer system underlying the County extend well beyond the County's jurisdictional boundaries. Several processes are responsible for recharge of the groundwater basin. On a regional scale, surface water flowing over the surface expression of the geologic formations (surface outcrops) allows for direct infiltration into the hydrogeologic system. Figure 26 depicts contours of equal groundwater elevations, superimposed over the surface geology, for the Sacramento Valley Groundwater Basin. Groundwater flow is perpendicular and down gradient to the contour interval. On the east side of the Sacramento Valley Groundwater Basin, the groundwater contours become parallel to and follow the margin of the valley, indicating groundwater is moving through the subsurface from the east to the west. Locally, groundwater recharge occurs where surface water flows over permeable sediments (gravel and sand) in the river channels, allowing for the direct infiltration of surface water. Deep percolation of applied irrigation water also recharges the groundwater basin. Additionally, surface water deliveries have increased the quantity of water flowing down the river, adding available water to recharge the underlying aquifers helping to improve groundwater elevations.

The amount of groundwater recharge is dependent on the available storage space within the aquifer(s). Depending on the degree of separation between the elevation of the bottom of the river or stream and that of the groundwater, streams can either "lose" water into the underlying aquifer(s) or "gain" water. Where groundwater levels are at or above the elevation of surface water, groundwater will discharge into the stream (gaining stream). Where there is a separation between the groundwater and surface water, water flowing downstream will recharge into (losing stream) the groundwater basin (although the contribution has not been

studied). Conversely, if groundwater levels are at land surface, there will be refusal of any "new" water into the subsurface.

The State Water Resources Control Board has identified hydrogeological vulnerable areas, meaning vulnerable to groundwater contamination, where geologic conditions allow recharge to the underlying aquifers. Generally, these areas include the coarse deposits associated with the Feather River.

4.8. Groundwater Infrastructure

According to DWR records, 6,742 well completion reports have been filed for wells constructed in Sutter County. Well completion reports are not always filed with DWR, even though they are required by law, so the number of reports likely under-represent the actual total for the County. Of the wells for which well completion reports have been filed:

- 3,344 are domestic wells
- 1,167 are irrigation wells
- 854 have unknown or other uses
- 308 are monitoring wells
- 75 are municipal wells
- 34 are industrial wells
- 13 are test wells
- Seven (7) are stock-watering wells
- 12 are fire or frost protection wells
- Two (2) are cathodic protection wells

Figure 27 shows the number of DWR well completion reports filed for Sutter County from 1928 through 2007. The figure only illustrates wells that were classified as either: domestic, irrigation, or public supply. Domestic wells were constructed at a rate of approximately five per year from 1941 through 1950, but have been constructed at a rate of approximately 59 per year since then. Irrigation wells tend to be constructed more frequently during drought periods, in the mid-1970's and early 1990's. On average, 16 irrigation wells are constructed per year; however, significantly more wells are constructed during droughts. Municipal well construction has averaged two-and-a-half per year. Of the wells for which records exist, approximately 700 wells are classified as either abandoned or destroyed.

Figure 28 shows the average depth of wells constructed from 1950 through 2005. The average depth of domestic wells has fluctuated since the 1930's, but has generally been about 100 feet deep. The average depth of irrigation wells has fluctuated significantly, but has been about 160 feet deeper than the average depth of domestic wells in any give year, or an average of about 260 feet deep. Municipal well depths are inconsistent and vary widely in

depth, from about 50 to 700 feet deep. Combined with the small number constructed annually, calculation of an average depth of new municipal wells would not be meaningful.

5. GROUNDWATER MANAGEMENT PLAN REQUIRED, VOLUNTARY, AND RECOMMENDED COMPONENTS

California Water Code §10750 et seq., as amended by Senate Bill (SB) 1938, defines the required and voluntary components of a GMP and establishes procedures by which they must be developed. DWR recommends additional elements to include in a GMP in Bulletin 118 Update 2003, Appendix C. The Sutter County GMP includes the components required in the Water Code and has been developed in accordance with the required procedures. This GMP also includes many of the voluntary and recommended GMP components. This GMP also includes components designed to address the requirements of California Water Code §10920 et seq., which establish requirements for groundwater monitoring that affect eligibility for grant funding.

5.1. California Water Code Requirements

Section 10750 et seq. of the California Water Code, as amended by SB 1938, requires GMPs to include six mandatory components to be eligible for the award of funds administered by DWR for the construction of groundwater projects or groundwater quality projects. These components are listed below.

Description	*GMP Section*
Make available to the public a written statement describing the manner in which interested parties would be allowed to participate in the development of the GMP.	1.4
Include Basin Management Objectives (BMOs), including components relating to the monitoring and management of groundwater levels, groundwater quality degradation, inelastic land subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping.	6.2
Prepare a plan that involves other agencies that enables Sutter County to work cooperatively with other public entities whose service area or boundary overlies the groundwater basin.	7.1.5
Prepare a map that details the area of the groundwater basins, Sutter County's boundaries, and other local agencies within the groundwater basins.	Figure 1

Description	*GMP Section*
Adopt monitoring protocols to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence, and flow and quality of surface water that directly affects groundwater levels or quality or are caused by groundwater pumping.	7.1
For areas outside the groundwater basins, use geologic and hydrologic principles appropriate to those areas.	4.2.5;7.1.4

5.2. DWR Bulletin 118 Recommended Components

DWR's Bulletin 118 recommends other components that may voluntarily be included in a GMP. These are listed below.

Description	*GMP Section*
Establish an advisory committee of stakeholders to help guide the development and implementation of the plan and provide a forum for resolution of controversial issues.	1.4
Describe the area to be managed under the GMP.	1.3
Describe how meeting each BMO will contribute to a more reliable long-term groundwater supply, and describe management actions to achieve each BMO.	6.2
Describe GMP monitoring program.	7.1
Describe integrated water management planning efforts.	7.1.5
Periodically report groundwater basin conditions and management activities.	7.1.6
Evaluate GMP periodically.	7.1.6

5.3. California Water Code Voluntary Requirements

California Water Code §10753.8 lists twelve issues of groundwater management which may voluntarily be included in a groundwater management plan.

Description	*GMP Section*
Control of saline water intrusion.	6.1.3
Identification and management of wellhead protection areas and recharge areas.	4.7; 6.1.3
Regulation of the migration of contaminated groundwater.	N/A
Administration of well abandonment and well destruction program.	6.1.3
Mitigation of conditions of overdraft.	4.3
Replenishment of groundwater extracted by water producers.	N/A
Monitoring of groundwater levels and storage.	4.3; 5.4
Facilitating conjunctive use operations.	6.1.3
Identification of well construction policies.	6.1.3
The construction and operation of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.	N/A
The development of relationships with state and federal regulatory agencies.	7.1.5
Review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.	7.1.6

5.4. California Water Code Groundwater Monitoring Components

On November 4, 2009 the State Legislature amended the Water Code with Senate Bill SBx7-6, which mandates a statewide groundwater elevation monitoring program to track seasonal and long-term trends in groundwater elevations in California's groundwater basins. To achieve that goal, the amendment requires collaboration between local monitoring entities

and DWR to collect groundwater elevation data. Collection and evaluation of such data on a statewide scale is an important fundamental step toward improving management of California's groundwater resources.

In accordance with this amendment to the Water Code, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) program. The intent of the CASGEM program is to establish a permanent, locally-managed program of regular and systematic monitoring in all of California's alluvial groundwater basins. The CASGEM program will rely and build on the many, established local long-term groundwater monitoring and management programs. DWR's role is to coordinate the CASGEM program, to work cooperatively with local entities, and to maintain the collected elevation data in a readily and widely available public database. DWR will also continue its current network of groundwater monitoring as funding allows.

The law anticipates that the monitoring of groundwater elevations required by the enacted legislation will be done by local entities. The law requires local entities to notify DWR in writing by January 1, 2011 if the local agency or party seeks to assume groundwater monitoring functions in accordance with the law (Water Code §10928).

Additionally, on or before January 1, 2012, the law requires that Monitoring Entities shall begin reporting seasonal groundwater elevation measurements to DWR (Water Code §10932).

Local entities in Sutter County that have submitted official notifications to DWR to be considered for CASGEM Monitoring Entities include:

- Sutter Extension Water District
- Feather Water District
- Reclamation District 1500 (including RD 1500, Pelger Mutual Water Company and Sutter Mutual Water Company)
- Natomas Central Mutual Water Company
- South Sutter Water District

Garden Highway Mutual Water Company has shown interest in participating in CASGEM but has not yet completed the official notification submittal process include.

Local entities that submit complete Monitoring Entity notifications and adequate groundwater monitoring plans and well networks will be officially designated by DWR to be

the Monitoring Entities for their respective subbasin or portion of a subbasin for the purposes of the CASGEM Program. However, if no local monitoring entity volunteers or is identified for a particular area or groundwater basin, DWR may assume the monitoring and reporting duties and certain entities in the basin may not be eligible for water grants or loans administered by the state.

Sutter County is severely limited in its ability to take a lead in groundwater monitoring because of budget and staff shortages. Furthermore, the County does not own any groundwater monitoring wells and does not conduct any groundwater monitoring on its own. For this reason, Sutter County does not seek to assume groundwater monitoring functions under California Water Code §10920 et seq. However, the County does promote the coordinated collection of groundwater elevation data through its Groundwater Monitoring Program, discussed in Section 7.1 of this GMP.

6. GROUNDWATER MANAGEMENT GOALS AND BASIN MANAGEMENT OBJECTIVES

6.1. Groundwater Management Goals

Sutter County's groundwater management goals represent the overarching intent of the County with regard to groundwater management. Basin Management Objectives (BMOs) and Management Actions must be consistent with these Groundwater Management Goals, and must contribute to achieving the goals. Sutter County's goals for groundwater management (as developed with input from the public through PAG meetings and workshops) are:

- To promote responsible groundwater use in Sutter County so groundwater is available to meet present and future demands.
- To provide groundwater users with information and guidance to help them be responsible stewards of the groundwater resources in Sutter County.
- To discourage activities that could reduce the long-term availability of high-quality groundwater in Sutter County.

Each of the Groundwater Management Goals is discussed below.

6.1.1. To Promote Responsible Groundwater Use in Sutter County So Groundwater is Available to Meet Present and Future Demands.

One of Sutter County's main goals for groundwater management is to ensure that a reliable water supply is available so that water users in the County can be confident that water will be available to meet domestic, irrigation, and other demands on an ongoing basis.

The goal to promote responsible groundwater use in Sutter County is intended to provide the County with useable groundwater resources now and in the future. This is important because the socio-economic well being of the County could be adversely affected if the groundwater supply becomes less useable from a supply or quality standpoint. Ensuring responsible groundwater use will help protect groundwater rights and maintain local control because adjudication of the groundwater basin will not be warranted if long-term groundwater sustainability can be achieved.

6.1.2. To Provide Groundwater Users with Information and Guidance to Help Them Be Responsible Stewards of the Groundwater Resources in Sutter County.

It is important to understand that in order to responsibly manage groundwater to ensure long-term groundwater sustainability, it is necessary to thoroughly understand the groundwater system underlying the County, along with its capabilities and limitations. Sutter County's water resources should be viewed as a dynamic system with the amount of available surface water and groundwater varying over time with fluctuations in hydrologic and climatic conditions. The implementation of a surface/groundwater monitoring program to observe and document the County's resources is essential to provide the community with the necessary information to accomplish this management objective.

6.1.3. To Discourage Activities that Could Reduce Long-Term Availability of High-Quality Groundwater in Sutter County.

It is important to recognize that this management objective is not intended to restrict the users within the community from exercising their legal rights to groundwater. Groundwater is a resource that should remain available for the people of the County to use beneficially on their property. The intent of this objective is for groundwater management to be accomplished in a way that minimizes activities that could potentially reduce the long-term availability of high-quality groundwater in Sutter County. There are a number of management practices that can be utilized to accomplish this goal. Two of the main practices that should be considered are conjunctive use programs and improving County well standards.

The goal of optimizing the conjunctive use of surface water and groundwater will enhance the County's water supply reliability and maximize the available water supply. The term "conjunctive use" basically means using surface water and groundwater together to meet water demands, using different proportions of each depending upon availability. For example, in years of reduced surface water availability, more groundwater would be used and groundwater levels might decline. Conversely, in years of full surface water availability, less groundwater would be used and groundwater levels would be allowed to recover. Optimizing conjunctive use generally means that, whenever possible, surface water is used to the fullest extent with groundwater serving as a "back-up" supply. This maximizes the available water supply because unused surface water generally flows downstream and is lost, but unused groundwater remains in the ground and would be available for later use.

On the other hand, the potential may exist in some areas of the County where groundwater levels are (and have historically been) high, to utilize more groundwater and thus induce more recharge (by creating additional storage space within the aquifer) thereby increasing the total water supply available in the County.

A related goal is to "even out" water availability in the County. There are cases when surplus water is available in some areas of the County, but other areas have inadequate supplies. For example, an area with high groundwater levels may have adequate or excess surface water, while another area may have low groundwater levels and inadequate surface water. In this case, groundwater could be pumped in the area with high groundwater levels, and their surface water could be transferred to the area with low groundwater levels so that area does not have to rely as much on groundwater. If possible, undertaking such projects will help improve the overall water supply reliability in the County.

The goal for updating the County's well standards is to add additional levels of protection to ensure that the design of new well structures prohibit the downward migration of surface/shallow contaminants or cross contamination of aquifers. The County has adopted standards as set forth in Chapter II of the State Department of Water Resources Bulletin 74-81, and as supplemented by Bulletin 74-90, entitled "Water Well Standards: State of California", except as otherwise provided in Section 700, Chapter 765 "Water Wells" of the Sutter County Municipal Code[6]. Some amendments that could be made to the existing well standards are: (1) require the use of geophysical surveys for all new well projects, (2) increase the required minimum sanitary seal depths, (3) institute water quality sampling during cable tool well drilling, (4) institute well restriction zones where poor water quality is known, and (5) improve/implement well destruction programs.

Requiring the use of geophysical surveys (spontaneous potential, 16- and 64-inch resistivity) in all new boreholes can help to enhance groundwater protection by identifying the zone(s) of poor water quality, as well as the depths of confining layers, which can be used to design adequate sanitary/annular seals. With this data, future wells can be designed to effectively seal against poor water quality while providing adequate measures for aquifer protection.

Increasing the minimum sanitary seal depth required for new wells is a proactive measure that can effectively increase aquifer protection. Increasing the required sanitary seal to a minimum depth of 50 feet for all new wells can seal off shallower aquifers with poorer water quality from the deeper aquifers with better water quality, as well as impede the

[6] http://www.co.sutter.ca.us/doc/government/bos/ordinance

downward migration of surface contaminants. Currently, the standards in force require a minimum 50-foot sanitary seal for municipal supply wells and 20-foot sanitary seal for all other wells (Bulletin 74-90).

Many wells in Sutter County have been drilled and constructed utilizing the cable tool drilling method. One of the main troubles with cable tool wells is that they usually are constructed across, and connect, multiple aquifer zones. Some of these well structures likely have become conduits for the downward migration and cross contamination of aquifer zones. Water quality sampling during the drilling of these wells (field tests for TDS or specific conductance) would delineate between problematic and non-problematic aquifer zones. If an existing well is deemed problematic (i.e. poor water quality), corrective measures through well modification or even well destruction could help mitigate the movement of poorer water quality between aquifer zones.

Implementing well restriction zones where water quality contamination is known to exist in specific aquifers can aide in protecting aquifers with acceptable water quality. Restricting the construction of wells or requiring specific seal intervals can provide an additional level of aquifer protection. Certain areas within Sutter County have localities of poorer water quality. It may be beneficial to assess the risk of drilling and constructing new wells within these areas. If adequate aquifer protection can not be achieved during construction activities, it may be warranted to designate well exclusion zones.

Unused, unsecured, abandoned, or improperly destroyed wells can act as a direct conduit for surface water infiltration or degradation of one or more aquifers, if they are connected by the well structure. Well destruction requirements adopted by the County currently require abandoned wells to be destroyed. Currently, these requirements require the uppermost 20 feet of the well/borehole be filled with impervious material. Special situations, in the case where vertical movement of poor water quality could contaminate an aquifer with good water quality, require impervious sealing material to be placed adjacent to confining layers. Increasing oversight of the permitting process during the planning and design of well destruction programs can ensure added protection against the vertical migration of poor water quality.

6.2. Basin Management Objectives

Basin Management Objectives (BMOs) are guidelines established to ensure that the County's basin management goals are being fulfilled. BMOs create a systematic method for collecting and monitoring data for specific components of the groundwater system and to provide for the dissemination of such information to the public. The objective of the BMOs is not to assign a fixed value, or level, to each parameter, but to allow for the early identification of

potential problems with sufficient time for the County and its groundwater users to formulate an action plan to mitigate adverse effects to its groundwater resource.

Sutter County's BMOs address the following parameters:

- Groundwater levels
- Groundwater quality
- Inelastic land subsidence
- Surface water
- Coordination

6.2.1. Groundwater Levels BMO

There are three BMOs for groundwater levels:

- *Avoid ongoing declines in groundwater levels during water year types identified by DWR to be "above normal" or "wet" for the Sacramento Valley.*
- *Avoid problematically high groundwater levels.*
- *Provide assistance with assessing problems and resolve disputes related to groundwater levels.*

Groundwater levels are to be managed to ensure adequate water supplies while avoiding adverse impacts and mitigating them if and when they do occur. Adverse impacts related to groundwater levels can occur from excessively high or low groundwater levels. What constitutes an excessively high or low groundwater level may change over time, and will also vary by land use and hydrologic and climatic conditions.

Excessively high groundwater levels are problematic in some areas of the County. High groundwater levels in Sutter County are often naturally occurring. However, groundwater levels can be raised by application of water to the ground surface through irrigation, surface storage, or recharge projects. When groundwater levels are high, there is no storage capacity available in the underlying aquifer for groundwater recharge from precipitation, stream flow, or excess applied irrigation water. This represents a lost opportunity to capture recharge and increase the overall water supply for the County. Adverse impacts related to high groundwater levels include:

- Damage to foundations, roads, and other infrastructure.

- Water-logging the root zone of certain crops.

Groundwater levels decline when pumping exceeds recharge and rise when recharge exceeds pumping. It is important to note that periodic short-term declines in groundwater levels (during drought periods and/or increased pumping), which are then followed by recovery to at or near historic highs (during wet periods and/or decreased pumping), are normal and do not represent overdraft. Excessively low groundwater levels that are caused by long-term declines without recovery, thus overdraft, can be avoided by reducing pumpage. This can be accomplished by expanding the conjunctive use with surface water. Adverse impacts related to low groundwater levels include:

- Infrastructure problems when lowered groundwater levels dewater pumps or wells, so groundwater cannot be extracted using existing infrastructure even though it is available at greater depths.
- Depleted available groundwater supply.
- Inelastic land subsidence.
- Riparian and/or native vegetation destroyed.
- Reduced surface water flow due to increases in streambed infiltration, or increases in the capture of groundwater that otherwise would have contributed to increasing the base flow of a surface water system.

6.2.2. Groundwater Quality BMO

The BMO for groundwater quality is to:

- *Improve the understanding of groundwater quality in Sutter County.*
- *Maintain or improve groundwater quality.*

Adverse impacts to groundwater quality most commonly occur when degradation of groundwater renders groundwater unsuitable for intended uses. Accordingly, what constitutes a significant adverse impact to groundwater quality is related to the purposes for which groundwater is used, and may change over time as land uses and water quality regulations change. Groundwater quality degradation can occur when groundwater pumping causes poor quality water (surface water or groundwater) to migrate into areas with good quality groundwater. It can also occur when surface contaminants migrate into groundwater. As a consequence, it is important to coordinate land use planning and

resource management activities in order not to create opportunities for water quality deterioration. Adverse impacts related to groundwater quality include:

- Degradation of groundwater quality so that yields are reduced for crops irrigated with groundwater.
- Degradation of groundwater quality so that it does not comply with drinking water quality standards.
- Degradation of groundwater quality so that it is no longer suitable for beneficial uses.

There are some areas in Sutter County that currently have problems with groundwater quality (particularly arsenic and salinity) that appear to be naturally-occurring. The BMO of maintaining or improving groundwater quality reflects the County's desire to improve the quality of naturally-occurring groundwater where possible, so that it is more useful as a water supply.

6.2.3. Inelastic Land Subsidence BMO

The BMO for inelastic land subsidence is to:

- *Avoid inelastic land subsidence that is linked to declines in groundwater levels.*

Inelastic land subsidence is the permanent compaction of the subsurface. In Sutter County, the activities that have the most potential to cause inelastic land subsidence are withdrawals of groundwater or natural gas from the subsurface. Adverse impacts related to inelastic land subsidence include:

- Reduction in the volume of the subsurface that results in a permanent loss in aquifer storage.
- Damage to foundations, roads, bridges, and/or other infrastructure.
- Change in surface topography that reverses the gradients in canals and ditches, and/or changes floodplains.

6.2.4. Surface Water

There are three BMOs for surface water:

- *To improve the understanding of the relationship between surface water and groundwater.*

- *To avoid changes in surface water flow and surface water quality that adversely affect groundwater levels or are caused by groundwater pumping.*
- *Avoid changes in surface water flow and water quality that adversely affect groundwater quality.*

Pumping from very shallow aquifer zones or poorly sealed wells has the potential to affect surface water or wetlands. Adverse impacts related to surface water or wetlands include:

- Depletion of surface flows and/or degradation of water quality.
- Destroying riparian and/or native vegetation and habitat.

6.2.5. Coordination

This BMO for coordination is to:

- *Coordinate County groundwater management efforts with other groundwater management efforts within and surrounding Sutter County.*

This BMO establishes the importance of local coordination of groundwater management and sharing of hydrogeologic data. To make effective and relevant decisions, the County must rely on current data regarding the quality and quantity of the underlying groundwater.

7. PLAN IMPLEMENTATION

Sutter County intends to implement this GMP through a Groundwater Monitoring Program and an Action Plan. In order to recognize and mitigate adverse impacts to the underlying groundwater system, a system is required to collect and disseminate information to the appropriate groundwater users and agencies.

7.1. Groundwater Monitoring Program

The role of monitoring is essential to implementing the BMOs. Monitoring is the process of collecting data that is used to better understand the groundwater basin underlying the County, evaluate groundwater conditions, facilitate groundwater management, and other related activities. In order for the County to promote sustainable groundwater management, as well as for groundwater users to make effective and relevant decisions, the data needs to be made publicly available.

7.1.1. Groundwater Level Monitoring

There is an extensive network of DWR monitored wells, both dedicated monitoring wells and wells with other uses, within Sutter County. Additionally, several water purveyors within the County monitor groundwater levels within their service areas by means of dedicated monitoring wells and production wells. There is an extensive inventory of wells with groundwater measurements within Sutter County. Historically, DWR and its partners have monitored 172 wells in Sutter County, including 15 dedicated monitoring wells. The earliest recorded DWR water level measurement in Sutter County took place in 1929. Wells accessible to DWR are typically agricultural or domestic wells in which the land owners have previous agreements with DWR to allow access for measurements. Overall, the County has adequate spatial distribution of its current network to obtain groundwater level measurements. For this GMP, DWR utilized 122 of the 172 wells to produce groundwater contour maps of equal elevation.

Water level measurements are generally made two times each year, in spring and fall. Measurements have been made at some monitoring wells on an almost-monthly basis. Twice-annual (spring/fall) water level measurements are generally sufficient for the purpose of determining changes in overall groundwater conditions over time. However, these measurements should reflect the annual high (spring) and low (fall) water levels. More frequent (i.e. at most monthly) measurements are necessary to confirm that the months chosen for spring and fall measurements reflect the months with the highest and lowest groundwater elevations, on average. Water level data is currently available from DWR's Water Data Library, at: http://well.water.ca.gov.

7.1.1.1. Vertical Groundwater Gradients – Nested and/or Clustered Monitoring Wells

The vertical gradients between aquifer zones are important because they give an indication of the direction (up or down) that groundwater will migrate if a pathway, such as a well that connects multiple aquifer zones, is present. To evaluate the vertical gradient between aquifer zones, data for the different aquifer zones at a single location is needed. The preferred way to obtain this data is with nested and/or clustered monitoring wells. Nested monitoring wells have multiple wells within a single borehole, with each well isolated from the others by annular seals. Clustered monitoring wells have a single well in each borehole, with the boreholes in close proximity to one another. Figure 19 shows the locations of the 15 nested and/or clustered monitoring wells in Sutter County. Eleven of these wells are in the DWR monitoring network with measurements taken twice a year, in spring and fall. The remaining four nested monitoring wells are pending inclusion into the network because they were constructed by private parties. All of these wells are dedicated monitoring wells.

7.1.1.2. Groundwater Flow Direction – Contour Maps

The direction of groundwater flow is evaluated with groundwater level contour maps. Groundwater contours are created which connect surfaces of equal elevation (or levels). Figure 17 illustrates the contours of equal groundwater elevation for measurements taken in the spring of 2010.

The current water level monitoring network spacing is suitable for contouring groundwater elevations. Additionally, it would be beneficial to include data from nearby monitored wells in Butte, Yolo, Sacramento, and Yuba Counties to better characterize the groundwater flow direction at the County lines.

7.1.2. Water Quality

Water quality samples from wells within the County have, in the past, been obtained either by local water purveyors, the DWR, or the USGS. Currently, the County only samples groundwater in Robbins, its only public water supply system. Groundwater samples have been collected for analysis in a total of 133 wells. The DWR has sampled 34 of these wells in Sutter County, fifteen of which are nested multiple-completion monitoring wells, as shown in Figure 19. The USGS has sampled 94 of these wells, and the remaining wells were sampled by water purveyors which have shared their data. The DWR expects to conduct water quality sampling of these wells every three years, or as funds are available. The water quality data is disseminated on the DWR WDL.

The results for the USGS water quality sampling are available on the National Water Information System (NWIS) website[7]. The USGS sampled these wells as part of a larger investigation to document the condition of the groundwater throughout the valley. It is not expected that the USGS will routinely sample these wells.

The current water quality monitoring network consists of DWR owned multiple-completion monitoring wells with a sparse distribution covering the entire County. Routine sampling of these wells will allow for water quality trends to be identified. As stated within this GMP, the County does not own any dedicated monitoring wells. In conjunction with DWRs efforts to collect and distribute water quality information of the groundwater resource, the County encourages private water purveyors to disseminate their water quality data to aid in documenting depth specific and County-wide water quality trends.

7.1.3. Land Subsidence

Land subsidence has not been historically reported or documented within Sutter County. Nevertheless, DWR installed an extensometer and began monitoring for ground surface displacement in 1994. Measurements are recorded on a daily basis, offering real-time and site specific measurements. On a more regional scale, DWR and its cooperating agencies, have implemented the Sacramento Valley GPS Height Modernization Project which will provide significant enhancements to a Sacramento Valley subsidence monitoring program. It is reported by DWR that the GPS monuments will be re-surveyed approximately every three years. The monitoring of land surface elevations will allow for periodic measurements of permanent land subsidence induced by groundwater pumping and/or natural processes. The surveys will be conducted in accordance with the National Geodetic Survey Standards for two centimeter accuracy.

When used in conjunction with surface subsidence survey data (GPS), the extensometer data could aide in identifying whether subsidence is occurring over the total depth of the monitoring well.

7.1.4. Future Groundwater Monitoring

The County's existing monitoring network is described above. Groundwater monitoring within the County is currently conducted by DWR and local water purveyors. The County will continue to cooperate with DWR and encourage the local water purveyors to continue to monitor groundwater levels. Under the voluntary guidelines of SBx7-6, selected local water purveyors will continue to monitor groundwater elevations for their

[7] http://waterdata.usgs.gov/nwis

respective service area(s), along with the DWR, under protocols established by DWR. The possibility exists that in the future, DWR may cease their monitoring if they lose funding for groundwater level measurements, and the responsibility of groundwater level monitoring will be entirely upon the local water purveyors.

All new wells should be sampled for basic water chemistry (i.e. specific conductance, arsenic, manganese, and nitrate). Although not required, the County may, in the future, consider requesting copies of laboratory reports to be submitted through the permit process. Water quality results from wells sampled by DWR are routinely placed on the WDL, and are often sampled every three years, or as funding allows.

The overall subsidence monitoring program should continue to be monitored by the extensometer and GPS monuments throughout the County. The Sacramento Valley GPS Network incorporates existing GPS networks and monuments to create a regional network that covers part or all of Colusa, Sutter, Glenn, Butte, Yolo, Yuba, Tehama, and Placer Counties.

For the area encompassing the Sutter Buttes, which is outside of a DWR delineated groundwater basin, groundwater is likely contained in the fractures of the volcanic rock as well as in the marine sands that compromise the Sutter Buttes. The area encompassing the Sutter Buttes is primarily privately owned and groundwater use is unknown but is likely limited to domestic wells or stock watering wells. It is suggested that private well owners monitor groundwater levels at least twice a year (fall and spring) in order to realize changing conditions. It is also good practice to test the quality of the groundwater for health based constituents.

7.1.5. Local and Regional Groundwater Management Coordination

Coordinating local and regional groundwater management is important to meeting Sutter County's Groundwater Management Goals because groundwater, like other resources, does not respect administrative/jurisdictional boundaries, and actions outside the County can affect groundwater in the County. Further, in order to achieve the Groundwater Management Goals, the County needs to be an "effective participant" in local and regional management efforts and work cooperatively with water managers to conduct effective groundwater management. To be an "effective participant", the County needs to be informed of its groundwater conditions and activities underway or planned, which may affect the resources positively or negatively. With time and appropriate documentation of water management activities and monitoring, an understanding of the resources can be obtained so that groundwater conditions can be the result of deliberate water management choices.

Coordinating groundwater management across local and regional jurisdictions will contribute to ensuring a reliable water supply by working towards management of entire groundwater basins, not just the portions underlying the County. Involvement in regional activities will help ensure that activities outside of Sutter County that affect the reliability of the groundwater supply in the County can be addressed through regional management actions. This involvement will also help protect water rights because the County's involvement with regional groundwater management will allow it to be part of a larger group that can exert more influence in preserving water rights north of the Delta. Finally, regional coordination will help the County maintain local control by ensuring that the County's interests are represented in regional groundwater management activities.

Sutter County recognizes the importance of regional coordination, collaboration, and communication and is signatory to the "Four-County Group," which has evolved into the "Northern Sacramento Valley – Integrated Regional Water Management Group", consisting of Butte, Glenn, Colusa, Tehama, Shasta, and Sutter Counties.

In addition to the water management coordination addressed above, which is more at a technical and operational level, it is important that coordination occur at the policy level as well. This is especially important for effective and consistent operations within water purveyors whose geographic jurisdiction extends beyond Sutter County. The processes to addressing water transfers, in particular, are different in each of the three counties. It would be important, as the GMP is implemented and the institutional structure and management processes become solidified, that a dialogue be established with the neighboring counties to address the need for developing consistency in processes that affect the management and operation of the respective water purveyors.

7.1.6. State of the Basin Report - Groundwater Condition and Groundwater Management Plan Evaluation

In the future, Sutter County and local water purveyors may benefit from preparing an annual report of the conditions of its groundwater basin. However, the present County staffing and funding levels are unable to accommodate this work effort. Groundwater elevation data for the County will be available through the CASGEM program and continued DWR monitoring. Additionally, new and/or current water quality data is periodically submitted and is available through the DWR Water Data Library. The County encourages cooperation among all groundwater users to share data (groundwater level and/or quality) which is not reported or what is readily available through the Water Data Library. Water quality data is also accessible through the Department of Public Health for permitted public water systems. Through this report, the County will encourage its groundwater users to be responsible stewards of the County's resources.

This GMP prepared by the County is not intended to be a static document. As conditions change, such as population, land uses, or climate, it may be warranted to revisit the County's goals and BMOs to ensure that the overall goals of sustaining its groundwater resources to meet current and future demands for the County are being satisfied. The County encourages cooperation among its groundwater users to keep these goals in mind. It is not Sutter County's intent of this GMP to be an enforcer with regards to groundwater use; however, as climatic and groundwater usage change in the future, it may be necessary to "check in" and adjust or expand this GMP.

7.2. Action Plan

7.2.1. Actions for Groundwater Levels BMO

To avoid ongoing declines in groundwater, to avoid abnormally high groundwater levels, the County has taken and will take the following actions:

Action	*Frequency*	*Status*
Participation in the "Northern Sacramento Valley – Integrated Regional Water Management Group"	As needed	2008 - Present
Maintain relationships with state and federal agencies	Annual	1850 - Present
Promote conjunctive use through public outreach	Annual	2008 - Present
Coordination with local and regional jurisdictions on groundwater.	Annual	2008 - Present
Ensure compliance with adopted policies in 2008 General Plan (Goal ER 6)	Annual	2008 - Present
Review groundwater contour maps prepared by DWR	Annual	2008 - Present
Disseminate groundwater level data on County's website	As needed	2010 - Present

7.2.2. Actions for Groundwater Quality BMO

To improve the understanding of groundwater quality, the County has taken and will take the following actions:

Action	*Frequency*	*Status*
Cooperate with DWR in its monitoring efforts	Annual	2010 - Present
Maintain relationships with neighboring counties	Annual	1850 - Present
Ensure compliance with adopted policies in 2008 General Plan (Goal ER 6)	Annual	2008 - Present
Ongoing coordination with local and regional jurisdictions on groundwater	Annual	unknown - Present

7.2.3. Actions for Inelastic Land Subsidence BMO

To avoid inelastic land subsidence that is linked to declines in groundwater levels, the County has taken and will take the following actions:

Action	*Frequency*	*Status*
Cooperate with DWRs monitoring efforts	Annual	2010 - Present
Participate in the "Northern Sacramento Valley – Integrated Regional Water Management Group"	Annual	2008 - Present
Establish and update a groundwater management plan website	Annual	2008 - Present
Review data from the extensometer installed in Sutter County	6 months	2010 - Present
Maintain relationships with state and federal agencies	Annual	1850 - Present

7.2.4. Actions for Surface Water BMO

To improve the understanding of the relationship between surface water and groundwater; to avoid changes in surface water flow and surface water quality that directly affect groundwater levels or are caused by groundwater pumping; and to avoid changes in surface flow and surface water quality that directly affect groundwater quality, the County has taken and will take the following actions:

Action	*Frequency*	*Status*
Engage in the "Northern Sacramento Valley – Integrated Regional Water Management Group"	Annual	2008 - Present
Establish a groundwater management plan website	Annual	2008 - Present
Maintain relationships with state and federal agencies	Annual	1850 - Present
Ensure compliance with adopted policies in 2008 General Plan (Goal ER 5)	Annual	2008 - Present

7.2.5. Actions for Coordination BMO

To coordinate County groundwater management efforts with other groundwater management efforts within and surrounding Sutter County, the County has taken and will take the following actions:

Action	*Frequency*	*Status*
Engage in the "Northern Sacramento Valley – Integrated Regional Water Management Group"	Annual	2008 - Present
Maintain relationships with state and federal agencies	Annual	1850 - Present
Establish and update a groundwater management plan website	As needed	2008 - Present

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Public-supply Assessment (PSA)

Study Unit: Middle Sacramento Valley

Study Area: East Sac Valley

Project ID: ESAC-11

USGS Station ID: 391900121480001

Public Supply Code: na

Altitude (ft): 66

Depth to Top of Screen (ft): 220

Depth to Bottom of Screen (ft): 510

Well Depth (ft): 520

Concentration (µg/L): 70

Category: High

*na, not available; ns, not sampled.



ca.water.usgs.gov/projects/gama/water-quality-results/

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USGS CA GAMA-PBP Groundwater-Quality Results: Assessment and

DISPLAY DATA

Groundwater Sites by Study Type:

All Sites

Consitiuent Group:

Trace Elements

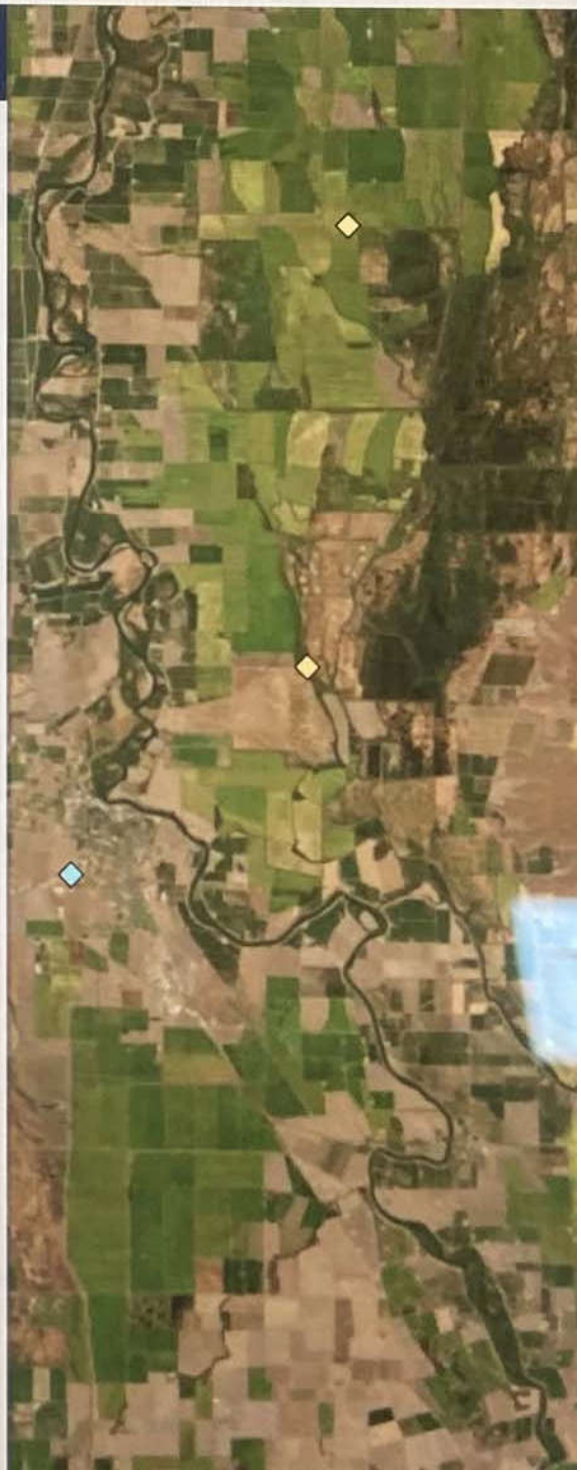
Constituent:

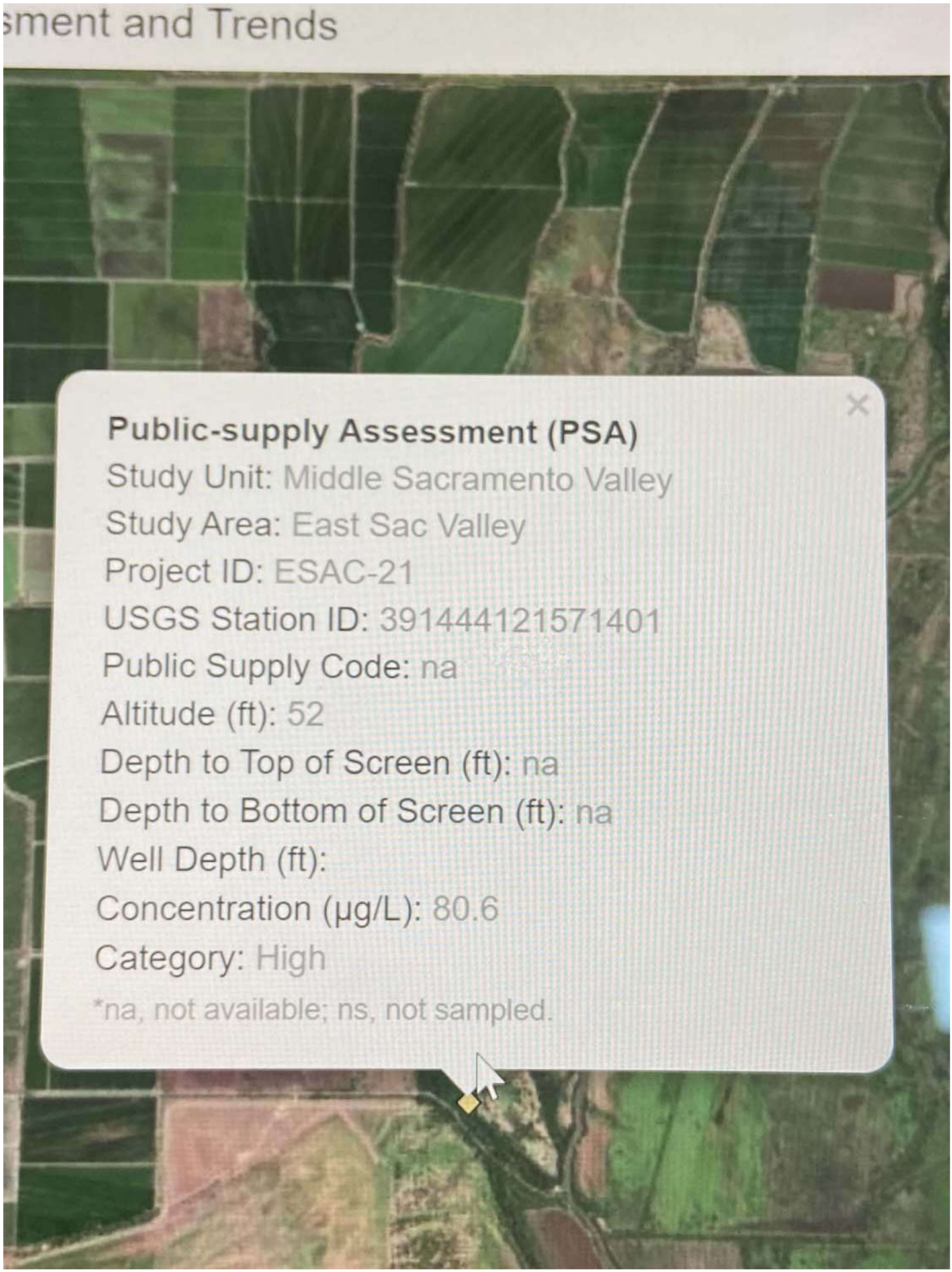
Arsenic

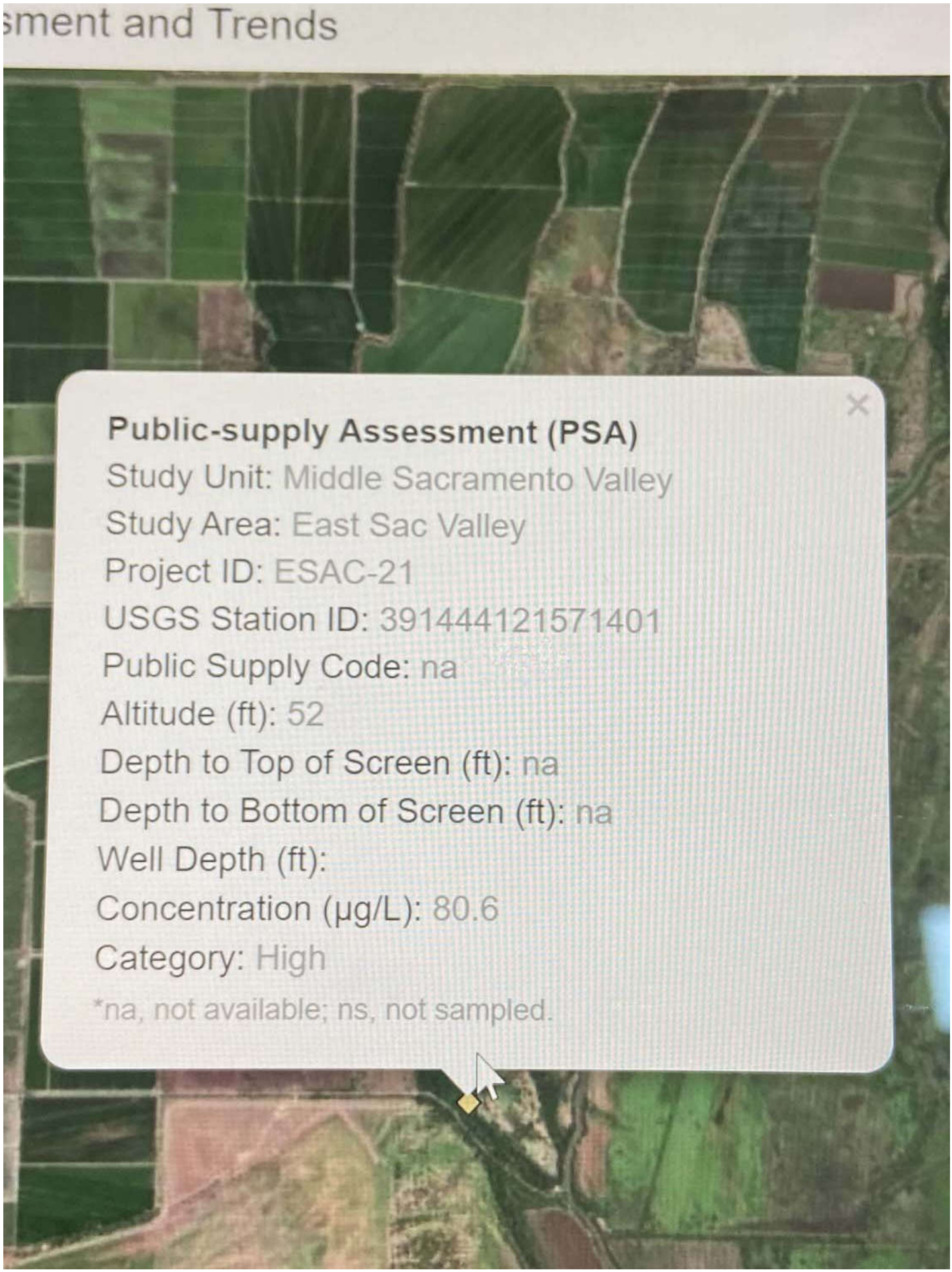
ADDITIONAL LAYERS

- [x] Domestic-supply Assessment Grid Cells
- [ ] Public-supply Assessment Grid Cells
- [ ] Domestic-supply Assessment Study Units
- [ ] Public-supply Assessment Study Units
- [ ] Hydrogeologic Provinces

The Groundwater Ambient Monitoring and Assessment - Priority Basin Project (GAMA - PBP) is a cooperative program between the California State




Public-supply Assessment (PSA)
Study Unit: Middle Sacramento Valley
Study Area: East Sac Valley
Project ID: ESAC-21
USGS Station ID: 391444121571401
Public Supply Code: na
Altitude (ft): 52
Depth to Top of Screen (ft): na
Depth to Bottom of Screen (ft): na
Well Depth (ft):
Concentration (µg/L): 80.6
Category: High
*na, not available; ns, not sampled.


Public-supply Assessment (PSA)
Study Unit: Middle Sacramento Valley
Study Area: East Sac Valley
Project ID: ESAC-21
USGS Station ID: 391444121571401
Public Supply Code: na
Altitude (ft): 52
Depth to Top of Screen (ft): na
Depth to Bottom of Screen (ft): na
Well Depth (ft):
Concentration (µg/L): 80.6
Category: High
*na, not available; ns, not sampled.

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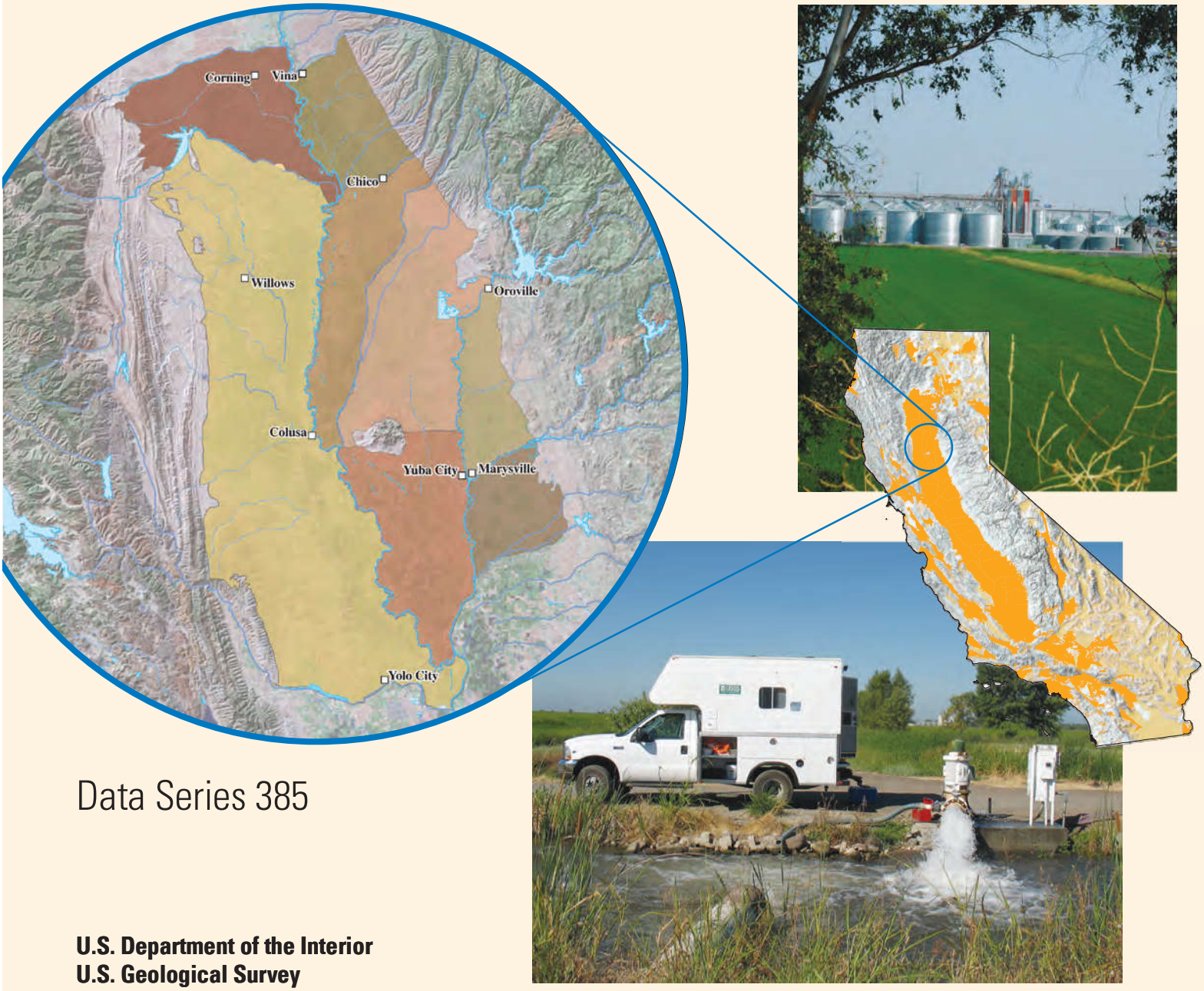
Ground-Water Quality Data in the Middle Sacramento Valley Study Unit, 2006—Results from the California GAMA Program



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Top: Rice field and grain silos in Colusa County, California, July 2008. (Photograph taken by Cathy Munday, U.S. Geological Survey.)
Bottom: Irrigation well in Butte County, California, July 2008. (Photograph taken by Michael Judd, U.S. Geological Survey.)

Ground-Water Quality Data in the Middle Sacramento Valley Study Unit, 2006—Results from the California GAMA Program

By Stephen J. Schmitt, Miranda S. Fram, Barbara J. Milby Dawson, and Kenneth Belitz

Prepared in cooperation with the California State Water Resources Control Board

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Abbreviations and Acronyms

(Additional information or clarification given in parentheses)

AB	Assembly Bill (through the California State Assembly)
AL	action level
AL-US	action level (USEPA)
CAS	Chemical Abstracts Service (American Chemical Society)
CSU	combined standard uncertainty
D	detected
DLR	detection level for the purpose of reporting (CDPH)
E	estimated or having a higher degree of uncertainty
ESAC	East study area of the Middle Sacramento Valley study unit
FP	flow path
GAMA	Groundwater Ambient Monitoring and Assessment (program)
GPS	global positioning system
HAL-US	Lifetime Health Advisory Level (USEPA)
HPLC	high-performance liquid chromatography
IBW	inorganic blank water
LRL	laboratory reporting level
LSD	land-surface datum
LT-MDL	long-term method detection level
MCL	maximum contaminant level
MCL-CA	maximum contaminant level (CDPH)
MCL-US	maximum contaminant level (USEPA)
MDL	method detection limit
MRL	minimum reporting level
MSACV	Middle Sacramento Valley study unit
MU	method uncertainty
N	normal (1-gram-equivalent per liter of solution)
na	not available
NAWQA	National Water Quality Assessment (USGS)
nc	sample not collected
NL	notification level
NL-CA	California notification level (CDPH)
NRP	National Research Program (USGS)
NWIS	National Water Information System (USGS)
P	probability
PCFF-GAMA	Personal Computer Field Forms program designed for GAMA sampling
pK	logarithm of the reciprocal of the equilibrium constant for a specified reaction under specific conditions
QC	quality control
RICE	rice agriculture
RPD	relative percent difference
RSD	relative standard deviation
RSD5	risk-specific dose at 10^{-5}

Abbreviations and Acronyms—Continued

RSD5-US	risk-specific dose at 10^{-5} (USEPA)
SMCL	secondary maximum contaminant level
SMCL-CA	secondary maximum contaminant level (CDPH)
SMCL-US	secondary maximum contaminant level (USEPA)
SSMDC	sample-specific minimum detectable concentration
TT	treatment technique
TT-US	treatment technique (USEPA)
U.S.	United States
V	analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results
VBW	VOC-free (nitrogen-purged) blank water
VPDB	Vienna Peedee Belemnite (the international reference standard for carbon isotopes)
VSMOW	Vienna Standard Mean Ocean Water (an isotopic water standard defined in 1968 by the International Atomic Energy Agency)
WSAC	West study area of the Middle Sacramento Valley study unit

Organizations

CDPH	California Department of Public Health (formerly the California Department of Health Services until July 1, 2007)
LLNL	Lawrence Livermore National Laboratory
MWH	Montgomery Watson Harza (laboratory)
NELAP	National Environmental Laboratory Accreditation Program
NWQL	National Water Quality Laboratory (USGS)
SWRCB	State Water Resources Control Board (California)
TML	Trace Metal Laboratory (USGS)
USEPA	U.S. Environmental Protection Agency
USGS	U. S. Geological Survey

Selected Chemical Names

$CaCO_3$	calcium carbonate
CO_3^{-2}	carbonate
DOC	dissolved organic carbon
HCl	hydrochloric acid
HCO_3^-	bicarbonate
MTBE	methyl *tert*-butyl ether
NDMA	*N*-Nitrosodimethylamine
1,2,3-TCP	1,2,3-trichloropropane
TDS	total dissolved solids
THM	trihalomethane
VOC	volatile organic compound

Abbreviations and Acronyms—Continued

Units of Measurement

ft	foot (feet)
in.	inch
L	liter
mg	milligram
mg/L	milligrams per liter (parts per million)
mi	mile
mL	milliliter
mm of Hg	millimeters of mercury
µg/L	micrograms per liter (parts per billion)
µL	microliter
µm	micrometer
NTU	nephelometric turbidity units
pCi/L	picocuries per liter
per mil	parts per thousand
$\delta^{i}E$	standard delta notation, the ratio of a heavier isotope of an element (^{i}E) to the more common lighter isotope of that element, relative to a standard reference material, expressed in per mil

Notes

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is equivalent to parts per million (ppm) and micrograms per liter is equivalent to parts per billion (ppb).

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Ground-Water Quality Data in the Middle Sacramento Valley Study Unit, 2006—Results from the California GAMA Program

By Stephen J. Schmitt, Miranda S. Fram, Barbara J. Milby Dawson, and Kenneth Belitz

Abstract

Ground-water quality in the approximately 3,340 mi^2 Middle Sacramento Valley study unit (MSACV) was investigated from June through September, 2006, as part of the California Groundwater Ambient Monitoring and Assessment (GAMA) program. The GAMA Priority Basin Assessment project was developed in response to the Groundwater Quality Monitoring Act of 2001 and is being conducted by the U.S. Geological Survey (USGS) in cooperation with the California State Water Resources Control Board (SWRCB).

The Middle Sacramento Valley study was designed to provide a spatially unbiased assessment of raw ground-water quality within MSACV, as well as a statistically consistent basis for comparing water quality throughout California. Samples were collected from 108 wells in Butte, Colusa, Glenn, Sutter, Tehama, Yolo, and Yuba Counties. Seventy-one wells were selected using a randomized grid-based method to provide statistical representation of the study unit (grid wells), 15 wells were selected to evaluate changes in water chemistry along ground-water flow paths (flow-path wells), and 22 were shallow monitoring wells selected to assess the effects of rice agriculture, a major land use in the study unit, on ground-water chemistry (RICE wells).

The ground-water samples were analyzed for a large number of synthetic organic constituents (volatile organic compounds [VOCs], gasoline oxygenates and degradates, pesticides and pesticide degradates, and pharmaceutical compounds), constituents of special interest (perchlorate, *N*-nitrosodimethylamine [NDMA], and 1,2,3-trichloropropane [1,2,3-TCP]), inorganic constituents (nutrients, major and minor ions, and trace elements), radioactive constituents, and microbial indicators. Naturally occurring isotopes (tritium, and carbon-14, and stable isotopes of hydrogen, oxygen, nitrogen, and carbon), and dissolved noble gases also were measured to help identify the sources and ages of the sampled ground water.

Quality-control samples (blanks, replicates, laboratory matrix spikes) were collected at approximately 10 percent of the wells, and the results for these samples were used to evaluate the quality of the data for the ground-water samples. Field blanks rarely contained detectable concentrations of any constituent, suggesting that contamination was not a noticeable source of bias in the data for the ground-water samples. Differences between replicate samples were within acceptable ranges, indicating acceptably low variability. Matrix spike recoveries were within acceptable ranges for most constituents.

This study did not attempt to evaluate the quality of water delivered to consumers; after withdrawal from the ground, water typically is treated, disinfected, or blended with other waters to maintain acceptable water quality. Regulatory thresholds apply to treated water that is served to the consumer, not to raw ground water. However, to provide some context for the results, concentrations of constituents measured in the raw ground water were compared with health-based thresholds established by the U.S. Environmental Protection Agency (USEPA) and California Department of Public Health (CDPH) and thresholds established for aesthetic concerns (secondary maximum contaminant levels, SMCL-CA) by CDPH. Comparisons between data collected for this study and drinking-water thresholds are for illustrative purposes only and are not indicative of compliance or noncompliance with regulatory thresholds.

Most constituents that were detected in ground-water samples were found at concentrations below drinking-water thresholds. VOCs were detected in less than one-third and pesticides and pesticide degradates in just over one-half of the grid wells, and all detections of these constituents in samples from all wells of the MSACV study unit were below health-based thresholds. All detections of trace elements in samples from MSACV grid wells were below health-based thresholds, with the exceptions of arsenic and boron.

Arsenic concentrations were above the USEPA maximum contaminant level (MCL-US) threshold in eight grid wells, and boron concentrations were above the CDPH notification level (NL-CA) in two grid wells. Arsenic was detected above the MCL-US in two flow-path wells. Arsenic, barium, boron, molybdenum, strontium, and vanadium were detected above health-based thresholds in a few of the RICE wells; these wells are not used to supply drinking water. All detections of radioactive constituents were below health-based thresholds, although six samples had activities of radon-222 above the lower proposed MCL-US threshold. Most of the samples from the MSACV wells had concentrations of major elements, total dissolved solids, and trace elements below the non-enforceable thresholds set for aesthetic concerns. Chloride and sulfate concentrations exceeded SMCL-CA thresholds in two and one grid well, respectively. Iron, manganese, and total dissolved solids concentrations were above the SMCL-CA thresholds in 1, 12, and 6 grid wells, respectively. Nitrate (nitrite plus nitrate, as dissolved nitrogen) concentrations from two grid wells were above the MCL-US threshold. There were no detections of microbial indicators in MSACV.

Introduction

Ground water comprises nearly half of the public water supply used in California (Hutson and others, 2004). To assess the quality of ground water from public-supply wells and establish a program for monitoring trends in ground-water quality, the California State Water Resource Control Board (SWRCB), in collaboration with the U.S. Geological Survey (USGS) and Lawrence Livermore National Laboratory (LLNL), implemented a statewide Groundwater Ambient and Monitoring and Assessment (GAMA) program (http://www.waterboards.ca.gov/gama). The GAMA program consists of three projects: Priority Basin Assessment, conducted by the USGS (http://ca.water.usgs.gov/gama/); Voluntary Domestic Well Assessment, conducted by the SWRCB; and Special Studies, conducted by LLNL.

The SWRCB initiated the GAMA Priority Basin Assessment project in response to the Ground-Water Quality Monitoring Act of 2001 (Sections 10780–10782.3 of the California Water Code, Assembly Bill 599). AB 599 is a public mandate to assess and monitor the quality of ground water used as public supply for municipalities in California. The project is a comprehensive assessment of statewide ground-water quality designed to help better understand and identify risks to ground-water resources and to increase the availability of information about ground-water quality to the public. As part of the AB 599 process, the USGS, in collaboration with the SWRCB, developed the monitoring plan for the project (Belitz and others, 2003; State Water Resources Control Board, 2003). Key aspects of the project are interagency collaboration and cooperation with local water agencies and well owners. Local participation in the project is entirely voluntary.

The GAMA Priority Basin Assessment project is unique in California because the data collected during the study include analyses for an extensive number of chemical constituents at very low concentrations—analyses that are not normally available. A broader understanding of ground-water composition will be especially useful for providing an early indication of changes in water quality and for identifying the natural and human factors affecting water quality. Additionally, the GAMA Priority Basin Assessment project will analyze a broader suite of constituents than required by the California Department of Public Health (CDPH, formerly the California Department of Health Services). An understanding of the occurrence and distribution of these constituents is important for the long-term management and protection of ground-water resources.

The range of hydrologic, geologic, and climatic conditions that exist in California must be considered in an assessment of ground-water quality. Belitz, and others (2003) partitioned the state into 10 hydrogeologic provinces, each with distinctive hydrologic, geologic, and climatic characteristics (fig. 1), and representative regions in all 10 provinces were included in the project design. Eighty percent of California's approximately 16,000 public-supply wells are located in ground-water basins within these hydrologic provinces. These ground-water basins, defined by the California Department of Water Resources, generally consist of relatively permeable, unconsolidated deposits of alluvial or volcanic origin (California Department of Water Resources, 2003). Ground-water basins were prioritized for sampling on the basis of the number of public-supply wells in the basin, with secondary consideration given to municipal ground-water use, agricultural pumping, the number of leaking underground fuel tanks, and pesticide applications within the basins (Belitz, and others, 2003). In addition, some ground-water basins or groups of adjacent similar basins with relatively few public-supply wells were assigned high priority so that all hydrogeologic provinces would be represented in the subset of basins sampled. The 116 priority basins were grouped into 35 study units. Some areas not in the defined ground-water basins were included in several of the study units to achieve representation of the 20 percent of public-supply wells not located in the ground-water basins.



Figure 1. The hydrogeologic provinces of California and the location of the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study unit (black area).

Three types of water-quality assessments are being conducted with the data collected in each study unit: (1) Status: assessment of the current quality of the ground-water resource, (2) Trends: detection of changes in ground-water quality, and (3) Understanding: identification of the natural and human factors affecting ground-water quality (Kulongoski and Belitz, 2004). This report is one of a series of status reports presenting water-quality data collected in each study unit; previous reports in this series include Wright and others (2005), Kulongoski and others (2006), Bennett and others (2006), Fram and Belitz (2007), Dawson and others (2008), and Kulongoski and Belitz (2007). Subsequent GAMA reports will address the trends and understanding aspects of the water-quality assessments.

The Middle Sacramento Valley GAMA study unit, hereinafter referred to as "MSACV," lies in the Central Valley hydrogeologic province (Belitz and others, 2003). MSACV contains eight subbasins of the Sacramento Valley ground-water basin (California Department of Water Resources, 2003) (fig. 2). MSACV was considered high priority for sampling because of the number of public-supply wells, basin area, number of sections with pesticide applications, and the amount of agricultural pumping (Belitz and others, 2003).

Purpose and Scope

The purposes of this report are: (1) to describe the study design and study methods; (2) to present the sampling, analytical, and quality assurance methods used during the study; (3) to present the results of quality-control (QC) tests; and (4) to present the analytical results for ground-water samples collected in MSACV.

Ground-water samples were analyzed for organic, inorganic, and microbial constituents, field parameters, and chemical tracers. The chemical and microbial data presented in this report were evaluated by comparison with state and federal drinking-water regulatory thresholds and other health-based standards that are applied to treated drinking water. Regulatory thresholds considered for this report are those established by the U.S. Environmental Protection Agency (USEPA) and the California Department of Public Health (CDPH) (U.S. Environmental Protection Agency, 2008a, 2008b, 2008c; California Department of Public Health, 2008a, 2008b).

The data presented in this report are intended to characterize the quality of untreated ground-water resources within the study unit, not the treated drinking water delivered to consumers by water purveyors. Discussions of the factors that influence the distribution and occurrence of the constituents detected in ground-water samples will be the subject of subsequent publications.

Acknowledgments

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Hydrogeologic Setting

Knowledge of the hydrogeologic setting is important in the design of a ground-water-quality investigation. MSACV lies within the Central Valley hydrogeologic province of California and covers approximately 3,340 mi^2 in Butte, Colusa, Glenn, Sutter, Tehama, Yolo, and Yuba Counties (fig. 2). The long axis of the study unit trends north-south for a distance of approximately 90 mi along the Sacramento River, and the short axis is approximately 40 mi long and corresponds to the width of the Central Valley between the Coast Ranges to the west and the Sierra Nevada to the east (fig. 2). MSACV contains eight subbasins of the Sacramento Valley ground-water basin (California Department of Water Resources, 2003) (fig. 2). For the purposes of this study, these eight subbasins were grouped into the East and West study areas, separated by the Sacramento River (fig. 3). The East study area includes the subbasins of Vina, West Butte, East Butte, North Yuba, South Yuba, and Sutter, whereas the West study area includes the Colusa and Corning subbasins.

The main water-bearing deposits of MSACV are primarily composed of continental and marine sediments overlying the consolidated Sierra Nevada block (California Department of Water Resources, 2003). These recent Quaternary (Holocene) to Late Tertiary (Miocene) deposits have a cumulative thickness of several hundred feet near the foothills of the Coast Ranges and Sierra Nevada and deepen to approximately 2,000 ft near the valley center. Sources of ground-water recharge include deep infiltration of precipitation, river and stream flow, and agricultural irrigation return flow.

The primary surface-water features of MSACV include the Sacramento River and smaller rivers and their principal tributaries. The rivers and tributaries include Stony Creek and Cache Creek in the West study area, and Butte Creek, the Feather, Yuba, and Bear Rivers in the East study area (fig. 2).

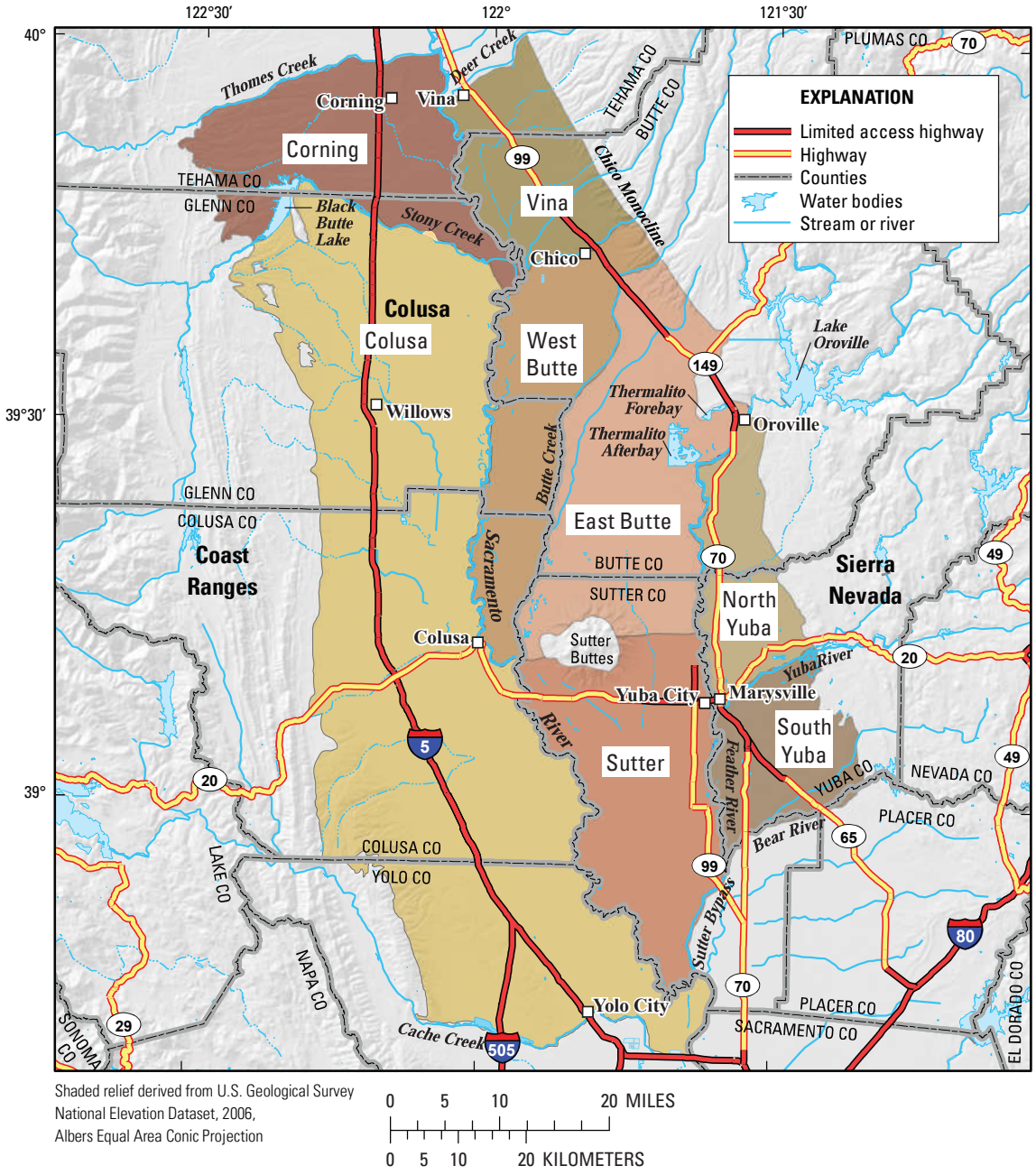

Figure 2. The Middle Sacramento Groundwater Ambient Monitoring and Assessment (GAMA) study unit showing the California Department of Water Resources defined ground-water basins and major hydrologic features within the study unit.

West Study Area—Corning and Colusa Subbasins

The West study area is bounded to the north by Thomes Creek, to the south by Cache Creek, to the west by the Coastal Ranges, and to the east by the Sacramento River (fig. 3). It covers an area of approximately 1,756 mi^2 and includes parts of Colusa, Glenn, Tehama, and Yolo Counties (California Department of Water Resources, 2003). The average annual precipitation ranges from 17 to 27 in., increasing to the north and west. The main water-bearing aquifer within this study area is the Tehama formation (Pliocene). The formation consists of unconsolidated to moderately consolidated coarse- and fine-grained sediments, indicative of floodplain deposits. The Tehama formation is up to 2,000 ft thick and varies in depth from a few feet to several hundred feet below the land surface with depth generally increasing to the east. The Tehama formation is confined by the Tertiary-age Tuscan formation, which contains low permeability lahar layers (California Department of Water Resources, 2003).

East Study Area—Vina, W. Butte, E. Butte, N. Yuba, S. Yuba, and Sutter Subbasins

The East study area is bounded to the north by Deer Creek, to the south by Sutter Bypass and Bear River, to the west by the Sacramento River, and to the east by the Chico Monocline and the Sierra Nevada (fig. 3). It covers an area of approximately 1,584 mi^2 and includes parts of Butte, Colusa, Glenn, Sutter, Tehama and Yuba Counties (California Department of Water Resources, 2003). The average annual precipitation is 17 to 32 in., with increasing rainfall to the north and east. Aquifers within this study area are composed of Tertiary to late Quaternary age deposits, with the younger Quaternary deposits typically representing the unconfined portion of the aquifer system. The Quaternary portion of the aquifer system is largely composed of unconsolidated gravel, sand, silt, and clay stream channel and alluvial fan deposits. South and east of the Sutter Buttes, the deposits contain Pleistocene alluvium, which is composed of loosely compacted silts, sands, and gravels that are moderately permeable; however, nearly impermeable hardpans and claypans do exist in this deposit, which restrict the vertical movement of ground water. The confined portion of the aquifer system includes the Tertiary-age Tuscan and Laguna formations. The Tuscan formation consists of volcanic mudflows, tuff breccia, tuffaceous sandstone, and volcanic ash deposits up to 1,250 ft thick. The Laguna formation consists of moderately consolidated and poorly to well cemented interbedded alluvial sand, gravel, and silt with a low permeability, overall (California Department of Water Resources, 2003).

Methods

The methods used for the GAMA program were selected to achieve the following objectives: (1) design a sampling plan suitable for statistical analysis, (2) collect samples in a consistent manner, (3) analyze samples using proven and reliable laboratory methods, (4) assure the quality of the ground-water data, and (5) maintain data securely and with relevant documentation.

Study Design

The wells selected for sampling in this study reflect the combination of two well selection strategies. Seventy-one wells were selected to provide a statistically unbiased, spatially distributed assessment of the quality of ground-water resources used for public drinking-water supply (fig. 3), and 37 additional wells were selected to provide greater sampling density in several areas to address specific ground-water quality issues in the study unit (fig. 4).

The spatially distributed wells were selected using a randomized grid-based method (Scott, 1990). Each of the study areas was subdivided into grid cells that were 38.6 mi^2 (100 km^2) in area. This grid-cell size met GAMA objectives for the Central Valley hydrogeologic province of a sampling density of at least one well per 38.6 mi^2 and having at least 10 grid cells per study area. For this assessment, the East study area was divided into 41 grid cells and the West study area into 46 grid cells.

Seventy-one of the 87 grid cells in MSACV contained wells that could be sampled; the other 16 grid cells did not contain accessible wells. If a grid cell contained more than one public-supply well, each well was randomly assigned a rank. The highest ranking well that met basic sampling criteria (for example, sampling point prior to treatment, capability to pump for several hours, and available well-construction information), and for which permission to sample could be obtained was then sampled. If a grid cell contained no accessible public-supply wells, domestic and irrigation wells were considered for sampling. An attempt was made to select domestic and irrigation wells with depths and screened intervals similar to those in public-supply wells in the area. Wells sampled as part of the randomized grid-cell network are hereinafter referred to as “grid wells.” Grid wells sampled in MSACV were numbered in the order of sample collection, with the following prefixes that are based on study area: “ESAC” for the East study area of the Middle Sacramento Valley study unit, and “WSAC” for the West study area of the Middle Sacramento Valley study unit.

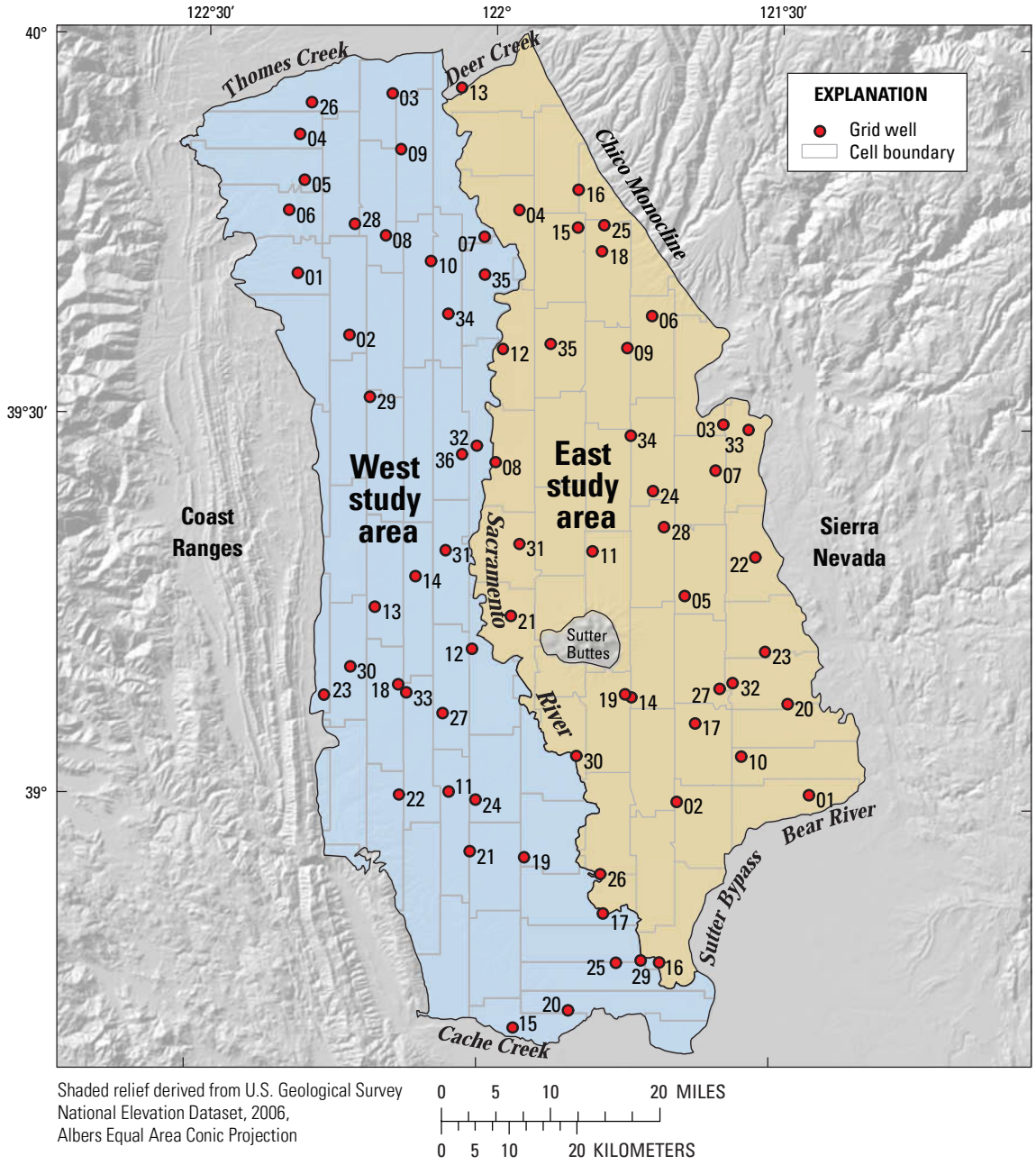

Figure 3. The East and West study areas of the Middle Sacramento Groundwater Ambient Monitoring and Assessment (GAMA) study unit showing the distribution of study area grids cells, the locations of sampled grid cell wells, and the study area boundaries.

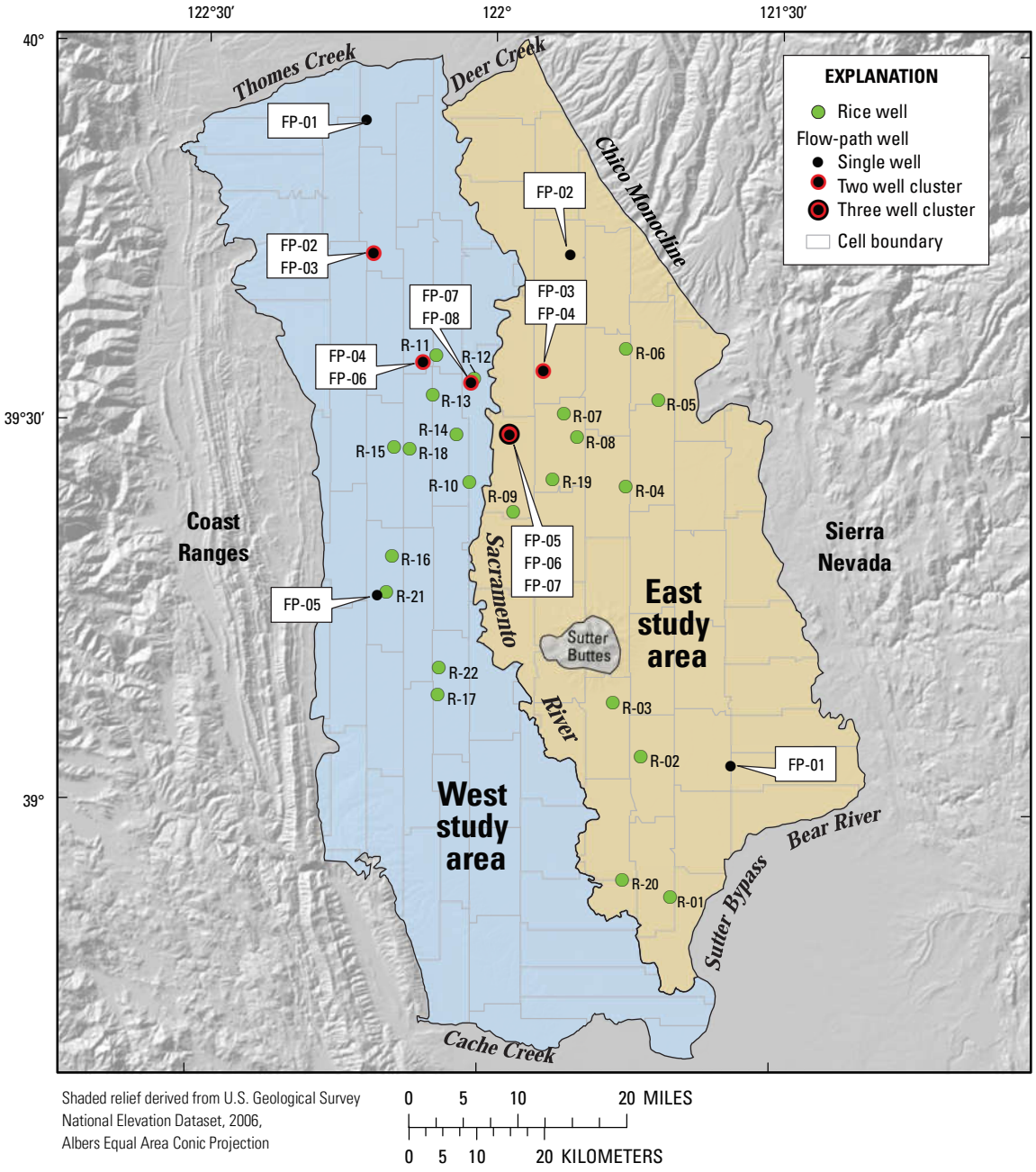

Figure 4. The East and West study areas of the Middle Sacramento Groundwater Ambient Monitoring and Assessment (GAMA) study unit showing the distribution of study area grid cells, the locations of sampled flow-path (FP) and RICE (R) wells (RICE wells are part of a well network monitoring the shallow ground-water quality associated with rice agriculture), and the study area boundaries.

In addition to the 71 grid wells, two types of nonrandomized wells were sampled in the East and West study areas. The first type of nonrandomized wells included 15 wells to evaluate changes in water chemistry along ground-water flow paths; these wells are referred to as "flow-path wells." Flow-path wells were numbered in the order of sample collection, with the prefixes ESAC-FP for wells in the East Sacramento Valley study area and WSAC-FP for wells in the West Sacramento Valley study area. The second type of nonrandomized wells consisted of 22 shallow monitoring wells selected to assess the effects of rice agriculture, a major land-use in the study unit, on shallow ground-water chemistry. In 1997, the USGS installed and sampled a set of monitoring wells in rice-growing areas of the Sacramento Valley as part of the National Water-Quality Assessment Program (Milby Dawson, 2001). Many of those monitoring wells are in the MSACV area and were resampled as part of this study. The monitoring wells are numbered in the order of sample collection with the prefix "RICE." Flow-path wells and RICE wells sampled as part of this study for better understanding were not included in the statistical characterization of water quality in MSACV, as the inclusion of these wells would have caused overrepresentation of certain grid wells and of shallow ground water.

Table 1 provides the GAMA alphanumeric identification number for each well, along with the date sampled, sampling schedule, well elevation, and well-construction information.

Well locations and identifications were verified using a global positioning system (GPS) receiver, 1:24,000 scale USGS topographic maps, comparison with existing well information in USGS and CDPH databases, and information provided by well owners. Drillers' logs for wells were obtained when available. Well information was recorded by hand on field sheets and electronically using specialized software on field laptop computers. All information was verified and then uploaded into the USGS's National Water Information System (NWIS). Well owner information is confidential. Well location information and all chemical data are currently inaccessible from NWIS's public website.

The wells in MSACV were sampled using a tiered analytical approach. All wells were sampled for a standard set of constituents, including field water-quality indicators, volatile organic compounds (VOCs), pesticides and pesticide degradates, perchlorate, stable isotopes of water, and dissolved noble gases and tritium and helium age dates. The standard set of constituents was termed the fast schedule (table 2). Wells on the intermediate schedule were sampled for all the constituents on the fast schedule, plus pharmaceuticals, *N*-nitrosodimethylamine (NDMA), 1,2,3-trichloropropane (1,2,3-TCP), nutrients, stable isotopes of oxygen and nitrogen in nitrate, major and minor ions, trace elements, species of arsenic, iron, and chromium, and carbon isotopes. Wells on the slow schedule were sampled for all the constituents on the intermediate schedule, plus dissolved organic carbon, radium 226/228, radon-222, gross alpha and beta radiation, coliform, coliphage, alkalinity, and turbidity (table 2). Fast, intermediate, and slow refer to the time required to sample the well for all the analytes on the schedule. Generally, one slow, two intermediate, or three fast wells could be sampled in one day. RICE wells were sampled on a modified intermediate schedule. In MSACV, 26 wells were sampled on the fast schedule, 52 were sampled on the intermediate schedule, 8 on the slow schedule, and 22 on the RICE monitoring-well schedule (table 2).

Sample Collection and Analysis

Samples were collected in accordance with the protocols established by the USGS's National Water Quality Assessment (NAWQA) program (Koterba and others, 1995) and the National Field Manual (U.S. Geological Survey, variously dated). These sampling protocols ensure that a representative sample of ground water is collected at each site, and that the samples are collected and handled in a way that minimizes the potential for contamination. The methods used for sample collection are described in the Appendix section "Sample Collection and Analysis."

Tables 3A–L list the compounds analyzed in each constituent class. Raw (untreated) ground-water samples were analyzed for 85 VOCs (table 3A) and 8 gasoline additives (table 3B), 135 pesticide and pesticide degradates (tables 3C, 3D), 14 pharmaceutical compounds (table 3E), 3 constituents of special interest (table 3F), 5 nutrients and dissolved organic carbon (table 3G), 10 major and minor ions and total dissolved solids (table 3H), 25 trace elements (table 3H), 6 species of arsenic, iron, and chromium (table 3I), 5 stable isotope ratios and 7 radioactive constituents, tritium, and carbon-14 (table 3J), 5 dissolved noble gases, helium stable isotope ratios, and tritium (table 3K), and 4 microbial constituents (table 3L). The methods used for sample analysis are described in the Appendix section "Sample Collection and Analysis."

Data Reporting

The methods and conventions used for reporting the data are described in the Appendix. Thirteen constituents analyzed in this study were measured by more than one method at the USGS's National Water Quality Laboratory (NWQL), but only the results from the preferred method for each of the constituents are reported. Arsenic, iron, and chromium concentrations, and tritium activities were analyzed by more than one laboratory, and both sets of results are reported.

Quality Assurance

The protocols used for this study are those used by the NAWQA program (U.S. Geological Survey, variously dated; Koterba and others, 1995), and the quality assurance protocols are described in the NWQL quality assurance plan (Maloney, 2005; Pirkey and Glodt, 1998). QC samples collected in the MSACV study include source-solution blanks, field blanks, replicates, and matrix and surrogate spikes. QC samples were collected to evaluate contamination, bias, and variability of the water-quality data that may have resulted from sample collection, processing, storage, transportation, and laboratory analysis. Quality-assurance methods and results are described in the Appendix section "Quality Assurance."

Water-Quality Results

Quality-Control Sample Results

Results of QC analyses (blanks, replicates, matrix spikes, and surrogates) were used to evaluate the quality of the data for the ground-water samples (see Appendix). Assessment of the QC data from blanks resulted in some ground-water samples being censored, as indicated with "V" codes in tables 5–14. Of the 300 constituents analyzed, 35 were detected in at least one field blank. For 15 of these constituents, concentrations detected in the field blanks were below the lowest concentration detected in ground-water samples, or the constituent was not detected in ground-water samples; thus, no data were affected. Some reported detections for five organic constituents in ground-water samples were flagged as potentially contaminated, and, therefore, were not considered as detections for ground-water quality assessment. Some low concentration detections of 12 inorganic constituents were flagged because contamination may have raised the concentrations sufficiently to have changed a nondetection into a low-level detection relative to the stated reporting limit.

Data from replicates indicate that variability between measurements generally was low, with relative standard deviations (RSD) below 5 percent for most replicate pairs for most constituents. Of the 30 pairs with RSDs above the acceptable limit of 20 percent, 29 had data that were estimated concentrations at or below the laboratory reporting level (LRL) for the constituent analyzed. At these low concentrations, small differences in the measured values in the replicate pairs account for the large RSDs. These results from the replicates confirm that the procedures used to collect and analyze the samples were consistent.

Median matrix-spike recoveries for 35 of the 232 constituents analyzed were lower than the acceptable limits, which may indicate that these constituents might not have been detected in some samples if they were present at very low concentrations.

More than 90 percent of the samples analyzed with surrogates had surrogate recoveries within acceptable limits. The QC results are described in the Appendix section "Quality-Control Sample Results."

Comparison Thresholds

Concentrations in ground-water samples were compared with CDPH and USEPA drinking-water health-based thresholds. Concentrations were also compared with thresholds established for aesthetics—secondary maximum contaminant levels (SMCLs) (California Department of Health Services, 2007a; California Department of Public Health, 2008a, 2008b; U.S. Environmental Protection Agency, 2006, 2008a, 2008b, 2008c). CDPH became the California Department of Health Services (CDHS) on July 1, 2007. The chemical and microbial data presented in this report are meant to characterize the quality of the untreated ground-water resources within MSACV, and are not intended to represent the treated drinking water delivered to consumers by water purveyors. The chemical and microbial composition of treated drinking water may differ from untreated ground water because treated drinking water may be subjected to disinfection, filtration, mixing with other waters, and exposure to the atmosphere prior to its delivery to consumers.

The following thresholds were used for comparisons:

MCL—Maximum Contaminant Level. Legally enforceable standards that apply to public-water systems and are designed to protect public health by limiting the levels of contaminants in drinking water. National MCLs established by the USEPA are the minimum standards with which states are required to comply, and individual states may choose to set more stringent standards. CDPH has established MCLs for additional constituents not regulated by the USEPA, as well as lowered the threshold concentration for a number of constituents with MCLs established by the USEPA. In this report, a threshold set by the USEPA is labeled "MCL-US," and one set by CDPH that is different from the MCL-US is labeled "MCL-CA." CDPH is notified when constituents are detected at concentrations exceeding MCL-US or MCL-CA thresholds in samples collected for the GAMA Priority Basin Assessment, but these detections do not constitute violations of CDPH regulations

AL—Action Level. Legally enforceable standards that apply to public-water systems and are designed to protect public health by limiting the levels of copper and lead in drinking water. Detections of copper or lead above the action-level thresholds trigger requirements for mandatory water treatment to reduce the corrosiveness of water to water pipes. The action levels established by the USEPA and CDPH are the same, thus these thresholds are labeled "AL-US" in this report.

TT—Treatment Technique. Legally enforceable standards that apply to public-water systems and are designed to protect public health by limiting the levels of microbial constituents in drinking water. Detections of microbial

constituents above the treatment-technique thresholds trigger requirements for mandatory additional disinfection during water treatment. The action levels established by the USEPA and CDPH are the same, thus these thresholds are labeled "TT-US" in this report.

SMCL—Secondary Maximum Contaminant Level. Non-enforceable standards applied to constituents that affect the aesthetic qualities of drinking water, such as taste, odor, and color, or technical qualities of drinking water, such as scaling and staining. Both the USEPA and CDPH define SMCLs, but unlike MCLs, SMCLs established by CDPH are not required to be at least as stringent as those established by USEPA. SMCLs established by CDPH are used in this report (SMCL-CA) for all constituents that have SMCL-CA values. The SMCL-US is used for pH because no SMCL-CA has been defined.

NL—Notification Level. Health-based notification levels established by CDPH for some of the constituents in drinking water that lack MCLs (NL-CA). If a constituent is detected above its NL-CA, California state law requires timely notification of local governing bodies and recommends consumer notification.

HAL—Lifetime Health Advisory Level. The maximum concentration of a constituent at which its presence in drinking water is not expected to cause any adverse carcinogenic effects for a lifetime of exposure. HALs are established by the USEPA (HAL-US) and are calculated assuming consumption of two liters of water per day over a 70-year lifetime by a 70-kilogram adult and that 20 percent of a person's exposure comes from drinking water.

RSD5—Risk-Specific Dose. The concentration of a constituent in drinking water corresponding to an excess estimated lifetime cancer risk of 1 in 100,000. RSD5 is an acronym for risk-specific dose at 10^{-5}. RSD5s are calculated by dividing the 10^{-4} cancer risk concentrations established by the USEPA by ten (RSD5-US).

For constituents with MCLs, detections in ground-water samples were compared with the MCL-US or MCL-CA. Constituents with SMCLs were compared with the SMCL-CA. For chloride, sulfate, specific conductance, and total dissolved solids, CDPH defines a "recommended" and an "upper" SMCL-CA; detections of these constituents in ground-water samples were compared with both levels. The SMCL-US for these constituents corresponds to the recommended SMCL-CA. Detected concentrations of constituents that lack MCLs and SMCLs were compared with NL-CAs. For constituents that lack an MCL, SMCL, or NL-CA, detected concentrations were compared with the HAL-US. For constituents that lack an MCL, SMCL, NL-CA, or HAL-CA, detected concentrations were compared with the RSD5-US. Note this hierarchy of selection of comparison thresholds means that for constituents with multiple types of established thresholds, the threshold used for comparison purposes may not be the one with the lowest concentration. The comparison thresholds used in this report are listed in tables 3A–L for all constituents and in tables 4–14 for constituents detected in ground-water samples from the MSACV. Not all constituents analyzed for this study have established thresholds. Concentrations greater than the selected comparison threshold are marked with asterisks in tables 4–14.

Ground-Water-Quality Data

Results from analyses of raw (untreated) ground-water samples from MSACV are presented in tables 4–14. Ground-water samples collected in MSACV were analyzed for up to 280 constituents, and 195 of those constituents were not detected in any of the samples (tables 3A–L). The results tables present only the constituents that were detected and list only samples that had at least one constituent detected. For constituent classes that were analyzed at all of the grid wells, the tables include the number of wells at which each analyte was detected, the frequency at which it was detected (in relation to the number of grid wells), and the total number of constituents detected at each well. Results from the flow-path and RICE wells are presented in the tables, but these results were excluded from the detection frequency calculations to avoid statistically over-representing the areas in the vicinity of these wells.

Table 4 includes water-quality indicators measured in the field and at NWQL. Tables 5–14 present the results of ground-water laboratory analyses organized by compound classes:

- Organic constituents
  - VOCs and gasoline oxygenates and degradates (table 5)
  - Pesticides and pesticide degradates (table 6)
- Constituents of special interest (table 7)
- Inorganic constituents
  - Nutrients and dissolved organic carbon (table 8)
  - Major and minor ions (table 9)
  - Trace elements (table 10)
  - Species of inorganic arsenic, iron, and chromium (table 11)
- Inorganic tracer constituents
  - Hydrogen and oxygen isotopes and tritium (table 12)
  - Stable isotopes of nitrogen and carbon and carbon-14 (table 13)
- Radioactive constituents (table 14)

Results for pharmaceutical compounds, dissolved noble gases, and tritium/helium age dates are not presented in this report; they will be included in subsequent GAMA

publications. No summary table is presented for microbial constituents because none were detected in any of the samples analyzed.

Water-Quality Indicators

Field and laboratory measurements of water-quality indicators, including dissolved oxygen, pH, specific conductance, alkalinity, and associated parameters (turbidity and water temperature) are presented in table 4. Dissolved oxygen and alkalinity are used as indicators of natural processes that control water chemistry. Specific conductance is the unit electrical conductivity of the water and is proportional to the amount of total dissolved solids (TDS) in the water. The pH value indicates the acidity or basicity of the water. Six wells (3 grid wells, 2 flow-path wells, and 1 RICE well) had pH values outside of the SMCL-CA range for pH. Laboratory pH values may be higher than field pH values because the pH of ground water often increases upon exposure to the atmosphere (see Appendix). Twenty-two wells (11 grid, 1 flow-path well, and 10 RICE wells) had specific conductance values above the recommended SMCL-CA, with 9 of those wells (4 grid wells and 5 RICE wells) above the upper threshold.

Organic Constituents

VOCs are widely used and can be found in paints, solvents, fuels, fuel additives, refrigerants, fumigants, and disinfected water and are characterized by their tendency to evaporate. VOCs generally persist longer in ground water than in surface water because ground water is isolated from the atmosphere.

Of the 85 VOCs analyzed, 24 were detected in ground-water samples; all detections were below health-based thresholds and most were less than one-hundredth of the threshold values (table 5). The only VOC detected in more than 10 percent of the grid wells was chloroform, a byproduct of drinking-water disinfection. Chloroform was the most frequently detected VOC in ground water nationally (Zogorski and others, 2006).

Pesticides include herbicides, insecticides, and fungicides, and are used to control weeds, insects, fungi, and other pests in agricultural, urban, and suburban settings. Of the 135 pesticides and pesticide degradates analyzed, 30 were detected in ground-water samples; all detections were below health-based thresholds and all were less than one-hundredth of the threshold values (table 6). The only pesticides detected in more than 10 percent of the grid wells were the herbicides bentazon, simazine, atrazine, and deethylatrazine, a degradate of atrazine. Simazine, atrazine, and deethlyatrazine are among the most commonly detected pesticide compounds in ground water nationally (Gilliom and others, 2006). Bentazon is primarily used in rice agriculture.

Constituents of Special Interest

Perchlorate, 1,2,3-TCP, and NDMA are constituents of special interest in California because they may adversely affect water quality and recently have been found in water supplies (California Department of Health Services, 2007b). Perchlorate is used as an oxidizer in rocket fuel and explosives, 1,2,3-TCP is used as a chemical synthesis product, and NDMA is an industrial by-product. Perchlorate was detected in approximately 6 percent of the grid wells, and all concentrations measured in the MSACV wells were less than one-third of the NL-CA (table 7). 1,2,3-TCP and NDMA were not detected in any samples.

Inorganic Constituents

Unlike the organic constituents and the constituents of special interest, most of the inorganic constituents are naturally present in ground water, although their concentrations may be influenced by human activities.

The nutrients, nitrogen and phosphorus, and dissolved organic carbon present in ground water can affect biological activity in aquifers and in surface water bodies that receive ground-water discharge. Nitrogen may be present in the form of ammonia, nitrite, or nitrate depending on the oxidation–reduction state of the ground water. High concentrations of nitrate can adversely affect human health, particularly the health of infants. Ground-water samples from two grid wells in MSACV had concentrations of nitrate (nitrite plus nitrate, dissolved as nitrogen) above the health-based threshold (table 8). All concentrations of nitrite and ammonia measured in ground-water samples were below health-based thresholds. Concentrations of orthophosphate (as phosphorus) and dissolved organic carbon were also low.

The major-ion composition, total dissolved solids (TDS) content, and levels of certain trace elements in ground water may produce undesirable effects on the aesthetic and technical properties of the water. Undesirable aesthetic properties include poor taste, color, or odor, and staining. Undesirable technical properties include scaling, and reduced effectiveness of treatment for other contaminants. CDPH has established non-enforceable thresholds (SMCL-CAs) that are based on aesthetic or technical properties rather than on health-based concerns for the major ions chloride and sulfate, TDS, and several trace elements. Chloride was detected in two grid wells above the recommended SMCL-CA, with one of those detections above the upper SMCL-CA. Sulfate was detected in one grid well above the lower SMCL-CA. Samples from six grid wells contained TDS above the recommended SMCL-CA, although only two of these samples were also above the upper SMCL-CA for TDS (table 9).

Iron and manganese are trace elements whose concentrations are affected by the oxidation–reduction state of the ground water. Precipitation of minerals containing iron or manganese may cause orange or black staining of surfaces. Samples from 12 grid wells had manganese concentrations above the SMCL-CA, and one of these samples also had an iron concentration above the MCL-CA (table 10).

Eighteen of the 25 trace elements analyzed in this study have health-based thresholds. Of the 18 trace elements with health-based thresholds, 2 were not detected in any samples, and all detections of 16 trace elements were below health-based thresholds (table 10). Samples from eight grid wells had arsenic concentrations above the MCL-US and samples from two grid wells had concentrations of boron above the NL-CA.

Arsenic, iron, and chromium occur in different species depending on the oxidation–reduction state of the ground water. The oxidized and reduced species have different solubilities in ground water and may have different effects on human health. The relative proportions of the oxidized and reduced species of each element can be used to aid in interpretation of the oxidation–reduction state of the aquifer. Table 11 reports measured concentrations of total arsenic, iron, and chromium, and the concentrations of the oxidized or the reduced species of each element. The concentration of the other species can be calculated by difference. For example, chromium(III) is equal to chromium(total) minus chromium(VI). The concentrations of arsenic, iron, and chromium reported in table 11 may be different than those reported in table 10 because different analytical methods were used (see Appendix). The concentrations reported in table 10 are considered more accurate.

Inorganic Tracer Constituents

Stable isotope ratios, tritium and carbon-14 activities, and noble gas concentrations are used as tracers of natural processes affecting ground-water composition. The stable isotope ratios of oxygen and hydrogen in water (table 12) may aid in interpretation of ground-water recharge sources. These stable isotope ratios reflect the altitude, latitude, and temperature of precipitation and the extent of evaporation of surface water or soil water. The nitrogen and oxygen stable isotope ratios in nitrate (table 13) may aid in interpretation of sources and processes affecting nitrate concentrations in ground water. Concentrations of dissolved noble gases are used to estimate the conditions of ground-water recharge, particularly the temperature of the recharge water. Noble gases from air dissolve in water that is in contact with the atmosphere, and the solubilities of the different noble gases vary with temperature. Results of noble gas analyses were not available in time for inclusion in this report; they will be presented in a subsequent GAMA report.

Tritium activities (table 12), carbon-14 activities (table 13), and helium isotope ratios provide information about the age of the ground water. Tritium is a short-lived radioactive isotope of hydrogen that is incorporated into the water molecule. Low levels of tritium are continuously produced by interaction of cosmic radiation with the earth's atmosphere, and a large amount of tritium was produced by atmospheric testing of nuclear weapons between 1952 and 1963. Thus, concentrations of tritium above background levels generally indicate the presence of water recharged since the early 1950s (Thatcher and others, 1977). Helium isotope ratios are used in conjunction with tritium concentrations to estimate ages for young ground water. Helium isotope analyses were not completed in time for inclusion in this report; they will be presented in a subsequent GAMA report.

Carbon-14 (table 13) is a radioactive isotope of carbon. Low levels of carbon-14 are continuously produced by interaction of cosmic radiation with the earth's atmosphere and incorporated into atmospheric carbon dioxide. The carbon dioxide dissolves in precipitation and water that is in contact with the atmosphere. Because carbon-14 decays with a half-life of approximately 5,700 years, low activities of carbon-14 relative to modern values generally indicate presence of ground water that is several thousand years old.

Of the inorganic tracer constituents analyzed for this study, the only one with a health-based threshold is tritium. All measured tritium activities in samples from MSACV wells were less than one-thousandth of the MCL-CA (table 12).

Radioactive Constituents

Radioactivity is the release of energy or energetic particles during changes in the structure of the nucleus of an atom. Most of the radioactivity in ground water comes from decay of naturally occurring isotopes of uranium and thorium that are present in minerals in the sediments or fractured rocks of an aquifer. Both uranium and thorium decay in a series of steps, eventually forming stable isotopes of lead. Radium-226, radium-228, and radon-222 are radioactive isotopes formed during the uranium and thorium decay series. In each step of the decay series, one radioactive element turns into a different radioactive element by emitting an alpha or a beta particle from its nucleus. For example, radium-226 emits an alpha particle and, therefore, turns into radon-222. Radium-228 decays to form actinium-228 by emission of a beta particle. The alpha and beta particles emitted during radioactive decay are hazardous to human health because these energetic particles may damage cells. Radiation damage to cell DNA may increase the cancer risk in humans.

Activity is often used instead of concentration for reporting the presence of radioactive constituents. Activity of radioactive constituents in ground water is measured in units of picocuries per liter (pCi/L), and one picocurie is approximately equal to two atoms decaying per minute. The number of atoms decaying is equal to the number of alpha or beta particles emitted.

The eight MSACV samples analyzed for radioactive constituents had activities of radium and of gross alpha and beta emitters less than established health-based thresholds (table 14). Activities of radon-222 in samples from six grid wells were above the proposed MCL-US of 300 pCi/L, but all were below the proposed alternative MCL-US of 4,000 pCi/L. The alternative MCL-US will apply if the state or local water agency has an approved multimedia mitigation program to address radon levels in indoor air (U.S. Environmental Protection Agency, 1999a).

Microbial Indicators

Water is disinfected during drinking-water treatment to prevent diseases that may be spread by water-borne microbial constituents derived from human or animal wastes. The specific viruses and bacteria responsible for diseases generally are not measured because routine analytical methods are not available. Measurements are made of more easily analyzed microbial constituents that serve as indicators of the presence of human or animal waste in water. Drinking-water purveyors respond to detections of microbial indicators by applying additional disinfection techniques to the water.

Samples from eight MSACV wells were analyzed for microbial indicators. None of the samples contained viral indicators F-specific and somatic coliphage, and none contained the bacterial indicator *Escherichia* coliform (*E. coli*) or total coliforms.

Future Work

Subsequent reports will focus on assessment of the data presented in this report using a variety of statistical, qualitative, and quantitative approaches to evaluate the natural and human factors affecting ground-water quality. Water-quality data contained in the CDPH and NWIS databases, and water-quality data available from other state and local water agencies, will be compiled, evaluated, and used in combination with the data presented in this report.

Summary

Ground-water quality in the approximately 3,340 mi^2 Middle Sacramento Valley study unit (MSACV) was investigated from June to September, 2006, as part of the Priority Basin Assessment project of Ground-Water Ambient Monitoring and Assessment (GAMA) program. The California State Water Resources Control Board (SWRCB), in collaboration with the U.S. Geological Survey and the Lawrence Livermore National Laboratory, is implementing the GAMA program (http://www.waterboards.ca.gov/gama/). The Priority Basin Assessment project was designed by the SWRCB and the USGS in response to the Ground-Water Quality Monitoring Act of 2001 (Belitz and others, 2003; State Water Resources Control Board, 2003). The project is a comprehensive assessment of statewide ground-water quality designed to identify and characterize risks to ground-water resources and to increase the availability of information about ground-water quality to the public. MSACV was the twelfth study unit sampled as part of the project.

MSACV is in the Central Valley hydrogeologic province, and includes within it eight ground-water basins, as defined by the California Department of Water Resources (California Department of Water Resources, 2003). The MSACV study included assessment of ground-water quality from 108 wells in Butte, Colusa, Glenn, Sutter, Tehama, Yolo, and Yuba Counties. Seventy-one of the wells (grid wells) were selected using a spatially distributed, randomized grid-based method to achieve statistically unbiased representation of the portion of the ground-water resource used for public drinking-water supplies. Fifteen of the wells (flow-path wells) were selected to provide additional sampling density to aid in understanding processes affecting ground-water quality. Twenty-two of the wells (RICE wells) were sampled for better understanding of the contribution of rice agriculture land use to ground-water conditions.

Ground-water samples were analyzed for volatile organic compounds (VOCs), pesticides and pesticide degradates, constituents of special interest, pharmaceutical compounds, nutrients, major and minor ions, trace elements, radioactivity, and microbial indicators. Naturally occurring isotopes (stable isotopes of hydrogen, oxygen, nitrogen, and carbon, and activities of tritium and carbon-14) and dissolved noble gases also were measured to provide a dataset that will be used to help interpret the source and age of the sampled ground water. This report describes the hydrogeologic setting of the MSACV region, details the sampling, analytical, and quality-assurance methods used in the study, and presents the results of the chemical and microbial analyses made of the ground-water samples collected during June to September, 2006.

QC samples (blanks, replicates, samples for matrix spikes) were collected at approximately 10 percent of the wells, and the results for these samples were used to evaluate the quality of the data for the ground-water samples. Field blanks rarely contained detectable concentrations of any constituent, suggesting that contamination was not a noticeable source of bias in the data for the ground-water samples. Most of the differences between replicate samples were within acceptable ranges, indicating acceptably low variability. Matrix spike recoveries were within acceptable ranges for most compounds.

This study did not attempt to evaluate the quality of water delivered to consumers; after withdrawal from the ground, water typically is treated, disinfected, and blended with other waters to maintain acceptable water quality. Regulatory

thresholds apply to treated water that is served to the consumer, not to raw ground water. However, to provide some context for the results, concentrations of constituents measured in the raw ground water were compared with health-based thresholds established by the U.S. Environmental Protection Agency (USEPA) and the California Department of Public Health (CDPH).

All detections of VOCs, pesticides, and pesticide degradates were below health-based thresholds, and most were less than one-hundredth of the threshold values. All detections of perchlorate, and radioactive constituents were below established thresholds. Arsenic, nitrate, and boron were the only constituents detected at concentrations above health-based thresholds in samples from the grid wells. Total dissolved solids, specific conductance, pH, iron, chloride, sulfate, and manganese were detected at concentrations above the SMCL-CA, a non-enforceable threshold set for aesthetic concerns, in samples from several of the grid wells.

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Table 1. Identification, sampling, and construction information for wells sampled for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; ft, foot (feet); LSD, land surface datum; mm/dd/yy, month/day/year; na, not available; no., number; RICE, rice agriculture; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path]

GAMA identification no.	Sampling information		Well type	Construction information			
	Date (mm/dd/yy)	Sampling schedule[1]		Elevation of LSD (ft above NAVD88)[2]	Well depth (ft below LSD)	Top perforation (ft below LSD)	Bottom perforation (ft below LSD)
Grid wells							
ESAC-01	6/29/06	Fast	Production	76	278	150	252
ESAC-02	6/29/06	Fast	Production	38	160	140	160
ESAC-03	7/10/06	Intermediate	Production	176	272	110	150
ESAC-04	7/10/06	Fast	Production	154	200	140	200
ESAC-05	7/10/06	Intermediate	Production	77	410	207	395
ESAC-06	7/12/06	Intermediate	Production	182	260	148	260
ESAC-07	7/12/06	Fast	Production	153	220	80	220
ESAC-08	7/12/06	Fast	Production	89	108	68	108
ESAC-09	7/13/06	Fast	Production	129	554	140	554
ESAC-10	7/13/06	Intermediate	Production	60	316	96	303
ESAC-11	7/13/06	Intermediate	Production	68	520	220	510
ESAC-12	7/17/06	Intermediate	Production	107	375	0	370
ESAC-13	7/17/06	Fast	Production	207	355	na	na
ESAC-14	7/17/06	Fast	Production	47	280	140	280
ESAC-15	7/20/06	Intermediate	Production	197	500	200	480
ESAC-16	7/20/06	Intermediate	Production	297	560	240	540
ESAC-17	7/20/06	Intermediate	Production	52	200	150	na
ESAC-18	7/20/06	Intermediate	Production	220	560	240	540
ESAC-19	7/20/06	Intermediate	Production	48	265	185	265
ESAC-20	7/25/06	Fast	Production	84	354	212	354
ESAC-21	7/25/06	Intermediate	Production	53	na	na	na
ESAC-22	7/26/06	Intermediate	Production	105	90	na	na
ESAC-23	7/26/06	Fast	Production	93	72	na	na
ESAC-24	7/26/06	Fast	Production	94	327	84	318
ESAC-25	7/27/06	Slow	Production	264	570	290	550
ESAC-26	7/31/06	Slow	Production	37	200	160	200
ESAC-27	8/2/06	Slow	Production	54	135	65	125
ESAC-28	8/3/06	Slow	Production	92	360	102	360
ESAC-29	8/3/06	Intermediate	Production	31	223	199	215
ESAC-30	8/7/06	Intermediate	Production	43	na	na	na
ESAC-31	8/7/06	Intermediate	Production	62	235	48	235
ESAC-32	8/17/06	Intermediate	Production	66	140	64	124
ESAC-33	8/17/06	Fast	Production	212	335	na	na
ESAC-34	8/17/06	Intermediate	Production	102	60	na	na
ESAC-35	8/24/06	Intermediate	Production	114	558	74	558
WSAC-01	7/10/06	Fast	Production	446	na	na	na
WSAC-02	7/11/06	Fast	Production	179	na	na	na
WSAC-03	7/11/06	Slow	Production	274	na	115.5	253
WSAC-04	7/11/06	Intermediate	Production	452	880	320	880
WSAC-05	7/12/06	Fast	Production	367	236	136	236
WSAC-06	7/12/06	Intermediate	Production	485	na	na	na
WSAC-07[3]	7/18/06, 8/10/06	Fast	Production	152	220	71	200
WSAC-08	7/18/06	Slow	Production	248	180	56	170
WSAC-09[3]	7/18/06, 8/10/06	Fast	Production	222	na	na	na
WSAC-10[3]	7/18/06, 8/10/06	Intermediate	Production	187	225	145	225
WSAC-11[3]	7/19/06, 8/9/06	Intermediate	Production	142	570	240	561
WSAC-12	7/19/06	Slow	Production	52	490	na	na
WSAC-13	7/24/06	Fast	Production	87	na	na	na

Table 1. Identification, sampling, and construction information for wells sampled for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; ft, foot (feet); LSD, land surface datum; mm/dd/yy, month/day/year; na, not available; no., number; RICE, rice agriculture; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path]

GAMA identification no.	Sampling information		Well type	Construction information			
	Date (mm/dd/yy)	Sampling schedule[1]		Elevation of LSD (ft above NAVD88)[2]	Well depth (ft below LSD)	Top perforation (ft below LSD)	Bottom perforation (ft below LSD)
WSAC-14	7/24/06	Intermediate	Production	62	159	157	159
WSAC-15	7/31/06	Intermediate	Production	147	610	280	610
WSAC-16	7/31/06	Fast	Production	30	332	313	na
WSAC-17	8/1/06	Intermediate	Production	32	260	230	260
WSAC-18	8/1/06	Slow	Production	85	402	160	380
WSAC-19	8/1/06	Fast	Production	37	364	348	356
WSAC-20	8/2/06	Fast	Production	81	340	253	340
WSAC-21	8/2/06	Intermediate	Production	168	369	237	256
WSAC-22	8/8/06	Intermediate	Production	358	870	408	870
WSAC-23	8/8/06	Fast	Production	43	56	31	56
WSAC-24	8/9/06	Fast	Production	75	185	165	185
WSAC-25	8/9/06	Intermediate	Production	45	na	na	na
WSAC-26	8/14/06	Intermediate	Production	413	330	110	330
WSAC-27	8/15/06	Fast	Production	65	300	140	300
WSAC-28	8/15/06	Intermediate	Production	292	165	145	165
WSAC-29	8/16/06	Intermediate	Production	142	759	173	651
WSAC-30	8/16/06	Intermediate	Production	121	na	na	na
WSAC-31	8/21/06	Intermediate	Production	60	260	145	245
WSAC-32	8/21/06	Fast	Production	93	180	110	180
WSAC-33	8/22/06	Fast	Production	88	205	na	na
WSAC-34	8/22/06	Intermediate	Production	144	197	60	180
WSAC-35	8/23/06	Intermediate	Production	143	410	100	410
WSAC-36	8/23/06	Intermediate	Production	82	260	160	260
Flow-path wells							
ESAC-FP-01	7/13/06	Intermediate	Production	51	750	580	720
ESAC-FP-02	8/21/06	Intermediate	Monitoring	181	na	na	na
ESAC-FP-03	8/23/06	Intermediate	Monitoring	105	130	98.8	109
ESAC-FP-04	8/23/06	Intermediate	Monitoring	107	583	509	562
ESAC-FP-05	8/24/06	Intermediate	Monitoring	105	100	80	90
ESAC-FP-06	8/24/06	Intermediate	Monitoring	105	380	340	350
ESAC-FP-07	8/25/06	Intermediate	Monitoring	105	555	520	530
WSAC-FP-01	8/14/06	Intermediate	Monitoring	312	na	na	na
WSAC-FP-02	8/15/06	Intermediate	Monitoring	257	421	390	400
WSAC-FP-03	8/15/06	Intermediate	Monitoring	257	310	270	290
WSAC-FP-04	8/16/06	Intermediate	Monitoring	131	200	138	180
WSAC-FP-05	8/16/06	Intermediate	Production	94	625	540	625
WSAC-FP-06	8/16/06	Intermediate	Monitoring	131	540	445	525
WSAC-FP-07	8/17/06	Intermediate	Monitoring	99	490	415	470
WSAC-FP-08	8/17/06	Intermediate	Monitoring	99	280	190	260
RICE wells							
RICE-01	7/17/06	RICE	Monitoring	24	50	40	45
RICE-02	7/18/06	RICE	Monitoring	38	44	34	39
RICE-03	7/18/06	RICE	Monitoring	43	35	25	30
RICE-04	7/18/06	RICE	Monitoring	88	35	25	30
RICE-05	7/19/06	RICE	Monitoring	126	35	25	30
RICE-06	7/19/06	RICE	Monitoring	138	35	25	30
RICE-07	7/20/06	RICE	Monitoring	91	45	35	40
RICE-08	7/20/06	RICE	Monitoring	88	35	25	30
RICE-09	7/24/06	RICE	Monitoring	70	34	24	28

Table 1. Identification, sampling, and construction information for wells sampled for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; ft, foot (feet); LSD, land surface datum; mm/dd/yy, month/day/year; na, not available; no., number; RICE, rice agriculture; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path]

GAMA identification no.	Sampling information		Well type	Construction information			
	Date (mm/dd/yy)	Sampling schedule[1]		Elevation of LSD (ft above NAVD88)[2]	Well depth (ft below LSD)	Top perforation (ft below LSD)	Bottom perforation (ft below LSD)
RICE-10	7/24/06	RICE	Monitoring	80	35	25	30
RICE-11	7/25/06	RICE	Monitoring	127	35	25	30
RICE-12	7/25/06	RICE	Monitoring	98	35	25	30
RICE-13	7/26/06	RICE	Monitoring	110	35	25	30
RICE-14	7/26/06	RICE	Monitoring	82	36	26	30
RICE-15	7/27/06	RICE	Monitoring	100	35	25	30
RICE-16	7/27/06	RICE	Monitoring	82	35	25	30
RICE-17	8/15/06	RICE	Monitoring	57	35	25	30
RICE-18	8/16/06	RICE	Monitoring	99	38	28	34
RICE-19	8/16/06	RICE	Monitoring	74	38	28	34
RICE-20	8/17/06	RICE	Monitoring	24	29	19	24
RICE-21	9/12/06	RICE	Monitoring	76	35	25	30
RICE-22	9/13/06	RICE	Monitoring	51	35	25	30

[1] Sampling schedules are described in table 2.

[2] Land-surface datum (LSD) is a datum plane that is approximately at land surface at each well. The elevation of the LSD is described in feet above the North American Vertical Datum 1988.

[3] Well sampled twice (well was partially resampled to replace some sample containers lost in shipping prior to analysis).

Table 2. Classes of water-quality indicators, chemical constituents, and microbial constituents collected for the slow, intermediate, fast, and RICE well sampling schedules in the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[DO, dissolved oxygen; NDMA, *N*-nitrosodimethylamine; SC, specific conductance]

Analyte classes	Analyte list table	Slow schedule	Intermediate schedule	Fast schedule	RICE schedule
Water-quality indicators					
DO, SC, pH, temperature		X	X	X	X
Alkalinity, turbidity		X			X
Organic constituents					
Volatile organic compounds	3A	X	X	X	X
Gasoline additives and oxygenates	3B	X			
Pesticides and pesticide degradates	3C, 3D	X	X	X	X
Pharmaceutical compounds	3E	X	X		X
Constituents of special interest					
Perchlorate	3F	X	X	X	X
N-Nitrosodimethylamine (NDMA)	3F	X	X		
1,2,3-Trichloropropane (1,2,3-TCP)	3F	X	X		
Inorganic constituents					
Nutrients	3G	X	X		X
Dissolved organic carbon (DOC)	3G	X			X
Major and minor ions and trace elements	3H	X	X		X
Arsenic, iron, and chromium speciation	3I	X	X		X
Stable isotopes					
Stable isotopes of hydrogen and oxygen in water	3J	X	X	X	X
Stable isotopes of nitrogen and oxygen in nitrate	3J	X	X		
Stable isotopes of carbon and carbon-14 abundance	3J	X	X		
Radioactivity and gases					
Tritium	3J	X	X	X	
Tritium and noble gases	3K	X	X	X	X
Radium isotopes	3J	X			
Radon-222	3J	X			
Gross alpha and beta radiation	3J	X			
Microbial constituents					
Escherichia coliform and total coliform	3L	X			
F-specific and somatic coliphage	3L	X			

Table 3A. Volatile organic compounds, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 2020.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); THM, trihalomethane; USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type	Threshold value (µg/L)	Detection
Acetone	Solvent	81552	67-64-1	6	na	na	D
Acrylonitrile	Organic synthesis	34215	107-13-1	0.8	RSD5-US	0.6	—
Benzene	Gasoline hydrocarbon	34030	71-43-2	0.021	MCL-CA	1	D
Bromobenzene	Solvent	81555	108-86-1	0.028	na	na	—
Bromochloromethane	Fire retardant	77297	74-97-5	0.12	HAL-US	90	—
Bromodichloromethane	Disinfection by-product (THM)	32101	75-27-4	0.028	MCL-US[1]	80	D
Bromoform (Tribromomethane)	Disinfection by-product (THM)	32104	75-25-2	0.10	MCL-US[1]	80	D
2-Butanone (MEK, Methyl ethyl ketone)	Solvent	81595	78-93-3	2	HAL-US	4,000	D
n-Butylbenzene	Gasoline hydrocarbon	77342	104-51-8	0.12	NL-CA	260	—
sec-Butylbenzene	Gasoline hydrocarbon	77350	135-98-8	0.06	NL-CA	260	—
tert-Butylbenzene	Gasoline hydrocarbon	77353	98-06-6	0.06	NL-CA	260	—
Carbon disulfide	Organic synthesis	77041	75-15-0	0.038	NL-CA	160	D
Carbon tetrachloride (Tetrachloromethane)	Solvent	32102	56-23-5	0.06	MCL-CA	0.5	D
Chlorobenzene	Solvent	34301	108-90-7	0.028	MCL-CA	70	—
Chloroethane	Solvent	34311	75-00-3	0.12	na	na	—
Chloroform (Trichloromethane)	Disinfection by-product (THM)	32106	67-66-3	0.024	MCL-US[1]	80	D
Chloromethane	Refrigerant/organic synthesis	34418	74-87-3	0.17	HAL-US	30	D
3-Chloro-1-propene	Organic synthesis	78109	107-05-1	0.5	na	na	—
2-Chlorotoluene	Solvent	77275	95-49-8	0.04	NL-CA	140	—
4-Chlorotoluene	Solvent	77277	106-43-4	0.05	NL-CA	140	—
Dibromochloromethane	Disinfection by-product (THM)	32105	124-48-1	0.10	MCL-US[1]	80	D
1,2-Dibromo-3-chloropropane (DBCP)	Fumigant	82625	96-12-8	0.51	MCL-US	0.2	—
1,2-Dibromoethane (EDB)	Fumigant	77651	106-93-4	0.036	MCL-US	0.05	—
Dibromomethane	Solvent	30217	74-95-3	0.050	na	na	—
1,2-Dichlorobenzene	Solvent	34536	95-50-1	0.048	MCL-CA	600	—
1,3-Dichlorobenzene	Solvent	34566	541-73-1	0.03	HAL-US	600	—
1,4-Dichlorobenzene	Fumigant	34571	106-46-7	0.034	MCL-CA	5	—
trans-1,4-Dichloro-2-butene	Organic synthesis	73547	110-57-6	0.70	na	na	—
Dichlorodifluoromethane (CFC-12)	Refrigerant	34668	75-71-8	0.18	NL-CA	1,000	—
1,1-Dichloroethane	Solvent	34496	75-34-3	0.035	MCL-CA	5	D
1,2-Dichloroethane	Solvent	32103	107-06-2	0.13	MCL-CA	0.5	—
1,1-Dichloroethene (DCE)	Organic synthesis	34501	75-35-4	0.024	MCL-CA	6	—
cis-1,2-Dichloroethene	Solvent	77093	156-59-2	0.024	MCL-CA	6	D
trans-1,2-Dichloroethene	Solvent	34546	156-60-5	0.032	MCL-CA	10	D
Dichloromethane (Methylene chloride)	Solvent	34423	75-09-2	0.06	MCL-US	5	—
1,2-Dichloropropane	Fumigant	34541	78-87-5	0.029	MCL-US	5	—
1,3-Dichloropropane	Fumigant	77173	142-28-9	0.06	na	na	—
2,2-Dichloropropane	Fumigant	77170	594-20-7	0.05	na	na	—
1,1-Dichloropropene	Organic synthesis	77168	563-58-6	0.026	na	na	—
cis-1,3-Dichloropropene	Fumigant	34704	10061-01-5	0.05	RSD5-US[2]	4	—
trans-1,3-Dichloropropene	Fumigant	34699	10061-02-6	0.09	RSD5-US[2]	4	—
Diethyl ether	Solvent	81576	60-29-7	0.08	na	na	—
Diisopropyl ether (DIPE)	Gasoline oxygenate	81577	108-20-3	0.10	na	na	—
Ethylbenzene	Gasoline hydrocarbon	34371	100-41-4	0.030	MCL-CA	300	—
Ethyl *tert*-butyl ether (ETBE)	Gasoline oxygenate	50004	637-92-3	0.030	na	na	—

Table 3A. Volatile organic compounds, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 2020.—Continued

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); THM, trihalomethane; USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type	Threshold value (µg/L)	Detection
Ethyl methacrylate	Organic synthesis	73570	97-63-2	0.18	na	na	—
1-Ethyl-2-methylbenzene (*o*-Ethyl toluene)	Gasoline hydrocarbon	77220	611-14-3	0.06	na	na	D
Hexachlorobutadiene	Organic synthesis	39702	87-68-3	0.14	RSD5-US	90	—
Hexachloroethane	Solvent	34396	67-72-1	0.14	HAL-US	1	—
2-Hexanone (*n*-Butyl methyl ketone)	Solvent	77103	591-78-6	0.4	na	na	—
Isopropylbenzene (Cumene)	Gasoline hydrocarbon	77223	98-82-8	0.038	NL-CA	770	—
4-Isopropyl-1-methylbenzene	Gasoline hydrocarbon	77356	99-87-6	0.08	na	na	D
Methyl acrylate	Organic synthesis	49991	96-33-3	1.0	na	na	—
Methyl acrylonitrile	Organic synthesis	81593	126-98-7	0.40	na	na	—
Methyl bromide (Bromomethane)	Fumigant	34413	74-83-9	0.33	HAL-US	10	—
Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	78032	1634-04-4	0.10	MCL-CA	13	D
Methyl iodide (Iodomethane)	Organic synthesis	77424	74-88-4	0.50	na	na	—
Methyl isobutyl ketone (MIBK)	Solvent	78133	108-10-1	0.37	NL-CA	120	—
Methyl methacrylate	Organic synthesis	81597	80-62-6	0.20	na	na	—
Methyl *tert*-pentyl ether (*tert*-Amyl methyl ether, TAME)	Gasoline oxygenate	50005	994-05-8	0.04	na	na	—
Naphthalene	Gasoline hydrocarbon	34696	91-20-3	0.52	NL-CA	17	—
n-Propylbenzene	Solvent	77224	103-65-1	0.042	NL-CA	260	—
Styrene	Gasoline hydrocarbon	77128	100-42-5	0.042	MCL-US	100	—
1,1,1,2-Tetrachloroethane	Solvent	77562	630-20-6	0.03	HAL-US	70	—
1,1,2,2-Tetrachloroethane	Solvent	34516	79-34-5	0.08	MCL-CA	1	—
Tetrachloroethene (PCE)	Solvent	34475	127-18-4	0.030	MCL-US	5	D
Tetrahydrofuran	Solvent	81607	109-99-9	1.2	na	na	—
1,2,3,4-Tetramethylbenzene	Gasoline hydrocarbon	49999	488-23-3	0.14	na	na	D
1,2,3,5-Tetramethylbenzene	Gasoline hydrocarbon	50000	527-53-7	0.18	na	na	D
Toluene	Gasoline hydrocarbon	34010	108-88-3	0.02	MCL-CA	150	D
1,2,3-Trichlorobenzene	Organic synthesis	77613	87-61-6	0.18	na	na	—
1,2,4-Trichlorobenzene	Solvent	34551	120-82-1	0.12	MCL-CA	5	—
1,1,1-Trichloroethane (TCA)	Solvent	34506	71-55-6	0.032	MCL-US	200	—
1,1,2-Trichloroethane	Solvent	34511	79-00-5	0.04	MCL-US	5	—
Trichloroethene (TCE)	Solvent	39180	79-01-6	0.038	MCL-US	5	D
Trichlorofluoromethane (CFC-11)	Refrigerant	34488	75-69-4	0.08	MCL-CA	150	D
1,2,3-Trichloropropane (1,2,3-TCP)	Solvent/organic synthesis	77443	96-18-4	0.18	NL-CA	0.005	—
1,1,2-Trichloro-1,2,2-trifluoroethane (CFC-113)	Refrigerant	77652	76-13-1	0.038	MCL-CA	1,200	—
1,2,3-Trimethylbenzene	Gasoline hydrocarbon	77221	526-73-8	0.09	na	na	—
1,2,4-Trimethylbenzene	Gasoline hydrocarbon	77222	95-63-6	0.056	NL-CA	330	D
1,3,5-Trimethylbenzene	Organic synthesis	77226	108-67-8	0.044	NL-CA	330	D
Vinyl bromide (Bromoethene)	Fire retardant	50002	593-60-2	0.10	na	na	—
Vinyl chloride (Chloroethene)	Organic synthesis	39175	75-01-4	0.08	MCL-CA	0.5	—
m- and *p*-Xylene	Gasoline hydrocarbon	85795	108-38-3 / 106-42-3	0.06	MCL-CA	1,750	D
o-Xylene	Gasoline hydrocarbon	77135	95-47-6	0.038	MCL-CA	1,750	—

[1] The MCL-US and MCL-CA thresholds for trihalomethanes are the sum of chloroform, bromoform, bromodichloromethane, and dibromochloromethane.

[2] The RSD5 threshold for 1,3-dichloropropene is the sum of its isomers (*cis* and *trans*).

Table 3B. Gasoline oxygenates and their degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 4024.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; DLR-CA, detection level for the purpose of reporting (CDPH); LRL, laboratory reporting level; MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type	Threshold value (µg/L)	Detection
Acetone	Degradate	81552	67-64-1	1.8	na	na	D
tert-Amyl alcohol	Gasoline oxygenate	77073	75-85-4	1	na	na	—
tert-Butyl alcohol (TBA)	Oxygenate/degradate	77035	75-65-0	1	NL-CA	12	—
Diisopropyl ether	Gasoline oxygenate	81577	108-20-3	0.04	na	na	—
Ethyl *tert*-butyl ether (ETBE)	Gasoline oxygenate	50004	637-92-3	0.06	DLR-CA	3	—
Methyl acetate	Degradate	77032	79-20-9	0.43	na	na	—
Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	78032	1634-04-4	0.05	MCL-US	13	D
Methyl *tert*-pentyl ether	Gasoline oxygenate	50005	994-05-8	0.05	DLR-CA	3	—

Table 3C. Pesticides and pesticide degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032 and 2033.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Rice wells were sampled for Schedule 2033, whereas all other wells were sampled for Schedule 2032. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent[1]	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Type of comparison threshold	Threshold (µg/L)	Detection
Acetochlor	Herbicide	49260	34256-82-1	0.006	na	na	D
Alachlor	Herbicide	46342	15972-60-8	0.005	MCL-US	2	—
Atrazine	Herbicide	39632	1912-24-9	0.007	MCL-CA	1	D
Azinphos-methyl	Insecticide	82686	86-50-0	0.05	na	na	—
Azinphos-methyl-oxon	Degradate	61635	961-22-8	0.042	na	na	—
Benfluralin	Herbicide	82673	1861-40-1	0.01	na	na	—
Carbaryl	Insecticide	82680	63-25-2	0.041	RSD5	400	D
Carbofuran	Herbicide	82674	1563-66-2	0.02	MCL-CA	18	—
2-Chloro-2,6-diethylacetanilide	Degradate	61618	6967-29-9	0.0065	na	na	—
2-Chloro-4-isopropylamino-6-amino-s-triazine (deethylatrazine)	Degradate	04040	6190-65-4	0.014	na	na	D
4-Chloro-2-methylphenol	Degradate	61633	1570-64-5	0.005	na	na	—
Chlorpyrifos	Insecticide	38933	2921-88-2	0.005	HAL-US	2	D
Chlorpyrofos, oxygen analog	Degradate	61636	5598-15-2	0.0562	na	na	—
Cyanazine[2]	Herbicide	04041	21725-46-2	0.018	HAL-US	1	—
Cyfluthrin	Insecticide	61585	68359-37-5	0.053	na	na	—
λ-Cyhalothrin	Insecticide	61595	91465-08-6	0.014	na	na	—
Cypermethrin	Insecticide	61586	52315-07-8	0.046	na	na	—
DCPA (Dacthal) monoacid	Herbicide	82682	1861-32-1	0.003	HAL-US	70	—
Desulfinylfipronil	Degradate	62170	na	0.012	na	na	D
Desulfinylfipronil amide	Degradate	62169	na	0.029	na	na	—
Diazinon	Insecticide	39572	333-41-5	0.005	HAL-US	1	—
3,4-Dichloroaniline	Degradate	61625	95-76-1	0.0045	na	na	D
3,5-Dichloroaniline[2]	Degradate	61627	626-43-7	0.012	na	na	—
Dichlorvos	Fumigant	38775	62-73-7	0.013	na	na	—
Dicrotophos	Insecticide	38454	141-66-2	0.0843	na	na	—
Dieldrin	Insecticide	39381	60-57-1	0.009	RSD5	0.2	—
2,6-Diethylaniline	Degradate	82660	579-66-8	0.006	na	na	—
Dimethoate	Insecticide	82662	60-51-5	0.0061	na	na	—
Disulfoton[2]	Insecticide	82677	298-04-4	0.021	HAL-US	0.7	—
Disulfoton sulfone[2]	Degradate	61640	218208	0.014	na	na	—
α-Endosulfan[2]	Insecticide	34362	959-98-8	0.011	na	na	—
Endosulfan sulfate[2]	Degradate	61590	1031-07-8	0.022	na	na	—
EPTC[2]	Herbicide	82668	759-94-4	0.004	na	na	—
Ethion	Insecticide	82346	563-12-2	0.016	na	na	—
Ethion monoxon	Degradate	61644	17356-42-2	0.021	na	na	—
Ethoprophos[2]	Insecticide	82672	13194-48-4	0.012	na	na	—
2-Ethyl-6-methylaniline	Degradate	61620	24549-06-2	0.01	na	na	—
Fenamiphos	Insecticide	61591	22224-92-6	0.029	HAL-US	0.7	—
Fenamiphos sulfone	Degradate	61645	31972-44-8	0.053	na	na	—
Fenamiphos sulfoxide	Degradate	61646	31972-43-7	0.04	na	na	—
Fipronil	Insecticide	62166	120068-37-3	0.016	na	na	D
Fipronil sulfide	Degradate	62167	120067-83-6	0.013	na	na	D
Fipronil sulfone	Degradate	62168	120068-36-2	0.024	na	na	D
Fonofos	Insecticide	04095	944-22-9	0.0053	HAL-US	10	—
Hexazinone	Herbicide	04025	51235-04-2	0.026	HAL-US	400	D
Isofenphos	Insecticide	61594	25311-71-1	0.011	na	na	—
Malaoxon	Degradate	61652	1634-78-2	0.039	na	na	—

Table 3C. Pesticides and pesticide degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032 and 2033.—Continued

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Rice wells were sampled for Schedule 2033, whereas all other wells were sampled for Schedule 2032. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent[1]	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Type of comparison threshold	Threshold (µg/L)	Detection
Malathion	Insecticide	39532	121-75-5	0.027	HAL-US	100	—
Metalaxyl	Fungicide	61596	57837-19-1	0.0069	na	na	—
Methidathion	Insecticide	61598	950-37-8	0.0087	na	na	—
Methyl paraoxon[2]	Degradate	61664	950-35-6	0.019	na	na	—
Methyl parathion	Insecticide	82667	298-00-0	0.015	HAL-US	1	—
Metolachlor	Herbicide	39415	51218-45-2	0.006	HAL-US	700	D
Metribuzin	Herbicide	82630	21087-64-9	0.028	HAL-US	70	—
Molinate	Herbicide	82671	2212-67-1	0.003	MCL-CA	20	D
Myclobutanil	Fungicide	61599	88671-89-0	0.033	na	na	—
1-Naphthol	Degradate	49295	90-15-3	0.0882	na	na	—
Oxyfluorfen[2]	Herbicide	61600	42874-03-3	0.017	na	na	—
Pendimethalin	Herbicide	82683	40487-42-1	0.022	na	na	—
cis-Permethrin	Insecticide	82687	54774-45-7	0.006	na	na	—
Phorate	Insecticide	82664	298-02-2	0.055	na	na	—
Phorate oxygen analog	Degradate	61666	2600-69-3	0.027	na	na	—
Phosmet	Insecticide	61601	732-11-6	0.0079	na	na	D
Phosmet oxon	Degradate	61668	3735-33-9	0.0511	na	na	D
Prometon	Herbicide	04037	1610-18-0	0.01	HAL-US	100	—
Prometryn	Herbicide	04036	7287-19-6	0.0059	na	na	—
Pronamide	Herbicide	82676	23950-58-5	0.004	RSD5	200	—
Propargite[2]	Insecticide	82685	2312-35-8	0.023	na	na	—
Propanil	Herbicide	82679	709-98-8	0.011	na	na	D
cis-Propiconazole	Fungicide	79846	60207-90-1	0.013	na	na	D
trans-Propiconazole	Fungicide	79847	60207-90-1	0.034	na	na	D
Simazine	Herbicide	04035	122-34-9	0.005	MCL-US	4	D
Tebuconazole[2]	Fungicide	62852	107534-96-3	0.0136	na	na	—
Tebuthiuron	Herbicide	82670	34014-18-1	0.016	HAL-US	500	D
Tefluthrin[2]	Insecticide	61606	79538-32-2	0.0033	na	na	—
Terbufos	Insecticide	82675	13071-79-9	0.017	HAL-US	0.4	—
Terbufos oxygen analog sulfone	Degradate	61674	56070-15-6	0.045	na	na	—
Terbuthylazine	Herbicide	04022	5915-41-3	0.0083	na	na	—
Thiobencarb	Herbicide	82681	28249-77-6	0.01	MCL-CA	70	—
Tribufos	Herbicide	61610	78-48-8	0.035	na	na	—
Trifluralin	Herbicide	82661	1582-09-8	0.009	HAL-US	10	—

[1] Constituents on both Schedules 2032 and 2033 unless noted otherwise.

[2] Constituent on Schedule 2033 only.

Table 3D. Pesticides and pesticide degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 2060.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Type of comparison threshold	Threshold (µg/L)	Detection
Acifluorfen	Herbicide	49315	50594-66-6	0.028	na	na	—
Aldicarb	Insecticide	49312	116-06-3	0.15	MCL-US	3	—
Aldicarb sulfone	Insecticide/degradate	49313	1646-88-4	0.018	MCL-US	2	—
Aldicarb sulfoxide	Degradate	49314	1646-87-3	0.1	MCL-US	4	—
Atrazine	Herbicide	39632	1912-24-9	0.008	MCL-CA	1	D
Bendiocarb	Insecticide	50299	22781-23-3	0.08	na	na	—
Benomyl	Fungicide	50300	17804-35-2	0.022	na	na	—
Bensulfuron-methyl	Herbicide	61693	83055-99-6	0.018	na	na	D
Bentazon	Herbicide	38711	25057-89-0	0.024	MCL-CA	18	D
Bromacil	Herbicide	04029	314-40-9	0.018	HAL-US	70	—
Bromoxynil	Herbicide	49311	1689-84-5	0.044	na	na	—
Caffeine	Beverages	50305	58-08-2	0.018	na	na	—
Carbaryl	Insecticide	49310	63-25-2	0.018	RSD5	400	D
Carbofuran	Herbicide	49309	1563-66-2	0.016	MCL-CA	18	—
Chloramben, methyl ester	Herbicide	61188	7286-84-2	0.024	na	na	—
Chlorimuron-ethyl	Herbicide	50306	90982-32-4	0.032	na	na	D
2-Chloro-6-ethylamino-4-amino-*s*-triazine (deisopropylatrazine)	Degradate	04038	1007-28-9	0.08	na	na	D
2-Chloro-4-isopropylamino-6-amino-*s*-triazine (deethylatrazine)	Degradate	04040	6190-65-4	0.028	na	na	D
3-(4-Chlorophenyl)-1-methyl urea	Degradate	61692	5352-88-5	0.036	na	na	—
Clopyralid	Herbicide	49305	1702-17-6	0.067	na	na	—
Cycloate	Herbicide	04031	1134-23-2	0.014	na	na	—
DCPA (Dactal) monoacid	Degradate	49304	887-54-7	0.028	na	na	—
Dicamba	Herbicide	38442	1918-00-9	0.036	HAL-US	400	—
2,4-D and 2,4-D methyl ester, summed on molar basis, reported as 2,4-D	Herbicide	66496	94-75-7	0.009	MCL-US	70	D
4-(2,4-Dichlorophenoxy)butyric acid (2,4-DB)	Herbicide	38746	94-82-6	0.020	na	na	—
Dichlorprop	Herbicide	49302	120-36-5	0.028	na	na	—
Dinoseb	Herbicide	49301	88-85-7	0.038	MCL-US	7	D
Diphenamid	Herbicide	04033	957-51-7	0.010	HAL-US	200	—
Diuron	Herbicide	49300	330-54-1	0.016	RSD5	200	D
Fenuron	Herbicide	49297	101-42-8	0.01	na	na	—
Flumetsulam	Herbicide	61694	98967-40-9	0.04	na	na	—
Fluometuron	Herbicide	38811	2164-17-2	0.016	HAL-US	90	—
3-Hydroxycarbofuran	Degradate	49308	16655-82-6	0.008	na	na	—
2-Hydroxy-4-isopropylamino-6-ethylamino-*s*-triazine (hydroxyatrazine)	Degradate	50355	2163-68-0	0.032	na	na	D
Imazaquin	Herbicide	50356	81335-37-7	0.036	na	na	—
Imazethapyr	Herbicide	50407	81335-77-5	0.038	na	na	—
Imidacloprid	Insecticide	61695	138261-41-3	0.02	na	na	—
Linuron	Herbicide	38478	330-55-2	0.014	na	na	—
Metalaxyl	Fungicide	50359	57837-19-1	0.03	na	na	—
Methiocarb	Insecticide	38501	2032-65-7	0.034	na	na	—
Methomyl	Insecticide	49296	16752-77-5	0.07	HAL-US	200	—
2-Methyl-4-chlorophenoxyacetic acid (MCPA)	Herbicide	38482	94-74-6	0.07	HAL-US	4	D

Table 3D. Pesticides and pesticide degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 2060.—Continued

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Type of comparison threshold	Threshold (µg/L)	Detection
4-(2-Methyl-4-chlorophenoxy) butyric acid (MCPB)	Herbicide	38487	94-81-5	0.1	na	na	—
Metsulfuron methyl[1]	Herbicide	61697	74223-64-6	0.067	na	na	—
Neburon	Herbicide	49294	555-37-3	0.012	na	na	—
Nicosulfuron	Herbicide	50364	111991-09-4	0.04	na	na	—
Norflurazon	Herbicide	49293	27314-13-2	0.02	na	na	—
Oryzalin	Herbicide	49292	19044-88-3	0.023	na	na	—
Oxamyl	Insecticide	38866	23135-22-0	0.05	MCL-CA	50	—
Picloram	Herbicide	49291	1918-02-01	0.032	MCL-US	500	—
Propham	Herbicide	49236	122-42-9	0.03	HAL-US	100	—
Propiconazole	Fungicide	50471	60207-90-1	0.01	na	na	D
Propoxur	Insecticide	38538	114-26-1	0.008	na	na	—
Siduron	Herbicide	38548	1982-49-6	0.02	na	na	—
Sulfometuron-methyl	Herbicide	50337	74222-97-2	0.09	na	na	—
Tebuthiuron	Herbicide	82670	34014-18-1	0.026	HAL-US	500	D
Terbacil	Herbicide	04032	5902-51-2	0.026	HAL-US	90	—
Triclopyr	Herbicide	49235	55335-06-3	0.026	na	na	D

[1] These constituents were reported using method reporting levels (MRLs) during the period of this study.

Table 3E. Pharmaceutical compounds, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 2080.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Thresholds and threshold values as of February 10, 2007. CAS, Chemical Abstracts Service; MDL, method detection limit; na, not available; µg/L, micrograms per liter]

Constituent	Primary use or source	USGS parameter code	CAS number	MDL[1] (µg/L)	Threshold type	Threshold value (µg/L)
Acetaminophen	Analgesic	62000	103-90-2	0.60	na	na
Albuterol	Anti-inflammatory; bronchodilator	62020	18559-94-9	0.03	na	na
Caffeine	Stimulant	50305	58-08-2	0.40	na	na
Carbamazapine	Anticonvulsant; mood stabilizer	62793	298-46-4	0.02	na	na
Codeine	Opiod narcotic	62003	76-57-3	0.02	na	na
Cotinine	Nicotine metabolite	62005	486-56-6	0.03	na	na
Dehydronifedipine	Antianginal metabolite	62004	67035-22-7	0.03	na	na
Diltiazem	Antianginal; antihypertensive	62008	42399-41-7	0.02	na	na
Diphenhydramine	Antihistamine	62796	58-73-1	0.03	na	na
Paraxanthine	Caffeine metabolite	62030	611-59-6	0.10	na	na
Sulfamethoxazole	Antibacterial, antiprotozoal	62021	723-46-6	0.05	na	na
Thiabendazole	Anthelmintic	62801	148-79-8	0.02	na	na
Trimethoprim	Antibacterial	62023	738-70-5	0.01	na	na
Warfarin	Anticoagulant	62024	81-81-2	0.03	na	na

[1]The California Groundwater Ambient Monitoring and Assessment (GAMA) program uses more conservative reporting limits for the pharmaceutical compounds than recommended by the USGS's National Water Quality Laboratory. For albuterol, carbamazepine, codeine, dehydronifedipine, diltiazem, sulfamethoxazole, thiabendazole, trimethoprim, and warfarin, the MDL corresponds to the long-term method detection limit determined by the USGS's Branch of Quality Systems in October 2007 (BQS LT-MDL). For acetaminophen, caffeine, cotinine, diphenhydramine, and paraxanthine, the MDL corresponds to the effective method detection limit determined from assessment of quality-control data associated with GAMA samples collected from May 2004 to September 2007 (GAMA E-MDL). The GAMA E-MDL is higher than the BQS LT-MDL for those compounds. Detections reported by the USGS's National Water Quality Laboratory with concentrations lower than the BQS LT-MDL or GAMA E-MDL are reported as nondetections by the GAMA program.

Table 3F. Constituents of special interest, primary uses or sources, comparative thresholds, and reporting information for the Montgomery Watson Harza laboratory.

[The five-digit U.S. Geological Survey (USGS) parameter code is used to uniquely identify a specific constituent or property. Thresholds and threshold values as of October 18, 2007. The laboratory entity code for the Montgomery Watson Harza laboratory in the USGS's National Water Information System (NWIS) is CA-MWHL. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-CA, Lifetime Health Advisory Level (CDPH); MCL-CA, maximum contaminant level (CDPH); MRL, minimum reporting level; NL-CA, notification level (CDPH); µg/L, micrograms per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	MRL (µg/L)	Threshold type	Threshold value (µg/L)	Detection
Perchlorate	Rocket fuel, fireworks, flares	61209	14797-73-0	0.5	MCL-CA	6	D
1,2,3-Trichloropropane (1,2,3-TCP)	Fumigant, solvent	77443	96-18-4	0.005	HAL-CA	40	—
N-Nitrosodimethylamine (NDMA)	Rocket fuel, plasticizer	64176	62-75-9	0.002	NL-CA	10	—

Table 3G. Nutrients and dissolved organic carbon, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 2755 and parameter code 2613.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstracts Service; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-US, maximum contaminant level (USEPA); mg/L, milligrams per liter; na, not available; USEPA, U.S. Environmental Protection Agency]

Constituent	USGS parameter code	CAS number	LRL (mg/L)	Threshold type	Threshold value (mg/L)	Detection
Ammonia (as nitrogen)	00608	7664-41-7	0.01	HAL-US	30	D
Nitrate plus nitrite (as nitrogen)	00631	na	0.06	MCL-US	10	D
Nitrite (as nitrogen)	00613	14797-65-0	0.002	MCL-US	1	D
Total nitrogen (ammonia + nitrate + nitrite + organic nitrogen as nitrogen)	62854	17778-88-0	0.06	na	na	D
Orthophosphate (as phosphorus)	00671	14265-44-2	0.006	na	na	D
Dissolved organic carbon (DOC)	00681	na	0.33	na	na	D

Table 3H. Major and minor ions and trace elements, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 1948.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); mg/L, milligrams per liter; na, not available; NL-CA, notification level (CDPH); SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, not detected]

Constituent	USGS parameter code	CAS number	LRL	Threshold type	Threshold value	Detection
Major and minor ions (mg/L)						
Bromide	71870	24959-67-9	0.02	na	na	D
Calcium	00915	7440-70-2	0.02	na	na	D
Chloride	00940	16887-00-6	0.2	SMCL-CA	250 (500)[1]	D
Fluoride	00950	16984-48-8	0.1	MCL-CA	2	D
Iodide	78165	7553-56-2	0.002	na	na	D
Magnesium	00925	7439-95-4	0.008	na	na	D
Potassium	00935	7440-09-7	0.16	na	na	D
Silica	00955	7631-86-9	0.04	na	na	D
Sodium	00930	7440-23-5	0.2	na	na	D
Sulfate	00945	14808-79-8	0.18	SMCL-CA	250 (500)[1]	D
Total dissolved solids (TDS)	70300	na	10	SMCL-US	500 (1,000)[1]	D
Trace elements (µg/L)						
Aluminum	01106	7429-90-5	1.6	MCL-CA	1,000	D
Antimony	01095	7440-36-0	0.2	MCL-US	6	D
Arsenic	01000	7440-38-2	0.12	MCL-US	10	D
Barium	01005	7440-39-3	0.2	MCL-CA	1,000	D
Beryllium	01010	7440-41-7	0.06	MCL-US	4	—
Boron	01020	7440-42-8	8	NL-CA	1,000	D
Cadmium	01025	7440-43-9	0.04	MCL-US	5	D
Chromium	01030	7440-47-3	0.4	MCL-CA	50	D
Cobalt	01035	7440-48-4	0.04	na	na	D
Copper	01040	7440-50-8	0.4	AL-US	1,300	D
Iron	01046	7439-89-6	6	SMCL-CA	300	D
Lead	01049	7439-92-1	0.08	AL-US	15	D
Lithium	01130	7439-93-2	0.6	na	na	D
Manganese	01056	7439-96-5	0.2	SMCL-CA	50	D
Mercury	71890	7439-97-6	0.01	MCL-US	2	—
Molybdenum	01060	7439-98-7	0.4	HAL-US	40	D
Nickel	01065	7440-02-0	0.06	MCL-CA	100	D
Selenium	01145	7782-49-2	0.8	MCL-US	50	D
Silver	01075	7440-22-4	0.2	SMCL-CA	100	—
Strontium	01080	7440-24-6	0.4	HAL-US	4,000	D
Thallium	01057	7440-28-0	0.04	MCL-US	2	D
Tungsten	01155	7440-33-7	0.06	na	na	D
Uranium	22703	7440-61-1	0.04	MCL-US	30	D
Vanadium	01085	7440-62-2	0.1	NL-CA	50	D
Zinc	01090	7440-66-6	0.6	SMCL-US	5,000	D

[1] The recommended SMCL-CA thresholds for chloride, sulfate, and TDS are listed with the upper SMCL-CA thresholds in parentheses.

Table 3I. Arsenic, chromium, and iron species, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) Trace Metal Laboratory, Boulder, Colorado.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. The laboratory entity code for the USGS Trace Metal Laboratory in the USGS's National Water Information System (NWIS) is USGSTMCO. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); MDL, method detection limit; na, not available; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter]

Constituent (valence state)	USGS parameter code	CAS number	MDL (µg/L)	Threshold type	Threshold level (µg/L)	Detection
Inorganic Arsenic(III)	99034	22569-72-8	1	na	na	D
Inorganic Arsenic(Total)	99033	7440-38-2	0.5	MCL-US	10	D
Chromium(VI)	01032	18540-29-9	1	na	na	D
Chromium(Total)	01030	7440-47-3	1	MCL-CA	50	D
Iron(II)	01047	7439-89-6	2	na	na	D
Iron(Total)	01046	7439-89-6	2	SMCL-CA	300	D

Table 3J. Isotopic and radioactive constituents, comparative thresholds, and reporting information for laboratories.

[The five-digit U.S. Geological Survey (USGS) parameter code is used to uniquely identify a specific constituent or property. The laboratory entity codes for the laboratories in the USGS's National Water Information System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; hr, hour; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); MRL, minimum reporting level; MU, method uncertainty; na, not available; pCi/L, picocuries per liter; SSMDC, sample-specific minimum detectable concentration; USEPA, U.S. Environmental Protection Agency; —, not detected]

Constituent	USGS parameter code	CAS number	Reporting level type	Reporting level or uncertainty	Threshold type[1]	Threshold value	Detection
Stable isotope ratios (per mil)							
$\delta^{2}H$ of water[2]	82082	na	MU	2	na	na	D
$\delta^{18}O$ of water[2]	82085	na	MU	0.20	na	na	D
$\delta^{15}N$ of nitrate[2]	82690	na	MU	0.50	na	na	D
$\delta^{18}O$ of nitrate[2]	63041	na	MU	1.00	na	na	D
$\delta^{13}O$ of dissolved carbonates[3]	82081	na	1 sigma	0.05	na	na	D
Radioactive constituents (percent modern)							
Carbon-14[4]	49933	14762-75-5	1 sigma	0.0015	na	na	D
Radioactive constituents (pCi/L)							
Radon-222[5]	82303	14859-67-7	SSMDC	see table 14	Proposed MCL-US[2]	[6]300 (4,000)	D
Tritium[7]	07000	10028-17-8	MRL	1	MCL-CA	20,000	D
Gross-alpha radioactivity, 72-hr count and 30-day counts[8]	62636, 62639	12587-46-1	SSMDC	see table 14	MCL-US	15	D
Gross-beta radioactivity, 72-hr count and 30-day counts[8]	62642, 62645	12587-47-2	SSMDC	see table 14	MCL-CA	50	D
Radium-226[8]	09511	13982-63-3	SSMDC	see table 14	MCL-US[9]	5	D
Radium-228[8]	81366	15262-20-1	SSMDC	see table 14	MCL-US[9]	5	D

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA).

[3] University of Waterloo (contract laboratory) (CAN-UWIL).

[4] University of Arizona, Accelerator Mass Spectrometry Laboratory (contract laboratory) (AZ-UAMSL).

[5] USGS National Water Quality Laboratory (USGSNWQL).

[6] Two MCLs have been proposed for radon-222. The proposed alternaltive MCL is given in parentheses.

[7] USGS Stable Isotope and Tritium Laboratory, Menlo Park, California (USGSH3CA).

[8] Eberline Analytical Services (contract laboratory) (CA-EBERL).

[9] The MCL-US threshold for radium is the sum of radium-226 and radium-228.

Table 3K. Noble gases and tritium, comparison thresholds and reporting information for the Lawrence Livermore National Laboratory.

[The five-digit U.S. Geological Survey (USGS) parameter code is used to uniquely identify a specific constituent or property. The laboratory entity code for the Lawrence Livermore National Laboratory in the USGS's National Water Information System (NWIS) is CA-LLNL. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; cm^3 STP/g H_2O, cubic centimeters of gas at standard temperature and pressure per gram of water; MCL-CA, maximum contaminant level (CDPH); na, not available; pCi/L, picocuries per liter]

Constituent	USGS parameter code	CAS number	MU (percent)	Reporting units	Threshold type	Threshold value (pCi/L)	Detection
Helium-3/Helium-4	61040	na/7440-59-7	0.75	atom ratio	na	na	na
Argon	85563	7440-37-1	2	cm^3STP/g H_2O	na	na	na
Helium-4	85561	7440-59-7	2	cm^3STP/g H_2O	na	na	na
Krypton	85565	7439-90-9	2	cm^3STP/g H_2O	na	na	na
Neon	61046	7440-01-09	2	cm^3STP/g H_2O	na	na	na
Xenon	85567	7440-63-3	2	cm^3STP/g H_2O	na	na	na
Tritium	07000	10028-17-8	1	pCi/L	MCL-CA	20,000	na

Table 3L. Microbial constituents, comparison thresholds, and reporting information for the U.S. Geological Survey's (USGS) Ohio Microbiology Laboratory parameter codes 90901, 90900, 99335, and 99332.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. The laboratory entity code for the USGS's Ohio Microbiology Laboratory in the USGS's National Water Information System (NWIS) is given in footnote 3. MCL-US, maximum contaminant level (USEPA); MDL, method detection limit; mL, milliliters; na, not available; TT-US, U.S. Environmental Protection Agency treatment technique—a required process intended to reduce the level of contamination in drinking water; USEPA, U.S. Environmental Protection Agency; —, analyzed but not detected]

Constituent	USGS parameter code	Primary source	MDL	Threshold type[1]	Threshold value	Detection
Escherichia coliform[2]	90901	Sewage and animal waste indicator/intestinal tracts of humans and animals	1 colony/100 mL	TT-US	No fecal coliforms are allowed.	—
Total coliform (including fecal coliform and *E. coli*)[2]	90900	Water-quality indicator/ soil, water and intestinal tracts of animals	1 colony/100 mL	MCL-US	No more then 5 percent samples total coliform-positives in a month. Every sample that has total coloforms must be analyzed for fecal coliforms; no fecal coliforms are allowed.	—
F-specific coliphage[3]	99335	Viral indicator/intestinal tracts of warm-blooded animals	na	TT-US	99.99 percent killed/ inactivated	—
Somatic coliphage[3]	99332	Viral indicator/fecal contaminated waters	na	TT-US	99.99 percent killed/ inactivated	—

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] Analyzed in the field.

[3] Analyzed by the USGS's Ohio Microbiology Laboratory (laboratory entity code USGSOHML).

Table 4. Water-quality indicators in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[The five-digit number below the constituent name in the headings is the U.S. Geological Survey (USGS) parameter code used to uniquely identify a specific constituent or property. °C, degrees Celsius; CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; mg/L, milligrams per liter; mm, millimeter; na, not available; nc, sample not collected; no., number; NTU, nephelometric turbidity unit; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); SMCL-U.S., secondary maximum contaminant level (USEPA); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µS/cm, microsiemens per centimeter; *, value above recommended threshold level; **, value above upper threshold level; <, less than]

GAMA identification no.	Turbidity (NTU) (63676)	Dissolved oxygen (mg/L) (00300)	Water temperature (°C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab (µS/cm at 25°C) (90095)	Specific conductance, field (µS/cm at 25°C) (00095)	Alkalinity, lab (mg/L as $CaCO_3$) (29801)	Alkalinity, field (mg/L as $CaCO_3$) (29802)
Reporting limit or range	**0.1**	**0.2**	**0.0-38.5**	**0-14**	**0-14**	**5**	**5**	**1**	**1**
Threshold type	**na**[1]	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA**[2]	**SMCL-CA**[2]	**na**	**na**
Threshold level	**na**[1]	**na**	**na**	**6.5–8.5**	**6.5–8.5**	**900 (1,600)**	**900 (1,600)**	**na**	**na**
				Grid wells					
ESAC-01	nc	2.4	19.0	nc	nc	nc	372	nc	nc
ESAC-02	nc	<0.2	19.0	nc	nc	nc	** 2,040	nc	nc
ESAC-03	nc	3.2	23.0	7.8	7.8	432	417	146	nc
ESAC-04	nc	6.8	19.5	nc	7.5	nc	422	nc	nc
ESAC-05	nc	1.6	19.0	7.7	7.1	511	507	195	nc
ESAC-06	nc	6.9	21.0	7.5	7.1	209	208	106	nc
ESAC-07	nc	4.7	21.5	nc	7.7	nc	255	nc	nc
ESAC-08	nc	1.9	16.5	nc	7.7	nc	459	nc	nc
ESAC-09	nc	2.6	19.0	nc	* 6.3	nc	418	nc	nc
ESAC-10	nc	0.4	19.5	7.6	7.3	511	513	210	nc
ESAC-11	nc	0.4	21.0	7.7	7.4	212	220	111	nc
ESAC-12	nc	nc	18.5	7.9	nc	338	341	179	nc
ESAC-13	nc	3.9	16.5	nc	nc	nc	322	nc	nc
ESAC-14	nc	2.5	19.5	nc	7.0	nc	373	nc	nc
ESAC-15	nc	10.1	18.0	7.8	7.6	281	280	118	nc
ESAC-16	nc	9.9	20.0	7.7	7.5	385	380	134	nc
ESAC-17	nc	<0.2	19.0	7.7	7.3	* 959	898	304	nc
ESAC-18	nc	8.7	19.0	7.9	7.7	227	227	111	nc
ESAC-19	nc	2.3	21.0	7.6	7.0	429	421	191	nc
ESAC-20	nc	<0.2	20.6	nc	7.5	nc	321	nc	nc
ESAC-21	nc	<0.2	17.5	7.9	7.6	** 2,380	** 2,370	218	nc
ESAC-22	nc	8.9	18.5	7.0	* 6.5	312	314	81	nc
ESAC-23	nc	3.4	17.0	nc	* 6.3	nc	254	nc	nc
ESAC-24	nc	nc	19.5	nc	7.5	nc	281	nc	nc
ESAC-25	0.2	6.9	21.5	7.8	7.2	205	207	106	98
ESAC-26	0.1	<0.2	16.0	7.9	7.9	306	292	162	148
ESAC-27	0.1	0.8	19.0	7.3	7.1	497	486	221	212

Table 4. Water-quality indicators in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[The five-digit number below the constituent name in the headings is the U.S. Geological Survey (USGS) parameter code used to uniquely identify a specific constituent or property. °C, degrees Celsius; CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; mg/L, milligrams per liter; mm, millimeter; na, not available; nc, sample not collected; no., number; NTU, nephelometric turbidity unit; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); SMCL-U.S., secondary maximum contaminant level (USEPA); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µS/cm, microsiemens per centimeter; *, value above recommended threshold level; **, value above upper threshold level; <, less than]

GAMA identification no.	Turbidity (NTU) (63676)	Dissolved oxygen (mg/L) (00300)	Water temperature (°C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab (µS/cm at 25°C) (90095)	Specific conductance, field (µS/cm at 25°C) (00095)	Alkalinity, lab (mg/L as $CaCO_3$) (29801)	Alkalinity, field (mg/L as $CaCO_3$) (29802)
Reporting limit or range	**0.1**	**0.2**	**0.0-38.5**	**0-14**	**0-14**	**5**	**5**	**1**	**1**
Threshold type	**na[1]**	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA[2]**	**SMCL-CA[2]**	**na**	**na**
Threshold level	**na[1]**	**na**	**na**	**6.5–8.5**	**6.5–8.5**	**900 (1,600)**	**900 (1,600)**	**na**	**na**
ESAC-28	0.1	2.1	20.0	7.4	7.4	371	368	186	180
ESAC-29	nc	<0.2	17.0	8.0	nc	473	465	225	nc
ESAC-30	nc	0.2	15.5	7.9	7.8	432	408	121	nc
ESAC-31	nc	<0.2	18.5	7.8	7.6	642	613	297	nc
ESAC-32	nc	1.0	18.0	7.4	7.2	356	362	174	nc
ESAC-33	nc	4.1	20.0	nc	7.0	nc	367	nc	nc
ESAC-34	nc	2.5	17.5	7.6	7.2	593	591	273	nc
ESAC-35	nc	nc	17.5	7.7	7.4	331	324	168	nc
WSAC-01	nc	2.0	22.5	nc	8.1	nc	367	nc	nc
WSAC-02	nc	6.3	19.0	nc	7.3	nc	476	nc	nc
WSAC-03	0.1	7.7	20.0	7.5	7.3	338	337	133	122
WSAC-04	nc	<0.2	24.5	8.2	7.9	318	321	173	nc
WSAC-05	nc	<0.2	19.0	nc	7.9	nc	354	nc	nc
WSAC-06	nc	2.7	19.5	7.3	7.0	572	574	275	nc
WSAC-07	nc	7.0	18.0	nc	nc	nc	500	nc	nc
WSAC-07	nc	5.4	18.0	nc	7.1	nc	481	nc	nc
WSAC-08	0.2	4.1	20.5	7.4	7.0	535	536	221	202
WSAC-09	nc	6.3	19.0	nc	nc	nc	392	nc	nc
WSAC-09	nc	5.9	18.5	nc	6.9	nc	387	nc	nc
WSAC-10	nc	6.9	19.5	7.5	7.4	597	602	231	nc
WSAC-10	nc	6.2	19.5	nc	7.2	nc	562	nc	nc
WSAC-11	nc	7.1	23.5	7.8	7.8	652	649	189	nc
WSAC-11	nc	5.6	20.5	nc	7.7	nc	625	nc	nc
WSAC-12	0.3	<0.2	20.5	8.1	7.6	719	729	213	nc
WSAC-13	nc	2.1	20.0	nc	7.1	nc	782	nc	nc
WSAC-14	nc	<0.2	17.5	7.8	7.2	** 2,040	** 2,100	324	nc
WSAC-15	nc	6.9	18.0	7.6	7.1	* 938	* 931	388	nc

Table 4. Water-quality indicators in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[The five-digit number below the constituent name in the headings is the U.S. Geological Survey (USGS) parameter code used to uniquely identify a specific constituent or property. °C, degrees Celsius; CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; mg/L, milligrams per liter; mm, millimeter; na, not available; nc, sample not collected; no., number; NTU, nephelometric turbidity unit; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); SMCL-U.S., secondary maximum contaminant level (USEPA); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µS/cm, microsiemens per centimeter; *, value above recommended threshold level; **, value above upper threshold level; <, less than]

GAMA identification no.	Turbidity (NTU) (63676)	Dissolved oxygen (mg/L) (00300)	Water temperature (°C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab (µS/cm at 25°C) (90095)	Specific conductance, field (µS/cm at 25°C) (00095)	Alkalinity, lab (mg/L as $CaCO_3$) (29801)	Alkalinity, field (mg/L as $CaCO_3$) (29802)
Reporting limit or range	**0.1**	**0.2**	**0.0-38.5**	**0-14**	**0-14**	**5**	**5**	**1**	**1**
Threshold type	**na[1]**	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA[2]**	**SMCL-CA[2]**	**na**	**na**
Threshold level	**na[1]**	**na**	**na**	**6.5–8.5**	**6.5–8.5**	**900 (1,600)**	**900 (1,600)**	**na**	**na**
WSAC-16	nc	<0.2	19.0	nc	7.5	nc	* 1,240	nc	nc
WSAC-17	nc	1.3	18.0	7.5	7.2	428	429	204	nc
WSAC-18	0.1	<0.2	20.5	7.8	7.8	* 1,080	* 1,050	320	295
WSAC-19	nc	0.7	20.5	nc	7.6	nc	567	nc	nc
WSAC-20	nc	5.9	17.0	nc	7.0	nc	* 958	nc	nc
WSAC-21	nc	7.8	20.0	7.6	7.0	416	415	172	nc
WSAC-22	nc	5.1	21.0	7.8	7.7	516	523	211	nc
WSAC-23	nc	5.4	19.0	nc	7.2	nc	* 1,210	nc	nc
WSAC-24	nc	6.8	20.0	nc	7.2	nc	* 1,470	nc	nc
WSAC-25	nc	<0.2	19.5	8.0	7.8	465	449	222	nc
WSAC-26	nc	10.8	20.0	7.7	7.6	325	325	158	nc
WSAC-27	nc	0.5	18.5	nc	7.8	nc	* 914	nc	nc
WSAC-28	nc	4.8	19.5	7.4	7.2	433	425	168	nc
WSAC-29	nc	3.2	20.0	8.1	8.0	423	422	201	nc
WSAC-30	nc	2.2	19.0	7.7	7.4	** 1680	** 1,670	204	nc
WSAC-31	nc	1.8	19.0	8.2	8.0	279	280	129	nc
WSAC-32	nc	1.8	18.0	nc	7.8	nc	409	nc	nc
WSAC-33	nc	5.4	19.5	nc	7.6	nc	733	nc	nc
WSAC-34	nc	20.4	18.5	7.4	7.1	835	816	259	nc
WSAC-35	nc	13.3	18.5	7.6	7.3	475	478	206	nc
WSAC-36	nc	nc	18.5	7.9	7.6	424	461	216	nc
				Flow-path wells					
ESAC-FP-01	nc	<0.2	23.5	7.7	7.6	547	553	75	nc
ESAC-FP-02	6.6	4.0	23.5	7.5	7.2	441	449	202	nc
ESAC-FP-03	0.3	0.3	20.5	7.5	7.5	379	379	197	nc
ESAC-FP-04	1.0	0.5	20.5	8.2	8.3	206	206	108	nc
ESAC-FP-05	0.2	1.5	22.0	7.7	7.5	742	742	355	nc
ESAC-FP-06	3.1	0.2	22.0	* 8.9	* 8.8	315	316	134	nc

Table 4. Water-quality indicators in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[The five-digit number below the constituent name in the headings is the U.S. Geological Survey (USGS) parameter code used to uniquely identify a specific constituent or property. °C, degrees Celsius; CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; mg/L, milligrams per liter; mm, millimeter; na, not available; nc, sample not collected; no., number; NTU, nephelometric turbidity unit; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); SMCL-U.S., secondary maximum contaminant level (USEPA); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µS/cm, microsiemens per centimeter; *, value above recommended threshold level; **, value above upper threshold level; <, less than]

GAMA identification no.	Turbidity (NTU) (63676)	Dissolved oxygen (mg/L) (00300)	Water temperature (°C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab (µS/cm at 25°C) (90095)	Specific conductance, field (µS/cm at 25°C) (00095)	Alkalinity, lab (mg/L as $CaCO_3$) (29801)	Alkalinity, field (mg/L as $CaCO_3$) (29802)
Reporting limit or range	**0.1**	**0.2**	**0.0-38.5**	**0-14**	**0-14**	**5**	**5**	**1**	**1**
Threshold type	**na**[1]	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA**[2]	**SMCL-CA**[2]	**na**	**na**
Threshold level	**na**[1]	**na**	**na**	**6.5–8.5**	**6.5–8.5**	**900 (1,600)**	**900 (1,600)**	**na**	**na**
ESAC-FP-07	2.9	0.2	21.5	8.5	8.3	405	407	158	nc
WSAC-FP-01	0.7	5.7	24.0	7.9	7.6	342	338	182	nc
WSAC-FP-02	2.6	2.7	22.5	8.2	8.2	315	323	143	nc
WSAC-FP-03	3.6	5.8	23.0	8.0	7.8	416	421	176	nc
WSAC-FP-04	1.1	<0.2	20.0	* 8.6	* 8.6	315	312	148	nc
WSAC-FP-05	nc	0.2	21.5	8.0	8.0	* 928	* 934	250	nc
WSAC-FP-06	2.1	<0.2	21.0	8.5	8.4	349	344	142	nc
WSAC-FP-07	0.6	0.2	20.5	8.4	8.2	326	330	145	nc
WSAC-FP-08	1.4	1.4	20.5	7.9	7.6	403	409	185	nc
				RICE wells					
RICE-01	4.0	<0.2	19.0	7.0	6.8	** 13,600	** 13,800	nc	nc
RICE-02	0.3	<0.2	18.5	7.8	7.3	591	593	nc	335
RICE-03	0.2	<0.2	19.5	7.5	7.0	853	875	nc	432
RICE-04	0.7	0.4	17.5	7.4	6.8	630	644	nc	328
RICE-05	0.3	0.2	18.0	7.0	* 6.4	890	* 930	nc	426
RICE-06	0.2	<0.2	18.0	7.1	6.6	720	756	nc	384
RICE-07	1.1	0.2	20.0	7.8	7.3	784	803	nc	421
RICE-08	0.1	0.4	18.0	7.7	7.3	780	796	nc	378
RICE-09	1.8	<0.2	19.5	7.9	7.2	239	267	nc	128
RICE-10	0.4	<0.2	21.0	8.0	7.4	330	363	nc	169
RICE-11	0.9	0.2	20.0	7.3	7.0	*937	* 968	nc	414
RICE-12	0.9	<0.2	21.5	7.7	7.3	798	818	nc	397
RICE-13	1.0	<0.2	19.0	7.5	7.1	*915	* 944	nc	416
RICE-14	0.5	<0.2	18.5	7.3	7.0	823	844	nc	401
RICE-15	0.5	<0.2	17.0	7.8	7.3	* 947	* 944	nc	436
RICE-16	0.6	1.5	20.0	7.8	7.3	** 1,870	** 1840	nc	596

Table 4. Water-quality indicators in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[The five-digit number below the constituent name in the headings is the U.S. Geological Survey (USGS) parameter code used to uniquely identify a specific constituent or property. °C, degrees Celsius; CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; mg/L, milligrams per liter; mm, millimeter; na, not available; nc, sample not collected; no., number; NTU, nephelometric turbidity unit; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); SMCL-U.S., secondary maximum contaminant level (USEPA); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µS/cm, microsiemens per centimeter; *, value above recommended threshold level; **, value above upper threshold level; <, less than]

GAMA identification no.	Turbidity (NTU) (63676)	Dissolved oxygen (mg/L) (00300)	Water temperature (°C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab (µS/cm at 25°C) (90095)	Specific conductance, field (µS/cm at 25°C) (00095)	Alkalinity, lab (mg/L as $CaCO_3$) (29801)	Alkalinity, field (mg/L as $CaCO_3$) (29802)
Reporting limit or range	**0.1**	**0.2**	**0.0-38.5**	**0-14**	**0-14**	**5**	**5**	**1**	**1**
Threshold type	**na**[1]	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA**[2]	**SMCL-CA**[2]	**na**	**na**
Threshold level	**na**[1]	**na**	**na**	**6.5–8.5**	**6.5–8.5**	**900 (1,600)**	**900 (1,600)**	**na**	**na**
RICE-17	0.5	<0.2	18.5	7.7	7.4	** 4,770	** 4750	nc	350
RICE-18	0.4	<0.2	19.0	7.7	7.3	855	863	nc	343
RICE-19	0.2	<0.2	18.5	7.8	7.4	481	489	nc	245
RICE-20	0.2	<0.2	18.0	7.7	7.3	* 1,000	* 1,010	nc	407
RICE-21	0.1	0.2	18.5	7.6	7.3	** 1,650	** 1,680	nc	347
RICE-22	0.6	0.2	18.0	7.5	7.3	** 3,290	** 3,310	nc	415

[1]A TT-US threshold of 5 NTU does exist, but it applies to surface water and, therefore, is not included with this table.

[2] Specific conductance has a recommended and an upper threshold value. The upper value is shown in parentheses.

Table 5. Volatile organic compounds (VOCs), and gasoline oxygenates and degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use or source, and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Trihalomethanes			Gasoline Hydrocarbons and Oxygenates										
	Chloroform (Trichloromethane) (µg/L) (32106)	Bromodichloromethane (µg/L) (32101)	Bromoform (µg/L) (32104)	Methyl *tert*-butyl ether (MTBE) (µg/L) (78032)	1,2,4-Trimethylbenzene (µg/L) (77222)	1,3,5-Trimethylbenzene (µg/L) (77226)	1,2,3-Trimethylbenzene (µg/L) (77221)	1,2,3,4-Tetramethylbenzene (µg/L) (49999)	1,2,3,5-Tetramethylbenzene (µg/L) (50000)	2-Ethyltoluene (µg/L) (77220)	4-Isopropyltoluene (µg/L) (77356)	Benzene (µg/L) (34030)	*m*- and *p*-Xylene (µg/L) (85795)	Toluene (µg/L) (34010)
[LRL]	[0.024]	[0.028]	[0.1]	[0.1]	[0.056]	[0.044]	[0.09]	[0.14]	[0.18]	[0.06]	[0.08]	[0.021]	[0.06]	[0.02]
Threshold type[1]	MCL-US	MCL-US	MCL-US	MCL-CA	NL-CA	NL-CA	na	na	na	na	na	MCL-CA	MCL-CA	MCL-CA
Threshold (µg/L)	[2]80	[2]80	[2]80	13	330	330	na	na	na	na	na	1	1750	150
Grid wells														
ESAC-01	V0.01	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-02	V0.01	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-03	0.14	—	—	E0.1	—	—	—	—	—	—	—	—	—	—
ESAC-07	E0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-15	E0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-17	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-21	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-22	—	—	—	—	E0.07	E0.02	—	—	—	—	—	—	—	—
ESAC-25	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—
ESAC-27	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—
ESAC-28	E0.09	—	—	—	V0.05	—	—	—	—	—	—	—	—	—
ESAC-32	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-33	0.86	E0.04	—	0.1	—	—	—	—	—	—	—	—	—	—
WSAC-03	0.2	E0.03	0.11	—	—	—	—	—	—	—	—	—	—	—
WSAC-05	—	—	—	E0.1	—	—	—	—	—	—	—	—	—	—
WSAC-11	E0.08	—	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-12	—	—	—	—	V0.02	—	—	—	—	—	—	—	—	—
WSAC-16	0.16	E0.02	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-17	E0.05	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 5. Volatile organic compounds (VOCs), and gasoline oxygenates and degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use or source, and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Trihalomethanes			Gasoline Hydrocarbons and Oxygenates											
	Chloroform (Trichloromethane) (µg/L) (32106)	Bromodichloromethane (µg/L) (32101)	Bromoform (µg/L) (32104)	Methyl *tert*-butyl ether (MTBE) (µg/L) (78032)	1,2,4-Trimethylbenzene (µg/L) (77222)	1,3,5-Trimethylbenzene (µg/L) (77226)	1,2,3-Trimethylbenzene (µg/L) (77221)	1,2,3,4-Tetramethylbenzene (µg/L) (49999)	1,2,3,5-Tetramethylbenzene (µg/L) (50000)	2-Ethyltoluene (µg/L) (77220)	4-Isopropyltoluene (µg/L) (77356)	Benzene (µg/L) (34030)	*m*- and *p*-Xylene (µg/L) (85795)	Toluene (µg/L) (34010)
[LRL]	[0.024]	[0.028]	[0.1]	[0.1]	[0.056]	[0.044]	[0.09]	[0.14]	[0.18]	[0.06]	[0.08]	[0.021]	[0.06]	[0.02]
Threshold type[1]	MCL-US	MCL-US	MCL-US	MCL-CA	NL-CA	NL-CA	na	na	na	na	na	MCL-CA	MCL-CA	MCL-CA
Threshold (µg/L)	[2]80	[2]80	[2]80	13	330	330	na	na	na	na	na	1	1750	150
WSAC-18	—	—	—	—	0.15	—	—	—	—	—	—	—	—	—
WSAC-24	V0.02	—	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-27	—	—	—	—	V0.06	E0.04	E0.1	E0.1	E0.1	E0.02	E0.01	—	—	—
WSAC-28	—	—	—	—	V0.04	—	—	—	—	—	—	—	—	—
WSAC-33	E0.08	—	—	—	—	—	—	—	—	—	—	—	—	—
Number of wells with detections	10	3	1	4	3	2	1	1	1	1	1	0	0	0
Detection frequency (percent)	14	4	1	6	4	3	1	1	1	1	1			
Flow-path wells														
ESAC-FP-02	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-FP-03	—	—	—	—	—	—	—	—	—	—	—	—	—	V0.02
ESAC-FP-06	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-FP-07	—	—	—	—	V0.02	—	—	—	—	—	—	—	—	—
WSAC-FP-04	—	—	—	—	—	—	—	—	E0.1	—	—	—	—	—
WSAC-FP-05	—	—	—	—	V0.03	—	—	—	—	—	—	—	—	—
WSAC-FP-06	—	—	—	—	—	—	—	—	E0.2	—	—	—	—	—
RICE wells														
RICE-01	—	—	—	—	—	—	—	—	—	—	—	E0.02	—	—
RICE-05	—	—	—	—	—	—	—	—	—	—	—	—	V0.01	—

Table 5. Volatile organic compounds (VOCs), and gasoline oxygenates and degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Contined

[Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use or source, and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Solvents								Organic synthesis	Refrigerant	VOC detections per well
	Perchloroethene (PCE) (µg/L) (34475)	1,1-Dichloroethane (µg/L) (34496)	*cis*-1,2-Dichloroethene (µg/L) (77093)	Carbon tetrachloride (µg/L) (32102)	*trans*-1,2-Dichloroethene (µg/L) (34546)	Trichloroethene (TCE) (µg/L) (39180)	Acetone (µg/L) (81552)	2-Butanone (MEK, Methyl ethyl ketone) (µg/L) (81595)	Carbon disulfide (µg/L) (77041)	Trichlorofluoromethane (CFC-11) (µg/L) (34488)	
[LRL]	[0.03]	[0.035]	[0.024]	[0.06]	[0.032]	[0.038]	[6]	[2]	[0.038]	[0.08]	
Threshold type[1]	MCL-US	MCL-CA	MCL-CA	MCL-CA	MCL-CA	MCL-US	na	HAL-US	NL-CA	MCL-CA	
Threshold (µg/L)	5	5	6	0.5	10	5	na	4000	160	150	
Grid wells											
ESAC-01	—	—	—	—	—	—	—	—	—	—	0
ESAC-02	—	—	—	—	—	—	—	—	—	—	0
ESAC-03	E0.02	E0.03	—	—	—	—	—	—	—	—	4
ESAC-07	—	—	—	—	—	—	—	—	—	—	1
ESAC-15	0.51	0.11	2.06	—	E0.01	0.11	—	—	—	—	6
ESAC-17	—	—	—	—	—	—	—	—	0.15	—	1
ESAC-21	—	—	—	—	—	—	—	—	E0.05	—	1
ESAC-22	—	—	—	—	—	—	—	—	—	—	2
ESAC-25	—	—	—	—	—	—	—	—	—	—	1
ESAC-27	—	—	—	—	—	—	—	—	—	—	1
ESAC-28	—	—	—	—	—	—	—	—	—	—	1
ESAC-32	E0.05	—	—	—	—	—	—	—	—	—	1
ESAC-33	0.96	—	—	—	—	—	—	—	—	0.11	5
WSAC-03	—	—	—	—	—	—	—	—	—	—	3
WSAC-05	—	—	—	—	—	—	—	—	—	—	1
WSAC-11	—	—	—	—	—	—	—	—	—	—	1
WSAC-12	—	—	—	—	—	—	—	—	—	—	0
WSAC-16	—	—	—	—	—	—	—	—	—	—	2
WSAC-17	—	—	—	—	—	—	—	—	—	—	1

Table 5. Volatile organic compounds (VOCs), and gasoline oxygenates and degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Contined

[Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use or source, and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Solvents								Organic synthesis	Refrigerant	VOC detections per well
	Perchloroethene (PCE) (µg/L) (34475)	1,1-Dichloroethane (µg/L) (34496)	*cis*-1,2-Dichloroethene (µg/L) (77093)	Carbon tetrachloride (µg/L) (32102)	*trans*-1,2-Dichloroethene (µg/L) (34546)	Trichloroethene (TCE) (µg/L) (39180)	Acetone (µg/L) (81552)	2-Butanone (MEK, Methyl ethyl ketone)	Carbon disulfide (µg/L) (77041)	Trichlorofluoromethane (CFC-11) (µg/L) (34488)	
[LRL]	[0.03]	[0.035]	[0.024]	[0.06]	[0.032]	[0.038]	[6]	[2]	[0.038]	[0.08]	
Threshold type[1]	MCL-US	MCL-CA	MCL-CA	MCL-CA	MCL-CA	MCL-US	na	HAL-US	NL-CA	MCL-CA	
Threshold (µg/L)	5	5	6	0.5	10	5	na	4000	160	150	
WSAC-18	—	—	—	—	—	—	—	—	—	—	1
WSAC-24	—	—	—	E0.04	—	—	—	—	—	—	1
WSAC-27	—	—	—	—	—	—	—	—	—	—	6
WSAC-28	—	—	—	—	—	—	—	—	—	—	0
WSAC-33	—	—	—	—	—	—	—	—	—	—	1
Number of wells with detections	4	2	1	1	1	1	0	0	2	1	
Detection frequency (percent)	6	3	1	1	1	1			3	1	[3]28
Flow-path wells											
ESAC-FP-02	E0.03	—	—	0.18	—	—	—	—	—	—	2
ESAC-FP-03	—	—	—	—	—	—	—	—	—	—	0
ESAC-FP-06	—	—	—	—	—	—	—	—	E0.03	—	1
ESAC-FP-07	—	—	—	—	—	—	E2	6.4	E0.03	—	3
WSAC-FP-04	—	—	—	—	—	—	—	—	—	—	1
WSAC-FP-05	—	—	—	—	—	—	—	—	—	—	0
WSAC-FP-06	—	—	—	—	—	—	—	—	—	—	1
RICE wells											
RICE-01	—	—	—	—	—	—	—	—	—	—	1
RICE-05	—	—	—	—	—	—	—	—	—	—	0

[1]Maximum contaminant level thresholds are listed as MCL-US when MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The MCL-US threshold for trihalomethanes is the sum of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

[3] Frequency of detection of at least one VOC in the grid wells. Detections with V remark codes are not included.

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

	Herbicides											
GAMA identification no.	**Bentazon (µg/L) (38711)**	**Atrazine (µg/L) (39632)**	**Simazine (µg/L) (04035)**	**Metolachlor (µg/L) (39415)**	**Hexazinone (µg/L) (04025)**	**Dinoseb (µg/L) (49301)**	**Molinate (µg/L) (82671)**	**Prometon (µg/L) (04037)**	**Acetochlor (µg/L) (49260)**	**Metribuzin (µg/L) (82630)**	**Tebuthiuron (µg/L) (82670)**	**Propanil (µg/L) (82679)**
[LRL]	**[0.024]**	**[0.008]**	**[0.005]**	**[0.006]**	**[0.026]**	**[0.038]**	**[0.003]**	**[0.01]**	**[0.006]**	**[0.028]**	**[0.026]**	**[0.011]**
Threshold type[1]	**MCL-CA**	**MCL-CA**	**MCL-US**	**HAL-US**	**HAL-US**	**MCL-US**	**MCL-CA**	**HAL-US**	**na**	**HAL-US**	**HAL-US**	**na**
Threshold value	**18**	**1**	**4**	**700**	**400**	**7**	**20**	**100**	**na**	**70**	**500**	**na**
Grid wells												
ESAC-01	—	E0.004	E0.003	—	—	—	—	—	—	—	—	—
ESAC-05	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-09	0.09	—	E0.004	—	—	—	E0.02	—	—	—	—	0.097
ESAC-10	0.47	0.008	—	—	—	—	—	—	—	—	—	—
ESAC-20	0.02	—	—	—	—	—	0.013	—	—	—	—	—
ESAC-22	—	E0.004	E0.004	—	—	—	—	—	—	—	—	—
ESAC-23	—	0.077	—	0.028	—	—	—	0.02	0.059	—	—	—
ESAC-24	—	E0.007	E0.005	—	—	—	—	—	—	—	—	—
ESAC-26	—	—	0.011	—	—	—	—	—	—	—	—	—
ESAC-27	0.03	0.011	0.024	—	—	—	—	—	—	—	—	—
ESAC-28	0.05	E0.005	—	—	—	—	—	—	—	—	—	—
ESAC-31	0.43	—	—	—	—	—	—	—	—	—	—	—
ESAC-32	0.04	—	—	—	—	—	—	—	—	—	—	—
ESAC-33	0.04	E0.004	—	—	—	E0.004	—	—	—	—	—	—
ESAC-34	0.1	—	—	—	—	E0.01	—	—	—	—	—	—
ESAC-35	0.08	—	—	—	—	—	—	—	—	—	—	—
WSAC-02	—	0.04	E0.005	—	—	—	—	—	—	—	—	—
WSAC-06	—	E0.004	E0.004	—	—	—	—	—	—	—	—	—
WSAC-07	—	E0.005	E0.005	—	—	—	—	—	—	—	—	—
WSAC-08	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-09	—	E0.007	E0.004	—	—	—	—	—	—	—	—	—
WSAC-11	—	—	E0.005	—	—	—	—	—	—	—	—	—
WSAC-12	0.09	—	—	—	—	—	—	—	—	—	—	—
WSAC-13	0.08	—	—	—	—	—	—	—	—	—	—	—
WSAC-14	E0.01	—	—	—	—	—	—	—	—	—	—	—
WSAC-15	—	—	0.009	E0.005	E0.009	—	—	—	—	—	0.03	—
WSAC-16	E0.005	—	—	—	—	—	—	—	—	—	—	—

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Herbicides											
	Bentazon (µg/L) (38711)	Atrazine (µg/L) (39632)	Simazine (µg/L) (04035)	Metolachlor (µg/L) (39415)	Hexazinone (µg/L) (04025)	Dinoseb (µg/L) (49301)	Molinate (µg/L) (82671)	Prometon (µg/L) (04037)	Acetochlor (µg/L) (49260)	Metribuzin (µg/L) (82630)	Tebuthiuron (µg/L) (82670)	Propanil (µg/L) (82679)
[LRL]	**[0.024]**	**[0.008]**	**[0.005]**	**[0.006]**	**[0.026]**	**[0.038]**	**[0.003]**	**[0.01]**	**[0.006]**	**[0.028]**	**[0.026]**	**[0.011]**
Threshold type[1]	**MCL-CA**	**MCL-CA**	**MCL-US**	**HAL-US**	**HAL-US**	**MCL-US**	**MCL-CA**	**HAL-US**	**na**	**HAL-US**	**HAL-US**	**na**
Threshold value	**18**	**1**	**4**	**700**	**400**	**7**	**20**	**100**	**na**	**70**	**500**	**na**
WSAC-17	—	—	E0.006	—	E0.008	—	—	—	—	—	—	—
WSAC-18	E0.02	—	—	—	—	—	—	—	—	—	—	—
WSAC-20	—	E0.004	0.01	E0.005	—	—	—	—	—	0.113	—	—
WSAC-23	—	—	0.008	—	—	—	—	—	—	—	—	—
WSAC-27	0.29	—	—	—	—	—	—	—	—	—	—	—
WSAC-28	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-29	E0.004	E0.006	—	—	—	—	—	—	—	—	—	—
WSAC-31	0.09	—	—	—	—	—	—	—	—	—	—	—
WSAC-32	E0.01	E0.005	E0.004	—	—	—	—	—	—	—	—	—
WSAC-34	—	E0.008	—	—	—	—	—	—	—	—	—	—
WSAC-35	E0.005	E0.005	E0.004	—	E0.016	—	—	—	—	—	—	—
WSAC-36	0.11	—	—	—	—	—	—	—	—	—	—	—
Number of wells with detections	21	17	17	3	3	2	2	1	1	1	1	1
Detection frequency (percent)	30	24	24	4	4	3	3	1	1	1	1	1
Flow-path wells												
ESAC-FP-03	0.15	—	—	—	—	—	—	—	—	—	—	—
ESAC-FP-05	E0.01	—	—	—	—	—	—	—	—	—	—	—
ESAC-FP-06	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-FP-07	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-FP-06	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-FP-08	0.13	—	—	—	—	—	—	—	—	—	—	—

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Herbicides											
	Bentazon (µg/L) (38711)	Atrazine (µg/L) (39632)	Simazine (µg/L) (04035)	Metolachlor (µg/L) (39415)	Hexazinone (µg/L) (04025)	Dinoseb (µg/L) (49301)	Molinate (µg/L) (82671)	Prometon (µg/L) (04037)	Acetochlor (µg/L) (49260)	Metribuzin (µg/L) (82630)	Tebuthiuron (µg/L) (82670)	Propanil (µg/L) (82679)
[LRL]	**[0.024]**	**[0.008]**	**[0.005]**	**[0.006]**	**[0.026]**	**[0.038]**	**[0.003]**	**[0.01]**	**[0.006]**	**[0.028]**	**[0.026]**	**[0.011]**
Threshold type[1]	**MCL-CA**	**MCL-CA**	**MCL-US**	**HAL-US**	**HAL-US**	**MCL-US**	**MCL-CA**	**HAL-US**	**na**	**HAL-US**	**HAL-US**	**na**
Threshold value	**18**	**1**	**4**	**700**	**400**	**7**	**20**	**100**	**na**	**70**	**500**	**na**
RICE wells												
RICE-01	—	—	—	—	—	—	0.008	—	—	—	—	—
RICE-03	—	E0.007	E0.005	—	—	—	—	—	—	—	—	E0.006
RICE-04	0.11	—	—	—	—	—	—	—	—	—	—	—
RICE-06	0.04	—	E0.003	—	—	—	—	—	—	—	—	—
RICE-07	1.46	—	—	—	—	—	—	—	—	—	—	—
RICE-08	E0.02	—	—	—	—	—	—	—	—	—	—	—
RICE-09	—	—	E0.004	—	E0.013	—	—	—	—	—	—	—
RICE-10	—	—	0.082	—	—	—	—	—	—	—	—	—
RICE-11	0.03	E0.007	E0.005	—	—	—	—	—	—	—	—	—
RICE-12	0.42	E0.005	E0.008	—	—	—	—	—	—	—	—	—
RICE-13	0.32	—	—	—	—	—	—	—	—	—	—	—
RICE-14	0.14	—	—	—	—	—	—	—	—	—	0.02	—
RICE-15	0.32	E0.007	—	—	—	—	—	—	—	—	—	—
RICE-16	0.29	—	—	—	—	—	—	—	—	—	—	—
RICE-17	1.7	—	—	—	—	—	—	—	—	—	—	—
RICE-18	1.82	—	—	—	—	—	—	—	—	—	—	—
RICE-19	0.08	0.008	—	—	—	—	—	—	—	—	—	—
RICE-20	0.21	—	E0.004	—	—	—	—	—	—	—	—	—
RICE-21	0.45	—	—	—	—	—	—	—	—	—	—	—
RICE-22	0.23	—	—	—	E0.014	—	—	—	—	—	—	—

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Herbicides—continued						Insecticides		
	Bensulfuron-methyl (µg/L) (61693)	MCPA (µg/L) (38482)	Triclopyr (µg/L) (49235)	2,4-D, (µg/L) (39732)	Chlorimuron (µg/L) (50306)	Bromacil (µg/L) (04029)	Chlorpyrifos (µg/L) (38933)	Carbaryl (µg/L) (82680)	Fipronil (µg/L) (62166)
[LRL]	**[0.018]**	**[0.07]**	**[0.026]**	**[0.038]**	**[0.032]**	**0.018**	**[0.005]**	**[0.041]**	**[0.016]**
Threshold type[1]	**na**	**HAL-US**	**na**	**MCL-US**	**na**	**HAL-US**	**HAL-US**	**RSD5-US**	**na**
Threshold value	**na**	**30**	**na**	**70**	**na**	**70**	**2**	**400**	**na**
				Grid wells					
ESAC-01	—	—	—	—	—		—	—	—
ESAC-05	—	—	—	—	—	V0.01	—	—	—
ESAC-09	E0.01	E0.02	0.12	—	—	—	—	E0.007	—
ESAC-10	—	—	na	—	—	—	—	—	—
ESAC-20	—	—	na	—	—	—	—	—	—
ESAC-22	—	—	—	—	—	V0.03	—	—	—
ESAC-23	—	—	na	—	—	—	0.008	—	E0.017
ESAC-24	—	—	na	—	—	—	—	—	—
ESAC-26	—	—	na	—	—	—	—	—	—
ESAC-27	—	—	na	—	—	—	—	—	—
ESAC-28	—	—	—	—	—	—	—	—	—
ESAC-31	—	—	—	—	—	—	—	—	—
ESAC-32	—	—	—	—	—	—	—	—	—
ESAC-33	—	—	—	—	—	—	—	—	—
ESAC-34	—	—	—	—	—	—	—	—	—
ESAC-35	—	—	—	—	—	—	—	—	—
WSAC-02	—	—	—	—	—	—	—	—	—
WSAC-06	—	—	—	—	—	—	—	—	—
WSAC-07	—	—	—	—	—	V0.004	—	—	—
WSAC-08	—	—	na	—	—	—	—	—	—
WSAC-09	—	—	—	—	—	—	—	—	—
WSAC-11	—	—	—	—	—	—	—	—	—
WSAC-12	—	—	—	—	—	—	—	—	—
WSAC-13	—	—	na	—	—	—	—	—	—
WSAC-14	—	—	na	—	—	—	—	—	—
WSAC-15	—	—	—	—	—	—	—	—	—
WSAC-16	—	—	na	—	—	—	—	—	—
WSAC-17	—	—	na	—	—	—	—	—	—

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Herbicides—continued						Insecticides		
	Bensulfuron-methyl (µg/L) (61693)	MCPA (µg/L) (38482)	Triclopyr (µg/L) (49235)	2,4-D, (µg/L) (39732)	Chlorimuron (µg/L) (50306)	Bromacil (µg/L) (04029)	Chlorpyrifos (µg/L) (38933)	Carbaryl (µg/L) (82680)	Fipronil (µg/L) (62166)
[LRL]	**[0.018]**	**[0.07]**	**[0.026]**	**[0.038]**	**[0.032]**	**0.018**	**[0.005]**	**[0.041]**	**[0.016]**
Threshold type[1]	**na**	**HAL-US**	**na**	**MCL-US**	**na**	**HAL-US**	**HAL-US**	**RSD5-US**	**na**
Threshold value	**na**	**30**	**na**	**70**	**na**	**70**	**2**	**400**	**na**
WSAC-18	—	—	—	—	—	—	—	—	—
WSAC-20	—	—	—	—	—	—	—	—	—
WSAC-23	—	—	—	—	—	—	—	—	—
WSAC-27	—	—	—	—	—	—	—	—	—
WSAC-28	—	—	—	—	—	—	—	—	—
WSAC-29	—	—	—	—	—	—	—	—	—
WSAC-31	—	—	—	—	—	—	—	—	—
WSAC-32	—	—	—	—	—	—	—	—	—
WSAC-34	—	—	—	—	—	—	—	—	—
WSAC-35	—	—	—	—	—	—	—	—	—
WSAC-36	—	—	—	—	—	—	—	—	—
Number of wells with detections	1	1	1	0	0	0	1	1	1
Detection frequency (percent)	1	1	1				1	1	1
Flow-path wells									
ESAC-FP-03	—	—	—	—	—	—	—	—	—
ESAC-FP-05	—	—	—	E0.004	—	—	—	—	—
ESAC-FP-06	—	—	E0.02	—	—	—	—	—	—
ESAC-FP-07	—	—	E0.01	—	—	—	—	—	—
WSAC-FP-06	—	—	—	—	—	—	—	—	—
WSAC-FP-08	—	—	—	—	—	—	—	—	—

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Herbicides—continued						Insecticides		
	Bensulfuron-methyl (µg/L) (61693)	MCPA (µg/L) (38482)	Triclopyr (µg/L) (49235)	2,4-D, (µg/L) (39732)	Chlorimuron (µg/L) (50306)	Bromacil (µg/L) (04029)	Chlorpyrifos (µg/L) (38933)	Carbaryl (µg/L) (82680)	Fipronil (µg/L) (62166)
[LRL]	**[0.018]**	**[0.07]**	**[0.026]**	**[0.038]**	**[0.032]**	**0.018**	**[0.005]**	**[0.041]**	**[0.016]**
Threshold type[1]	**na**	**HAL-US**	**na**	**MCL-US**	**na**	**HAL-US**	**HAL-US**	**RSD5-US**	**na**
Threshold value	**na**	**30**	**na**	**70**	**na**	**70**	**2**	**400**	**na**
RICE wells									
RICE-01	—	—	—	—	—	—	—	—	—
RICE-03	—	—	—	—	—	—	—	—	—
RICE-04	—	—	—	—	—	—	—	—	—
RICE-06	—	—	—	—	—	—	—	—	—
RICE-07	—	—	—	—	—	—	—	—	—
RICE-08	—	—	—	—	—	—	—	—	—
RICE-09	—	—	—	—	—	—	—	—	—
RICE-10	—	—	—	—	1.57	—	—	—	—
RICE-11	—	—	—	—	—	—	—	—	—
RICE-12	—	—	—	—	—	—	—	—	—
RICE-13	—	—	—	—	—	—	—	—	—
RICE-14	—	—	—	—	—	—	—	—	—
RICE-15	—	—	—	—	—	—	—	—	—
RICE-16	—	—	—	—	—	—	—	—	—
RICE-17	—	—	—	—	—	—	—	—	—
RICE-18	—	—	—	—	—	—	—	—	—
RICE-19	—	—	—	—	—	—	—	—	—
RICE-20	—	—	—	—	—	—	—	—	—
RICE-21	—	—	—	—	—	—	—	—	—
RICE-22	—	—	—	—	—	—	—	—	—

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Fungicides		Degradates							Pesticide detections per well
	cis-Propiconazole (µg/L) (79846)	*trans*-Propiconazole (µg/L) (79847)	Deethylatrazine (µg/L) (04040)	3,4-Dichloroaniline (µg/L) (61625)	Hydroxyatrazine (µg/L) (50355)	Desulfinylfipronil (µg/L) (62170)	Fipronil sulfide (µg/L) (62167)	Fipronil sulfone (µg/L) (62168)	Deisopropylatrazine (µg/L) (04038)	
[LRL]	[0.013]	[0.034]	[0.028]	[0.0045]	[0.032]	[0.012]	[0.013]	[0.024]	[0.08]	
Threshold type[1]	na	na	na	na	na	na	na	na	na	
Threshold value	na	na	na	na	na	na	na	na	na	
Grid wells										
ESAC-01	—	—	E0.006	—	—	—	—	—	—	3
ESAC-05	—	—	—	—	—	—	—	—	—	0
ESAC-09	—	—	—	E0.541	—	—	—	—	—	9
ESAC-10	—	—	E0.008	—	—	—	—	—	—	3
ESAC-20	—	—	—	—	—	—	—	—	—	2
ESAC-22	—	—	—	—	—	—	—	—	—	2
ESAC-23	—	—	E0.022	—	—	E0.008	E0.006	E0.008	—	10
ESAC-24	—	—	E0.007	—	—	—	—	—	—	3
ESAC-26	—	—	—	—	—	—	—	—	—	1
ESAC-27	—	—	E0.011	—	—	—	—	—	—	4
ESAC-28	—	—	E0.009	—	—	—	—	—	—	3
ESAC-31	—	—	—	—	—	—	—	—	—	1
ESAC-32	—	—	—	—	—	—	—	—	—	1
ESAC-33	—	—	E0.01	—	—	—	—	—	—	4
ESAC-34	—	—	—	—	—	—	—	—	—	2
ESAC-35	—	—	—	—	—	—	—	—	—	1
WSAC-02	—	—	E0.057	E0.006	E0.003	—	—	—	—	5
WSAC-06	—	—	E0.007	—	na	—	—	—	—	3
WSAC-07	—	—	E0.006	—	—	—	—	—	—	3
WSAC-08	—	—	E0.007	—	—	—	—	—	—	1
WSAC-09	—	—	E0.009	—	—	—	—	—	—	3
WSAC-11	—	—	—	—	—	—	—	—	—	1
WSAC-12	—	—	—	—	—	—	—	—	—	1
WSAC-13	—	—	—	—	—	—	—	—	—	1
WSAC-14	—	—	—	—	—	—	—	—	—	1
WSAC-15	—	—	E0.005	—	—	—	—	—	—	5
WSAC-16	—	—	—	—	—	—	—	—	—	1

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Fungicides		Degradates							Pesticide detections per well
	cis-Propiconazole (µg/L) (79846)	*trans*-Propiconazole (µg/L) (79847)	Deethylatrazine (µg/L) (04040)	3,4-Dichloroaniline (µg/L) (61625)	Hydroxyatrazine (µg/L) (50355)	Desulfinylfipronil (µg/L) (62170)	Fipronil sulfide (µg/L) (62167)	Fipronil sulfone (µg/L) (62168)	Deisopropylatrazine (µg/L) (04038)	
[LRL]	**[0.013]**	**[0.034]**	**[0.028]**	**[0.0045]**	**[0.032]**	**[0.012]**	**[0.013]**	**[0.024]**	**[0.08]**	
Threshold type[1]	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	
Threshold value	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	
WSAC-17	—	—	—	E0.005	E0.024	—	—	—	—	4
WSAC-18	—	—	—	—	—	—	—	—	—	1
WSAC-20	—	—	E0.006	—	—	—	—	—	—	5
WSAC-23	—	—	—	—	—	—	—	—	—	1
WSAC-27	—	—	—	—	—	—	—	—	—	1
WSAC-28	—	—	E0.005	—	—	—	—	—	—	1
WSAC-29	—	—	E0.005	—	—	—	—	—	—	3
WSAC-31	—	—	—	—	—	—	—	—	—	1
WSAC-32	—	—	E0.006	—	—	—	—	—	—	4
WSAC-34	—	—	E0.007	—	—	—	—	—	—	2
WSAC-35	—	—	E0.006	E0.006	—	—	—	—	—	6
WSAC-36	—	—	—	—	—	—	—	—	—	1
Number of wells with detections	0	0	19	4	3	1	1	1	0	
Detection frequency (percent)			27	6	4	1	1	1		[2]54
Flow-path wells										
ESAC-FP-03	—	—	—	—	—	—	—	—	—	1
ESAC-FP-05	—	—	—	—	—	—	—	—	—	2
ESAC-FP-06	E0.001	E0.01	—	—	—	—	—	—	—	3
ESAC-FP-07	—	—	—	—	—	—	—	—	—	1
WSAC-FP-06	—	—	—	—	—	—	—	—	E0.04	1
WSAC-FP-08	—	—	—	—	—	—	—	—	—	1

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Fungicides		Degradates							Pesticide detections per well
	cis-Propicon-azole (µg/L) (79846)	*trans*-Propicon-azole (µg/L) (79847)	Deethyl-atrazine (µg/L) (04040)	3,4-Dichloro-aniline (µg/L) (61625)	Hydroxy-atrazine (µg/L) (50355)	Desulfinyl-fipronil (µg/L) (62170)	Fipronil sulfide (µg/L) (62167)	Fipronil sulfone (µg/L) (62168)	Deisopropyl-atrazine (µg/L) (04038)	
[LRL]	[0.013]	[0.034]	[0.028]	[0.0045]	[0.032]	[0.012]	[0.013]	[0.024]	[0.08]	
Threshold type[1]	na	na	na	na	na	na	na	na	na	
Threshold value	na	na	na	na	na	na	na	na	na	
RICE wells										
RICE-01	—	—	—	—	—	—	—	—	—	1
RICE-03	—	—	E0.006	—	—	—	—	—	—	4
RICE-04	—	—	—	—	—	—	—	—	—	1
RICE-06	—	—	—	E0.004	—	—	—	—	—	3
RICE-07	—	—	—	—	—	—	—	—	—	1
RICE-08	—	—	—	—	—	—	—	—	—	1
RICE-09	—	—	—	—	—	—	—	—	—	2
RICE-10	—	—	—	E0.091	—	—	—	—	0.15	4
RICE-11	—	—	E0.006	—	—	—	—	—	—	4
RICE-12	—	—	E0.006	E0.006	—	—	—	—	—	5
RICE-13	—	—	—	—	—	—	—	—	—	1
RICE-14	—	—	—	—	—	—	—	—	—	2
RICE-15	—	—	—	—	—	—	—	—	—	2
RICE-16	—	—	—	—	—	—	—	—	—	1
RICE-17	—	—	—	E0.005	—	—	—	—	—	2
RICE-18	—	—	—	—	—	—	—	—	—	1
RICE-19	—	—	E0.006	—	—	—	—	—	—	3
RICE-20	—	—	—	—	—	—	—	—	—	2
RICE-21	—	—	—	—	—	—	—	—	—	1
RICE-22	—	—	—	—	—	—	—	—	—	2

[1] Maximum contaminant level thresholds are listed as MCL-US when MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] Frequency of detection of at least one pesticide in the grid wells. Detections with V remark codes are not included.

Table 7. Constituents of special interest (perchlorate, *N*-nitrosodimethylamine [NDMA], and 1,2,3-trichloropropane [1,2,3-TCP]) detected in samples collected in the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from all 108 wells were analyzed for perchlorate; samples from 45 grid wells and 15 flow-path wells were sampled for NDMA and 1,2,3-TCP; only wells with at least one detection are listed. Analyses done by the Mongomery Watson Harza laboratory. The laboratory entity code for the Montgomery Watson Harza laboratory in the U. S. Geological Survey's National Water Information System (NWIS) is CA-MWHL. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; MCL-CA, maximum contaminant level (CDPH); MRL, minimum reporting level; no., number; RICE, RICE well; WSAC, West study area of the middle Sacramento Valley study unit; µg/L, micrograms per liter]

GAMA identification no.	**Perchlorate (µg/L)**
Threshold Type	**MCL-CA**
Threshold (µg/L)	**6**
[MRL]	**[0.5]**
Grid wells	
ESAC-03	0.6
ESAC-04	1.4
WSAC-20	0.6
WSAC-24	1.4
Number of wells with detections	4
Detection frequency (percent)	6
RICE wells	
RICE-10	1.3

Table 8. Nutrients and dissolved organic carbon detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed for nutrients; samples from all slow grid wells and all RICE wells were analyzed for dissolved organic carbon. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-US, maximum contaminant level (USEPA); mg/L, milligrams per liter; na, not available; nc, not collected; no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Ammonia (mg/L) as nitrogen (00608)	Nitrite plus nitrate (mg/L) as nitrogen (00631)	Nitrite (mg/L) as nitrogen (00613)	Total nitrogen (nitrate + nitrite + ammonia + organic-N) (mg/L) (62854)	Orthophosphate (mg/L) as phosphorus (00671)	Dissolved organic carbon (DOC) (mg/L) (00681)
[LRL]	**[0.01]**	**[0.06]**	**[0.002]**	**[0.06]**	**[0.006]**	**[0.33]**
Threshold type[1]	**HAL-US**	**MCL-US**	**MCL-US**	**na**	**na**	**na**
Threshold value	**[2]24.7**	**10**	**1**	**na**	**na**	**na**
			Grid wells			
ESAC-03	—	2.46	—	2.50	0.075	nc
ESAC-05	—	6.25	—	6.25	0.168	nc
ESAC-06	—	0.79	—	0.82	0.118	nc
ESAC-10	0.016	0.30	0.005	0.34	0.095	nc
ESAC-11	—	—	—	—	0.100	nc
ESAC-12	—	0.82	—	[3]0.81	0.058	nc
ESAC-15	E0.008	—	—	[4]—	V0.003	nc
ESAC-16	E0.008	0.78	—	[5]0.71	0.092	nc
ESAC-17	0.075	—	—	V0.07	0.167	nc
ESAC-18	E0.006	0.74	—	[5]0.67	0.086	nc
ESAC-19	—	0.50	—	[5]0.45	0.090	nc
ESAC-21	0.117	—	—	V0.16	0.120	nc
ESAC-22	—	*10.4	—	8.81	0.053	nc
ESAC-25	—	0.54	—	0.54	0.112	E0.2
ESAC-26	0.056	—	—	V0.04	0.499	0.5
ESAC-27	E0.008	0.86	—	0.92	0.100	0.8
ESAC-28	—	1.62	—	[3]1.58	0.194	E0.3
ESAC-29	0.095	—	—	V0.12	0.240	nc
ESAC-30	—	0.13	0.011	V0.16	0.256	nc
ESAC-31	E0.006	0.13	E0.001	V0.14	0.101	nc
ESAC-32	—	0.92	—	0.95	0.090	nc
ESAC-34	—	0.89	—	0.91	0.108	nc
ESAC-35	—	0.76	—	0.78	0.066	nc
WSAC-03	—	3.38	—	[3]3.3	0.036	E0.2
WSAC-04	E0.005	—	—	[4]—	0.040	nc
WSAC-06	—	1.03	—	1.10	0.028	nc
WSAC-08	E0.006	3.43	—	[3]3.23	0.031	E0.3
WSAC-10	—	6.49	—	[3]6.35	0.027	nc
WSAC-11	—	2.27	—	[3]2.13	0.065	nc
WSAC-12	0.124	—	—	V0.17	0.200	0.5
WSAC-14	0.011	1.29	0.003	[3]1.26	0.077	nc
WSAC-15	—	*13	—	13.50	0.047	nc

Table 8. Nutrients and dissolved organic carbon detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed for nutrients; samples from all slow grid wells and all RICE wells were analyzed for dissolved organic carbon. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-US, maximum contaminant level (USEPA); mg/L, milligrams per liter; na, not available; nc, not collected; no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Ammonia (mg/L) as nitrogen (00608)	Nitrite plus nitrate (mg/L) as nitrogen (00631)	Nitrite (mg/L) as nitrogen (00613)	Total nitrogen (nitrate + nitrite + ammonia + organic-N) (mg/L) (62854)	Orthophosphate (mg/L) as phosphorus (00671)	Dissolved organic carbon (DOC) (mg/L) (00681)
[LRL]	**[0.01]**	**[0.06]**	**[0.002]**	**[0.06]**	**[0.006]**	**[0.33]**
Threshold type[1]	**HAL-US**	**MCL-US**	**MCL-US**	**na**	**na**	**na**
Threshold value	**[2]24.7**	**10**	**1**	**na**	**na**	**na**
WSAC-17	—	0.73	—	[3]0.72	0.257	nc
WSAC-18	—	0.57	0.003	0.59	0.070	E0.2
WSAC-21	—	6.04	—	[3]5.73	0.081	nc
WSAC-22	E0.008	1.24	—	[3]1.22	0.047	nc
WSAC-25	E0.006	E0.05	—	V0.06	0.101	nc
WSAC-26	E0.005	3.02	—	3.15	0.049	nc
WSAC-28	—	2.54	—	2.64	0.097	nc
WSAC-29	E0.005	1.84	—	1.89	0.043	nc
WSAC-30	E0.005	7.38	—	[3]7.36	0.037	nc
WSAC-31	—	0.77	—	[3]0.75	0.077	nc
WSAC-34	—	9.10	—	[3]8.99	0.032	nc
WSAC-35	—	0.97	—	1.04	0.036	nc
WSAC-36	—	0.45	—	0.51	0.103	nc
			Flow-path wells			
ESAC-FP-01	0.320	—	—	V0.33	0.031	nc
ESAC-FP-02	—	2.37	0.010	[3]2.20	0.033	nc
ESAC-FP-03	—	0.33	0.018	V0.35	0.084	nc
ESAC-FP-04	—	0.16	0.002	V0.14	0.056	nc
ESAC-FP-05	—	6.01	E0.002	[3]5.61	0.100	nc
ESAC-FP-06	0.027	—	—	[4]—	0.062	nc
ESAC-FP-07	0.028	—	—	[4]—	0.077	nc
WSAC-FP-01	V0.007	1.32	—	1.42	0.050	nc
WSAC-FP-02	V0.007	0.76	—	0.76	0.038	nc
WSAC-FP-03	V0.009	2.82	E0.001	2.78	0.040	nc
WSAC-FP-04	0.014	—	—	[4]—	0.063	nc
WSAC-FP-05	E0.009	E0.03	E0.002	V0.07	0.064	nc
WSAC-FP-06	—	0.27	0.008	V0.27	0.034	nc
WSAC-FP-07	V0.009	—	—	[4]—	0.055	nc
WSAC-FP-08	—	1.89	—	1.97	0.052	nc

Table 8. Nutrients and dissolved organic carbon detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed for nutrients; samples from all slow grid wells and all RICE wells were analyzed for dissolved organic carbon. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-US, maximum contaminant level (USEPA); mg/L, milligrams per liter; na, not available; nc, not collected; no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Ammonia (mg/L) as nitrogen (00608)	Nitrite plus nitrate (mg/L) as nitrogen (00631)	Nitrite (mg/L) as nitrogen (00613)	Total nitrogen (nitrate + nitrite + ammonia + organic-N) (mg/L) (62854)	Orthophosphate (mg/L) as phosphorus (00671)	Dissolved organic carbon (DOC) (mg/L) (00681)
[LRL]	**[0.01]**	**[0.06]**	**[0.002]**	**[0.06]**	**[0.006]**	**[0.33]**
Threshold type[1]	**HAL-US**	**MCL-US**	**MCL-US**	**na**	**na**	**na**
Threshold value	[2]**24.7**	**10**	**1**	**na**	**na**	**na**
			RICE wells			
RICE-01	0.517	—	—	0.51	0.109	—
RICE-02	—	0.88	—	0.86	0.149	V0.8
RICE-03	—	1.72	—	1.67	0.057	V0.9
RICE-04	V0.007	0.47	—	0.55	0.093	1.1
RICE-05	V0.013	—	—	V0.13	0.099	2.4
RICE-06	V0.005	0.27	—	V0.32	0.079	1.6
RICE-07	V0.006	0.11	—	V0.11	0.098	1.0
RICE-08	—	1.83	—	1.78	0.082	V0.5
RICE-09	—	E0.04	—	V0.07	0.101	V0.7
RICE-19	V0.008	—	—	V0.06	0.106	1.1
RICE-20	V0.005	3.77	0.005	3.80	0.326	1.4
RICE-10	—	0.36	—	V0.37	0.160	1.0
RICE-11	V0.008	4.93	0.006	4.98	0.058	2.6
RICE-12	V0.01	0.40	0.006	0.47	0.115	1.4
RICE-13	—	3.82	0.026	3.75	0.104	2.3
RICE-14	—	—	—	V0.1	0.051	2.3
RICE-15	—	0.30	—	V0.31	0.097	1.3
RICE-16	V0.007	0.08	0.003	V0.1	0.086	1.2
RICE-17	V0.005	0.88	—	0.99	0.100	2.1
RICE-18	V0.006	0.71	—	0.78	0.076	V0.7
RICE-21	V0.011	0.17	—	V0.21	0.041	V0.8
RICE-22	V0.011	—	—	V0.08	0.048	1.3

[1]Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The HAL-US is 30 mg/L "as ammonia." To facilitate comparison to the analytical results, we have converted and reported this HAL-US as 24.7 mg/L "as nitrogen."

[3]Total nitrogen in these samples is less than the sum of the filtered nitrogen analytes, but falls within the USGS's National Water Quality Laboratory acceptance criteria of a 10 percent relative percent difference.

[4]Total nitrogen in these samples is less than the sum of the filtered nitrogen analytes and exceeds the USGS's National Water Quality Laboratory acceptance criteria of 10 percent relative difference, but the sum of the filtered nitrogen analytes is less than the LRL for total nitrogen.

[5]Total nitrogen in these samples is less than the sum of the filtered nitrogen analytes and exceeds the USGS's National Water Quality Laboratory acceptance criteria of 10 percent relative difference. Values were verified by the laboratory.

Table 9. Major and minor ions and total dissolved solids detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); mg/L, milligrams per liter; na, not available; no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, analyzed but not detected; *, value above threshold level; **, value above upper threshold level]

GAMA identification no.	Bromide (mg/L) (71870)	Calcium (mg/L) (00915)	Chloride (mg/L) (00940)	Fluoride (mg/L) (00950)	Iodide (mg/L) (71865)	Magnesium (mg/L) (00925)	Potassium (mg/L) (00935)	Silica (mg/L) (00955)	Sodium (mg/L) (00930)	Sulfate (mg/L) (00945)	Total dissolved solids (TDS) (mg/L) (70301)	Bicarbonate[1] (mg/L as $CaCO_3$)	Carbonate[1] (mg/L as $CaCO_3$)
Threshold type[2]	**na**	**na**	**SMCL-CA[3]**	**MCL-CA**	**na**	**na**	**na**	**na**	**na**	**SMCL-CA[3]**	**SMCL-CA[3]**	**na**	**na**
Threshold (mg/L)	**na**	**na**	**250 (500)**	**2.00**	**na**	**na**	**na**	**na**	**na**	**250 (500)**	**500 (1,000)**	**na**	**na**
[LRL]	**[0.02]**	**[0.02]**	**[0.2]**	**[0.1]**	**[0.002]**	**[0.008]**	**[0.16]**	**[0.04]**	**[0.2]**	**[0.18]**	**[10]**	**[1]**	**[1]**
Grid wells													
ESAC-03	0.06	29.1	21.5	E0.09	0.002	16.4	1.39	34.2	38.1	33.5	274	177	1
ESAC-05	0.11	32.7	7.85	E0.07	0.002	36.8	3.51	63.6	19.1	44.1	353	237	1
ESAC-06	—	18.1	2.26	E0.08	—	12.1	1.75	71.7	7.33	1.5	183	129	—
ESAC-10	0.11	40.6	36.6	0.15	0.036	28.1	1.73	42.7	23.6	13.9	316	255	—
ESAC-11	0.03	13.6	4.62	E0.07	0.019	10.5	3.73	75.7	17.1	2.0	194	135	—
ESAC-12	0.05	23.9	12.9	0.12	E0.001	12.5	1.59	34.9	30	9.5	237	217	1
ESAC-15	0.03	22.4	8.13	E0.07	—	14.4	1.17	60.0	11.9	6.3	195	143	—
ESAC-16	0.08	18.9	36.3	E0.08	—	14.0	3.25	63.7	35.9	10.3	267	163	—
ESAC-17	0.23	55.4	124	0.11	0.079	48.9	5.10	50.3	61.7	22.0	* 552	369	1
ESAC-18	—	17.9	5.12	E0.09	—	11.3	2.38	59.1	10.7	2.6	179	134	—
ESAC-19	E0.01	38.1	9.65	0.24	—	17.8	3.46	69.5	24.7	25.0	306	232	—
ESAC-21	1.71	58.2	** 626	—	1.110	25.0	8.28	36.8	401	—	**1,290	264	1
ESAC-22	0.05	23.0	11.4	—	E0.001	17.4	0.31	60.6	12	21.0	240	99	—
ESAC-25	—	17.2	2.07	E0.09	—	11.3	1.35	67.4	8.43	2.5	177	129	—
ESAC-26	—	8.84	4.12	0.14	0.025	7.85	1.20	47.4	47.7	4.0	212	196	1
ESAC-27	0.14	39.6	19.6	E0.06	0.037	29.0	1.68	50.1	20.6	20.6	312	269	—
ESAC-28	0.02	24.1	5.55	0.14	E0.001	26.4	2.62	61.2	15.2	6.8	259	226	—
ESAC-29	0.07	24.5	15.0	E0.08	0.068	15.6	2.44	37.1	54.8	10.6	297	272	1
ESAC-30	0.16	18.7	58.5	0.11	0.040	21.7	1.67	48.6	36.6	7.3	268	146	1
ESAC-31	0.09	50.1	27.9	E0.08	0.105	32.2	2.49	50.3	49.5	17.4	410	360	1
ESAC-32	E0.02	32.5	4.62	—	—	21.7	1.45	52.1	9.17	12.6	243	212	—
ESAC-34	0.08	50.3	13.5	0.11	0.003	34.4	1.83	62.4	26.9	38.6	397	332	1
ESAC-35	—	28.8	2.60	—	—	19.2	1.55	57.0	10.2	8.4	232	204	—
WSAC-03	—	32.3	7.11	0.10	—	16.2	0.70	28.9	12.8	20.8	207	162	—
WSAC-04	0.03	16.5	5.11	0.18	0.021	15.9	0.56	24.9	34.2	1.2	203	208	2
WSAC-06	0.05	40.5	15.2	0.29	0.003	37.7	0.57	30.3	24.4	24.7	344	335	—
WSAC-08	0.05	67.5	21.4	E0.09	E0.001	19.7	0.84	19.5	17.9	25.8	310	269	—
WSAC-10	0.06	66.5	23.1	E0.08	E0.002	23.8	0.87	21.8	21.8	31.8	329	281	—
WSAC-11	0.28	29.4	87.4	0.21	0.006	29.9	1.05	30.0	51.9	10.5	365	229	1
WSAC-12	0.25	22.8	50.8	0.11	0.125	16.2	1.50	41.3	115	62.3	440	257	1
WSAC-14	0.81	84.5	236	0.42	0.524	70.4	2.12	42.0	259	* 429	** 1,330	393	1
WSAC-15	0.12	48.6	27.1	0.29	0.010	35.6	1.80	26.0	101	49.5	* 584	472	1

Table 9. Major and minor ions and total dissolved solids detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); mg/L, milligrams per liter; na, not available; no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, analyzed but not detected; *, value above threshold level; **, value above upper threshold level]

GAMA identification no.	Bromide (mg/L) (71870)	Calcium (mg/L) (00915)	Chloride (mg/L) (00940)	Fluoride (mg/L) (00950)	Iodide (mg/L) (71865)	Magnesium (mg/L) (00925)	Potassium (mg/L) (00935)	Silica (mg/L) (00955)	Sodium (mg/L) (00930)	Sulfate (mg/L) (00945)	Total dissolved solids (TDS) (mg/L) (70301)	Bicarbonate[1] (mg/L as $CaCO_3$)	Carbonate[1] (mg/L as $CaCO_3$)
Threshold type[2]	**na**	**na**	**SMCL-CA[3]**	**MCL-CA**	**na**	**na**	**na**	**na**	**na**	**SMCL-CA[3]**	**SMCL-CA[3]**	**na**	**na**
Threshold (mg/L)	**na**	**na**	**250 (500)**	**2.00**	**na**	**na**	**na**	**na**	**na**	**250 (500)**	**500 (1,000)**	**na**	**na**
[LRL]	**[0.02]**	**[0.02]**	**[0.2]**	**[0.1]**	**[0.002]**	**[0.008]**	**[0.16]**	**[0.04]**	**[0.2]**	**[0.18]**	**[10]**	**[1]**	**[1]**
WSAC-17	E0.01	27.3	7.38	0.12	0.008	23.4	1.62	37.6	29.7	20.6	275	248	—
WSAC-18	0.40	50.5	96.4	0.47	0.420	37.6	1.26	28.2	117	110	* 623	388	1
WSAC-21	0.04	27.6	14.0	0.30	0.003	19.8	0.50	29.9	26.9	7.0	257	209	—
WSAC-22	0.16	29.8	34.1	0.20	0.026	24.5	1.05	22.4	39.9	12.0	297	256	1
WSAC-25	0.08	23.0	17.5	0.18	0.013	22.4	2.35	41.5	44.1	8.3	294	268	1
WSAC-26	0.03	33.3	2.80	0.43	—	16.3	0.56	30.0	11.7	3.9	208	192	—
WSAC-28	0.04	43.8	20.1	E0.08	—	22.1	0.69	26.1	10.9	21.0	258	204	—
WSAC-29	0.05	20.9	8.49	0.29	0.008	21.5	0.80	23.3	36.2	11.9	253	242	1
WSAC-30	1.29	79.5	* 358	0.64	—	68.5	0.53	21.4	136	87.0	* 910	248	1
WSAC-31	0.03	18.9	4.23	0.19	E0.002	11.3	0.74	28.2	25	11.1	181	155	1
WSAC-34	0.08	88.9	74.0	E0.09	E0.002	38.5	1.10	23.4	23.4	39.4	486	315	—
WSAC-35	0.02	45.2	16.9	E0.07	0.003	18.9	0.86	22.9	23.6	19.9	277	250	—
WSAC-36	—	24.6	4.41	0.17	0.020	22.5	1.03	30.7	31.7	8.0	256	262	1
Flow-path wells													
ESAC-FP-01	0.31	45.3	124	E0.09	0.026	9.09	1.87	65.1	39	—	331	91	—
ESAC-FP-02	0.03	40.3	13.5	E0.06	E0.002	26.0	1.54	60.2	18.5	11.3	304	246	—
ESAC-FP-03	—	33.0	2.43	E0.05	0.008	23.5	1.34	56.4	10.3	9.2	257	240	—
ESAC-FP-04	—	14.3	1.79	—	E0.002	11.2	2.29	57.7	10.9	2.1	166	130	1
ESAC-FP-05	—	66.1	9.43	E0.08	0.006	41.5	2.75	51.0	22.4	26.5	460	431	1
ESAC-FP-06	0.07	13.5	19.4	E0.09	0.054	3.99	2.88	41.8	51.7	1.4	216	152	6
ESAC-FP-07	0.13	14.6	35.9	E0.09	0.101	4.69	2.73	46.9	68.8	0.3	270	187	3
WSAC-FP-01	E0.02	24.7	2.33	0.33	—	20.5	0.76	31.1	19.9	1.7	217	220	1
WSAC-FP-02	0.04	20.6	11.1	0.15	0.002	16.7	0.75	27.3	21.8	8.9	197	172	1
WSAC-FP-03	0.05	35.4	15.7	0.13	E0.001	24.8	0.75	30.2	16.4	16.7	259	213	1
WSAC-FP-04	0.05	19.9	13.9	0.13	0.032	7.34	1.89	21.3	34.5	0.6	189	174	3
WSAC-FP-05	0.41	28.7	100	0.29	0.227	25.3	2.38	40.4	128	88.4	* 565	302	1
WSAC-FP-06	0.10	16.0	22.4	0.18	0.055	15.8	0.87	21.1	30.4	7.6	202	168	2
WSAC-FP-07	0.07	15.9	15.1	0.12	0.041	7.21	1.56	37.1	41.1	7.2	213	173	2
WSAC-FP-08	0.04	36.9	10.5	0.12	E0.002	18.6	0.73	25.5	18.5	12.6	244	224	1

Table 9. Major and minor ions and total dissolved solids detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); mg/L, milligrams per liter; na, not available; no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, analyzed but not detected; *, value above threshold level; **, value above upper threshold level]

GAMA identification no.	Bromide (mg/L) (71870)	Calcium (mg/L) (00915)	Chloride (mg/L) (00940)	Fluoride (mg/L) (00950)	Iodide (mg/L) (71865)	Magnesium (mg/L) (00925)	Potassium (mg/L) (00935)	Silica (mg/L) (00955)	Sodium (mg/L) (00930)	Sulfate (mg/L) (00945)	Total dissolved solids (TDS) (mg/L) (70301)	Bicarbonate[1] (mg/L as $CaCO_3$)	Carbonate[1] (mg/L as $CaCO_3$)
Threshold type[2]	na	na	SMCL-CA[3]	MCL-CA	na	na	na	na	na	SMCL-CA[3]	SMCL-CA[3]	na	na
Threshold (mg/L)	na	na	250 (500)	2.00	na	na	na	na	na	250 (500)	500 (1,000)	na	na
[LRL]	[0.02]	[0.02]	[0.2]	[0.1]	[0.002]	[0.008]	[0.16]	[0.04]	[0.2]	[0.18]	[10]	[1]	[1]
RICE wells													
RICE-01	12.60	814	** 4730	—	nc	447	11.50	24.3	1250	[4]—	** 7,390	135	—
RICE-02	0.05	41.5	8.07	E0.08	nc	36.5	0.87	52.4	33.3	23.3	402	406	1
RICE-03	0.19	67.4	34.4	E0.08	nc	43.9	2.54	58.4	53.3	37.8	* 566	525	1
RICE-04	—	63.3	7.05	0.18	nc	40.2	2.05	57.3	16.9	17.7	404	399	—
RICE-05	0.07	85.1	16.9	0.13	nc	54.7	1.66	70.2	35.5	48.0	* 569	519	—
RICE-06	—	68.7	2.44	0.11	nc	51.9	1.36	67.9	16.1	15.2	456	468	—
RICE-07	0.04	73.0	3.88	0.15	nc	52.4	1.36	52.3	23.1	28.1	488	511	1
RICE-08	0.05	68.2	9.57	E0.1	nc	49.0	1.12	52.4	34.3	36.4	487	459	1
RICE-09	—	22.5	3.05	E0.09	nc	15.1	0.77	39.6	11	5.1	174	155	1
RICE-10	0.03	36.8	3.85	0.24	nc	18.8	0.69	28.5	11.2	7.8	212	204	1
RICE-11	0.10	91.3	26.8	0.18	nc	60.6	0.62	33.4	27.8	49.4	* 562	504	—
RICE-12	0.08	59.9	14.0	0.32	nc	45.6	0.50	30.5	55	20.4	468	482	1
RICE-13	0.10	66.5	26.7	0.12	nc	50.2	0.91	32.7	56.7	37.4	* 539	506	1
RICE-14	0.07	59.5	9.67	0.19	nc	50.9	0.49	28.8	47.7	38.4	478	488	—
RICE-15	0.04	39.2	7.10	0.89	nc	47.7	0.45	21.9	105	79.5	* 566	529	2
RICE-16	0.15	29.2	23.9	1.70	nc	31.9	0.56	17.6	356	* 375	** 1,200	723	2
RICE-17	0.60	92.8	147	1.70	nc	114	0.72	21.5	838	** 2,080	** 3,510	423	2
RICE-18	0.05	59.4	9.18	0.26	nc	38.3	0.81	27.4	72.8	104.0	* 522	416	1
RICE-19	0.04	38.0	3.56	E0.07	nc	25.4	1.23	42.3	27.4	8.5	294	297	1
RICE-20	0.21	47.9	46.9	0.41	nc	64.1	0.85	46.6	81	63.2	* 614	494	1
RICE-21	0.42	77.2	106	0.62	nc	44.3	0.54	19.9	232	* 359	** 1,050	422	1
RICE-22	0.65	73.1	156	0.90	nc	50.0	0.53	16.7	603	** 1,080	** 2,240	505	1

[1]Bicarbonate and carbonate concentrations were calculated from the laboratory alkalinity and pH values (table 4) using the advance speciation method (http://or.water.usgs.gov/alk/methods.html).

[2]Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[3]The SMCL-CA for chloride, sulfate, and total dissolved solids have recommended and upper threshold values. The upper value is shown in parentheses.

[4]Laboratory reporting level is 4.5 mg/L.

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in groundwater quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Aluminum (µg/L) (01106)	Antimony (µg/L) (01095)	Arsenic (µg/L) (01000)	Barium (µg/L) (01005)	Boron (µg/L) (01020)	Cadmium (µg/L) (01025)	Chromium (µg/L) (01030)	Cobalt (µg/L) (01035)	Copper (µg/L) (01040)	Iron (µg/L) (01046)	Lead (µg/L) (01049)
[LRL]	[1.6]	[0.2]	[0.12]	[0.2]	[8]	[0.04]	[0.04]	[0.04]	[0.4]	[6]	[0.08]
Threshold type[1]	MCL-CA	MCL-US	MCL-US	MCL-CA	NL-CA	MCL-US	MCL-CA	na	AL-US	SMCL-CA	AL-US
Threshold level	1000	6	10	1000	1000	5	50	na	1300	300	15
					Grid wells						
ESAC-03	—	—	0.83	56	808	—	1.1	0.078	7.6	—	1.37
ESAC-05	—	E0.1	*19.6	104	26	—	4.9	0.084	1.2	—	0.24
ESAC-06	E1.5	—	0.97	15	—	—	1.2	—	3.3	—	2.11
ESAC-10	—	—	5	99	20	—	0.16	—	—	30	0.19
ESAC-11	—	0.87	*70	130	53	—	V0.02	E0.03	—	7	0.19
ESAC-12	4.5	—	4.4	87	107	—	6.0	—	3.2	E4	1.03
ESAC-15	E0.8	—	0.47	16	83	—	6.7	—	E0.21	—	0.14
ESAC-16	E1.1	—	0.78	25	316	—	0.58	—	—	—	0.1
ESAC-17	—	—	*15.9	385	379	—	V0.02	—	—	*355	0.2
ESAC-18	E1.4	—	0.73	21	70	—	0.94	—	—	—	0.09
ESAC-19	E1.1	0.38	9.2	147	96	—	6.9	—	0.72	8	0.43
ESAC-21	E1.5	—	*80.6	461	*1,010	E0.03	V0.04	E0.02	—	221	0.51
ESAC-22	—	—	0.39	19	13	—	1.1	0.07	1.7	—	0.86
ESAC-25	E1.3	—	0.83	13	16	—	0.73	—	0.57	—	0.15
ESAC-26	1.7	E0.11	*23.1	39	237	—	V0.02	—	—	6	0.26
ESAC-27	—	—	6.5	78	37	—	1.1	0.27	1.8	—	1.12
ESAC-28	—	—	*10.1	52	24	—	6.9	—	0.62	—	0.31
ESAC-29	E1.2	—	9.2	141	712	—	V0.03	—	—	295	0.08
ESAC-30	E1	E0.15	*17	38	111	—	V0.03	E0.02	E0.25	E4	E0.15
ESAC-31	E0.8	—	*12	124	140	—	0.12	E0.03	—	19	E0.1
ESAC-32	E1	—	2.6	29	14	—	3.0	—	1.9	E5	0.74
ESAC-34	E1.2	—	5.6	90	E6	—	4.6	—	E0.25	—	0.21
ESAC-35	1.9	—	0.8	23	27	—	4.5	—	E0.25	—	0.1

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Aluminum (µg/L) (01106)	Antimony (µg/L) (01095)	Arsenic (µg/L) (01000)	Barium (µg/L) (01005)	Boron (µg/L) (01020)	Cadmium (µg/L) (01025)	Chromium (µg/L) (01030)	Cobalt (µg/L) (01035)	Copper (µg/L) (01040)	Iron (µg/L) (01046)	Lead (µg/L) (01049)
[LRL]	**[1.6]**	**[0.2]**	**[0.12]**	**[0.2]**	**[8]**	**[0.04]**	**[0.04]**	**[0.04]**	**[0.4]**	**[6]**	**[0.08]**
Threshold type[1]	**MCL-CA**	**MCL-US**	**MCL-US**	**MCL-CA**	**NL-CA**	**MCL-US**	**MCL-CA**	**na**	**AL-US**	**SMCL-CA**	**AL-US**
Threshold level	**1000**	**6**	**10**	**1000**	**1000**	**5**	**50**	**na**	**1300**	**300**	**15**
WSAC-03	—	—	0.48	66	16	—	1.2	0.081	0.8	—	0.2
WSAC-04	—	—	3.6	98	33	—	—	0.041	E0.2	43	—
WSAC-06	—	—	0.63	86	87	—	0.72	—	2.6	E3	1.67
WSAC-08	—	—	0.24	103	160	—	1.1	—	0.56	E3	3.43
WSAC-10	—	—	0.36	123	197	—	1.6	—	2	—	0.16
WSAC-11	E1	—	2.6	232	599	—	11.1	—	0.47	—	0.27
WSAC-12	1.8	—	2.2	126	212	—	V0.04	—	E0.28	53	—
WSAC-14	E1.3	—	2.6	29	364	0.04	V0.05	0.09	2	E4	0.62
WSAC-15	E1	—	1.3	295	*2330	—	7.3	0.04	0.47	—	0.08
WSAC-17	E1	E0.17	6.7	48	344	—	0.80	E0.02	1.4	—	0.69
WSAC-18	E1.2	—	1.3	74	447	—	0.07	0.04	E0.24	—	1.37
WSAC-21	E1	—	1.4	198	193	—	8.0	—	E0.26	—	0.1
WSAC-22	E0.8	—	7.9	268	105	—	2.5	—	0.93	14	0.68
WSAC-25	E1	—	4	106	762	—	0.48	—	—	—	0.32
WSAC-26	E1.4	—	1.1	106	11	—	4.3	0.06	0.46	—	0.35
WSAC-28	—	—	0.33	63	36	—	1.3	—	E0.24	—	—
WSAC-29	E1	—	3.1	145	64	—	11.5	—	E0.25	—	0.42
WSAC-30	E0.8	—	0.39	58	339	—	6.0	—	2.7	E5	0.43
WSAC-31	E1.3	—	4.7	61	71	3.54	10.8	—	E0.22	—	0.17
WSAC-34	E0.9	—	0.46	197	—	—	2.7	E0.03	0.47	—	—
WSAC-35	E1.1	—	1.2	117	128	—	2.2	—	0.66	—	0.17
WSAC-36	E1.2	—	4.5	142	117	—	4.3	—	0.47	E4	0.32

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in groundwater quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Aluminum (µg/L) (01106)	Antimony (µg/L) (01095)	Arsenic (µg/L) (01000)	Barium (µg/L) (01005)	Boron (µg/L) (01020)	Cadmium (µg/L) (01025)	Chromium (µg/L) (01030)	Cobalt (µg/L) (01035)	Copper (µg/L) (01040)	Iron (µg/L) (01046)	Lead (µg/L) (01049)
[LRL]	**[1.6]**	**[0.2]**	**[0.12]**	**[0.2]**	**[8]**	**[0.04]**	**[0.04]**	**[0.04]**	**[0.4]**	**[6]**	**[0.08]**
Threshold type[1]	**MCL-CA**	**MCL-US**	**MCL-US**	**MCL-CA**	**NL-CA**	**MCL-US**	**MCL-CA**	**na**	**AL-US**	**SMCL-CA**	**AL-US**
Threshold level	**1000**	**6**	**10**	**1000**	**1000**	**5**	**50**	**na**	**1300**	**300**	**15**
					Flow-path wells						
ESAC-FP-01	1.3	—	1.1	73	171	—	V0.02	—	—	106	0.08
ESAC-FP-02	2.1	—	0.71	35	108	—	1.3	0.28	V0.2	65	0.13
ESAC-FP-03	V0.8	—	2.4	47	19	—	1.2	E0.03	—	134	0.11
ESAC-FP-04	V1.7	—	3.2	16	67	—	1.3	—	—	67	—
ESAC-FP-05	2.7	0.23	6.5	116	55	—	5.3	E0.03	—	—	—
ESAC-FP-06	39.4	E0.18	*12.7	17	208	—	0.70	E0.02	—	14	E0.07
ESAC-FP-07	17.2	—	9	35	243	—	0.22	E0.03	—	10	E0.05
WSAC-FP-01	V1.4	—	2.4	128	28	—	16.1	E0.02	—	—	—
WSAC-FP-02	2.2	E0.11	3.3	132	101	—	18.4	—	—	V6	—
WSAC-FP-03	3.7	E0.13	1.6	173	81	—	4.8	E0.02	V0.55	—	—
WSAC-FP-04	11.1	—	5.5	91	80	—	0.16	0.04	—	V6	—
WSAC-FP-05	4.5	—	8.3	42	230	E0.02	—	—	0.35	9	0.8
WSAC-FP-06	3.0	E0.15	4	167	98	—	0.33	—	—	15	—
WSAC-FP-07	4.4	—	*10.6	8	99	—	V0.07	—	—	40	—
WSAC-FP-08	V1.4	—	1.1	99	114	—	4.8	—	—	10	—

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in groundwater quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Aluminum (µg/L) (01106)	Antimony (µg/L) (01095)	Arsenic (µg/L) (01000)	Barium (µg/L) (01005)	Boron (µg/L) (01020)	Cadmium (µg/L) (01025)	Chromium (µg/L) (01030)	Cobalt (µg/L) (01035)	Copper (µg/L) (01040)	Iron (µg/L) (01046)	Lead (µg/L) (01049)
[LRL]	**[1.6]**	**[0.2]**	**[0.12]**	**[0.2]**	**[8]**	**[0.04]**	**[0.04]**	**[0.04]**	**[0.4]**	**[6]**	**[0.08]**
Threshold type[1]	**MCL-CA**	**MCL-US**	**MCL-US**	**MCL-CA**	**NL-CA**	**MCL-US**	**MCL-CA**	**na**	**AL-US**	**SMCL-CA**	**AL-US**
Threshold level	**1000**	**6**	**10**	**1000**	**1000**	**5**	**50**	**na**	**1300**	**300**	**15**
					RICE wells						
RICE-01	—[2]	—[2]	4.9	*5,900	*1,260	—[2]	0.42	E0.18	—[2]	*4,610	—[2]
RICE-02	V1.3	E0.11	*10.4	39	55	—	2.4	0.09	—	V3	—
RICE-03	V0.8	E0.14	6.2	188	117	—	2.0	E0.02	V0.31	V5	—
RICE-04	—	—	4.7	154	16	—	1.7	E0.03	V0.54	57	—
RICE-05	—	—	1.4	160	9	E0.02	0.14	0.27	V0.97	28	—
RICE-06	—	—	1.8	85	16	—	0.41	0.04	V0.62	V4	—
RICE-07	V1.0	—	6.2	78	25	—	1.6	E0.02	V0.24	—	—
RICE-08	V1.0	—	6	96	35	—	4.1	—	—	—	—
RICE-09	1.8	E0.18	4.6	26	62	—	V0.07	0.15	V0.28	V6	—
RICE-10	V1.1	E0.16	3.1	87	57	—	0.37	E0.02	V0.32	—	—
RICE-11	V1.1	E0.1	1.6	552	92	E0.02	1.3	0.21	V1.1	V4	—
RICE-12	V1.0	E0.1	3.2	408	223	—	0.08	0.31	—	218	E0.04
RICE-13	V1.2	E0.11	2.3	286	199	—	3.1	0.44	V1.1	—	0.08
RICE-14	V1.2	—	1.1	357	174	—	V0.10	0.39	V0.27	110	—
RICE-15	—	—	1.1	65	551	—	0.77	0.04	V0.48	—	—
RICE-16	V1.3	—	0.57	20	945	—	V0.05	0.13	—	*304	—
RICE-17	E2.4	—	1.6	15	*1,640	0.05	13.1	0.13	V0.83	—	—
RICE-18	2.9	—	1	81	204	—	7.8	0.06	V0.53	—	—
RICE-19	V1.6	E0.11	4.1	61	68	—	V0.08	0.05	V0.69	—	—
RICE-20	V1.4	E0.14	7.5	46	195	0.04	V0.02	0.6	V0.80	—	—
RICE-21	2.2	—	0.38	46	97	—	0.13	0.13	V0.29	155	0.13
RICE-22	—	—	1.9	15	*4,630	—	0.85	1.6	—	166	—

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)	Uranium (µg/L) (22703)
[LRL]	**[0.6]**	**[0.2]**	**[0.4]**	**[0.06]**	**[0.08]**	**[0.4]**	**[0.04]**	**[0.06]**	**[0.1]**	**[0.6]**	**[0.04]**
Threshold type[1]	**na**	**SMCL-CA**	**HAL-US**	**MCL-CA**	**MCL-US**	**HAL-US**	**MCL-US**	**na**	**NL-CA**	**SMCL-CA**	**MCL-US**
Threshold level	**na**	**50**	**40**	**100**	**50**	**4000**	**2**	**na**	**50**	**5000**	**30**
					Grid wells						
ESAC-03	14.1	E0.1	0.5	1.19	0.09	254	—	0.35	9.7	3.6	0.37
ESAC-05	E0.4	—	1.8	1.38	0.61	214	—	0.06	28.8	2.8	2.76
ESAC-06	2.1	E0.2	E0.2	0.26	E0.05	112	—	—	28.8	10.7	0.12
ESAC-10	E0.4	*95.1	0.6	0.18	1.0	319	—	E0.05	6.5	1.7	6.07
ESAC-11	20.9	*112	2.0	V0.04	—	138	—	0.27	40.4	V0.42	0.69
ESAC-12	2.8	0.2	2.3	0.13	0.40	290	—	0.11	12.2	4.4	0.45
ESAC-15	—	—	—	V0.07	0.16	145	—	—	17.7	V0.73	0.08
ESAC-16	6.5	E0.1	E0.2	0.14	E0.06	123	—	—	21.1	V0.52	0.23
ESAC-17	0.7	*568	1.8	0.22	—	488	—	0.23	E0.05	3.2	—
ESAC-18	1.6	—	E0.2	0.09	E0.04	116	—	E0.03	19.8	V0.58	0.35
ESAC-19	4.8	—	1.1	0.14	0.6	342	—	0.07	22.7	3.2	1.50
ESAC-21	3.8	*257	16.5	V0.07	—	460	—	0.1	0.11	1.3	—
ESAC-22	0.7	E0.2	—	0.58	0.09	111	—	—	6.8	6.3	0.04
ESAC-25	4.1	—	E0.3	0.12	E0.06	115	—	—	30.6	V1.2	0.07
ESAC-26	1.0	*80.2	4.2	—	—	112	—	0.53	9.6	1.3	0.21
ESAC-27	0.7	*110	0.8	0.57	0.24	258	—	—	8.4	V0.93	2.24
ESAC-28	E0.6	1.3	1.1	0.11	0.12	179	—	0.07	26.2	1.3	1.41
ESAC-29	2.4	*219	E4	0.09	—	276	—	0.23	0.42	12.2	—
ESAC-30	1.7	*99.6	1.4	0.08	0.31	195	—	0.28	35	V0.97	0.39
ESAC-31	1.9	*72.2	2.6	0.13	0.10	388	—	0.08	13.9	V0.92	1.88
ESAC-32	0.7	E0.1	—	0.17	0.16	227	—	—	9.5	4.5	1.09

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)	Uranium (µg/L) (22703)
[LRL]	[0.6]	[0.2]	[0.4]	[0.06]	[0.08]	[0.4]	[0.04]	[0.06]	[0.1]	[0.6]	[0.04]
Threshold type[1]	na	SMCL-CA	HAL-US	MCL-CA	MCL-US	HAL-US	MCL-US	na	NL-CA	SMCL-CA	MCL-US
Threshold level	na	50	40	100	50	4000	2	na	50	5000	30
ESAC-34	0.8	—	0.5	0.10	0.36	360	—	E0.03	38.5	137	3.71
ESAC-35	1.3	—	—	—	E0.05	197	—	E0.05	22.4	V0.84	1.05
WSAC-03	3.7	—	1.0	1.32	0.10	368	—	—	3.9	6.6	0.14
WSAC-04	4.4	43.3	1.6	0.59	—	199	—	E0.03	—	V1.2	—
WSAC-06	11.5	—	0.5	0.21	0.08	506	—	—	5.0	62.9	0.40
WSAC-08	3.9	0.2	1.0	0.12	0.09	841	—	—	1.8	10.2	0.54
WSAC-10	6.4	—	E0.7	E0.14	0.09	849	—	—	2.8	13.3	0.78
WSAC-11	21.6	—	—	—	0.50	360	—	—	8.3	V0.51	0.28
WSAC-12	3.8	*106	7.8	V0.05	—	256	—	0.42	0.53	V0.67	0.07
WSAC-14	24.8	*89.8	4.5	0.36	10.8	1570	E0.02	0.08	10.7	8.6	2.57
WSAC-15	37	E0.1	0.5	0.66	1.4	641	—	0.18	5.7	V0.68	2.61
WSAC-17	1.3	0.2	4.0	0.17	0.57	234	—	0.07	18.5	36.4	1.16
WSAC-18	18.6	*84.6	3.7	V0.05	1.2	877	—	E0.05	8.4	V0.37	E0.14
WSAC-21	14.9	E0.1	E0.3	0.08	0.36	276	—	—	5.5	28.1	0.18
WSAC-22	15	36.6	0.6	0.11	0.16	435	—	E0.03	2.6	16.4	0.25
WSAC-25	26.9	1.8	3.5	V0.05	0.31	332	—	0.19	10.8	5.4	0.64
WSAC-26	14.9	—	0.9	V0.07	0.10	254	—	—	3.8	8.9	0.33
WSAC-28	4.1	—	E0.4	0.12	E0.04	428	—	—	2.8	V0.43	0.10
WSAC-29	9.8	3.1	1.0	0.18	0.77	395	—	—	10.8	3.4	0.43
WSAC-30	22	E0.1	1.0	0.30	0.75	1480	—	—	3.7	4.5	1.06
WSAC-31	2.7	—	2.0	V0.03	0.77	226	—	0.06	17.9	V0.53	0.19
WSAC-34	6.9	—	0.7	0.33	0.08	1130	—	—	3.0	2.0	0.79
WSAC-35	5.5	—	0.8	0.11	0.17	619	—	—	3.8	3.3	0.46
WSAC-36	4.6	0.5	3.1	V0.06	0.30	439	—	E0.05	9.4	1.5	0.72

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)	Uranium (µg/L) (22703)
[LRL]	**[0.6]**	**[0.2]**	**[0.4]**	**[0.06]**	**[0.08]**	**[0.4]**	**[0.04]**	**[0.06]**	**[0.1]**	**[0.6]**	**[0.04]**
Threshold type[1]	**na**	**SMCL-CA**	**HAL-US**	**MCL-CA**	**MCL-US**	**HAL-US**	**MCL-US**	**na**	**NL-CA**	**SMCL-CA**	**MCL-US**
Threshold level	**na**	**50**	**40**	**100**	**50**	**4000**	**2**	**na**	**50**	**5000**	**30**
					Flow-path wells						
ESAC-FP-01	0.6	*184	0.8	V0.05	—	455	—	0.22	E0.05	6.4	—
ESAC-FP-02	—	14.5	0.7	2.2	E0.07	261	—	V0.05	7.5	6.3	0.46
ESAC-FP-03	—	16.8	E0.2	0.31	—	225	—	0.09	23.4	—	0.70
ESAC-FP-04	—	3.5	0.4	0.30	0.12	100	—	0.21	10.0	V0.68	0.09
ESAC-FP-05	1.3	V0.3	0.6	0.57	0.38	534	—	0.31	26.3	—	5.44
ESAC-FP-06	0.7	8.4	4.9	0.47	—	127	—	1.1	2.9	—	0.07
ESAC-FP-07	E0.4	16.4	8.3	0.76	—	96.7	—	0.69	0.7	—	0.05
WSAC-FP-01	12.7	—	0.8	0.31	0.57	439	—	0.03	8.9	—	0.36
WSAC-FP-02	8.5	V0.5	0.8	0.33	0.39	379	—	0.07	10.3	V0.6	0.20
WSAC-FP-03	13.4	V0.8	0.6	0.72	0.11	410	—	0.09	6.4	V1.2	0.12
WSAC-FP-04	16.9	8.4	1.9	1.1	—	635	—	1.4	0.19	—	0.07
WSAC-FP-05	5.6	*60.6	3.9	0.09	E0.06	758	—	0.21	0.82	2.4	0.56
WSAC-FP-06	7.6	7.2	1.1	0.33	0.20	449	—	0.36	8	V1.2	0.07
WSAC-FP-07	4	22.6	2.1	V0.17	—	296	—	0.33	—	—	0.04
WSAC-FP-08	5.5	V0.4	1.3	0.27	0.08	475	—	V0.03	6	V1.4	0.22

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)	Uranium (µg/L) (22703)
[LRL]	[0.6]	[0.2]	[0.4]	[0.06]	[0.08]	[0.4]	[0.04]	[0.06]	[0.1]	[0.6]	[0.04]
Threshold type[1]	na	SMCL-CA	HAL-US	MCL-CA	MCL-US	HAL-US	MCL-US	na	NL-CA	SMCL-CA	MCL-US
Threshold level	na	50	40	100	50	4000	2	na	50	5000	30
RICE wells											
RICE-01	E3.3	*3,420	E1.6	1.3	—[2]	*7,880	—[2]	nc	1.1	4.7	—[2]
RICE-02	E0.4	14.2	1.3	0.46	E0.06	354	—	nc	*51.3	V0.48	4.29
RICE-03	1.1	2.6	—	0.38	E0.04	800	—	nc	34.4	V0.56	4.44
RICE-04	0.8	19.9	0.6	0.96	0.09	449	—	nc	25.7	V0.75	3.36
RICE-05	0.7	*75.4	—	1.9	—	618	—	nc	27.1	V1.1	3.52
RICE-06	E0.3	34.1	—	0.86	E0.04	420	—	nc	40.9	V0.75	2.67
RICE-07	—	3.4	E0.4	0.28	—	660	—	nc	*57.4	V0.34	5.19
RICE-08	0.7	V0.2	E0.3	0.22	0.20	666	—	nc	38	V0.52	3.27
RICE-09	1.0	41.9	1.3	0.29	—	179	—	nc	18.4	—	0.34
RICE-10	2.5	7.9	2.5	0.22	E0.05	359	—	nc	10.9	—	0.64
RICE-11	18.3	9.1	0.5	1.6	—	1,340	—	nc	5.8	V1.0	1.13
RICE-12	14.3	*55.2	1.7	0.56	—	1,000	—	nc	2.2	V1.1	1.57
RICE-13	19.9	26.6	0.8	1.1	—	1,010	—	nc	8.4	V0.57	1.48
RICE-14	11.5	*379	1.2	1.3	—	919	—	nc	0.55	V0.99	1.65
RICE-15	23.3	1.3	5.4	0.40	0.43	812	—	nc	5.5	V0.47	4.44
RICE-16	26.1	*434	9.8	V0.20	11	795	—	nc	0.54	V0.53	7.76
RICE-17	31.2	27.5	*46.2	0.61	7.8	1,900	—	nc	8.5	V1.6	10.20
RICE-18	18.9	7.7	0.9	0.28	0.55	772	—	nc	5.2	V0.88	2.04
RICE-19	0.8	6.1	1.2	0.32	—	370	—	nc	24.8	V1.2	1.25
RICE-20	0.9	*216	10.9	1.3	0.32	461	—	nc	29.6	V0.44	4.90
RICE-21	19.7	*156	2.4	0.31	0.45	1200	—	nc	0.42	V0.8	2.38
RICE-22	102	*602	9.6	2.3	E0.77	*4,540	—	nc	E0.74	E4	4.81

[1] Maximum contaminant level thresholds are listed as MCL-US when MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] Laboratory reporting level is four times the LRL stated above.

Table 11. Species of inorganic arsenic, iron, and chromium detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed for iron, arsenic, and chromium; only wells with at least one detection are listed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Analyses made by the USGS's Trace Metals Laboratory. The laboratory entity code for the USGS's Trace Metals Laboratory in the USGS's National Water Information System (NWIS) is USGSTMCO. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); MDL, method detection limit; na, not available; no., number; NRP, National Research Program (USGS); NWQL, National Water Quality Laboratory (USGS); RICE, RICE well; RSD, relative standard deviation; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; * , value above threshold level]

GAMA identification no.	Iron(Total)[2] (µg/L) (01046)	Iron(II) (µg/L) (01047)	Inorganic Arsenic(Total)[2] (µg/L) (99033)	Inorganic Arsenic(III) (µg/L) (99034)	Chromium(Total) (µg/L) (01030)	Chromium(VI) (µg/L) (01032)
Threshold type[1]	**SMCL-CA**	**na**	**MCL-US**	**na**	**MCL-CA**	**na**
Threshold (µg/L)	**300**	**na**	**10**	**na**	**50**	**na**
[MDL]	**[2]**	**[2]**	**[0.5]**	**[1]**	**[1]**	**[1]**
			Grid wells			
ESAC-03	—	—	—	—	1	—
ESAC-05	—	—	* 17	—	4	4
ESAC-06	—	—	V3.6	—	—	—
ESAC-10	28	17	4.9	—	—	—
ESAC-11	6	4	[3]* 35	—	—	—
ESAC-12	3	—	3.6	—	6	5
ESAC-15	—	—	V0.7	—	2	—
ESAC-16	—	—	V1.2	—	—	—
ESAC-17	* 359	238	* 14	13	—	—
ESAC-18	—	—	V1.7	—	—	—
ESAC-19	6	—	8.0	—	5	5
ESAC-21	198	57	* 70	70	—	—
ESAC-22	—	—	—	—	1	1
ESAC-25	—	—	V4.3	—	—	—
ESAC-26	6	4	* 19	4	—	—
ESAC-27	—	—	6.2	—	—	—
ESAC-28	—	—	7.8	—	5	4
ESAC-29	* 304	26	8.7	7	—	—
ESAC-30	4	3	* 15	—	—	—
ESAC-31	21	18	* 11	4	—	—
ESAC-32	—	—	2.0	—	2	2
ESAC-34	—	—	5.1	—	4	3
ESAC-35	—	—	V1.7	—	3	2
WSAC-03	—	—	—	—	—	—
WSAC-04	36	23	V5.0	—	—	—
WSAC-06	—	—	V1.5	—	—	—
WSAC-08	2	—	V0.8	—	—	—
WSAC-10	4	—	—	—	1	1
WSAC-11	2	—	1.9	—	9	8
WSAC-12	54	36	1.9	1	—	—
WSAC-14	4	4	2.0	—	—	—

Table 11. Species of inorganic arsenic, iron, and chromium detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed for iron, arsenic, and chromium; only wells with at least one detection are listed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Analyses made by the USGS's Trace Metals Laboratory. The laboratory entity code for the USGS's Trace Metals Laboratory in the USGS's National Water Information System (NWIS) is USGSTMCO. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); MDL, method detection limit; na, not available; no., number; NRP, National Research Program (USGS); NWQL, National Water Quality Laboratory (USGS); RICE, RICE well; RSD, relative standard deviation; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Iron(Total)[2] (µg/L) (01046)	Iron(II) (µg/L) (01047)	Inorganic Arsenic(Total)[2] (µg/L) (99033)	Inorganic Arsenic(III) (µg/L) (99034)	Chromium(Total) (µg/L) (01030)	Chromium(VI) (µg/L) (01032)
Threshold type[1]	**SMCL-CA**	**na**	**MCL-US**	**na**	**MCL-CA**	**na**
Threshold (µg/L)	**300**	**na**	**10**	**na**	**50**	**na**
[MDL]	**[2]**	**[2]**	**[0.5]**	**[1]**	**[1]**	**[1]**
WSAC-15	—	—	1.6	—	6	5
WSAC-17	—	—	5.9	—	—	—
WSAC-18	—	—	1.3	—	—	—
WSAC-21	2	—	1.5	—	6	5
WSAC-22	11	—	6.5	—	2	1
WSAC-25	—	—	[3]2.6	—	—	—
WSAC-26	—	—	V1.8	—	3	2
WSAC-28	—	—	V0.9	—	—	—
WSAC-29	—	—	3.6	—	11	10
WSAC-30	4	—	—	—	7	5
WSAC-31	—	—	4.1	—	9	5
WSAC-34	—	—	V1.0	—	2	2
WSAC-35	—	—	V3.5	—	1	1
WSAC-36	4	3	5.7	—	3	2
			Flow-path wells			
ESAC-FP-01	103	82	V1.8	—	—	—
ESAC-FP-02	61	10	V1.4	—	4	2
ESAC-FP-03	130	69	1.8	—	2	—
ESAC-FP-04	62	—	3.5	—	2	1
ESAC-FP-05	—	—	6.0	—	5	4
ESAC-FP-06	12	6	* 12	—	—	—
ESAC-FP-07	8	2	8.0	—	—	—
WSAC-FP-01	—	—	1.5	—	17	17
WSAC-FP-02	5	—	2.7	—	21	19
WSAC-FP-03	3	—	1.1	—	4	3
WSAC-FP-04	6	—	5.4	4	—	—
WSAC-FP-05	10	—	6.9	—	—	—
WSAC-FP-06	13	3	4.3	—	—	—
WSAC-FP-07	39	11	9.3	9	—	—
WSAC-FP-08	6	—	0.7	—	4	4

Table 11. Species of inorganic arsenic, iron, and chromium detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed for iron, arsenic, and chromium; only wells with at least one detection are listed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Analyses made by the USGS's Trace Metals Laboratory. The laboratory entity code for the USGS's Trace Metals Laboratory in the USGS's National Water Information System (NWIS) is USGSTMCO. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); MDL, method detection limit; na, not available; no., number; NRP, National Research Program (USGS); NWQL, National Water Quality Laboratory (USGS); RICE, RICE well; RSD, relative standard deviation; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Iron(Total)[2] (µg/L) (01046)	Iron(II) (µg/L) (01047)	Inorganic Arsenic(Total)[2] (µg/L) (99033)	Inorganic Arsenic(III) (µg/L) (99034)	Chromium(Total) (µg/L) (01030)	Chromium(VI) (µg/L) (01032)
Threshold type[1]	**SMCL-CA**	**na**	**MCL-US**	**na**	**MCL-CA**	**na**
Threshold (µg/L)	**300**	**na**	**10**	**na**	**50**	**na**
[MDL]	**[2]**	**[2]**	**[0.5]**	**[1]**	**[1]**	**[1]**
			RICE wells			
RICE-01	* 4,790	4,720	3.7	4	1	—
RICE-02	3	—	8.8	—	—	—
RICE-03	4	2	[3]4	—	1	1
RICE-04	[3]4	4	4.0	—	1	—
RICE-05	28	28	0.9	—	—	—
RICE-06	4	3	1.5	—	—	—
RICE-07	2	2	5.5	—	1	—
RICE-08	3	3	5.3	—	4	4
RICE-09	3	2	3.8	—	—	—
RICE-10	2	2	2.8	—	—	—
RICE-11	—	—	V2.5	—	—	—
RICE-12	207	126	3.0	—	—	—
RICE-13	—	—	V3.5	—	2	2
RICE-14	112	96	0.7	—	—	—
RICE-15	—	—	V1.5	—	—	—
RICE-16	* 309	250	0.6	—	—	—
RICE-17	2	—	V3.0	—	12	9
RICE-18	—	—	1.1	—	6	5
RICE-19	—	—	3.5	—	—	—
RICE-20	—	—	6.8	—	—	—
RICE-21	140	130	—	—	—	—
RICE-22	[3]6	3	0.7	—	—	—

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] V codes were applied to ground-water samples for which the concentration measured by the NRP laboratory was greater than the concentration measured by the NWQL preferred method (table 10), and the difference between the results was greater than 20 percent RSD.

[3] Concentration measured by the NRP laboratory was less than the concentration measured by the NWQL preferred method (table 10), and the difference between the results was greater than 20 percent RSD.

Table 12. Stable isotope ratios of water and tritium detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from 70 of the grid wells (WSAC-14 not analyzed), the 15 flow-path wells, and 2 of the RICE wells were analyzed for stable isotopes of water; samples from 70 of the grid wells (WSAC-13 not analyzed), and the 15 flow-path wells were analyzed for tritium. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. The laboratory entity codes for the laboratories in the USGS's National Water Information System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; MCL-CA, maximum contaminant level (CDPH); nc, sample not collected; no., number; pCi/L, picocuries per liter; RICE, RICE well; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; <, less than]

GAMA identification no.	δ^{2}H of water[1] (per mil) (82082)	δ^{18}O of water[1] (per mil) (82085)	Tritium[2] (pCi/L) (07000)
Threshold type	**na**	**na**	**MCL-CA**
Threshold	**na**	**na**	**20,000**
	Grid wells		
ESAC-01	–63.1	–8.81	1.9
ESAC-02	–63.4	–8.68	11.5
ESAC-03	–63.4	–8.80	8
ESAC-04	–59.8	–8.19	2.8
ESAC-05	–63.8	–8.88	8
ESAC-06	–59.0	–8.25	1.3
ESAC-07	–56.6	–7.92	4.2
ESAC-08	–78.9	–11.02	9.9
ESAC-09	–56.6	–7.83	3.8
ESAC-10	–48.7	–6.65	2.9
ESAC-11	–60.0	–8.47	<1
ESAC-12	–71.1	–10.11	1
ESAC-13	–80.0	–11.35	3.5
ESAC-14	–57.0	–8.10	2.6
ESAC-15	–67.0	–9.73	1
ESAC-16	–60.0	–8.80	2.9
ESAC-17	–60.8	–8.28	3.5
ESAC-18	–66.1	–9.58	<1
ESAC-19	–56.3	–7.91	<1
ESAC-20	–54.3	–7.78	<1
ESAC-21	–75.2	–10.31	<1
ESAC-22	–53.0	–7.51	12.2
ESAC-23	–72.5	–10.43	10.2
ESAC-24	–57.9	–8.25	<1
ESAC-25	–61.2	–8.72	<1
ESAC-26	–82.2	–11.52	<1
ESAC-27	–55.2	–7.51	9.3
ESAC-28	–67.5	–9.48	7.4
ESAC-29	–59.2	–8.10	2.9
ESAC-30	–83.0	–11.74	<1
ESAC-31	–70.2	–9.41	8.6
ESAC-32	–67.6	–9.47	9.6
ESAC-33	–61.2	–8.70	12.5
ESAC-34	–55.9	–7.37	13.4
ESAC-35	–70.6	–9.88	4.2

Table 12. Stable isotope ratios of water and tritium detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from 70 of the grid wells (WSAC-14 not analyzed), the 15 flow-path wells, and 2 of the RICE wells were analyzed for stable isotopes of water; samples from 70 of the grid wells (WSAC-13 not analyzed), and the 15 flow-path wells were analyzed for tritium. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. The laboratory entity codes for the laboratories in the USGS's National Water Information System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; MCL-CA, maximum contaminant level (CDPH); nc, sample not collected; no., number; pCi/L, picocuries per liter; RICE, RICE well; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; <, less than]

GAMA identification no.	δ^{2}H of water[1] (per mil) (82082)	δ^{18}O of water[1] (per mil) (82085)	Tritium[2] (pCi/L) (07000)
Threshold type	**na**	**na**	**MCL-CA**
Threshold	**na**	**na**	**20,000**
WSAC-01	–72.1	–9.98	<1
WSAC-02	–63.0	–8.41	6.4
WSAC-03	–68.1	–9.64	7.4
WSAC-04	–67.4	–9.24	<1
WSAC-05	–65.0	–8.90	7.7
WSAC-06	–66.2	–9.46	8.6
WSAC-07	–66.9	–9.24	13.4
WSAC-08	–62.6	–8.61	11.8
WSAC-09	–63.3	–8.83	6.7
WSAC-10	–63.7	–8.82	7.4
WSAC-11	–59.5	–8.60	<1
WSAC-12	–76.3	–10.35	<1
WSAC-13	–63.9	–8.91	nc
WSAC-14	nc	nc	<1
WSAC-15	–44.7	–5.81	8.3
WSAC-16	–52.1	–6.93	2.6
WSAC-17	–75.9	–10.61	8.6
WSAC-18	–62.2	–8.45	1.6
WSAC-19	–58.7	–8.37	<1
WSAC-20	–44.4	–5.90	4.5
WSAC-21	–59.0	–8.38	1.9
WSAC-22	–59.5	–8.53	5.8
WSAC-23	–60.5	–8.15	7.7
WSAC-24	–59.1	–8.54	1.3
WSAC-25	–51.7	–7.14	<1
WSAC-26	–64.2	–9.08	3.8
WSAC-27	–65.4	–8.84	9.3
WSAC-28	–63.6	–8.75	11.8
WSAC-29	–64.4	–8.87	<1
WSAC-30	–66.9	–9.21	14.7
WSAC-31	–64.8	–9.21	<1
WSAC-32	–74.3	–10.51	8.3
WSAC-33	–62.0	–8.88	<1
WSAC-34	–64.8	–9.04	9.6
WSAC-35	–68.8	–9.37	7.4
WSAC-36	–66.6	–9.26	1.6

Table 12. Stable isotope ratios of water and tritium detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from 70 of the grid wells (WSAC-14 not analyzed), the 15 flow-path wells, and 2 of the RICE wells were analyzed for stable isotopes of water; samples from 70 of the grid wells (WSAC-13 not analyzed), and the 15 flow-path wells were analyzed for tritium. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. The laboratory entity codes for the laboratories in the USGS's National Water Information System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; MCL-CA, maximum contaminant level (CDPH); nc, sample not collected; no., number; pCi/L, picocuries per liter; RICE, RICE well; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; <, less than]

GAMA identification no.	δ^{2}H of water[1] (per mil) (82082)	δ^{18}O of water[1] (per mil) (82085)	Tritium[2] (pCi/L) (07000)
Threshold type	**na**	**na**	**MCL-CA**
Threshold	**na**	**na**	**20,000**
	Flow-path wells		
ESAC-FP-01	–53.6	–7.34	<1
ESAC-FP-02	–69.4	–10.06	3.5
ESAC-FP-03	–72.9	–10.11	6.4
ESAC-FP-04	–64.0	–9.14	<1
ESAC-FP-05	–61.7	–8.01	12.8
ESAC-FP-06	–75.5	–10.58	<1
ESAC-FP-07	–80.8	–11.08	<1
WSAC-FP-01	–65.3	–9.13	<1
WSAC-FP-02	–67.7	–9.55	<1
WSAC-FP-03	–63.5	–8.96	9.0
WSAC-FP-04	–66.6	–9.43	1.3
WSAC-FP-05	–71.6	–9.63	<1
WSAC-FP-06	–69.7	–9.66	<1
WSAC-FP-07	–72.9	–10.22	<1
WSAC-FP-08	–69.2	–9.70	12.8
	RICE wells		
RICE-07	–54.1	–6.63	nc
RICE-11	–63.0	–8.47	nc

[1] USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA).

[2] USGS Stable Isotope and Tritium Laboratory, Menlo Park, California (USGSH3CA).

Table 13. Nitrogen and oxygen isotopes in nitrate, nitrogen isotopes in nitrogen gas, and carbon-14 activities detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from 42 of the slow and intermediate grid wells (ESAC-35, WSAC-10, and WSAC-11 not analyzed) and the 15 flow-path wells were analyzed for isotopes of nitrate; samples from 43 of the slow and intermediate grid wells (ESAC-35 and WSAC-11 not analyzed) and the 15 flow-path wells were analyzed for carbon-14 activities. Nitrogen and oxygen isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. The laboratoroy entity codes for the laboratories in the USGS's National Water Information System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; na, not available; nc, sample not collected; no., number; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, nitrate not detected, therefore sample was not analyzed for nitrate isotopes]

GAMA identification no.	δ^{18}O of nitrate[1] (per mil) (63041)	δ^{15}N of nitrate[1] (per mil) (82690)	δ^{13}O of dissolved carbonates[2] (per mil) (82081)	[3]Carbon-14 (percent modern) (49933)
Threshold type	**na**	**na**	**na**	**na**
Threshold	**na**	**na**	**na**	**na**
		Grid wells		
ESAC-03	2.76	8.43	–16.37	89
ESAC-05	4.00	6.41	–15.53	98
ESAC-06	2.58	3.92	–17.02	91
ESAC-10	5.28	11.76	–14.19	106
ESAC–11	—	—	–16.57	25
ESAC-12	0.46	4.59	–15.62	62
ESAC-15	—	—	–14.19	95
ESAC-16	1.00	4.38	–17.44	88
ESAC-17	—	—	–14.18	81
ESAC-18	1.39	4.59	–14.84	93
ESAC-19	–0.55	4.55	–15.46	82
ESAC-21	—	—	5.57	11
ESAC-22	3.99	3.52	–18.13	111
ESAC-25	0.01	2.71	–16.03	90
ESAC-26	—	—	–12.79	50
ESAC-27	3.54	9.35	–17.24	93
ESAC-28	2.86	6.38	–15.29	99
ESAC-29	—	—	–15.00	53
ESAC-30	11.21	26.65	–12.86	56
ESAC-31	16.33	24.47	–17.50	82
ESAC-32	6.60	7.46	–19.37	108
ESAC-34	5.64	9.88	–17.47	100
WSAC-03	2.28	4.23	–16.32	103
WSAC-04	—	—	–8.58	34
WSAC-06	3.57	11.54	–16.17	102
WSAC-08	1.02	5.82	–14.29	23
WSAC-10	nc	nc	–14.04	114
WSAC-11	nc	nc	–15.69	66
WSAC-12	—	—	nc	nc
WSAC-14	14.65	25.43	–12.09	40
WSAC-15	3.37	4.53	–15.09	104

Table 13. Nitrogen and oxygen isotopes in nitrate, nitrogen isotopes in nitrogen gas, and carbon-14 activities detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from 42 of the slow and intermediate grid wells (ESAC-35, WSAC-10, and WSAC-11 not analyzed) and the 15 flow-path wells were analyzed for isotopes of nitrate; samples from 43 of the slow and intermediate grid wells (ESAC-35 and WSAC-11 not analyzed) and the 15 flow-path wells were analyzed for carbon-14 activities. Nitrogen and oxygen isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. The laboratoroy entity codes for the laboratories in the USGS's National Water Information System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; na, not available; nc, sample not collected; no., number; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, nitrate not detected, therefore sample was not analyzed for nitrate isotopes]

GAMA identification no.	δ^{18}O of nitrate[1] (per mil) (63041)	δ^{15}N of nitrate[1] (per mil) (82690)	δ^{13}O of dissolved carbonates[2] (per mil) (82081)	[3]Carbon-14 (percent modern) (49933)
Threshold type	**na**	**na**	**na**	**na**
Threshold	**na**	**na**	**na**	**na**
WSAC-17	5.58	13.78	–15.50	81
WSAC-18	12.82	27.24	–13.10	34
WSAC-21	0.29	1.58	–17.09	88
WSAC-22	0.34	7.46	–15.13	78
WSAC-25	16.81	28.19	–14.14	39
WSAC-26	1.29	2.55	–14.62	74
WSAC-28	0.40	3.67	–13.78	114
WSAC-29	0.06	4.85	–15.03	44
WSAC-30	6.20	10.21	–13.42	84
WSAC-31	–0.20	5.00	–15.56	41
WSAC-34	1.96	5.07	–15.62	114
WSAC-35	2.63	7.86	–14.93	94
WSAC-36	7.25	13.64	–15.42	65
		Flow-path wells		
ESAC-FP-01	—	—	–15.25	27
ESAC-FP-02	0.38	8.30	–14.82	100
ESAC-FP-03	11.89	19.89	–17.50	93
ESAC-FP-04	2.17	4.07	–17.45	58
ESAC-FP-05	0.98	5.65	–22.23	100
ESAC-FP-06	—	—	–14.98	9
ESAC-FP-07	—	—	–11.63	5
WSAC-FP-01	0.47	4.18	–13.49	43
WSAC-FP-02	–3.09	2.52	–13.19	23
WSAC-FP-03	0.07	4.49	–17.89	85
WSAC-FP-04	—	—	–14.00	18
WSAC-FP-05	10.56	20.26	–16.50	14
WSAC-FP-06	6.69	9.76	–14.40	15
WSAC-FP-07	—	—	–14.82	15
WSAC-FP-08	3.42	7.43	–15.22	93

[1] USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA).

[2] University of Waterloo (contract laboratory) (CAN-UWIL).

[3] University of Arizona, Accelerator Mass Spectrometry Laboratory (contract laboratory) (AZ-UAMSL).

Table 14. Radioactive constituents detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) Program, California, June to September, 2006.

[Samples from the eight slow grid wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Analyses by Eberline Analytical Services. The laboratory entity code for Eberline Analytical Services in the USGS's National Water Information System (NWIS) is CA-EBERL. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); no., number; pCi/L, picocuries per liter; USEPA, U.S. Environmental Protection Agency; WSAC, West study area of the middle Sacramento Valley study unit; <, nondetection; L<, nondetection, however, result may be biased low on the basis of matrix-spike results with the potential for a false nondetection; *, value above lower threshold]

GAMA identification no.	Radium-226 (pCi/L) (09511)	Radium-228 (pCi/L) (81366)	Radon-222 (pCi/L) (82303)	Gross alpha radioactivity, 72-hour count (pCi/L) (62636)	Gross alpha radioactivity, 30-day count (pCi/L) (62639)	Gross beta radioactivity, 72-hour count (pCi/L) (62642)	Gross beta radioactivity, 30-day count (pCi/L) (62645)
Threshold type[1]	**MCL-US**[2]	**MCL-US**[2]	**proposed MCL-US**[3]	**MCL-US**	**MCL-US**	**MCL-CA**	**MCL-CA**
Threshold value	**5**	**5**	**300 (4,000)**	**15**	**15**	**50**	**50**
			Grid wells				
ESAC-25	E0.02	<0.46	78	<2.2	<2.1	E1.1	E1.6
ESAC-26	E0.03	<0.46	*307	<1.2	<2.5	E1.9	E2.0
ESAC-27	E0.05	<0.51	*972	E1.5	E1.2	E1.6	E1.4
ESAC-28	E0.03	<0.62	*343	E1.1	<2.2	2.7	E3.2
WSAC-03	E0.03	<0.44	*447	E0.6	<3.3	<1.9	<2.8
WSAC-08[4]	E0.03	<0.54	*463	L<2.2	L<2.1	E1.7	<1.7
WSAC-12	0.09	E0.45	*411	<1.7	<2.7	<2.0	E1.0
WSAC-18[4]	E0.05	<0.54	214	L<4.9	L<3.1	E1.2	E1.6

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The MCL-US threshold for radium is the sum of radium-226 and radium-228.

[3] Two MCL-US thresholds have been proposed: 300 pCi/L and 4,000 pCi/L.

[4] Potential to be biased low for gross alpha 72-hour and gross alpha 30-day radioactivity counts because of relatively high concentration of calcium.

Appendix

The appendix discusses methods used to collect and analyze ground-water samples and to report the data for the MSACV study unit. These methods were selected to obtain representative samples of the ground water used for drinking-water supplies in the study and to minimize potential bias of the data. Procedures to analyze and interpret QC data collected as part of the ground-water sampling are also discussed.

Sample Collection and Analysis

Ground-water samples were collected using standard and modified USGS protocols (Koterba and others, 1995), the National Field Manual for the collection of water quality data (U.S. Geological Survey, variously dated) and protocols described by Weiss (1968), Shelton and others (2001), Ball and McClesky (2003a,b), and Wright and others (2005).

Prior to sampling, each well was pumped continuously to purge at least three casing-volumes of water from the well (Wilde and others, 1999). Wells were sampled using Teflon tubing with brass and stainless-steel fittings attached to a sampling point on the well discharge pipe as close to the well as possible. The sampling point was always located upstream of any well-head treatment system or water storage tank. If a chlorinating system was attached to the well, the chlorinator was shut off at least 24 hours prior to purging and sampling the well to clear all chlorine out of the system.

For the *fast* and *intermediate* schedules, samples were collected at the well head using a foot-long length of Teflon tubing. For the *slow* schedule, the samples were collected inside an enclosed chamber located inside a mobile laboratory and connected to the well head by a 10- to 50-ft length of Teflon tubing (Lane and others, 2003).

For intermediate monitoring schedules (flow-path and RICE wells), samples were collected using a portable, 2-in. diameter submersible pump (Grundfos RediFlo2 pump) attached to reels of approximately 300 ft of Teflon tubing. The 10- to 50-ft Teflon tubing used to sample slow schedules was attached to the outflow section of the reels and samples were collected inside an enclosed chamber in a mobile laboratory. Two separate submersible pumps and reels were used to collect samples from monitoring wells in MSACV. All fittings and lengths of tubing were cleaned between samples (Wilde, 2004).

For the field measurements, ground water was pumped through a flow-through chamber fitted with a multiprobe meter that simultaneously measures the water-quality indicators dissolved oxygen, temperature, pH, turbidity, and specific conductance. Field measurements were made in accordance with protocols in the USGS's National Field Manuals (Lewis, 2006; Radtke and others, 2005; Wilde, 2006; Wilde and others, 2006; Wilde and Radtke, 2005). All sensors on the multiprobe meter were calibrated daily. Measurements of temperature, dissolved oxygen, pH, and specific conductance values were recorded at 5-minute intervals for at least 30 minutes, and when these values remained stable for 20 minutes, samples for laboratory analyses were then collected. Field measurements and instrument calibrations were recorded by hand on field record sheets and electronically in PCFF ("Personal Computer Field Forms")-GAMA, a software package designed by the USGS with support from the GAMA program. Analytical service requests were also managed by PCFF-GAMA. Chain of custody documentation forms were completed by hand or electronically. Information from PCFF-GAMA was uploaded directly into NWIS at the end of every week of sample collection.

For analyses requiring filtered water, ground water was diverted through a 0.45-µm pore size vented capsule filter, a disk filter, or a baked glass-fiber filter depending on the protocol for the analysis (Wilde, 2004; Wilde and others, 1999). Prior to sample collection, polyethylene sample bottles were prerinsed twice using dionized water and once with sample water before collection. Samples requiring acidification were acidified to a pH of 2 or less with the appropriate acids using ampoules of certified, traceable concentrated acids obtained from NWQL.

Temperature-sensitive samples were stored on ice prior to, and during, daily shipping to the various laboratories. The nontemperature-sensitive samples, tritium, noble gases, chromium speciation, and stable isotopes were shipped monthly, whereas VOCs, pesticides and pesticide degradates, constituents of special interest, dissolved organic carbon, radium isotopes, gross alpha and beta radioactivity, and radon-222 samples were shipped daily.

Detailed sampling protocols for individual analyses and groups of analytes are described in Koterba and others (1995) and the USGS's National Field Manuals (Wilde, 2004; Wilde and others, 1999) and in the references for analytical methods listed in table A1; only brief descriptions are given here. VOCs and gasoline oxygenates and degradates, and 1,2,3-TCP samples were collected in 40-mL baked amber glass sample vials that were purged with three vial volumes of sample water before bottom-filling to eliminate atmospheric contamination. Six normal (6 N) hydrochloric acid (HCl) was added as a preservative to the VOC samples, but not to the gasoline oxygenate and degradate samples, or the 1,2,3-TCP samples. Perchlorate samples were collected in 125-mL polyethylene bottles. Tritium samples were collected by bottom-filling two 1-L polyethylene bottles with unfiltered ground water, after first overfilling the bottle with three volumes of water. Stable isotopes of water were collected in 60-mL clear glass bottles filled with unfiltered water, sealed with a conical cap, and secured with electrical tape to prevent leakage and evaporation.

Pesticides and pesticide degradation products, pharmaceutical compounds, and NDMA samples were collected in 1-L baked amber glass bottles. Pesticide and pharmaceutical samples were filtered with a glass-fiber filter during collection, whereas the NDMA samples were filtered at the Montgomery Watson Harza laboratory prior to analysis.

Ground-water samples for major and minor ions, trace elements, alkalinity, and total dissolved solids analyses required filling one 250-mL polyethylene bottle with raw ground water, and one 500-mL and one 250-mL polyethylene bottles with filtered ground water (Wilde, 2004). A Whatman capsule filter was used for filtration. Each 250-mL filtered sample was then preserved with an ampoule of 7.5 N nitric acid. Mercury samples were collected by filtering ground water into a 250-mL glass bottle and preserving with an ampoule of 6 N HCl. Arsenic and iron speciation samples were filtered into 250-mL polyethylene bottles that were covered with tape to prevent light exposure and preserved with 6 N HCl. Nutrient samples were filtered into 125-mL brown polyethylene bottles. Nitrate isotope samples were filtered into 125-mL polyethylene bottles. Radium isotopes and gross alpha and beta radiation samples were filtered into 1-L polyethylene bottles and acidified with nitric acid. Carbon isotope samples were filtered and bottom-filled into two 500-mL glass bottles that were first overfilled with three bottle volumes of ground water. These samples had no headspace and were sealed with a conical cap to avoid atmospheric contamination. Samples for alkalinity titrations were collected by filtering ground water into 500-mL polyethylene bottles.

Dissolved organic carbon (DOC), chromium, radon-222, dissolved gases, and microbial constituents were collected from the hose bib at or near the well head, regardless of the sampling schedule (fast, intermediate, or slow). DOC was collected after rinsing the sampling equipment with universal blank water (Wilde, 2004). Using a 50-mL syringe and 0.45-µm disk filter, ground-water samples were filtered into 125-mL baked amber glass bottles and preserved with 4.5 N sulfuric acid. Chromium speciation samples were collected using a 10-mL syringe with an attached 0.45-µm disk filter. After the syringe was thoroughly rinsed and filled with ground water, 4 mL was forced through the disk filter; the next 2 mL of the ground water was then slowly filtered into a small centrifuge vial for analysis of total chromium. Hexavalent chromium, Cr(VI), was then collected by attaching a small cation-exchange column to the syringe filter, and after conditioning the column with 2 mL of sample water, 2 mL was collected in a second centrifuge vial. Both vials were preserved with 10 µL of 7.5 N nitric acid (Ball and McClesky, 2003a,b).

For the collection of radon-222, a stainless steel and Teflon valve assembly was attached to the sampling port at the well head (Wilde, 2004). The valve was partially closed to create back pressure, and a 10-mL sample was taken through a Teflon septum on the value assembly using a glass syringe affixed with a stainless-steel needle. The sample was then injected into a 25-mL vial partially filled with scintillation mixture (mineral oil) and shaken. The vial was then placed in a cardboard tube to shield it from light during shipping.

Noble gases were collected in 3/8-in. copper tubes using reinforced nylon tubing connected to the hose bib at the wellhead. Ground water was flushed through the tubing to dislodge bubbles before flow was restricted with a back pressure valve. Clamps on either side of the copper tube were then tightened, trapping a sample of ground water for analyses of noble gases (Weiss, 1968).

Samples for analysis of microbial constituents also were collected at the well head (Bushon, 2003; Myers, 2004). Prior to the collection of samples, the sampling port was sterilized using isopropyl alcohol, and ground water was run through the sampling port for at least three minutes to remove any traces of the sterilizing agent. One sterilized 3-L carboy was filled for coliphage analyses (F-specific and somatic coliphage determinations), and two sterilized 250-mL bottles were filled with ground water for coliform (total coliforms and *Escherichia* coliform) analyses. Total coliforms and *Escherichia* coliform (*E. coli*) plates were prepared using sterilized equipment and reagents (Myers, 2004). Plates were counted under an ultraviolet light, following a 22- to 24-hour incubation time.

Turbidity and alkalinity were measured in the mobile laboratory at the well site. Turbidity was measured in the field with a calibrated turbidity meter. Alkalinity concentrations were measured on filtered samples by Gran's titration method (Rounds, 2006). Titration data were entered directly into PCFF-GAMA, and the concentrations of bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) were automatically calculated from the titration data using the advanced speciation method. Concentrations of HCO_3^- and CO_3^{2-} were also calculated from the laboratory alkalinity and pH measurements. Calculations were made in a spreadsheet using the advanced speciation method (http://or.water.usgs.gov/alk/methods.html) with pK_1 = 6.35, pK_2 = 10.33, and pK_W = 14.

Ten laboratories performed chemical and microbial analyses for this study (see table A1), with most of the analyses being performed at NWQL or by laboratories contracted by NWQL. NWQL maintains a rigorous quality-assurance program (Maloney, 2005; Pirkey and Glodt, 1998). Laboratory QC samples, including method blanks, continuing calibration verification standards, standard reference samples, reagent spikes, external certified reference materials, and external blind proficiency samples, are analyzed regularly. Method detection limits are continuously tested and laboratory reporting levels updated accordingly. NWQL maintains National Environmental Laboratory Accreditation Program

(NELAP) and other certifications (http://nwql.usgs.gov/Public/lab_cert.shtml). In addition, the Branch of Quality Systems within the USGS's Office of Water Quality maintains independent oversight of quality assurance at NWQL and laboratories contracted by NWQL. The Branch of Quality Systems also runs a National Field Quality Assurance program that includes annual testing of all USGS field personal for proficiency in making field water-quality measurements (http://bqs.usgs.gov/nfqa/). Results for analyses made at NWQL or by laboratories contracted by NWQL are uploaded directly into NWIS by NWQL.

Data Reporting

Laboratory Reporting Conventions

NWQL uses the LRL as a threshold for reporting analytical results. The LRL is set to minimize the reporting of false negatives (not detecting a compound when it is actually present in a sample) to less than 1 percent (Childress and others, 1999). The LRL is set at two-times the long-term method detection level (LT-MDL). The LT-MDL is derived from the standard deviation of at least 24 MDL determinations made over an extended period of time. LT-MDLs are continually monitored and updated. The method detection limit (MDL) is the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the concentration is greater than zero (at the MDL, there is less than 1 percent chance of a false positive) (Childress and others, 1999; U.S. Environmental Protection Agency, 2002a). NWQL updates LRL values regularly, and the values listed in this report were in effect during the period analyses were made for ground-water samples from the MSACV study (June to September, 2006).

Detections between the LRL and the LT-MDL are reported as estimated concentrations (designated with an "E" before the value in the tables and text). For information-rich methods, detections below the LT-MDL have high certainty of detection, but the precise concentration is uncertain. Information-rich methods are those that utilize gas chromatography or high-performance liquid chromatography (HPLC) with mass spectrometry detection (VOCs, gasoline oxygenates and degradates, and pesticides and pesticide degradates). For these methods, compounds are identified by presence of characteristic fragmentation patterns in their mass spectra in addition to being quantified by measurement of peak areas at their associated chromatographic retention times. E-coded values also may result from detections outside the range of calibration standards for detections that did not meet all laboratory QC criteria and for samples that were diluted prior to analysis (Childress and others, 1999).

Some compound concentrations in this study are reported using minimum reporting levels (MRLs) or method uncertainties. The MRL is the smallest measurable concentration of a constituent that may be reliably reported using a given analytical method (Timme, 1995). The method uncertainty generally indicates the precision of a particular analytical measurement; it gives a range of values wherein the true value will be found.

The reporting levels for radiochemical constituents (gross-alpha radioactivity, gross-beta radioactivity, radium-226, and radium-228) are based on a sample-specific minimum detectable concentration (SSMDC), a sample-specific critical value, and the combined standard uncertainty (CSU) (Bennett and others, 2006; U.S. Environmental Protection Agency, 2004). A result above the critical value represents a greater-than-95-percent certainty that the result is greater than zero (significantly different from the instrument's background response to a blank sample), and a result above the SSMDC represents a greater-than-95-percent certainty that the result is greater than the critical value. Using these reporting level elements, three unique cases were possible when screening the raw analytical data, as described in Bennett and others (2006). If the analytical result was less than the critical value (case 1), the analyte was considered not detected, and the concentration was reported as less than the SSMDC. If the analytical result was greater than the critical value, the ratio of the CSU to the analytical result was calculated as a percent (percent relative CSU). For those samples with percent relative CSU greater than 20 percent (case 2), concentrations were reported as estimated values (designated by an "E" preceding the value). For those samples with percent relative CSU less than 20 percent, concentrations were reported unqualified (case 3). For table clarity, only the screened results were reported in table 14; the raw analytical results with their corresponding SSMDCs, critical values, and CSUs, are on file at the USGS California Water Science Center.

Stable isotopic compositions of oxygen, hydrogen, carbon, and nitrogen are reported as relative isotope ratios in units of per mil using the standard delta notation $\delta^{i}E$ (Coplen and others, 2002):

$$\delta^{i}E = \left[\frac{R_{sample}}{R_{reference}} - 1\right] \bullet 1{,}000 \text{ per mil}, \quad (1)$$

where

^{i}E is the heavier isotope (^{18}C, ^{13}C, or ^{2}H),

R_{sample} is the ratio of the abundance of the heavier isotope to the lighter isotope (^{16}O, ^{12}C, or ^{1}H) in the sample, and

$R_{reference}$ is the ratio of the abundance of the heavier isotope to the lighter isotope (^{16}O, ^{12}C, or ^{1}H) in the reference material.

The reference material for oxygen and hydrogen is Vienna Standard Mean Ocean Water (VSMOW), which is assigned $\delta^{18}O$ and $\delta^{2}H$ values of 0 per mil (note than $\delta^{2}H$ is also written as δD because the common name of the heavier isotope of hydrogen, hydrogen-2, is deuterium). The reference material for carbon is Vienna Peedee Belemnite (VPDB), which is assigned a $\delta^{13}C$ value of 0 per mil. Positive values indicate enrichment of the heavier isotope and negative values indicate depletion of the heavier isotope, compared with the ratios observed in the standard reference material.

Constituents on Multiple Analytical Schedules

Eighteen constituents targeted in this study are measured by more than one analytical schedule or more than one laboratory (table A2). The preferred methods for these constituents were selected on the basis of the procedure recommended by NWQL (http://wwwnwql.cr.usgs.gov/USGS/Preferred_method_selection_procedure.html). Methods with full approval are preferred over those with provisional approval and approved methods are favored over research methods. The method with greater accuracy and precision and lower LRLs for the overlapping constituents is generally preferred. However, the method with higher LRLs may be selected as the preferred method to provide consistency with historical data analyzed by the same method.

Five constituents appear on NWQL Schedules 2020 and 4024, and the preferred method is Schedule 2020 to provide consistency. All samples collected for the GAMA Priority Basin Assessment project are analyzed using Schedule 2020, whereas, only a subset are analyzed using Schedule 4024. Six constituents appear on NWQL Schedules 2032/2033 and 2060, and the preferred method is Schedule 2032/2033 because it has greater precision and accuracy for the six overlapping constituents. For constituents that appear on two NWQL schedules, only the values determined by the preferred method are reported.

The water-quality indicators pH, specific conductance, and alkalinity were measured in the field and at NWQL. The field measurements are the preferred method for all three constituents; however, both are reported because the laboratory alkalinity measurements were made on a greater number of samples.

The field and laboratory data were compared using the Wilcoxon signed-rank test, a nonparametric statistical test that is analogous to the parametric statistical test the paired t-test (Helsel and Hirsch, 2002). A nonparametric test was used because the data are not normally distributed. The Wilcoxon signed-rank test evaluates the null hypothesis that the median of the paired differences between the two datasets is zero. Results are reported as the probability, P, of obtaining the observed distribution of data, or one even less likely, when the null hypothesis is true. Therefore, a P value of 0.01 indicates 99 percent confidence that the two datasets are different.

Specific conductance was measured in both the field and the laboratory for 82 samples, and there was no statistical significance between the two datasets (P = 0.1035). Both laboratory and field pH measurements were made for 80 samples, and the two datasets were systematically different (P = <0.0001). Field pH values were lower by a median of 0.3 pH units. The increase in pH between field and laboratory measurement may be explained by equilibration of the sample with the atmosphere after collection. The partial pressure of CO_2 in ground water is often greater than the atmospheric partial pressure (Appelo and Postma, 2005); thus, CO_2 degasses from the ground water when it is brought in contact with the atmosphere. CO_2 loss results in increased pH. Field and laboratory alkalinities were measured for seven samples, and the two datasets were significantly different (P = 0.0156). Field alkalinity values were lower by a median of 11 mg/L as $CaCO_3$. The differences between the field and laboratory values were greater than 5 percent for all but two samples.

For arsenic, chromium, and iron concentrations, the standard methods used by NWQL are preferred over the research methods used by the USGS National Research Program (NRP) Trace Metal Laboratory (TML) in Boulder, Colorado. The concentrations measured by TML are used only to

calculated ratios of redox species for each element, $\frac{As(V)}{As(III)}$ for arsenic, $\frac{Cr(VI)}{Cr(III)}$ for chromium, and $\frac{Fe(III)}{Fe(II)}$ for iron. For example:

$$\frac{Fe(III)}{Fe(II)} = \frac{Fe(T) - Fe(II)}{Fe(II)}, \quad (2)$$

where

Fe(T) is the total iron concentration (measured),

Fe(II) is the concentration of ferrous iron (measured), and

Fe(III) is the concentration of ferric iron (calculated).

Quality Assurance

The purpose of quality-assurance is to identify which data best represent environmental conditions and which may have been affected by contamination or bias during sample collection, processing, storage, transportation, or laboratory analysis. Four types of QC tests were used in this study: blank samples were collected to assess contamination; replicate samples were collected to assess reproducibility; matrix spike tests were done to assess accuracy of laboratory analytical methods; and surrogate compounds were added to samples analyzed for organic constituents to assess bias of laboratory analytical methods. In the tables of this report, detections of organic constituents in ground-water samples that may have resulted from contamination were flagged with a “V” remark code, and were not considered detections for calculations

of detection frequencies in water-quality assessments. Detections of inorganic constituents in ground-water samples that may have resulted from contamination were flagged with a "V" remark code to indicate that the amount of potential contamination may have been sufficient to change a nondetection into a detection relative to the stated reporting level.

The quality-assurance used for this study followed the protocols used by the USGS's NAWQA program (Koterba and others, 1995) and described in the National Field Manual (U.S. Geological Survey, variously dated). The quality assurance plan followed by NWQL, the primary laboratory used to analyze samples for this study, is described in Maloney (2005) and Pirkey and Glodt (1998).

Blanks

Blank samples (blanks) were collected using two types of water certified by NWQL to contain less than the LRL or MRL of the analytes investigated in the study. First, inorganic blank water (IBW) was used to collect sample blanks of perchlorate, major ions and trace elements, nutrients, arsenic and iron speciation, and chromium speciation. All other blanks were collected using VOC-free (nitrogen-purged) blank water (VBW). Two types of blanks were collected: source-solution and field blanks. Source-solution blanks were collected to verify that the blank water used for the field blanks was free of analytes. Field and source solution blanks were collected at approximately 10 percent of the wells sampled to determine if equipment or procedures used in the field or laboratory introduced contamination. Field blanks were analyzed for VOCs, gasoline oxygenates and their degradates, pesticides and pesticide degradates, pharmaceuticals, perchlorate, NDMA, 1,2,3-TCP, nutrients, DOC, major and minor ions, trace elements, iron, arsenic, and chromium speciation, and radioactive constituents (table A3). NWQL-certified blank water is not available for tritium or noble gases; thus, source solution and field blanks were not collected for these constituents.

Field blanks were collected by pumping or pouring blank water through the sampling equipment (fittings and tubing) used to collect ground water, then processing and transporting the blank samples using the same protocols for the ground-water samples. The equipment used to collect samples from monitoring wells was significantly different than that used to collect samples from production wells; thus, the field blanks were separated into monitoring well and production well groups for comparison with ground-water data. Source-solution blanks were collected at the sampling site by pouring blank water directly into sample containers that were preserved, stored, shipped, and analyzed in the same manner as the ground-water samples. Source-solution blanks were not divided into two classes because they were not collected using the field sampling equipment.

If a constituent was detected in field or source-solution blanks, the data for that constituent in ground-water samples were examined for potential contamination. Detections in ground-water samples with concentrations less than the highest concentration measured in a blank plus the LT-MDL were marked with a "V" in the data tables (LRL equals twice the LT-MDL). The highest concentration measured in a blank was assumed to represent the highest potential amount of contamination. Thus, the V remark code flags results that could have changed from a nondetection to a detection relative to the LT-MDL because of contamination. For example, if the LT-MDL for a constituent is 0.10 µg/L, the measured concentration in a ground-water sample with a true concentration of 0.05 µg/L would be reported as a nondetection. But, if the ground-water sample was contaminated with 0.20 µg/L of the constituent, the measured concentration would be reported as 0.25 µg/L, a detection. If the maximum potential amount of contamination is 0.20 µg/L, then ground-water samples with measured concentrations less than 0.30 µg/L may actually have true concentrations less than the LT-MDL.

For organic constituents, results with V codes are not considered to be detections of the constituent when calculating detection frequencies for ground-water quality assessments. For inorganic constituents, results with V codes are considered to have concentrations less than the reported value (including the possibility of the concentration being less than the LT-MDL).

Replicates

Sequential replicate samples were collected to assess variability that may result from the processing and analyses of inorganic and organic constituents. RSD of the measured values was used to express the variability between replicate pairs for each compound (table A4). The RSD is defined as the standard deviation divided by the mean concentration for each replicate pair of samples, multiplied by 100 percent. If one value in a sample pair was reported as a nondetection and the other value was reported as an estimated value below the LRL or MRL, the RSD was set to zero because the values are analytically identical. If one value in a sample pair was reported as a nondetection and the other value was greater than the LRL or MRL, then the nondetection value was set equal to one-quarter of the LRL, and the RSD was calculated (Hamlin and others, 2002). Values of RSD less than 20 percent are considered acceptable in this study. An RSD value of 20 percent corresponds to a relative percent difference (RPD) value of 29 percent. High RSD values for a compound may indicate analytical uncertainty at low concentrations, particularly for concentrations within an order of magnitude of LT-MDL or MDL. Sequential replicate samples were collected at approximately 10 percent of the wells sampled.

Matrix Spikes

Addition of a known concentration of a constituent ("spike") to a replicate environmental sample enables the laboratory to determine the effect of the matrix, in this case ground water, on the analytical technique used to measure the constituent. The compounds added as matrix spikes are the same as those being analyzed in the method. This enables an analysis of matrix interferences on a compound by compound basis. Matrix spikes were added at the laboratory performing the analysis. Compounds with low recoveries are of particular concern if environmental concentrations are close to the MCLs; a concentration below an MCL could be above this threshold. Conversely, compounds with high recoveries are of potential concern if the environmental concentrations exceed MCLs; a high recovery could falsely indicate a concentration above the MCL.

Acceptable ranges for matrix-spike recoveries are based on the acceptable ranges established for laboratory "set" spike recoveries. Laboratory set spikes are aliquots of laboratory blank water to which the same spike solution used for the matrix spikes has been added. One set spike is analyzed with each set of samples. Acceptable ranges for set spike recoveries are 70 to 130 percent for NWQL Schedules 2020 and 4024 (VOCs and gasoline additives; Connor and others, 1998; Rose and Sandstrom, 2003; Zaugg and others, 2002), 60 to 120 percent for NWQL Schedules 2032, 2033, and 2060 (pesticides; Sandstrom and others, 2001), and 60 to 130 percent for Schedule 2080 (pharmaceuticals; Kolpin and others, 2002). On the basis of these ranges, we defined 70 to 130 percent as the acceptable range for matrix-spike recoveries for organic compounds in this study.

Laboratory matrix spikes were performed for VOCs, gasoline oxygenate and their degradates, pesticide compounds, pharmaceutical compounds, NDMA, and 1,2,3-TCP because the analytical methods for these constituents are chromatographic methods that may be susceptible to matrix interferences. Replicate samples for matrix-spike additions were collected at approximately 10 percent of the wells sampled, although not all analyte classes were tested for every well (tables A5A–D).

Surrogates

Surrogate compounds are added to environmental samples in the laboratory prior to analysis to evaluate the recovery of similar constituents. Surrogate compounds were added to all ground-water and QC samples that were analyzed for VOCs, gasoline oxygenates and their degradates, pesticide compounds, NDMA, and 1,2,3-TCP (table A6). Most of the surrogate compounds are deuterated analogs of compounds being analyzed. For example, the surrogate toluene-*d*8 used in the VOC analytical method has the same chemical structure as toluene, except that the eight hydrogen-1 atoms on the molecule have been replaced by deuterium (hydrogen-2). Toluene-*d*8 and toluene behave very similarly in the analytical procedure, but the small mass difference between the two results in slightly different chromatographic retention times; thus, the use of a toluene-*d*8 surrogate does not interfere with the analysis of toluene. Only 0.015 percent of hydrogen atoms are deuterium (Firestone and others, 1996); thus, deuterated compounds like toluene-*d*8 do not occur naturally and are not found in environmental samples. Surrogates are used to identify general problems that may arise during sample analysis that could affect the analysis results for all compounds in that sample. Potential problems include matrix interferences (such as high levels of dissolved organic carbon) that produce a positive bias, or incomplete laboratory recovery (possibly attributed to improper maintenance and calibration of analytical equipment) that produces a negative bias. A 70 to 130 percent recovery of surrogates is generally considered acceptable. Values outside this range indicate possible problems with the processing and analysis of samples (Connor and others, 1998; Sandstrom and others, 2001).

Quality-Control Sample Results

Detections in Field and Source-Solution Blanks

Field blanks were collected at approximately 10 percent of the sites sampled in MSACV. Table A3 presents a summary of compound detections in field blanks. Field blank results were grouped according to sampling methods (see "Sample Collection and Analysis" section) and analyzed to determine how field blank detections affected environmental data.

Seven source-solution blanks, seven field blanks at production wells, and five field blanks at monitoring wells were collected for analysis of VOCs. Eleven VOC constituents were detected in field blanks collected at production wells or in source-solution blanks (table A3). Only 2 of these 11 VOCs—chloroform and 1,2,4-trimethylbenzene—were detected in ground-water samples collected at production wells. Chloroform was detected in one field blank at a concentration of E0.04 µg/L. Three detections in ground-water samples with concentrations less than 0.05 µg/L (E0.04 µg/L plus one-half of the LRL of 0.02 µg/L) were flagged with a V code (table 5). 1,2,4-trimethlybenzene was detected in one source-solution blank at a concentration of E0.04 µg/L. Four detections in production well samples with concentrations less than 0.07 µg/L (E0.04 µg/L plus one-half the LRL of 0.056 µg/L) were flagged with a V code (table 5). The V-coded results were counted as nondetections for calculation of the detection frequency of chloroform and 1,2,4-trimethylbenzene in the grid wells.

Three VOC constituents were detected in field blanks collected at monitoring wells or in source-solution blanks (table A3), and all three were detected in ground-water samples collected at monitoring wells. 1,2,4-trimethlybenzene was detected in one source-solution blank and one field blank with a maximum concentration of E0.04 µg/L. A single detection in a ground-water sample with a concentration less than 0.07 µg/L (E0.04 µg/L plus one-half the LRL of 0.056 µg/L) was flagged with a V code (table 5). *m-* and *p-Xylene* was detected was detected in two fields with a maximum concentration of E0.07 µg/L. *m-* and *p-Xylene* was detected in one ground-water sample collected from a monitoring well. The concentration of *m- and p-Xylene* detected in the sample was less than 0.10 µg/L (0.07 µg/L plus one-half the LRL of 0.06 µg/L) and was, therefore, flagged with a V code. Toluene was detected in three source solution blanks and three field blanks with a maximum concentration of E0.07 µg/L. Low levels of toluene were detected in source-solution and field blanks in many of the earlier GAMA study units (Bennett and others, 2006; Dawson and others, 2008; Fram and Belitz, 2007; Kulongoski and Belitz, 2007; Kulongoski and others, 2006; Wright and others, 2005). Toluene was detected in one ground-water sample collected from a monitoring well. The concentration of toluene detected in the sample was less than 0.08 µg/L (0.07 µg/L plus one-half the LRL of 0.02 µg/L), and was, therefore, flagged with a V code. Seven field blanks were collected at production wells and four field blanks were collected at monitoring wells for analysis of pesticides and pesticide degradates. Three pesticide compounds were detected in one field blank collected at a production well (table A3), and one of these compounds, bromacil, was detected in ground-water samples collected from production wells. The concentration of bromacil detected in the field blank was E0.11 µg/L. All three detections of bromacil in ground-water samples were less than 0.012 µg/L (0.11 µg/L plus one-half the LRL of 0.018 µg/L), and were, therefore, flagged with a V code (table 6). The V-coded results were counted as nondetections for calculation of the detection frequency of bromacil in the grid wells.

Constituents of special interest (perchlorate, 1,2,3-TCP, and NDMA) and radioactive constituents (radium isotopes and gross alpha and beta radiation) were not detected in any source-solution or field blanks. One field blank was collected at a production well for analysis of radium isotopes and gross alpha and beta radiation. Eleven source-solution blanks, seven field blanks at production wells, and four field blanks at monitoring wells were collected for analysis of perchlorate. Six source solution-blanks, five field blanks at production wells, and one field blank at a monitoring well were collected for analysis of 1,2,3-TCP and NDMA.

DOC was analyzed in one field blank collected at a production well and three field blanks collected at monitoring wells. DOC was detected in all three field blanks collected at monitoring wells, with a maximum concentration of 0.7 mg/L. Six ground-water samples collected at monitoring wells had detections of DOC at concentrations less than 0.9 mg/L (0.7 mg/L plus one-half the LRL of 0.33 mg/L). These six samples were flagged with V codes (table 8), indicating that the concentration of DOC in the samples may be as high as the reported value, but may also be as low as a nondetection relative to the stated detection limit (one-half the LRL).

Nutrients were analyzed in five field blanks collected at production wells and four field blanks collected at monitoring wells. Nitrate and nitrite were not detected in any of the field blanks. Orthophosphate was detected at a concentration of E0.003 mg/L in one field blank collected at a production well, and in two field blanks collected at monitoring wells. One production well sample had an orthophosphate concentration less than 0.006 mg/L (0.003 plus one-half the LRL of 0.006 µg/L); this result was flagged with a V code. Ammonia was detected in two field blanks collected at monitoring wells, with a maximum concentration of E0.007 mg/L. Seventeen ground-water samples collected from monitoring wells had ammonia concentrations less than 0.012 mg/L (E0.007 mg/L plus one-half the LRL of 0.01 mg/L). These results were flagged with V codes, indicating that the ammonia concentration in the samples could be as high as the reported value if no contamination had occurred, but also be as low as a nondetection relative to the LT-MDL of 0.005 mg/L if the maximum potential amount of contamination (0.003 mg/L) had occurred. Total nitrogen was detected in three field blanks collected at production wells, with a maximum concentration of 0.26 mg/L, and in two field blanks collected at monitoring wells with a maximum concentration of 0.45 mg/L. The LRL for total nitrogen is 0.06 mg/L; thus, the threshold concentration for flagging results with V codes was 0.29 mg/L for ground-water samples collected at production wells and 0.48 mg/L for ground-water sampled collected at monitoring wells. Total nitrogen results for the 10 ground-water samples collected from production wells and the 14 collected from monitoring wells with concentrations less than these threshold concentrations were flagged with V codes.

Major ions were analyzed in five field blanks collected at production wells and four collected at monitoring wells. Calcium, chloride, magnesium, and silica were each detected in at least one field blank (table A3). However, for all four ions, the maximum concentration detected in the field blanks plus one-half the LRL was less than the minimum concentrations detected in ground-water samples. Therefore, no data were flagged with V codes.

Trace elements were analyzed in five field blanks collected at production wells and in five field blanks collected at monitoring wells. Maximum concentrations for the three trace elements detected in field blanks collected at production wells were: chromium, 0.04 µg/L; nickel, 0.05 µg/L; and zinc, 1.0 µg/L (table A3). The threshold concentration for flagging results with V codes in table 10 was the maximum concentration of the constituent detected in a field blank plus one-half the LRL for that constituent. Nine detections of chromium with concentrations less than 0.06 µg/L, 10 detections of nickel with concentrations less than 0.08 µg/L, and 16 detections of zinc with concentrations less than 1.3 µg/L in ground-water samples collected from production wells were flagged with V codes, indicating that the concentration in the ground-water sample may be as high as the reported concentration, but also may be as low as a nondetection. In all cases, the results flagged with V codes had concentrations far below health-based or other drinking-water quality thresholds (the MCL-CA for chromium is 50 µg/L; the MCL-CA for nickel is 100 µg/L; and the SMCL-CA for zinc is 5,000 µg/L).

Maximum concentrations for the 11 trace elements detected in at least one field blank collected at a monitoring well were: aluminum, E1 µg/L; barium, E0.9 µg/L; chromium, 0.10 µg/L; copper, 1.80 µg/L; iron, 8 µg/L; manganese, 0.7 µg/L; nickel, 0.20 µg/L; strontium, 0.55 µg/L; tungsten, E0.04 µg/L; vanadium, E0.08 µg/L; and zinc, 2.4 µg/L (table A3). The threshold concentration for flagging results with V codes in table 10 was the maximum concentration of the constituent detected in a field blank plus one-half the LRL for that constituent. Sixteen detections of aluminum, 6 detections of chromium, 18 detections of copper, 7 detections of iron, 5 detections of manganese, 2 detections of nickel, 2 detections of tungsten, and 23 detections of zinc in ground-water samples collected from monitoring wells were flagged with V codes, indicating that the concentration in the ground-water sample may be as high as the reported concentration, but also may be as low as a nondetection. In all cases, the results flagged with V codes had concentrations far below health-based or other drinking-water quality thresholds (table 10). No detections of barium, strontium, or vanadium were flagged with V codes because the maximum concentration detected in the field blanks plus one-half the LRL was less than the minimum concentration detected in ground-water samples.

Arsenic and iron were detected in field blank samples analyzed by the NRP (table A3). Arsenic was detected in two of five field blanks collected at production wells and in two of five field blanks collected at monitoring wells. The maximum concentration of arsenic detected in a field blank analyzed by the NRP laboratory was 4.5 µg/L. Arsenic was not detected in any field blank samples analyzed by NWQL; therefore, the arsenic detected in field blanks analyzed at the NRP laboratory were considered to have originated in the laboratory. Because the arsenic contamination was not related to sampling equipment, there was no basis for assessing NRP arsenic data differently for the two different types of sampling equipment. Because the arsenic concentration data from NWQL Schedule 1948 are preferred over the concentration data from the NRP laboratory, comparisons between the two sets of data were used in conjunction with the detections in the field blanks analyzed at the NRP laboratory to assess the NRP arsenic data. Arsenic concentrations from the NRP were greater than those from NWQL for 27 of the 82 ground-water samples analyzed, and for 19 of the 27, the difference was greater than 20 percent RSD, the criteria for acceptable replicate pairs. The NRP arsenic concentrations were up to 3.5 µg/L greater than the NWQL arsenic concentration in these 19 ground-water samples, a difference that is comparable to the maximum concentration of arsenic detected in the field blanks. Arsenic results from the NRP laboratory for these 19 ground-water samples were flagged with V codes (table 11) to indicate that disagreement between the NWQL and NRP arsenic concentrations may be due to contamination of ground-water samples analyzed at the NRP laboratory. The ratio of arsenic species, $\frac{\text{As(V)}}{\text{As(III)}}$, for these 19 samples may not be representative of the redox conditions in the ground water.

Iron was detected in 2 of 10 field blanks analyzed by the NRP laboratory, with a maximum concentration of 15 µg/L. For eight ground-water samples with iron concentrations greater than 6 µg/L (the NWQL LRL for iron), iron concentrations measured by the NRP laboratory were higher than those measured by NWQL. However, all eight pairs differed by less than 10 percent RSD; thus, none of the NRP iron results were flagged with V codes.

Variability in Replicate Samples

Most of the replicate sample pairs collected during the MSACV study had relative standard deviations (RSDs) of less than 20 percent (table A4). Replicate sample pairs for analytes not detected in any ground-water samples are not reported in table A4. Thirty replicate sample pairs, representing 20 chemical constituents, had RSDs greater than 20 percent; see table A4 for details. However, the replicate sample pairs with high RSDs had very low concentrations. At low concentrations, small deviations in measured values account for large RSDs. Because the variability in measurements occurred at low concentrations, well below regulatory thresholds, this variability was not of QC concern, and no detections were censored as a result of variability in replicate samples.

Matrix Spike Recoveries

Tables A5A–D present a summary of matrix-spike recoveries for the MSACV study. The addition of a spike or known concentration of a constituent to an environmental sample enables the laboratory to determine the effect of the matrix, in this case ground water, on the analytical technique used to measure the constituent. Thirteen environmental samples were spiked with VOCs to calculate matrix-spike recoveries (table A5A). Seventy-one of the 85 VOCs had matrix-spike recoveries in the acceptable range between 70 and 130 percent. Eleven VOCs had at least one-matrix spike recovery greater than 130 percent; however, of these compounds, 6 were not detected in ground-water samples. Seven VOCs had a recoveries below 70 percent; however, of these compounds, 4 were not detected in ground-water samples. The three VOCs that had recoveries less than 70 percent and were detected in ground water included carbon disulfide, 1,2,3,4-tetramethylbenzene, and 1,2,3,5-tetramethylbenzene, with recoveries of 67, 69, and 62 percent, respectively. The four VOCs that had recoveries less than 70 percent, but were not detected in ground water included dichloromethane, 2,2-dichloropropane, styrene, and 1,2,3-trichlorobenzene, with recoveries of 28, 62, 69, and 56 percent, respectively (NOTE: low recoveries may indicate that these compounds may not have been detected if they were present at very low levels).

Twelve environmental samples were spiked with pesticide and pesticide degradate compounds to calculate matrix-spike recoveries, although the number of spiked samples varied depending on laboratory procedures (table A5B). Forty-one of the 136 spike compounds had recoveries in the acceptable range between 70 and 130 percent. Eighteen of the compounds detected in ground-water samples had spike recoveries that exceeded the acceptable range. Twenty-three spike compounds had at least one recovery greater than 130 percent. Ninety-one spike compounds had at least one recovery below 70 percent, with recovery of phosmet being particularly poor. (NOTE: low recoveries may indicate that the compound might not have been detected in some samples if it was present at a very low concentration).

One, 7, and 5 ground-water samples were spiked with perchlorate, 1,2,3-TCP, and NDMA, respectively (table A5C). All spike recoveries were within the acceptable range of 70 to 130 percent.

Two ground-water samples were spiked with radium-226 and radium-228 (table A5D). All spike recoveries were within the acceptable range of 70 to 130 percent with the exception of gross alpha 72-hour and gross alpha 30-day counts for one of the samples. The spiked sample (WSAC-08) that had poor recovery of alpha radioactivity had relatively high concentration of calcium (table 9). Because calcium is known to interfere with alpha counts (Sinojmeri, 1999), this sample and WSAC-18, which had similar major-ion chemistry, were coded as having the potential to be biased low for gross alpha 72-hour and gross alpha 30-day counts.

Surrogate Compound Recoveries

Surrogate compounds were added to environmental samples in the laboratory and analyzed to evaluate the recovery of similar constituents. Table A6 lists each surrogate, the analytical schedule on which it was applied, the number of analyses for blank and nonblank samples, the number of surrogate recoveries below 70 percent, and the number of surrogate recoveries above 130 percent for the blanks and environmental samples. Blanks and environmental samples were considered separately to assess whether the matrices present in ground water affect surrogate recoveries. No systematic differences between surrogate recoveries in blanks and environmental samples were observed. Ninety-one percent of the surrogate recoveries in analyses of VOC and gasoline oxygenate and degradates were in the acceptable range of 70 to 130 percent recovery, as were 96 percent of the surrogate recoveries for pesticides and pesticide degradates, and 89 percent for NDMA and 1,2,3-TCP analyses.

Table A1. Analytical methods used for the determination of organic, inorganic, and microbial constituents by the U.S. Geological Survey's (USGS) National Water Quality Laboratory (NWQL) and additional contract laboratories.

[MI agar, supplemented nutrient agar in which coliforms (total and *Escherichia*) produce distinctly different fluorescence under ultraviolet lighting; RSIL, Reston Stable Isotope Laboratory (USGS); UV, ultraviolet; VOCs, volatile organic compounds]

Analyte	Analytical Method	Laboratory and analytical schedule or lab code	Citation(s)
Organic constituents			
VOCs	Purge and trap capillary gas chromatography/mass spectrometry	NWQL, Schedule 2020	Connor and others, 1998
Gasoline oxygenates	Heated purge and trap/gas chromatography/mass spectrometry	NWQL, Schedule 4024	Rose and Sandstrom, 2003
Pesticides	Solid-phase extraction and gas chromatography/mass spectrometry	NWQL, Schedules 2032, 2033, and 2060	Furlong and others, 2001; Lindley and others, 1996; Madsen and others, 2003; Sandstrom and others, 2001; Zaugg and others, 1995
Pharmaceuticals	Solid-phase extraction and HPLC/mass spectrometry	NWQL, Schedule 2080	Kolpin and others, 2002
Constituents of special interest			
Perchlorate	Chromatography and mass spectrometry	Montgomery Watson Harza laboratory[1]	Hautman and others, 1999
N-nitrosodimethylamine (NDMA)	Chromatography and mass spectrometry	Montgomery Watson Harza laboratory[1]	U.S. Environmental Protection Agency, 1996; U.S. Environmental Protection Agency, 1999b
1,2,3-Trichloropropane	Gas chromatography/electron capture detector	Montgomery Watson Harza laboratory[1]	U.S. Environmental Protection Agency, 1995
Inorganic constituents			
Nutrients	Alkaline persulfate digestion, Kjedahl digestion	NWQL, Schedule 2755	Fishman, 1993; Patton and Kryskalla, 2003
Dissolved organic carbon	UV-promoted persulfate oxidation and infrared spectrometry	NWQL, Lab Code 2613	Brenton and Arnett, 1993
Major and minor ions, trace elements and nutrients	Atomic absorption spectrometry, colorimetry, ion-exchange chromatography, inductively-coupled plasma atomic-emission spectrometry and mass spectrometry	NWQL, Schedule 1948	American Public Health Association, 1998; Faires, 1993; Fishman, 1993; Fishman and Friedman, 1989; Garbarino, 1999; Garbarino and Damrau, 2001; Garbarino and others, 2006; McLain, 1993
Chromium, arsenic and iron speciation	Various techniques of ultraviolet visible (UV-VIS) spectrophotometry and atomic-absorbance spectroscopy	USGS Trace Metal Laboratory, Boulder, Colorado[1]	Ball and McCleskey, 2003a,b; McCleskey and others, 2003; Stookey, 1970; To and others, 1998
Stable isotopes			
Stable isotopes of water	Gaseous hydrogen and carbon dioxide-water equilibration and stable-isotope mass spectrometry	USGS Stable Isotope Laboratory, Reston, Virginia, Schedule 1142	Coplen, 1994; Coplen and others, 1991; Epstein and Mayeda, 1953
Nitrogen and oxygen isotopes of nitrate	Denitrifier method and mass spectrometry	USGS Stable Isotope Laboratory, Reston, Virginia, RSIL Lab Code 2900	Révész, K., and Casciotti, K., 2007
Carbon isotopes	Accelerator mass spectrometry	University of Waterloo, Environmental Isotope Lab[1]; University of Arizona Accelerator Mass Spectrometry Lab[1]	Donahue and others, 1990; Jull and others, 2004

Table A1. Analytical methods used for the determination of organic, inorganic, and microbial constituents by the U.S. Geological Survey's (USGS) National Water Quality Laboratory (NWQL) and additional contract laboratories.—Continued

[MI agar, supplemented nutrient agar in which coliforms (total and *Escherichia*) produce distinctly different fluorescence under ultraviolet lighting; RSIL, Reston Stable Isotope Laboratory (USGS); UV, ultraviolet; VOCs, volatile organic compounds]

Analyte	Analytical Method	Laboratory and analytical schedule or lab code	Citation(s)
Radioactivity and gases			
Tritium	Electrolytic enrichment-liquid scintillation	USGS Stable Isotope and Tritium Laboratory, Menlo Park, California, Lab Code 1565	Thatcher and others, 1977
Tritium and noble gases	Helium-3 in-growth and mass spectrometry	Lawrence Livermore National Laboratory[1]	Eaton and others, 2004; Moran and others, 2002
Radon-222	Liquid scintillation counting	NWQL, Schedule 1369	American Society for Testing and Materials, 1998; U.S. Environmental Protection Agency, 1999a
Radium 226/228	Alpha activity counting	Eberline Analytical Services, NWQL method 1262	U.S. Environmental Protection Agency, 1980 (USEPA methods 903 and 904)
Gross alpha and beta radioactivity	Alpha and beta activity counting	Eberline Analytical Services, NWQL method 1792	U.S. Environmental Protection Agency, 1980 (USEPA method 900.0)
Microbial constituents			
F-specific and somatic coliphage	Single-agar layer (SAL) and two-step enrichment methods	USGS Ohio Water Microbiology Laboratory[1]	U.S. Environmental Protection Agency, 2001
Total and *Escherichia* coliform	Membrane filter technique with "MI agar"	USGS field measurement	U.S. Environmental Protection Agency, 2002b

[1] The analytes have no schedule or lab code assigned to them.

Table A2. Preferred analytical schedules/methods for constituents appearing on multiple schedules/methods for samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September 2006.

[Preferred analytical schedules are the methods of analysis with the greatest accuracy and precision out of the ones used for the compound in question. MWH, Montgomery Watson Harza laboratory; TML, U.S. Geological Survey's (USGS) Trace Metal Laboratory in Boulder, Colorado; VOC, volatile organic compound]

Constituent	Primary constituent classification	Analytical schedules/method	Preferred analytical schedule/method
Results from preferred method reported			
Acetone	VOC, gasoline degradate	2020, 4024	2020
Diisopropyl ether	VOC, gasoline degradate	2020, 4024	2020
Ethyl *tert*-Butyl ether (ETBE)	VOC, gasoline degradate	2020, 4024	2020
Methyl *tert*-butyl ether (MTBE)	VOC, gasoline degradate	2020, 4024	2020
Methyl *tert*-pentyl ether	VOC, gasoline degradate	2020, 4024	2020
Atrazine	Pesticide	2032/2033, 2060	2032/2033
Carbaryl	Insecticide	2032/2033, 2060	2032/2033
Carbofuran	Herbicide	2032/2033, 2060	2032/2033
Deethlyatrazine	Pesticide degradate	2032/2033, 2060	2032/2033
Metalaxyl	Fungicide	2032/2033, 2060	2032/2033
Tebuthiuron	Pesticide	2032/2033, 2060	2032/2033
Results from both methods reported			
Alkalinity	Water-quality indicator	1948, field	field
Arsenic(Total)	Trace element	1948, TML[1]	1948
Chromium(Total)	Trace element	1948, TML[1]	1948
Iron(Total)	Trace element	1948, TML[1]	1948
pH	Water-quality indicator	1948, field	field
Specific conductance	Water-quality indicator	1948, field	field
1,2,3-Trichloropropane (1,2,3-TCP)	VOC	2020, MWH[1]	MWH[1]

[1] In the USGS's National Water Information System (NWIS), the laboratory entity code for TML is USGSTMCO and for MWH is CA-MWHL.

Table A3. Constituents detected in field blanks collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[E, estimated value; mg/L, milligrams per liter; µg/L, micrograms per liter; —, not detected]

Constituent	Source-solution blanks		Field blanks at production wells		Field blanks at monitoring wells		Number of ground-water data affected
	Number of detections/ analyses	Detected concentrations	Number of detections/ analyses	Detected concentrations	Number of detections/ analyses	Detected concentrations	
Volatile organic compounds (µg/L)							
Acetone	0/7	—	3/7	E3, 6, 11	0/5	—	0
Benzene	0/7	—	1/7	E0.01	0/5	—	0
Dichloromethane	0/7	—	1/7	E0.1	0/5	—	0
2-Butanone (MEK, Methyl ethyl ketone)	0/7	—	2/7	E1.4, 5.9	0/5	—	0
Ethylbenzene	0/7	—	2/7	E0.01, E0.02	0/5	—	0
1,2,4-Trimethyl-benzene	1/7	E0.04	0/7	—	1/5	E0.02	6
m- and *p*-Xylene	0/7	—	3/7	E0.04, E0.06, E0.06	2/5	E0.03, E0.07	1
o-Xylene	0/7	—	1/7	E0.03	0/5	—	0
Styrene	0/7	—	3/7	E0.01, E0.02, E0.02	0/5	—	0
Toluene	3/7	E0.01, E0.01, E0.02	3/7	E0.08, 0.10, 0.16	3/5	E0.02, E0.02, E0.07	1
Chloroform	0/7	—	1/7	E0.04	0/5	—	3
Pesticide and pesticide degradates (µg/L)							
Bromacil			1/7	E0.11	0/4	—	3
2,4-D and 2,4-D methyl ester			1/7	0.28	0/4	—	0
Diuron			1/7	0.03	0/4	—	0
Nutrients and dissolved organic carbon (DOC) (mg/L)							
Ammonia (as nitrogen)			0/5	—	2/4	E0.006, E0.007	17
Dissolved organic carbon (DOC)			0/1	—	3/3	E0.2, E0.7, 0.7	6
Orthophosphate (as phosphorus)			1/5	E0.003	2/4	E0.003, E0.003	1
Total nitrogen			3/5	E0.04, E0.04, 0.26	2/4	E0.04, 0.45	24
Major and minor ions (mg/L)							
Calcium			0/5	—	2/4	E0.01, 0.08	0
Chloride			0/5	—	1/4	E0.13	0
Magnesium			1/5	E0.005	2/4	E0.004, 0.039	0
Silica			0/5	—	1/4	E0.03	0
Trace elements (µg/L)							
Aluminum			0/5	—	2/5	E0.9, E1	16
Barium			0/5	—	2/5	E0.8, E0.9	0
Chromium			4/5	E0.03, E0.03, 0.04, 0.04	4/5	0.04, 0.05, 0.08, 0.10	15
Copper			0/5	—	2/5	0.73, 1.80	18
Iron			0/5	—	1/4	8	7
Manganese			0/5	—	1/5	0.7	5
Nickel			1/5	E0.05	4/5	0.08, 0.16, 0.17, 0.20	12
Strontium			0/5	—	2/5	E0.23, 0.55	0
Tungsten			0/5	—	2/2	E0.03, E0.04	2
Vanadium			0/5	—	2/5	E0.08, E0.08	0
Zinc			2/5	E0.3, 1.0	3/5	1.2, 1.6, 2.4	39
Trace element species (µg/L)							
Inorganic arsenic(Total)			2/5	3.3, 4.5	2/5	0.6, 0.7	19
Iron(Total)			1/5	3	1/5	15	0

Table A4. Quality-control summary of replicate samples for constituents collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[The laboratory entity codes for the laboratories in the U.S. Geological Survey's (USGS) National Water Infomation System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. E, estimated value; mg/L, milligrams per liter; pCi/L, picocuries per liter; RSD, relative standard deviation; TU, tritium unit; µg/L, micrograms per liter; <, less than; —, no value]

Constitutent	Number of RSDs greater than 20 percent/number of replicates	Maximum RSD (percent)	Median RSD (percent)	Concentrations for replicates with RSDs greater than zero (environmental, replicate)
Volatile organic compounds, gasoline oxygenates and additives from Schedules 2020 and 4024				
1,2,4-Trimethylbenzene (µg/L)	2/15	40.4	23.6	(E0.07, E0.05), (0.10, 0.18)
Toluene (µg/L)	1/15	47.1	47.1	(E0.02, E0.01)
Chloroform (Trichloromethane) (µg/L)	2/15	28.3	16.5	(E0.08, E0.06), (E0.02, E0.03)
All other VOCs from Schedules 2020 and 4024	0/15	< 20	—	—
Pesticides and pesticide degradates from Schedules 2032, 2033, and 2060				
All pesticides and pesticide degradates from Schedule 2032	0/12	< 20	—	—
All pesticides and pesticide degradates from Schedule 2033	0/2	< 20	—	—
All pesticides and pesticide degradates from Schedule 2060	0/13	< 20	—	—
Pharmaceuticals				
All pharmaceuticals from Schedule 2080	0/9	< 20	—	—
Constituents of special interest[1]				
Perchlorate	0/15	< 20	—	—
1,2,3-Trichloropropane (1,2,3-TCP)	0/7	< 20	—	—
N-Nitrosodimethylamine (NDMA)	0/5	< 20	—	—
Major ions, minor ions, trace elements, and nutrients				
Ammonia (mg/L)	1/11	23.6	23.6	(E0.005, E0.007)
Dissolved organic carbon (DOC) (mg/L)	1/5	26.2	5.2	(1.6, 1.1)
Bromide (mg/L)	2/10	122.6	1.3	(0.03, E0.02), (0.07, 0.005)
Aluminum (µg/L)	1/6	47.1	47.1	(2, E1)
Cadmium (µg/L)	1/8	47.1	47.1	(0.04, E0.02)
Cobalt (µg/L)	4/8	101	18.0	(0.01, 0.06), (0.07, E0.03), (0.06, E0.02), (E0.03, 0.04)
Copper (µg/L)	1/8	32.9	3.4	(E0.28, 0.45)
Iron (µg/L)	2/10	47.1	3.3	(E3, 6), (6, E3)
Lead (µg/L)	1/8	97.9	2.9	(0.10, 0.08)
Nickel (µg/L)	1/8	60.6	1.8	(1.10, 0.44)
Selenium (µg/L)	1/8	20.2	20.2	(0.08, E0.06)
Tungsten (µg/L)	1/8	28.3	28.3	(0.09, 0.06)
Zinc (µg/L)	1/8	41.9	2.2	(E0.51, 0.94)
All other nutrients from Schedule 2755	0/11	< 20	—	—
All other major ions from Schedule 1948	0/10	< 20	—	—
All other trace elements from Schedule 1948	0/8	< 20	—	—

Table A4. Quality-control summary of replicate samples for constituents collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[The laboratory entity codes for the laboratories in the U.S. Geological Survey's (USGS) National Water Infomation System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. E, estimated value; mg/L, milligrams per liter; pCi/L, picocuries per liter; RSD, relative standard deviation; TU, tritium unit; µg/L, micrograms per liter; <, less than; —, no value]

Constitutent	Number of RSDs greater than 20 percent/number of replicates	Maximum RSD (percent)	Median RSD (percent)	Concentrations for replicates with RSDs greater than zero (environmental, replicate)
Isotopes and radioactivity				
$\delta^{18}O$ of nitrate[2] (per mil)	1/4	84.8	7.2	(0.01, 0.04)
Tritium[3] (TU)	4/12	141.4	10.9	(0.3, 0), (0.3, 0), (1.3, 1.9), (1.3, 0.7)
Gross-beta radioactivity, 72-hour count[4] (pCi/L)	1/2	39.0	39	(E1.12, E1.97)
Gross-beta radioactivity, 30-day count[4] (pCi/L)	1/2	33.8	21.7	(E1.62, 2.64)
All additional isotopes and radioactivity	0/2	< 20	—	—
Microbial indicators				
F-specific and somatic coliphage	0/1	< 20	0	—
E. coli, and total coliforms	0/30	< 20	0	—

[1] Analyses performed at Montgomery Watson Harza laboratory, Monrovia, California (CA-MWHL).

[2] USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA).

[3] USGS Stable Isotope and Tritium Laboratory, Menlo Park, California (USGSH3CA).

[4] Analyses performed at Eberline Analytical Services, Richmond, California (CA-EBERL).

Table A5A. Quality-control summary for matrix-spike recoveries of volatile organic compounds (VOCs) and gasoline oxygenates and their degradates in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Acetone[1,2]	13	83	122	99
Acrylonitrile	13	93	104	102
tert-Amyl alcohol	2	97	107	102
Benzene[1]	13	91	109	104
Bromobenzene	13	98	115	102
Bromochloromethane[1]	13	83	115	105
Bromodichloromethane	13	91	130	104
Bromoform (Tribromomethane)[1]	13	85	123	98
2-Butanone (MEK, Methyl ethyl ketone)[1]	13	90	112	97
n-Butylbenzene	13	75	108	91
tert-Butyl alcohol (TBA)	2	94	104	99
sec-Butylbenzene	13	83	115	98
tert-Butylbenzene	13	89	126	107
Carbon disulfide[1]	13	67	125	82
Carbon tetrachloride (Tetrachloromethane)[1]	13	87	157	106
Chlorobenzene	13	92	115	102
Chloroethane	13	83	128	106
Chloroform (Trichloromethane)[1]	13	87	130	111
Chloromethane[1]	13	88	128	113
3-Chloro-1-propene	13	99	131	116
2-Chlorotoluene	13	91	109	102
4-Chlorotoluene	13	84	109	98
Dibromochloromethane[1]	13	85	122	101
1,2-Dibromo-3-chloropropane (DBCP)	13	84	113	96
1,2-Dibromoethane (EDB)	13	91	126	104
Dibromomethane	13	83	121	104
1,2-Dichlorobenzene	13	87	111	100
1,3-Dichlorobenzene	13	87	109	102
1,4-Dichlorobenzene	13	91	106	100
trans-1,4-Dichloro-2-butene	13	82	114	96
Dichlorodifluoromethane (CFC-12)	13	70	123	106
1,1-Dichloroethane[1]	13	97	142	112
1,2-Dichloroethane	13	90	132	111
1,1-Dichloroethene (DCE)	13	87	117	104
cis-1,2-Dichloroethene[1]	13	96	117	106
trans-1,2-Dichloroethene[1]	13	94	117	106
Dichloromethane (Methylene chloride)	13	28	128	106
1,2-Dichloropropane	13	94	119	106
1,3-Dichloropropane	13	92	126	106
2,2-Dichloropropane	13	62	124	96
1,1-Dichloropropene	13	93	145	104
cis-1,3-Dichloropropene	13	79	108	97
trans-1,3-Dichloropropene	13	80	116	92
Diethyl ether	13	91	118	102
Diisopropyl ether (DIPE)[2]	13	85	110	102
Ethylbenzene	13	89	115	100
Ethyl *tert*-butyl ether (ETBE)[2]	13	81	119	100
Ethyl methacrylate	13	82	107	96
1-Ethyl-2-methylbenzene (*o*-Ethyl toluene)[1]	13	82	106	94
Hexachlorobutadiene	13	70	108	85
Hexachloroethane	13	86	118	102

Table A5A. Quality-control summary for matrix-spike recoveries of volatile organic compounds (VOCs) and gasoline oxygenates and their degradates in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
2-Hexanone (*n*-Butyl methyl ketone)	13	92	112	99
Isopropylbenzene (Cumene)	13	91	119	104
4-Isopropyl-1-methylbenzene[1]	13	81	110	97
Methyl acetate	2	11	112	111
Methyl acrylate	13	95	111	99
Methyl acrylonitrile	13	86	110	104
Methyl bromide (Bromomethane)	13	81	179	111
Methyl *tert*-butyl ether (MTBE)[1,2]	13	86	123	102
Methyl iodide (Iodomethane)	13	75	145	108
Methyl isobutyl ketone (MIBK)	13	85	110	96
Methyl methacrylate	13	73	106	94
Methyl *tert*-pentyl ether (*tert*-Amyl methyl ether, TAME)[2]	13	89	124	100
Naphthalene	13	80	117	96
n-Propylbenzene	13	87	111	98
Styrene	13	69	104	94
1,1,1,2-Tetrachloroethane	13	83	121	102
1,1,2,2-Tetrachloroethane	13	89	116	104
Tetrachloroethene (PCE)[1]	13	91	119	106
Tetrahydrofuran	13	96	112	106
1,2,3,4-Tetramethylbenzene[1]	13	69	126	98
1,2,3,5-Tetramethylbenzene[1]	13	62	135	106
Toluene[1]	13	88	115	104
1,2,3-Trichlorobenzene	13	56	113	106
1,2,4-Trichlorobenzene	13	77	126	99
1,1,1-Trichloroethane (TCA)	13	96	133	106
1,1,2-Trichloroethane	13	84	113	104
Trichloroethene (TCE)[1]	13	91	121	104
Trichlorofluoromethane (CFC-11)[1]	13	96	143	118
1,2,3-Trichloropropane (1,2,3-TCP)	13	89	115	103
1,1,2-Trichloro-1,2,2-trifluoroethane (CFC-113)	13	79	113	98
1,2,3-Trimethylbenzene	13	84	116	105
1,2,4-Trimethylbenzene[1]	13	86	117	102
1,3,5-Trimethylbenzene[1]	13	85	108	100
Vinyl bromide (Bromoethene)	13	96	128	117
Vinyl chloride (Chloroethene)	13	90	128	117
m- and *p*-Xylene[1]	13	86	171	102
o-Xylene	13	82	113	98

[1] Constituents detected in ground-water samples.

[2] Constituents on schedules 2020 and 4024; only values from schedule 2020 are reported because it is the preferred analytical schedule.

Table A5B. Quality-control summary for matrix-spike recoveries of pesticides and pesticide degradates in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Acetochlor[1,2]	11	78	99	87
Acifluorfen	12	42	88	68
Alachlor[2]	11	83	97	91
Aldicarb	12	57	86	59
Aldicarb sulfone	12	28	103	65
Aldicarb sulfoxide	12	68	112	85
Atrazine[1,2,3]	11	87	98	92
Azinphos-methyl[2]	11	63	103	74
Azinphos-methyl oxon[2]	9	29	104	56
Bendiocarb	11	49	93	73
Benfluralin[2]	11	48	62	54
Benomyl	12	45	91	72
Bensulfuron-methyl[1]	12	91	146	108
Bentazon[1]	12	46	202	70
Bromacil[1]	12	51	109	86
Bromoxyni[1]	12	36	62	52
Caffeine	12	55	101	77
Carbaryl[1,2,3]	11	84	108	98
Carbofuran[2,3]	11	74	94	86
Chloramben, methyl ester	12	42	91	81
Chlorimuron-ethyl[1]	12	69	139	108
2-Chloro-2,6-diethylacetanilide[2]	11	80	98	93
2-Chloro-6-ethylamino-4-amino-*s*-triazine (deisopropylatrazine)[1]	12	24	95	76
2-Chloro-4-isopropylamino-6-amino-*s*-triazine (deethylatrazine)[1,2]	11	36	51	44
4-Chloro-2-methylphenol[2]	11	43	74	64
3-(4-Chlorophenyl)-1-methyl urea	12	42	115	76
Chlorpyrifos[1,2]	11	83	100	90
Chlorpyrifos, oxygen analog[2]	11	9	80	29
Clopyralid	12	55	81	69
Cyanazine	2	82	110	96
Cycloate	12	23	83	76
Cyfluthrin[2]	11	31	93	52
λ-Cyhalothrin[2]	11	16	53	37
Cypermethrin[2]	11	34	86	50
DCPA (Dacthal) monoacid	12	61	86	72
DCPA	11	88	104	97
Desulfinylfipronil[1,2]	11	73	97	87
Desulfinylfipronil amide[2]	11	50	108	76
Diazinon[2]	11	78	96	85
Dicamba	12	49	79	57
3,4-Dichloroaniline[1,2]	11	65	89	81
3,5-Dichloroaniline	2	81	95	88
2,4-D and 2,4-D methyl ester, summed on molar basis, reported as 2,4-D[1,4]	12	64	172	79
4-(2,4-Dichlorophenoxy)butyric acid (2,4-DB)	12	53	82	64
Dichlorprop	12	57	90	75
Dichlorvos[2]	11	9	60	30
Dicrotophos[2]	10	20	37	30
Dieldrin[2]	11	76	101	83
2,6-Diethylaniline[2]	11	87	105	96
Dimethoate[2]	11	27	34	29

Table A5B. Quality-control summary for matrix-spike recoveries of pesticides and pesticide degradates in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Dinoseb[1]	12	54	73	61
Diphenamid	12	42	101	90
Disulfoton	2	60	98	79
Disulfoton sulfone	2	100	118	109
Diuron[1]	12	71	97	88
α-Endosulfan	2	89	114	101
Endosulfan sulfate	2	89	125	107
EPTC	2	92	94	93
Ethion[2]	11	58	80	67
Ethion monoxon[2]	11	66	80	74
Ethoprophos	2	103	108	105
2-Ethyl-6-methylaniline[2]	11	81	108	92
Fenamiphos[2]	11	56	91	77
Fenamiphos sulfone[2]	11	40	172	70
Fenamiphos sulfoxide[2]	10	29	70	44
Fenuron	12	38	99	79
Fipronil[1,2]	11	60	105	81
Fipronil sulfide[1,2]	11	70	97	81
Fipronil sulfone[1,2]	11	52	127	71
Flumetsulam	12	75	158	86
Fluometuron	12	53	103	92
Fonofos[2]	11	77	93	83
Hexazinone[1,2]	11	61	112	77
3-Hydroxy carbofuran	11	52	95	74
2-Hydroxy-4-isopropylamino-6-ethylamino-*s*-triazine (hydroatrazine)[1]	12	13	106	97
Imazaquin	12	50	126	82
Imazethapyr	12	47	99	81
Imidacloprid	12	65	108	80
Isofenphos[2]	11	86	108	91
Linuron	12	65	97	90
Malaoxon[2]	11	67	93	80
Malathion[2]	11	82	103	92
Metalaxyl[2,3]	11	80	98	88
Methidathion[2]	11	71	108	93
Methiocarb	11	47	98	82
Methomyl	12	61	105	79
2-Methyl-4-chlorophenoxyacetic acid (MCPA)[1]	12	61	90	76
4-(2-Methyl-4-chlorophenoxy) butyric acid (MCPB)	12	53	82	65
Methyl paraoxon[2]	11	38	70	48
Methyl parathion[2]	11	57	83	65
Metolachlor[1,2]	11	96	110	102
Metribuzin[2]	11	57	239	70
Metsulfuron methyl[1]	12	55	150	80
Molinate[1,2]	11	87	110	93
Myclobutanil[2]	11	63	93	85
1-Naphthol[2]	11	20	70	30
Neburon	12	73	105	82
Nicosulfuron	12	61	154	96
Norflurazon	12	68	113	89
Oryzalin	12	19	85	76
Oxamyl	11	67	102	81

Table A5B. Quality-control summary for matrix-spike recoveries of pesticides and pesticide degradates in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Oxyfluorfen	2	58	88	73
Pendimethalin[2]	11	72	91	80
cis-Permethrin[2]	11	41	71	57
Phorate[2]	11	58	84	76
Phorate oxygen analog[2]	11	60	100	80
Phosmet[2]	6	8	8	8
Phosmet oxon[2]	6	47	50	50
Picloram	12	44	111	66
Prometon[2]	11	80	93	85
Prometryn[2]	11	84	104	94
Pronamide[2]	11	76	96	82
Propanil[1,2]	11	73	118	95
Propargite	2	90	137	113
Propham	12	39	99	87
Propiconazole	12	46	122	84
cis-Propiconazole[1,2]	11	84	109	90
trans-Propiconazole[1,2]	11	67	94	86
Propoxur	11	51	97	86
Siduron	12	61	105	93
Simazine[1,2]	11	81	115	94
Sulfometuron-methyl	12	94	141	106
Tebuconazole	2	70	98	84
Tebuthiuron[1,2,3]	11	56	230	101
Tefluthrin	2	53	67	60
Terbacil	12	55	104	87
Terbufos[2]	11	77	131	101
Terbufos oxygen analog sulfone[2]	11	60	101	77
Terbuthylazine[2]	11	85	102	95
Thiobencarb[2]	11	89	116	111
Tribuphos[2]	11	44	68	57
Triclopyr[1]	9	68	86	75
Trifluralin[2]	11	52	72	60

[1] Constituents detected in ground-water samples.

[2] Constituents on Schedules 2032 and 2033; only values from Schedule 2032 are reported because it is the preferred analytical schedule.

[3] Constituents on Schedules 2032 and 2060; only values from Schedule 2032 are reported because it is the preferred analytical schedule.

[4] 2,4-D and 2,4-D methyl ester summed on a molar basis and reported as 2,4-D.

Table A5C. Quality-control summary for matrix-spike recoveries of constituents of special interest in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Perchlorate[1]	1	99	99	99
1,2,3-Trichloropropane (1,2,3-TCP)	7	88	106	100
N-Nitrosodimethylamine (NDMA)	5	85	106	93

[1] Constituent detected in ground-water samples.

Table A5D. Quality-control summary for matrix-spike recoveries of radioactive constituents in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Acceptable recovery range is between 70 and 130 percent. hr, hour]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Radium-226[1]	2	102	104	103
Radium-228[1]	2	105	117	111
Gross-alpha radioactivity, 72-hr count[1]	2	55	118	86
Gross-alpha radioactivity, 30-day count[1]	2	85	95	90
Gross-beta radioactivity, 72-hr count[1]	2	68	100	84
Gross-beta radioactivity, 30-day count[1]	2	96	98	97

[1] Constituents detected in ground-water samples.

Table A6. Quality-control summary of surrogate recoveries of volatile organic compounds, and gasoline oxygenates and their degradates, pesticides and pesticide degradates, and constituents of special interest in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[The laboratory entity code for the Montgomery Watson Harza laboratory in the U.S. Geological Survey's National Water Information System (NWIS) is CA-MWHL. 1,2,3-TCP, 1,2,3-Trichloropropane; MWH, Montgomery Watson Harza laboratory; NDMA, *N*-nitrosodimethylamine; VOC, volatile organic compound]

Surrogate	Analytical schedule	Constitutent or constituent class analyzed	Number of blank analyses	Median recovery in blanks (percent)	Number of surrogate recoveries below 70 percent in blanks	Number of surrogate recoveries above 130 percent in blanks	Number of environmental sample analyses	Median recovery in environmental samples (percent)	Number of surrogate recoveries below 70 percent in environmental samples	Number of surrogate recoveries above 130 percent in environmental samples
1-Bromo-4-fluorobenzene	2020, 4024	VOC	21	98	1	0	139	97	14	0
1,2-Dichloroethane-*d*4	2020, 4024	VOC	21	116	0	1	139	118	0	27
Isobutyl alcohol-*d*6	4024	VOC	1	132	0	1	10	103	0	1
Toluene-*d*8	2020, 4024	VOC	21	100	0	0	139	99	0	0
Diazinon-*d*10	2032, 2033	Pesticide	11	106	0	0	137	95	4	1
α-HCH-*d*6	2032, 2033	Pesticide	11	89	0	0	138	92	0	0
2,4,5-T	2060	Pesticide	11	78	1	0	136	81	2	0
Barban	2060	Pesticide	11	94	1	0	136	89	4	0
Caffeine-^{13}C	2060	Pesticide	11	101	2	0	135	92	15	0
Toluene-*d*8	MWH	Special interest (1,2,3-TCP)	12	98	0	0	63	96	0	0
NDMA-*d*6	MWH	Special interest (NDMA)	12	86	3	0	59	87	13	0

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From: Ben King
To: Buck, Christina; Mary Fahey; Gosselin, Paul
Subject: RE: Arsenic and Connate Sea Water Contamination around the Sutter Buttes
Date: Wednesday, July 08, 2020 2:10:07 PM

CAUTION: This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Hi Christina,

Thank you very much. I appreciate the follow up.

Best Regards,

Ben

From: Buck, Christina <CBuck@buttecounty.net>
Sent: Wednesday, July 8, 2020 2:06 PM
To: Ben King <bking@pacgoldag.com>; Mary Fahey <mfahey@countyofcolusa.com>; Gosselin, Paul <PGosselin@buttecounty.net>
Subject: RE: Arsenic and Connate Sea Water Contamination around the Sutter Buttes

Hi Ben,

Thanks for the information and additional reports. I did reference some of the reports you had sent me earlier in the draft of the HCM for the Butte subbasin. That document will hit the street for public comment later this summer.

I will pass your emails and attachments along to the consultant team (Davids Engineering) for their reference and consideration as they continue supporting GSP development and completion.

I will also forward your emails to Tania Carlone, the facilitator for the Butte Advisory Board (BAB), so she can include it as correspondence in the future to the BAB since this is helpful follow up to the comment you made at their last meeting.

Best,
Christina

From: Ben King <bking@pacgoldag.com>
Sent: Monday, July 06, 2020 1:16 PM
To: Mary Fahey <mfahey@countyofcolusa.com>; Gosselin, Paul <PGosselin@buttecounty.net>
Cc: Buck, Christina <CBuck@buttecounty.net>; Ben King <bking@pacgoldag.com>
Subject: Arsenic and Connate Sea Water Contamination around the Sutter Buttes

ATTENTION: This message originated from outside **Butte County**. Please exercise judgment before opening

attachments, clicking on links, or replying.

I wanted to follow up regarding my public comment on the last Butte Basin call. As mentioned in my call, my concern is that the connate seawater under the Sutter Buttes is contaminating groundwater and drinking water quality.

I have previously sent the SWCB Bulletin No. 6 from 1952 and the PHD Paper by George Curtin from 1971. Bulletin No. 6 reported that pumping depressions were drawing salt brines to the surface causing groundwater contamination. Curtin's paper proposes that the connate seawater is moving laterally through faults around the Buttes and researched several hundred gas well logs to express this opinion.

According to the Sutter County GMP on Page 23 "The Sutter Buttes Rampart consists largely of gravel, sand, silt and clay sediments which were deposited circumferentially around the Buttes as a geologic apron. These sediments may extend up to 15 miles north and west beyond the Sacramento River. " On Page 32 the GMP addresses the arsenic contamination issue - "… recent data analysis suggest a possible correlation between elevated arsenic concentrations and the presence of volcaniclastic material of the Sutter Buttes Rampart formation." Since the Colusa and Butter Basins are within the 15 mile circumference of the Sutter Buttes this would impact the analysis for Lower Water Quality and potentially Seawater Intrusion SGMA Sustainability metrics. I am mentioning the Seawater Intrusion metric because of the hydraulic components of pumping depressions and the physics of natural occurring contaminants moving laterally from higher elevations to lower elevations in combination of the force of pulling water to the surface by the operation of groundwater wells.

You will see the elevated EC levels and arsenic levels in the GMP Figures attachments. On Figure 19, there was an observation at T15NR3E of arsenic at 350 ppm and an EC of 1126. To the south at 14NR2E the observation of arsenic at 370 ppm and an EC of 1400. Since this study was focused on Sutter County there were not observations for Colusa County and Butter County. For Colusa County – the attached report regarding Arsenic contamination in public drinking water systems has the Grimes water district at 23.9 ppm which is the worse levels of toxicity of any public system in the Sacramento Valley. To the northwest of the Buttes there is a USGS Gamma well ESAC 21 which seems to be located in the Colusa County portion of the Butte Basic which has an arsenic reading of 80 ppm. Finally ESAC 11 which is due north of the Buttes and appears to be located in Grey Lodge has an arsenic level of 70.

I can also note that the EPA assessment of the wastewater treatment facility for Yuba City reported that the high levels of arsenic in the wastewater was apparently from the portion of the Yuba infrastructure. Since most of the source of the water for Yuba City is surface water from the Feather River the arsenic contamination is pronounced where ground water is used. Finally as I mentioned in the past you probably are aware that the EPA has entered into an mitigation agreement with Sutter County regarding the arsenic contamination at Robbins. As you know Robins is at lower elevation and due south of the Buttes which would explain the contamination so far away

from the Buttes. Robbins arsenic levels are less than the levels observed at Grimes.

I will send the Yuba City EPA report and the USGS Gamma documents next.

My suggestion would be to pick up where the SWRCB left off in 1952 and examine salt water and arsenic levels within a 15 mile circumference around the Buttes and set up a monitoring network to monitor changes in ground water quality going forward. This would not only focus on the southern part of the Buttes but within the whole circumference.

Thank you for your time and consideration.

Best Regards,

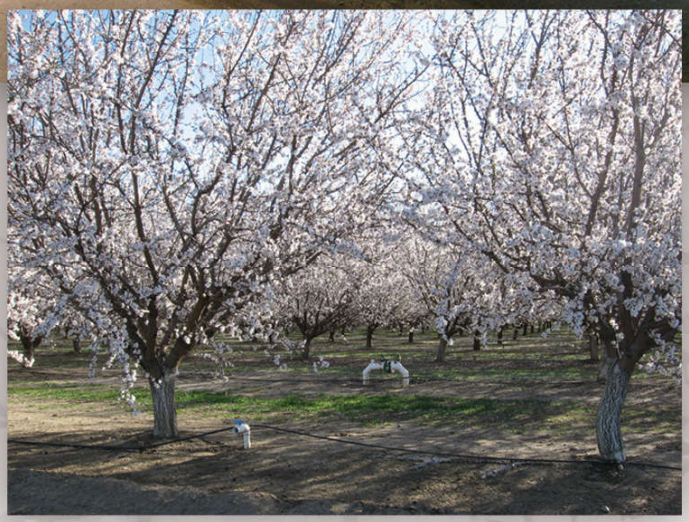
Ben

Sutter County

Groundwater Management Plan







March 2012

WOOD RODGERS

DEVELOPING INNOVATIVE DESIGN SOLUTIONS

Sutter County Groundwater Management Plan

Certificate and Seals

This report and analysis was prepared by Wood Rodgers, Inc. with data and technical assistance provided by the Sutter County Public Works Department - Water Resources Division and the California Department of Water Resources - North Central Region.

Lawrence H. Ernst Date: March 19, 2012

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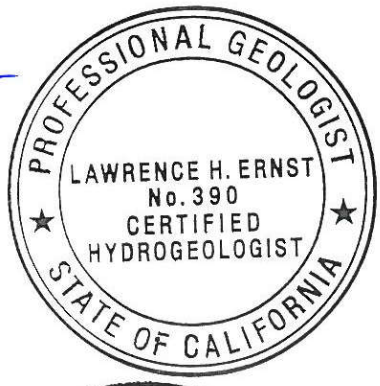

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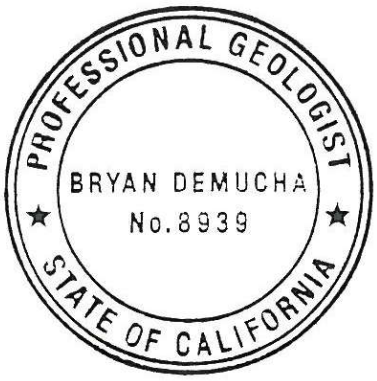

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1. INTRODUCTION

1.1. Purpose of Groundwater Management Plan

Sutter County (County) has prepared this Groundwater Management Plan (GMP) with input and direction from County stakeholders, and with financial and technical assistance from the California Department of Water Resources (DWR). Preparing this GMP is one step Sutter County is taking to promote and encourage groundwater users in the County to be responsible stewards of the water resources.

Sutter County's purposes for preparing this GMP are to:

- Summarize the current understanding of the groundwater underlying Sutter County and its role in the County's overall water supply, and make that information publicly available.
- Formulate goals and objectives that can be used as guidelines to help manage groundwater resources to meet current and future demands in Sutter County.
- Establish a plan for the County's involvement in ongoing monitoring and management of groundwater to promote those goals and objectives.
- Maintain eligibility for grant funding administered by the California Department of Water Resources to increase the understanding of the groundwater basins underlying Sutter County.

1.2. Sutter County's Role in Groundwater Management

Sutter County has the authority to adopt and implement this GMP under California Water Code §10750 et seq., which states that a local agency that overlies part of a groundwater basin can "by ordinance, or by resolution…adopt and implement a groundwater management plan…within all or part of its service area," so long as the area is:

- Not served by another local agency, a water corporation regulated by the Public Utilities Commission, or a mutual water company.
- Served by a local agency, when the majority of the agency's governing body declines to exercise its authority to manage groundwater and enters into an agreement with the local agency developing the GMP.

Sutter County's intended role in groundwater management, as discussed in this GMP, is to help coordinate the various groundwater users in the County, and encourage them to be

responsible stewards of the water resources. The County does not have the budget or staff to act as an "enforcer" with regards to groundwater use, and does not intend to do so.

1.3. Plan Area

Sutter County intends this GMP to be relevant for the entire County. Sutter County overlies the south central part of the Sacramento Valley Groundwater Basin, and specifically the Sutter Subbasin and portions of the East Butte and North American Subbasins, as shown in Figure 1. The majority of the County is serviced by water and irrigation districts, reclamation districts, cities, and public utility districts (Figure 2), which have the authority to manage groundwater in their service areas. Unless those entities decline to manage groundwater on their own, and instead enter into agreements with the County, this GMP does not formally apply to those areas. If those entities choose not to adopt their own GMPs, they have the option of taking formal action to adopt the Sutter County GMP for their areas. By doing so, they will fulfill the requirements of the groundwater management provisions of the California Water Code.

Some of the water purveyors in the County have prepared groundwater management plans established under provisions of Sections 10750-10756 of the California Water Code (Assembly Bill 3030). Four of these plans have been submitted to DWR for final adoption.

1.4. Public Involvement in Plan Development

Throughout the development of this GMP, Sutter County solicited public input to help guide the direction and content. Aside from the required public notices and hearings related to the GMP development, Sutter County undertook an extensive public outreach program to encourage public involvement in the GMP development and to solicit public input for the GMP. To help guide the development of the GMP, a Plan Advisory Group (PAG) was formed that included representatives of water purveyors, cities, and the general public (attendance sheets provided in Appendix A)

The Sutter County Water Resource Department and the Board of Supervisors approved a Public Outreach Plan (Appendix B) for the GMP process. The Public Outreach Plan established the following objectives:

- Establish an open process to facilitate stakeholder input.
- Provide information to facilitate stakeholder education on material forming the basis of the GMP.

- Provide a framework by which stakeholders are kept informed of the process, issues, and potential solutions.
- Incorporate public comments throughout the decision-making process.

Various entities – including the Board of Supervisors, Plan Advisory Group, and the general public – were involved in the development, approval, and adoption of the GMP.

While developing the GMP, eleven public meetings were held. The location and time for each of the PAG meetings were advertised in local media. Attendance at each PAG meeting was recorded and a mailing list was created to disseminate meeting times and important information regarding the GMP progress. Participation in the PAG was voluntary and the public was invited to attend and comment at public workshops held in Yuba City. At each of the public workshops, Wood Rodgers, Inc. presented a PowerPoint® presentation of the purpose, scope, and schedule for preparing the GMP, along with educational information related to groundwater, geology, wells, and information about the hydrogeology within the County. The PAG meetings were held in 2008 on June 10, August 14, October 17, and December 9; in 2009 on February 10; in 2010 on June 17, August 19, October 28, and December 15; and in 2011 on April 14[1] and October 20. The Sutter County Water Resources Department hosted a website for the GMP at:

http://www.co.sutter.ca.us/doc/government/depts/pw/wr/gmp/gmphome

All of the presentations and applicable meeting information were posted on the GMP website. Presentations, attendance sheets, and a summary of public comments from the workshops are included in Appendix B.

1.4.1. GMP Survey

The County circulated a voluntary Public Opinion Survey to obtain participation and feedback from stakeholders. The surveys were distributed to interested individuals at the PAG meetings and were also made available for download on the County's website. In order to differentiate between individual well owner concerns and water district concerns, two surveys were distributed. Unfortunately, due to the limited returns, the surveys were not beneficial in identifying countywide concerns related to groundwater.

[1] The reason the meetings extended over four years is that DWR issued a stop work order in 2009 due to uncertainties with the State of California budget. Consequently, the GMP process was temporarily delayed from February 2009 to May 2010. Resumption of the GMP process required approval of a new Notice of Intent and a contract amendment with DWR.

1.5. Issues of Concern

A variety of issues and/or concerns with regard to groundwater and groundwater management have been raised by residents of the County during the development of this GMP. These issues and concerns include the following.

1.5.1. Protect private groundwater rights.

The development of the GMP has raised concerns about how individual groundwater rights will be affected. California State Water Law gives property owners the right to make reasonable and beneficial use of the groundwater resource underlying their property. The GMP does not encroach upon or place any restrictions on groundwater rights. Furthermore, the County does not have the budget or staff to act as an "enforcer" with regards to groundwater use, and does not intend to do so.

1.5.2. Is there enough groundwater to sustain a drought?

Water districts within the County have been able to provide groundwater when surface water supplies were reduced during past droughts. Conversely, the use of groundwater when surface water is in short supply allows the aquifer(s) to recharge when surface water is available and is known as conjunctive use.

Increased use of groundwater in some areas is perceived to be taxing the available supply, and there is concern that wells will go dry during a drought. A related concern is that existing wells may be damaged by increased pumping. This concern is particularly widespread in the southeastern portion of the County, where groundwater is used extensively for irrigation. Additionally, changes in cropping trends to more permanent crops have raised concerns about the ability to reduce groundwater use during drought periods without sustaining substantial economic losses in areas that do not use groundwater conjunctively with surface water.

This concern is understandable given the history of significant groundwater level fluctuations in the southeastern portion of the County during past drought periods. Data also indicate that during wetter periods, or when pumping is reduced, groundwater levels have started to recover. The need for water supply reliability to support water users in the County can be addressed through the conjunctive use/management of available surface water, groundwater, and recycled water supplies. Together, these water sources comprise the irrigation water supply for the County, and can be used in fluctuating proportions to meet demands during different hydrologic (including climatic) and economic conditions. Successful management will also require better coordination among water users, and water users will need to work together to develop strategies for curtailing water use

during drought periods. If intra-county water transfers (transfers from one party to another within Sutter County) are possible, they can become an important water management tool and consideration during these periods.

1.5.3. Are there plans to "export" water out of Sutter County?

There is general concern that projects related to groundwater studies and groundwater management (including this GMP) are somehow related to the desire to "export" water from the County. Those who express this concern feel that the State (and other parties within and outside of the County) cannot be trusted to protect the interests of the community within the County. Currently, under state law, groundwater substitution water transfers are allowed. A groundwater substitution water transfers occurs when an entity with surface water rights makes an agreement to transfer some or all of its surface water to downstream users (by not diverting it), and then pumps groundwater to make up for the "lost source supply" that results from the transfer.

This concern can be somewhat allayed by maintaining local water district control of water management decisions. Also, establishing an open process for discussing groundwater conditions and making management decisions will help the stakeholders within the County have a better understanding of the resources and issues and to voice their concerns and have them addressed.

1.5.3.1. Sutter County Conjunctive Water Use Success (Case Study)

The Department of Water Resources provided the following case study for inclusion in this GMP to demonstrate the effectiveness of conjunctive water use.

"An example of a successful conjunctive use program was implemented by the South Sutter Water District (SSWD or District). The SSWD is located in southern Sutter and western Placer counties, with the Bear River as the northern boundary and stretching southwest between Highway 65 and Highway 70 to Pleasant Grove and Curry Creeks. The District was formed in 1954 to develop, store and distribute surface water supplies and to augment and replenish over-drafted groundwater supplies. Figures 3 and 4 are groundwater level hydrographs illustrating the recovery of groundwater levels after the implementation of the

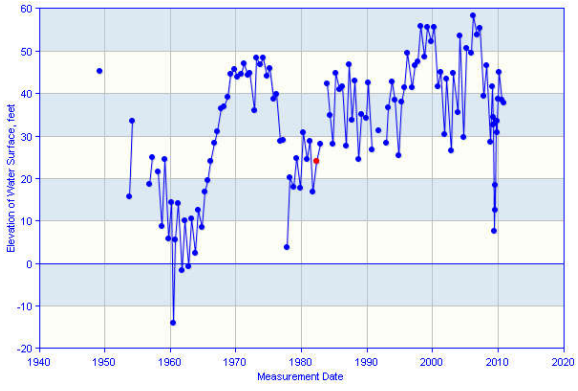

Figure 3 - Hydrograph for Well 13N/5E-30A1M

conjunctive use program. Today SSWD encompasses a total gross area of nearly 64,000 acres, including 57,012 acres that are authorized to receive surface water. According to the District,41,946 acres have actually been irrigated in recent years using a combination of surface and groundwater supplies. By far the majority of those acres grow rice (roughly 34,834 acres, or 83%), while the balance is apportioned between orchards (2,881 acres, or 5%), irrigated pasture (2,088 acres, or 5%), row and field crops (1,742 acres, or 4%) and the remaining 3%, which is fallowed in certain years.

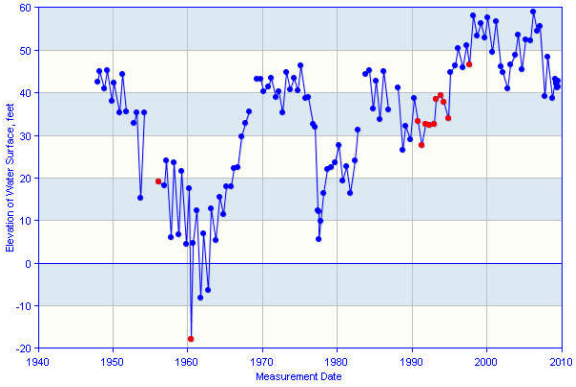

Figure 4 - Hydrograph for Well 13N/4E-13R1M

The enlarged New Camp Far West (NCFW) Reservoir was completed in 1964 with a storage capacity of 104,400 acre-feet (AF). SSWD and Camp Far West Irrigation District (CFWID), formed in 1924, holds the water rights for operating the reservoir. Surface supplies are managed conjunctively with groundwater supplies. The seven (7) megawatts of power generated by the NCFW powerhouse is wholesaled to Sacramento Municipal Utility District. The Federal Energy Commission (FERC) license for NCFW was issued on July 2, 1981.

One and a quarter miles downstream of NCFW Dam (and about 15 miles above the confluence with the Feather River), water is diverted by a diversion dam designed to move 30 cubic feet per second (cfs) north into the CFWID and 380 cfs south into the SSWD. In 1994, SSWD, CFWID, and the Department of Water Resources entered into a settlement agreement to meet the District's obligations under the State Water Resources Control Board's (SWRCB) Water Quality Control Plan for the Bay-Delta. Under the agreement, SSWD agreed to release up to 4,400 AF of water from NCFW, when requested by DWR, in all dry and critical year types. The present water rights require minimum in stream flows below the diversion works of 25 cfs from April 1 through June 30 and 10 cfs from July 1 through March 30. Under the new agreement, SSWD would increase the flow releases to the lower Bear up to 37 cfs in dry and critical years for up to sixty days in July through September.

SSWD receives anywhere from 5,000-20,000 AF of surplus water from Nevada Irrigation District (NID) annually. That water is currently conveyed to SSWD from Rollins Reservoir via the Bear River/Wise Canal system. When completed, SSWD's Canal Expansion project, including related conveyance system improvements, could

well provide previously-unforeseen opportunities for delivering a portion of surplus NID supplies to SSWD directly via the Bear River and NCFW Reservoir."

1.5.4. Will there be taxes or fees for groundwater use?

Concerns have been expressed about the sources of funding for the GMP and other groundwater programs in the County. Funding would be necessary should staff be required to perform new monitoring and evaluation activities or to undertake groundwater investigations. Funding for the latter may be available from DWR and other grant programs, under which this GMP maintains eligibility for the County. Currently, the County assesses fees only for exploratory drilling, well construction, and well destructions, as shown in the following table (Table 1).

Table 1
***Current* Sutter County Fee Assessments (as of January 1, 2012)**

Well Permit	***Fee***
Well Construction	$470.00
Well Destruction	$376.00
Water Exploration and Test Holes	$376.00
Permit Extension (1 year)	$47.00

There is concern about the potential for taxes and fees on groundwater use, and metering of pumps. This GMP does not contain any recommendation to meter groundwater pumping or to enact use-based fees or taxes, although they are considerations and are used in other areas. State law affords property owners the right to make beneficial use of groundwater on their land.

1.5.5. How can we obtain good quality water?

Water quality problems are significant within the County and concerns have been expressed about water quality with regard to salinity, arsenic, and manganese. The hydrogeology of the County as it relates to water quality is not well-understood, and further study will be necessary to develop guidelines for how to obtain good-quality water in different areas of the County, and to determine how to manage groundwater without causing water quality deterioration in areas with otherwise good quality water. As discussed in Section 4.4, this GMP illustrates water quality in different areas of the

County, and shows the geographic areas (and depths) where poorer quality groundwater can be anticipated. As more data becomes available, the County will be able to incorporate it into the existing understanding of the groundwater subbasins.

1.5.6. Is this going to generate new regulations on groundwater?

Concern has been expressed about the potential for additional layers of bureaucracy and regulations on groundwater use. In general, stakeholders recognize a need to better understand and manage groundwater in the County, but have expressed a desire for a "balance" between achieving this objective and minimizing bureaucracy and regulations.

To implement the GMP, an institutional framework (not yet determined) will be needed; however, the intent of this GMP is to minimize the bureaucracy and regulations needed to achieve the goals and objectives of the GMP. The GMP provides a framework and a forum for studying, discussing, and managing groundwater within the County. Ideally, management will be accomplished cooperatively amongst the groundwater users in the County.

2. THE COUNTY

2.1. Physical Setting

Sutter County encompasses approximately 607 square miles (389,443 acres) in the central portion of the Sacramento Valley. As shown in Figure 5, Sutter County is bound by Butte County to the north, Colusa and Yolo Counties to the west, Yuba and Placer Counties to the east, and Sacramento County to the south. The County seat, Yuba City, is located approximately 50 miles north of Sacramento. The 2010 U.S. Census reported that the population of the County in 2010 was 94,737, with the majority of the population residing in Yuba City and Live Oak, and about 25 percent of the population in the rural communities. Land use within the County is principally agricultural, with approximately 318,701 acres in production (Sutter 2010a).

The two main population centers in the County are Yuba City, with 67 percent of the population, and the City of Live Oak, approximately 10 percent of the population (U.S. Census 2010). The remaining County residents live within the small communities of Tierra Buena, Meridian, Rio Oso, Trowbridge, Sutter, Pleasant Grove, Nicolaus, East Nicolaus, Riego, Robbins, or in the vast rural agricultural areas which make up Sutter County. Future major growth areas planned for Sutter County include Sutter Pointe (Measure M). The Sutter Pointe Specific Plan details a large-scale development project that is currently on file with and being processed by Sutter County. This plan area is located in the southern most portion of the County adjacent to the Sacramento County border and a portion of the Placer County border. The plan area includes the development of approximately 7,500 acres into mixed use and residential properties and has been structured to facilitate future incorporation as an independent city (Sutter 2010).

The main transportation routes connecting the County with the region are Highway 99, which runs north-south through the County, California State Route 20, which runs east-west through the County and Highway 113, which runs from the south-west portion of the County and terminates at Highway 99 (connecting Woodland with the County).

Land elevations range between 80 and 20 feet above sea level throughout the County with the exception of the Sutter Buttes, where elevations are more than 2,100 feet above sea level. The lowest land elevations are located towards the southern portion of the County.

Sutter County has abundant surface water, including the Sacramento, Feather, and Bear Rivers, as shown in Figure 5. A number of the water districts in the County (Figure 2) divert and transfer surface water.

2.2. Water Purveyors and Users

Water resources in the County are managed by water purveyors and individual water users who have "hands on" control of both surface water and groundwater for agricultural, urban, environmental, and domestic uses. These water managers represent a complex mix of organized water purveyors, non-organized areas, and areas within National Wildlife Refuges. A brief discussion of each category is presented below.

2.2.1. Water Purveyors

There are 48 water purveyors in Sutter County which provide water service to their customers (Figure 2). These water purveyors include water districts, irrigation districts, reclamation districts, mutual water companies, public utilities districts, and incorporated cities. Additionally, there are many private water users including community service districts (CSD's) and farming interests.

Six water purveyors provide water service not only in Sutter County, but in the counties that share borders with Sutter. They are:

- Reclamation District No. 1004 (Colusa County)
- Biggs-West Gridley Water District (Butte County)
- Butte Water District (Butte County)
- Dry Creek Mutual Water Company (Yuba County)
- South Sutter Water District (Placer County)
- Natomas Central Mutual Water Company (Sacramento County)

2.2.2. Non-Organized Areas

The non-organized areas within the County are not within the boundaries or service area of established water purveyors.

2.2.3. National Wildlife Refuges

The Sacramento National Wildlife Refuge Complex consists of five national wildlife refuges and three wildlife management areas. Portions of Sutter County have been dedicated, both through public and private efforts, as wildlife refuges. Exclusively in Sutter County, the Sutter National Wildlife Refuge has 2,591 total acres, with the majority (83%) located inside the Sutter Bypass. According to U.S. Fish and Wildlife

Service, the refuge "consists of approximately 1,881 acres of seasonal and summer wetlands and approximately 674 acres of unmanaged wetlands, grasslands, and riparian habitats" (USFW 2009).

The Natomas Basin Conservancy also owns nearly 1,000 acres of wildlife habitat/mitigation lands within the southern portion of the County.

2.3. Land Use

The predominant land use within the County is agriculture. The 2008 Sutter County General Plan Technical Background Report estimates that 322,240 acres (83%) of Sutter County is agricultural land. An estimated 44,581 acres (11%) is designated as open space. The remaining 6% of the County is designated as residential, public and vacant, commercial, industrial, and transportation and utilities. As stated above, agriculture dominates land uses within Sutter County. Figure 6 shows the distribution of land uses, with regard to crop type and water source, for the entire County. It is apparent that permanent crops dominate the eastern portion of the County, along the Feather River, while rice and other non-permanent crops dominate the central and western portion of the County.

2.4. Water Use

The amount of water applied for agricultural production and urban or community use has been estimated using information from DWR with respect to unit crop, consumptive use, and applied water, with corresponding losses included and accounted for. Water use within cities and communities was estimated using limited production data from some water purveyors from 2008 to 2010.

2.4.1. Agricultural Water Use

Water use during the 2009 growing season was calculated based on the Sutter County 2009 Crop Report. Estimates of applied water for irrigated agriculture are 1,122,018 AF.

Sutter County's agricultural water usage is approximately 60 percent surface water, 20 percent groundwater, and 20 percent that is irrigated by both surface water and groundwater. Figure 6 illustrates the source of water for crops grown in the County. The predominant source of water for permanent crops is groundwater.

2.4.2. Urban/Community Water Use

Water for urban and community use is from groundwater and surface water. From available DWR records, the minimum urban water use was 1,770 AF in 2010 (records for

all urban water suppliers was not available). Yuba City provides mostly surface water (15,682 AF in 2008) while smaller communities rely exclusively on groundwater.

3. HYDROLOGY AND SURFACE WATER

3.1. Seasonal and Long-Term Hydrology

Annual fluctuations in northern California precipitation directly influence the volume of water flowing in the Sacramento River. Precipitation and climate data from the Western Regional Climate Center (WRCC) suggest the average annual precipitation for the west side of the County (Colusa Station) is 16.40 inches per year and on the east side of the County (Marysville Station), it is 20.96 inches per year. In Nicolaus, the average annual precipitation is 18.27 inches per year. Collectively, average annual precipitation is 18.54 inches per year. Snow-fall within Sutter County is rare, measuring on average 0.01 inches per year. Precipitation is highly variable throughout the State, from year to year. Precipitation usually takes place from October to May and on average no precipitation occurs from June to September. The water year, defined as starting on October 1 and ending September 30, is classified as one of five water year types: critical, dry, below normal, above normal, or wet[2]. Within the past ten years, only two water years were classified as wet and one year was classified above normal. The remaining years were either dry, critical, or below normal. The average annual temperature is approximately 62° F, with an average high of 95.7° F in July and an average low of 37.4° F in January.

Precipitation in the Sierra Nevada, Coast Range, Klamath, and Cascade Mountains contribute to surface water flow and groundwater recharge in the Sacramento River Basin. The general direction of surface water flow is toward the center of the valley, flowing south. Water diversions, evaporation, and groundwater recharge reduce flows as the Sacramento River approaches the Delta.

3.2. Surface Water

Sutter County is located in the Sacramento River Basin, with the Sacramento River on the west and the Feather River on the east. The Sacramento River is the largest river in northern California and drains the northern central part of California. The watershed for the Sacramento River includes tributaries originating in the Sierra Nevada, the Coast Range, and the Cascade Mountains. The main tributaries in Sutter County include the Feather River, Bear River, Dry Creek, Pleasant Grove Creek, Auburn Ravine, and Coon Creek.

During periods of heavy precipitation and runoff, a portion of the flow within the Sacramento River is diverted through the Sutter Bypass. The Sutter Bypass is a man-made feature in Sutter County and was designed to alleviate the flood control system along the Sacramento

[2] http://cdec.water.ca.gov/cgi-progs/iodir/wsihist

River. Aside from the major rivers and tributaries within Sutter County, there are no significant surface water storage reservoirs within Sutter County.

It is important to note that flows in all the major rivers in northern California are managed by dams, e.g. the Feather River by Lake Oroville and the Sacramento River by Lake Shasta. The reservoirs are managed to provide flood protection while collecting runoff from the watershed. Releases from the reservoirs occur from spring through summer to provide irrigation water for agriculture as well as to provide drinking water downstream.

The following discussion provides information on the location, ownership, infrastructure, and an overview of the operational practices of the major water bodies that relate to or are within Sutter County.

3.2.1. The Sacramento River

The Sacramento River is the major surface water feature in Sutter County. Running north-south along the western part of the County, the Sacramento River is the main drainage for the Sacramento Valley Basin on its way to the Delta and the San Francisco Bay. The Sacramento River supports many beneficial uses including recreational, agricultural, and wildlife. The river is currently not used for municipal or domestic water supplies in the County. There are, however, future plans to utilize the Sacramento River, in conjunction with groundwater, to provide municipal water supply to the Measure M Sutter Pointe development (Sutter 2011).

Many tributary streams flow from the mountains on both sides of the valley into the Sacramento River. According to a 2005 report by the Glenn County Department of Agriculture (GCDA), flows in the Sacramento River near Grimes in Southern Colusa County range from 6,500 cfs to 16,900 cfs for the period of record of 1946-2003 (GCDA 2005).

3.2.2. The Feather River

The Feather River is a major tributary of the Sacramento River and outlines a major portion of Sutter County's eastern boundary. The river trends north-south along the northern and central portions of the County to the convergence with the Bear River, where it changes course and flows southwest through the south-central portion of the County until it intersects the Sutter Bypass and the Sacramento River. Like the Sacramento River, the Feather River provides beneficial uses including recreation, agricultural, and wildlife. Yuba City obtains a large portion of its annual water supplies for municipal and domestic use from the Feather River.

3.2.3. The Bear River

The Bear River is a tributary of the Feather River and enters Sutter County from Placer County near the City of Wheatland in Yuba County. It forms the boundary between Sutter and Yuba Counties up to the convergence with the Feather River. The Bear River generally flows west until it converges with the Feather River, approximately one mile upstream from the rural community of Nicolaus. Although smaller than the Sacramento and Feather Rivers, the Bear River also provides beneficial uses that include recreation, agricultural, and wildlife. Discharges within the river are partially controlled by several upstream reservoirs. The Camp Far West Reservoir (located in the counties of Yuba, Placer and Nevada) is the last downstream reservoir on the river and subsequently regulates surface water discharges to downstream users, which has been the source of surface water for a very successful conjunctive water use program for the South Sutter Water District.

3.2.4. The Sutter Bypass

The Sutter Bypass (Bypass) is an artificial flood corridor constructed in the 1930's. As described by the Army Corp of Engineers, "the Sutter Bypass, which began operation in the 1930's, is a leveed portion of the natural floodway in the Sutter Basin. The bypass is south of the Sutter Buttes from Colusa to Verona between the Sacramento and Feather rivers. Flows enter the Sutter Bypass from the Butte Basin at its upper end near Colusa at the Butte Slough. Other flows enter from Wadsworth Canal, interior drainage from pumping plants, and the Sacramento River by way of the Tisdale Weir and Bypass. Flows exit the Sutter Bypass and combine with the Sacramento River, Feather River, Natomas Cross Canal, and Yolo Bypass upstream from the Fremont Weir near the town of Verona"(USACE).

3.3. Seasonal and Long-Term Water Quality

Under the USGS National Water Quality Assessment (NAWQA) Program, the USGS conducted an intensive study of the Sacramento River Basin and collected data between 1995 and 1998. Through the sampling process, the USGS selected indicator streams that were based upon the characterization that "they drain small to intermediate sized watersheds with relatively homogeneous land use and geology" (USGS 1998). The Colusa Basin Drain is located entirely in the Sacramento Valley and was chosen as an indicator stream to determine the impacts of agriculture on stream-water quality (USGS 1998). At the indicator water quality station, Colusa Basin Drain at Road 99E near Knights Landing, it was determined that pH levels were generally on the higher end, with declining suspended sediment concentrations over the two-year sampling period. The higher concentrations of mercury

correlate with suspended sediment because much of the load of total mercury is transported with the suspended material.

The findings of the USGS study also indicated that the water of the Sacramento River and its major tributaries is generally of good quality. As stated in the U.S. Geological Survey Circular 1215:

> "the amount of dissolved solids in the Sacramento River and its major tributaries (Yuba, Feather, and American rivers) was low at all of the sampled locations. Higher median concentrations of dissolved solids occurred at agricultural sites such as the Sacramento Slough and Colusa Basin Drain, but those are diluted upon mixing with Sacramento River water. Nutrient concentrations such as nitrate also were low throughout the Sacramento River Basin, and drinking-water standards for nitrate were not exceeded during the course of this study. The concentrations of Molinate and other pesticides (used in rice farming) measured during this study in the Colusa Basin Drain or in the Sacramento River, represent a significant improvement over concentrations measured in previous years".

3.4. Surface Water Supply Contracts

3.4.1. Settlement Contracts

USBR currently contracts with approximately 145 water districts, water purveyors, or private users for water rights to the Sacramento River. The total amount of water under the settlement contracts is approximately 2.2 million acre-feet and cover a total of almost 440,000 acres of land bordering the Sacramento River and its tributaries between Redding and Sacramento. The Settlement Contracts were originally executed in 1964 with a term not to exceed 40 years. New contracts have been executed with approximately 145 existing Sacramento River Settlement Contracts.

The Settlement Contracts include a Base Supply and Project Water. The Base Supply is the amount that reflects the agreed-upon water right of the respective entity. This is generally regarded as pre-1914 water rights and also water rights perfected after 1914 and reflect water that would be available to the respective entities under "natural" conditions. Project Water represents the amount of water the Bureau of Reclamation agrees to provide from its Central Valley Project (CVP) yield. Under the provisions of the Settlement Contracts both the Base Supply and Project Supply could be reduced by 25 percent of the total contract amount, but only in certain water year types.

3.4.2. Long-Term Renewal Contracts

In accordance with the CVP Improvement Act (CVPIA), the USBR negotiated long-term water service contracts in 2007. According to Section 3404c of the CVPIA, Renewal of Existing Long-Term Contracts requires the USBR to renew any existing long-term repayment or water service contract for the delivery of water from the CVP for a period of 25 years and may renew such contracts for successive periods of up to 25 years each. The USBR anticipates that, "as many as 113 CVP water service contracts, located within the Central Valley of California, may be renewed during this negotiation process" (USBR 2007a).

The long-term renewal contracts, unlike the Settlement Contracts, have no specified reduction in delivery; during critically dry or water-short years, the water supply available from the Project will be allocated among the contractors.

Also, the long-term renewal contracts contain a tiered pricing provision. The Base Supply is 80 percent of the total contract amount, and Tier 1 and Tier 2 supplies represent 10 percent each of the remaining contract amount. Each tier has an incrementally higher water cost. The Tier 1 and Tier 2 water, which is available in most years, is not used due to the incremental higher cost of water.

4. GROUNDWATER

4.1. Groundwater Basins and Subbasins

Sutter County is underlain by the Sacramento Valley Groundwater Basin. The Sacramento Valley Groundwater Basin covers a vast area and encompasses the alluvial deposits under the valley floor from the Sierra Nevada Mountains to the east, the Coast Range mountains to the west, the Sacramento-San Joaquin Delta to the south, and the Klamath and Cascade Ranges to the north. The Sacramento Valley Groundwater Basin covers over 5,900 square miles and 10 counties, and has been divided into 18 subbasins. The GMP area is underlain by three groundwater subbasins (Figure 1) as defined by the California Department of Water Resources (DWR) in "California's Groundwater, Bulletin 118 – Update 2003". These subbasins are: the East Butte Subbasin, the Sutter Subbasin, and the North American Subbasin. According to DWR,

"A groundwater basin is defined as an alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined […] features that significantly impede groundwater flow such as rock or sediments with very low permeability or a geologic structure such as a fault. […]

"A subbasin is created by dividing a groundwater basin into smaller units using geologic and hydrologic barriers or, more commonly, institutional boundaries […]. These subbasins are created for the purpose of collecting and analyzing data, managing water resources, and managing adjudicated basins."

4.2. Hydrogeology

4.2.1. Overview of Groundwater and Geology

Groundwater is water that is underground and below the water table (saturated zone), as opposed to surface water, which flows across the ground surface. There are three main types of subsurface geology where groundwater can exist:

- Hard Rock – Groundwater can be present in cracks or fractures in the rocks.
- Underground Caverns – Groundwater can fill these underground voids.
- Porous Sediments – Groundwater can fill the pore spaces between grains of sand and gravel.

In Sutter County, groundwater exists in porous sediments, alluvial aquifers, or fractured volcanic rock such as in the vicinity of the Sutter Buttes. Figure 7 shows a simplified surface geologic map with the major faults in the County. Sutter County is situated along

the axial portion of the Sacramento Valley Groundwater Basin. The subsurface aquifers consist generally of layers of gravel, sand, clay, and in some cases volcanic ash. The characteristics of different aquifers, and zones within each aquifer, are related to the aquifer materials (sands, gravels, clays, etc.). Within a single aquifer zone, nearby wells with similar construction can have very similar well yields and water quality. It should be noted that many of the geologic formations that make up the alluvial aquifers are continuous units that are also present in other counties as discussed.

In the northern portion of Sutter County, the geologic setting changes rapidly from the stratigraphic succession observed in the rest of the County. A thick sequence of volcaniclastic sediments derived from the Sutter Buttes volcanic epoch form a volcanic fan apron of alluvial deposits around its perimeter. These deposits have been characterized recently by DWR as consisting largely of gravel, sand, silt, and clay. These deposits are observed at ground surface around the Buttes, and may extend up to a 15 mile radius in the subsurface (Springhorn 2008). Sediments deposited under marine sedimentary processes are also observed at ground surface and at shallow depths in the subsurface around the Buttes. These deposits were elevated from depth to their current position during the emplacement of the volcanic intrusion which formed the Sutter Buttes. Water quality in these sediments is generally poor and deteriorates with depth.

There is a large amount of hydrogeologic data available in the Sacramento Valley which has been widely studied, and groundwater is continuous within specific aquifer zones (although discontinuous between different aquifer zones) over large areas within the Sacramento Valley.

4.2.2. Status of Understanding of Regional and Local Geology

The geology of the Sacramento Valley has been studied for at least 95 years, and much has been learned over this time. However, there are still many areas of active study and debate. In Sutter County, areas that are not well-understood and/or are actively being studied include:

- The connection between the Coast Range-sourced Tehama Formation and the analogous Sierra Nevada-sourced deposits, and where this interaction occurs.
- The possible existence of subsurface barriers to groundwater flow within the County.
- The source of poor water quality in parts of the County.

4.2.3. Regional Geology and Structure

The Sacramento Valley Groundwater Basin is a north-south trending structural trough which is filled with layers of sediments. The stratigraphic succession of the basin deposits, from oldest to youngest (deep to shallow), depict a regional change in depositional environment from one dominated by marine sedimentary processes to that of continental (alluvial) processes. The deepest portions of the basin generally consist of marine sedimentary rocks, ranging in age from Late Jurassic to early Miocene (160 million years ago to 24 million years ago). These marine deposits are overlain by younger alluvial and locally prominent volcanic rocks of early Miocene to Holocene age (Harwood and Helley 1987). Within the Basin, these deposits are disrupted by deformational stresses derived from east-west compressional forces associated with regional uplift along the western margin of the valley and extensional forces to the east, within the Basin and Range Provenance (Harwood and Helley 1987). Over time, these forces have applied great stresses and strain on valley deposits, creating complex and diversely-oriented fold and fault structures.

The prominent fault system that occurs in Sutter County is the Willows Fault. The Willows Fault is an active northwest-trending fault that dips steeply to the east and shows reverse displacement, meaning the ground east of the fault has moved up relative to the west side. The Willows Fault enters into the County from Colusa County southwest of the Sutter Buttes and extends to the southeast portion of the County towards Sacramento.

The most prominent and recognizable geologic feature in Sutter County are the Sutter Buttes. The Sutter Buttes are composed of late Cenozoic volcanic rocks that rise over 2,000 feet above the Sacramento Valley floor. The Sutter Buttes formed between 2.4 and 1.4 million years ago as magma at depth was injected into the overlying Cretaceous and Tertiary rocks, causing deformation in the form of faulting, folding, and uparching (Harwood and Helley 1987).

4.2.4. Regional Stratigraphy

The prominent non-marine, fresh water-bearing stratigraphic units found within the East Butte, Sutter, and North American Subbasins include (from youngest to oldest):

- Recent Alluvial Deposits (stream channel, basin, and flood plain);
- the Modesto Formation;
- the Riverbank Formation;

- the Sutter Buttes Rampart;
- the Victor Formation;
- the contiguous Laguna, Tuscan, and the Tehama Formations;
- the Mehrten Formation; and
- the informally named Sutter Formation (Springhorn 2008).

Except for the Sutter Formation, the stratigraphic descriptions presented herein are based upon the California Department of Water Resources "Bulletin 118 – California's Groundwater" and are shown in the geologic cross-sections (Figure 8). The location of the cross-section is shown in Figure 7.

Locally, the stratigraphic succession observed in each subbasin differs slightly; therefore, each subbasin and its associated geologic setting are described separately with regard to their relative positions and occurrences in the specific subbasin.

4.2.4.1. East Butte Subbasin (Basin Number 5-21.59)

The northern section of Sutter County is underlain by the East Butte Subbasin. The East Butte Subbasin is bounded by the Sutter Buttes to the south, Butte Creek to the west and northwest, the Cascade Mountain range to the northeast, and the Feather River to the southeast. The East Butte Subbasin aquifer system consists of late Tertiary to Quaternary aged deposits comprised of Sierra and Cascade sourced material, and in the southern portion of the subbasin around the Sutter Buttes, by volcanic and volcaniclastic rocks. The geologic formations that comprise the East Butte Subbasin are (from youngest to oldest):

- Recent Alluvial Deposits;
- the Pleistocene aged Modesto and Riverbank Formations;
- the Sutter Buttes Rampart; and
- the Tertiary aged Laguna and Tuscan Formations.

Recent Alluvial Deposits

Stream channel deposits are Holocene in age and were deposited between 11,000 years ago and present day. The stream channel deposits occur along the current and ancestral paths of streams and rivers in Sutter County. Where present, the stream channel deposits extend from ground surface up to a depth of 80 feet below ground surface (Helley and Harwood 1985). The stream channel deposits consist of unconsolidated gravels, sand, silt, and clay, derived from the erosion and reworking of the Modesto and Riverbank Formations (described below). This unit is moderately to highly permeable, but because of its shallow depth and limited thickness, it possesses limited water-bearing capacity.

Basin deposits are Holocene in age and, like the stream channel deposits, were deposited between 11,000 years ago and present day. Basin deposits occur where sediment-laden floodwaters breached natural stream and river levees and spread across lower-lying topography. Where present, the basin deposits extend from ground surface up to a depth of 150 feet. The basin deposits consist mainly of silt and clay. These units have low permeability and generally yield small quantities of water to wells.

The Modesto Formation

The Modesto Formation is Pleistocene in age and is a stream terrace deposit that was deposited between 12,000 to 50,000 years ago (Helley and Harwood, 1985). Within this subbasin, the Modesto Formation consists of poorly indurated gravel and cobbles, sand, and clay and is derived from the reworking and deposition of the Riverbank Formation, Laguna Formation, and Tuscan Formation (DWR 2004). The Modesto Formation was likely deposited by the same stream and river systems that flow today, because it generally borders existing channels (Blake et. al. 1999). This formation may extend across the entire subbasin and where present, may range in thicknesses from 50 to 150 feet (DWR 2000). The sediments of the Modesto Formation are moderately to highly permeable and can yield moderate quantities of water to wells.

The Riverbank Formation

The Riverbank Formation is Pleistocene in age and was deposited between 120,000 and 500,000 years ago (Helley and Harwood, 1985). The Riverbank Formation consists of gravel and small cobbles, and is interbedded with reddish-clay, sand and silt. Like the Modesto Formation, the Riverbank Formation is a stream terrace deposit. However, the Riverbank Formation is older than the Modesto Formation. The

Riverbank Formation may extend across the entire subbasin, underlying the Modesto Formation, with thicknesses ranging from 50 to 200 feet. The Riverbank Formation is poorly to highly permeable and can yield moderate quantities of water to wells.

Sutter Buttes Rampart

The Sutter Buttes Rampart was deposited during the Middle to Lower Pleistocene period and is encountered in the southern portion of the subbasin. This unit is up to 600 feet thick in the subsurface (DWR 2000). In several studies (William and Curtis 1977, Springhorn 2008) the Sutter Buttes Rampart has been separated into two distinct units: the Rhyolitic Rampart and the Andesitic Rampart. The Andesitic Rampart phase of volcanism was much larger than the Rhyolitic phase. All the large peaks of the Sutter Buttes are andesitic domes and comprise the majority of the Rampart on the surface and the subsurface. The Sutter Buttes Rampart consists largely of gravel, sand, silt, and clay sediments which were deposited circumferentially around the Buttes as a geologic apron. These sediments may extend up to 15 miles north of the Sutter Buttes and west beyond the Sacramento River. Certain zones within these units yield large quantities of water (DWR 2004).

Laguna Formation

The Laguna Formation is Plio-Pleistocene in age and was deposited between 4 million and 2 million years ago. The Laguna Formation is comprised of Sierra Nevada sourced sediments, consisting of consolidated alluvial gravel, sand, and silt, comprised of granitic, metamorphic, and volcanic material. Estimates of the thickness of the Laguna Formation range from 180 feet (Helley and Harwood 1985) to 1,000 feet (Olmstead and Davis 1961). The Laguna Formation is characterized as being moderately consolidated and poorly to moderately cemented. Because of this, the permeability of formation is generally low to moderate. Wells completed in this formation have been observed to yield only moderate quantities of water (DWR 2003).

Tuscan Formation

The Tuscan Formation has been the subject of much interest in recent years. The Tuscan Formation is a regional aquifer system wholly or in parts of Tehama, Butte, Glenn, Colusa, and Sutter County. Within Sutter County, there has been limited analysis done on the subsurface extent of the Tuscan Formation. It is likely that the Tuscan Formation is only present in the northern portion of the County and consequently is not a major water resource for the County.

The Tuscan Formation is Plio-Pleistocene in age and was deposited between 4 million and 2 million years ago. The Tuscan Formation was derived by alluvial deposition associated with the erosion of volcanic material derived from Cascade volcanism. The formation outcrops from Red Bluff, in the northern part of the Sacramento Valley, to Oroville, southeast of Chico, and has been recognized in the subsurface at a distance of about 15 miles west of the Sacramento River (DWR 2003a). The deposits of the Tuscan Formation thin from east to west, from about 1,600 feet thick in the foothills of the Sierra Nevada to about 300 feet thick in the subsurface of the Sacramento Valley (Lydon 1969). In surface outcrops, the exposures of the Tuscan Formation are described as four separate, but lithologically similar units: Units A through D (Helley and Harwood 1985). Units A, B, and C are found within the subsurface in the northern part of the subbasin and units A and B are found in the southern part of the subbasin (DWR 2004). All of the units of the Tuscan Formation contain stratigraphic sequences of volcanic mudflows, volcanic conglomerates, volcanic sandstones, siltstones, and tuff deposits. In the subsurface, the Tuscan Formation consists largely of black volcanic sand and gravel, with interbedded layers of tuff breccias and tuffaceous clays (Ferriz, H. 2001). Unit A is the oldest (deepest) water-bearing unit and is distinguished from Units B and C by the presence of metamorphic clasts. Unit B contains equal distributions of volcanic mudflows, conglomerates, and tuffaceous sandstones. Units A and B are referred to as the "Lower Tuscan Formation". Unit C is capped by massive volcanic mudflows with some interbedded conglomerates and sandstones. In the subsurface, the volcanic mudflows of Unit C act as a confining layer to groundwater flow, separating the more permeable deposits of the Lower Tuscan Formation (Helley and Harwood 1985).

4.2.4.2. Sutter Subbasin (Basin Number 5-21.62)

The Sutter Subbasin underlies the central portion of Sutter County and is wholly within the boundaries of the County. The subbasin is bound by the confluence of Butte Creek with the Sacramento River and the Sutter Buttes to the north, by the Feather River to the east, by the confluence of the Sutter Bypass and Sacramento River to the south, and by the Sacramento River to the west. The Sutter Subbasin aquifer system consists of late Tertiary to Quaternary aged deposits comprised of Sierra-sourced (Sierra Nevada) detritus and volcanic and clastic rocks in the northern portion of the subbasin around the Sutter Buttes. The identified geologic formations that comprise the Sutter Subbasin are (from youngest to oldest):

- Recent Alluvial Deposits;
- the Pleistocene aged Sutter Buttes Rampart and Victor Formation;
- the Pliocene Laguna Formation; and
- the informally named Sutter Formation.

Recent Alluvial Deposits

The Holocene aged stream channel and flood plain deposits occur along the current and ancestral paths of streams and rivers in Sutter County. The stream channel and flood plain deposits consist of unconsolidated gravel, sand, silt, and clay. Both thickness and grain size decrease as the distance increases from their source. Where present, the stream channel and flood plain deposits extend from ground surface to an estimated depth of 100 feet (Helley and Harwood 1985). These units are highly permeable and provide for large amounts of groundwater recharge within the subbasin. This unit is highly permeable, and yields significant quantities of water to wells (DWR 2000).

Sutter Buttes Rampart

The Sutter Buttes Rampart is Middle to Lower Pleistocene aged alluvial deposit that is encountered in the northern portion of the subbasin. This unit can be up to 600 feet thick in the subsurface (DWR 2000). In several studies (William and Curtis 1977, Springhorn 2008), the Sutter Buttes Rampart has been separated into two distinct units: The Sutter Buttes Rhyolitic Rampart and the Sutter Buttes Andesitic Rampart. The deposition and composition of Rhyolitic Rampart reflects the initial stages of volcanism and deposition around the Sutter Buttes, while the Andesitic Rampart reflects the later stages. These fan deposits form an apron around the Buttes and consist largely of gravel, sand, silt, and clay, and may extend up to 15 miles north of the Sutter Buttes and west beyond the Sacramento River. Certain zones within these units yield large quantities of water (DWR 2004).

Victor Formation

The Pleistocene aged Victor Formation is comprised of alluvial fan deposits composed of Sierra-sourced loosely consolidated gravel, sand, and silt. The Victor Formation has an estimated thickness of 100 feet (DWR 2004). This unit is observed to have an impermeable surface due to the presence of hardpan and clay pan soils (DWR 2003). At its base, the Victor Formation has been observed to have moderate

permeability and provides most of the groundwater for domestic and shallow irrigation wells in Sutter County (DWR 2003). Wells completed in this unit have been reported to have yields as high as 1,000 gpm.

Laguna Formation

The Laguna Formation is comprised of Sierra sourced, consolidated alluvial gravel, sand, and silt, which consist of granitic, metamorphic, and volcanic material. Estimates of the formations thickness range from 180 feet (Helley and Harwood 1985) to 1,000 feet (Olmstead and Davis 1961). The Laguna Formation is characterized as being moderately consolidated and being poorly-to-moderately cemented, because of this, the formation generally has a low to moderate permeability. Wells completed in this formation have been observed to yield only moderate quantities of water (DWR 2003).

Sutter Formation

The Mio-Pliocene aged Sutter Formation is an informally named stratigraphic unit that underlies the area around the Sutter Buttes and the central portion of Sutter County. The extent of the deposits have been characterized on a local to sub-regional scale and have been generally classified as volcanic and epiclastic[3] sediments derived from volcanic sources located to the east in the Sierra Nevada, western Nevada, and the southern Cascade Volcanic Province (Springhorn 2008). Due to the complexity of identifying distinguishable characteristics within these deposits, informal and formal stratigraphic units within this region have been grouped together. Some of the major regional stratigraphic units that have been included in the Sutter Formation (from youngest to oldest) are the Tuscan, Mehrten, and Princeton Valley fill deposits.

4.2.4.3. North American Subbasin (Basin Number 5-21.65)

A portion of the North American Subbasin underlies the southeastern section of Sutter County. The North American subbasin is bound by the Bear River to the north, the Feather River to the west, the Sacramento River to the south, and in the east by a north-south trending line that represents the approximate edge of the alluvial basin (DWR 2004). The North American Subbasin is dominated by late Tertiary to Quaternary aged deposits consisting of Sierra-sourced volcanic sediments and alluvial derived sediments. The identified geologic formations that comprise the North American Subbasin are (from youngest to oldest):

[3] Consisting of fragments of preexisting rocks

- Recent Alluvial Deposits;
- Older alluvial deposits (the Pleistocene aged Modesto, Riverbank, Victor, and Laguna Formations); and
- the Mio-Pliocene aged Mehrten Formation.

Recent Alluvial Deposits

Stream channel deposits are Holocene in age and were deposited between 11,000 years ago and present day. The stream channel deposits occur along the current and ancestral paths of streams and rivers in Sutter County. The stream channel deposits consist of unconsolidated gravels, sand, silt, and clay, derived from active stream deposition, overbank sedimentation, and the erosion and deposition of existing Quaternary stream terrace deposits such as the Modesto and Riverbank Formations. Where present, the stream channel deposits extend from ground surface to a depth of 100 feet (Helley and Harwood 1985). This unit is highly permeable, and yields significant quantities of water to wells (DWR 2000).

The flood plain deposits consist primarily of silt and clay size sediments, with intermittent lenses of stream channel deposits. These deposits are generally observed along the flanks of existing and ancestral stream and river systems. These deposits have an estimated thickness up to 100 feet. Being that this unit is primarily comprised of finer-grained material, permeability is generally poor and generally yields low quantities of water. Brackish water is commonly encountered within this unit (DWR 2000).

Older Alluvial Deposits

Within this subbasin, a number of geologic formations have been assigned to the category "older alluvium" including: the Modesto, Riverbank, Victor, and Laguna Formations (DWR 2004). These deposits generally underlie the Recent Alluvial Deposits and consist of loosely to moderately compacted gravel, sand, silt, and clay size sediments that were derived and deposited under alluvial conditions. The thickness of these units ranges from approximately 100 to 650 feet (DWR 2004).

Mehrten Formation

The Mehrten Formation is Mio-Pliocene in age and consists of a sequence of volcaniclastic and volcanic rocks. In the subsurface, the Mehrten Formation ranges in thickness from 200 feet to 1,000 feet along the axis of the Sacramento Valley (DWR

2003). The Mehrten Formation is comprised of two distinct geologic units. The first unit consists of sediments deposited under alluvial and fluvial conditions and are comprised of gravel, sand, silt, and clay size sediments. This unit is highly permeable and wells constructed within this unit have been observed to produce yields exceeding 1,000 gpm (DWR 2003). The second unit consists of dense volcanic flows of tuff breccias with some interbedded conglomerates and sandstones. This unit acts as a confining layer between sand intervals and has a thickness that ranges from 200 to 1,200 feet in the subsurface (DWR 2003).

4.2.5. Areas Outside a Designated Groundwater Basin

The only part of the County that is not within a designated groundwater basin is the area consisting of the Sutter Buttes. Groundwater is likely found in the subsurface in fractures of the volcanic rock; however, historic groundwater levels and water quality were not reviewed in the preparation of this GMP. There are no local entities, aside from private domestic water users, that utilize groundwater resources in this area.

4.3. Groundwater Levels

DWR does not currently consider any of the groundwater subbasins underlying the County to be in overdraft. Overdraft is characterized by a declining trend in groundwater levels over multiple years without recovery during recharge events. Historic groundwater level data were reviewed for each of the subbasins within the County. DWR maintains a publicly available on-line database, which includes groundwater level data for the County. The DWR Water Data Library (WDL) website can be found at http://www.wdl.water.ca.gov. Wells monitored by DWR and cooperating agencies are identified by the State Well Number (SWN). Data can be obtained for specific wells by means of a map interface, by groundwater basin, or by the assigned SWN.

A 79-year period of record for water level measurements in Sutter County depicts a groundwater system that has experienced changing conditions over time. A number of DWR monitored wells were selected throughout the County to represent these changes. The locations of these wells, along with their associated hydrographs illustrating the historic groundwater levels, are shown in Figure 9. Groundwater level data from well 10N/4E-12A1, a 290-foot-deep well located in the southeast portion of Sutter County, and well 13N/3E-32N1, a shallow (less than 100 feet deep) well located in the southern portion of the County show the groundwater levels typical of different areas of the County. Groundwater levels in well 10N/4E-12A1 are characteristic of areas of high groundwater use and differing water conditions. Water levels fluctuate, sometimes dramatically, in response to changes in groundwater use and hydrologic conditions. This well is located in an area where agricultural

demands are supplied entirely with groundwater. The Sacramento County Department of Water Resources website includes published groundwater elevation maps and indicates that this well is in close proximity to a large pumping depression in northern Sacramento County. Groundwater levels in well 13N/3E-32N1 are characteristic of areas with lower groundwater use and more stable water conditions, and as such, water levels have not exhibited significant fluctuations over times. This well is located in an area where agricultural demands have been met almost entirely with surface water and groundwater demands have consequently been small.

Groundwater levels in well 10N/4E-12A1 have varied from 20 to 80 feet below ground surface over time. The combination of high groundwater use, the close proximity to a pumping depression, and changing climatic conditions has led to significant declines in groundwater levels from the early 1950' through the late 1970's. In the middle to late 1970's, drought conditions increased the rate of decline of groundwater levels on an even larger scale. In the mid 1980's and early 1990's, private and municipal water agencies in a collaborative effort started to implement conjunctive water use programs. With the availability of surface water, and the decrease in groundwater pumpage, groundwater levels have been steadily recovering from the early 1980's through present. Groundwater levels in this well are currently about 35 to 40 feet higher than they were in the late 1970's.

Groundwater measurements in well 13N/3E-32N1 shows very stable groundwater levels since measurements began in 1942. Groundwater levels have remained virtually unchanged, with water levels within 5 to 6 feet of ground surface and seasonal fluctuations of less than 10 feet.

The direction of groundwater flow during the fall season within the County has not changed significantly from 1912-1913 (Bryan 1923) to 2007; with the exception of the southeastern portion of the County. Contours of equal groundwater levels from fall 1912-1913 and fall 2007 were compared to identify changes over the 95 year period. Figure 10 depicts changes in groundwater levels over the aforementioned period. In most areas within the County, groundwater levels were not dramatically different in 2007 than they were in 1912-1913. In the central portion of the County, an increase in groundwater levels is observed in the data, which may be likely due to applied surface water for irrigation. In the southeastern portion of the County, a significant decline in groundwater levels is observed, which can be related to the high usage of ground water for irrigation of crops, and the influence of the large pumping depression in the northern portion of Sacramento County.

Fall and spring contour maps of equal groundwater elevation for 2007, 2008, 2009, and spring 2010 were reviewed (Figures 11 through 17) to determine groundwater gradient and

flow direction. The fall 2009 and spring 2009 groundwater contours generally follow the topography of the County and indicate that groundwater flows from the Sierra Nevada toward the Sacramento Valley (east to west), and north to south within the Valley. The fall 2007 contour map of equal groundwater elevations indicates a few locations where small pumping depressions are present, but in general, suggests the same direction of groundwater flow as seen in the spring 2007 groundwater contour map. Differences in groundwater levels between fall and spring appear to be a result of normal fluctuations in groundwater conditions from seasonal pumping and from wet and dry climatic cycles.

Data from the nested monitoring well at the extensometer site in the southern portion of the County indicates that, for the 14 years of available data, the spring groundwater levels in the monitored aquifer zones have been very similar, within a few feet of one another; except for the deepest completion where groundwater levels are approximately 10 feet lower than the shallower completions.

4.4. Groundwater Quality

The quality of groundwater is a product of the material through which it flows, or that flows into it. Local variations in the quality of the County's groundwater can limit its use for either potable water supply and/or agricultural applications. Groundwater contamination is a result of naturally occurring, point source contamination, and/or regional contamination. Naturally occurring contaminants of concern include dissolved salts [as measured by the specific conductance or electrical conductance (EC)], boron, nitrate, manganese, arsenic, and mercury. Point source contamination typically involves solvent releases originating mostly from gas stations and dry cleaners. Regional sources of contamination include applied fertilizers, salts, and leaky septic systems (nitrate and salt loading).

Historic and current water quality data (collected by the DWR, USGS, and local water purveyors) for wells located within the County were analyzed to characterize spatial and depth dependent water quality trends within the County's groundwater subbasins. The data was separated by well depth into the following three categories: less than 150 feet deep, 150 to 400 feet deep and more than 400 feet deep, as shown in Figures 18 through 23. The categories were chosen based on the occurrence at which certain stratigraphic units are observed in the subsurface in Sutter County.

4.4.1. Specific Conductance

Specific conductance was selected as an indicator of overall water quality. Specific conductance is a property of groundwater that is relatively simple to collect in the field at the well head and can help identify and characterize the condition of the non-marine fresh water

bearing aquifer system. Specific conductance is a measure of how effectively water will conduct electricity and is reported in micro Siemens (µS/cm) per centimeter and provides for the indirect measurement of the amount of dissolved solids (salts) in the groundwater. Lower specific conductance generally indicates better water quality (fresh water) while higher specific conductance generally indicates poorer water quality (brackish to saline water).

Applied irrigation and fertilizers can add salts to the water that percolate into the hydrogeologic system, increasing the specific conductance of the groundwater. Increased specific conductance values of the groundwater can also be attributed to naturally occurring brackish or saline water, such as geologic formations (aquifers) which are, or have been in the past, directly connected to a salt water body or where geologic formations were deposited under marine (salt water) conditions and which have inherently high dissolved salt concentrations. As shown in Figures 18 and 19, specific conductance values within the County are generally acceptable for agricultural and domestic use east of Highway 99 and in the northern half of the County. Elevated values for specific conductance are near to and/or exceed the recommended maximum contaminant level (MCL)[4] for domestic use in the shallow aquifers near the Sacramento River and in the aquifers below 900 feet. The elevated specific conductance could potentially be problematic for agricultural use. It is unclear why there is elevated specific conductance in this area.

4.4.2. Boron

Boron is a naturally occurring element. As shown in Figure 20, boron concentrations in the County are generally acceptable. Some deeper wells, which likely encounter more marine sediments, do contain elevated boron concentrations. Boron is a necessary element for agriculture, but may become toxic to crops above 500 micrograms per liter (µg/L). For public drinking water systems, the California Department of Public Health (CDPH) has established a notification level of 1,000 µg/L for boron. Increased concentrations of boron are observed in wells greater than 400 feet as well as in the southwestern portion of the County.

4.4.3. Nitrate

Nitrate is a contaminant which does not naturally occur in the subsurface. Elevated concentrations of nitrate are widespread in the Sacramento Valley. As shown in Figure 21, concentrations of nitrate in the populated areas of Sutter County are near or above the MCL for nitrate (as NO_3). The CDPH has established a primary MCL of 45 milligrams per liter (mg/L) for nitrate (as NO_3). Near the Sutter Buttes and Yuba City, nitrate concentrations in several wells (less than 150 feet) exceed the MCL. Where present, elevated concentrations of

[4] Recommended CDPH MCL for Specific Conductance is 900 µS/cm; upper limit is 1,600 µS/cm; short term is 2,200 µS/cm

nitrate are likely a result of overlying land uses, such as septic systems, animal enclosures, or applied fertilizers.

4.4.4. Manganese

Manganese is a naturally occurring element found in rocks and minerals. Its presence in groundwater is a result of the dissolution of the naturally occurring element in sediments containing minerals composed of manganese. As illustrated in Figure 22, manganese concentrations are elevated in all portions of the County, at levels that may cause aesthetic problems (odor or staining) for domestic and municipal uses, but generally below levels that could represent a health risk. There are, however, a few locations where manganese concentrations are near or exceed the CDPH established Notification Level of 50 µg/L, and may pose a health risk.

4.4.5. Arsenic

Arsenic is a naturally occurring element commonly found in alluvial sediments. Its presence in groundwater is a result of the dissolution of the element in sediments containing minerals containing arsenic. The CDPH has established a primary MCL of 10 µg/L for arsenic. As illustrated in Figures 19 and 23, arsenic concentrations are near to or above the CDPH MCL throughout the County in each of the aquifer zones assessed; conversely, concentrations of arsenic below the CDPH MCL are also present throughout the County in each of the aquifer zones assessed. Countywide, arsenic concentrations do not appear to be isolated to any one specific aquifer zone in the subsurface. However, recent data analysis suggests a possible correlation between elevated arsenic concentrations and the presence of volcaniclastic material of the Sutter Buttes Rampart formation. Concentrations of arsenic in the stratigraphic units that occur above and below the Rampart are generally less than 10 µg/L, whereas concentrations of arsenic within the Rampart material are between 10 to 370 µg/L (Springhorn, 2008). Concentrations of arsenic tend to be under the CDPH MCL southeast of Highway 99 and in the shallow aquifers.

4.4.6. Mercury

Historic gold mining processes and operations introduced toxic mercury into the surface water system throughout Northern California in the late 1800's. Due to the proximity of these operations to Sutter County, the PAG requested an assessment of the concentrations of mercury in the groundwater. A limited number of wells have been sampled within Sutter County for mercury, and as such, concentrations of mercury in the groundwater within Sutter County can not be well characterized. The few wells that have been sampled for mercury

indicate that mercury concentrations were low. In most cases, the concentrations were below the analytical detection limit (not detectable by the laboratory method used at the time).

4.5. Land Subsidence

Land subsidence is the gradual or sudden lowering of the land surface due to compaction of the underlying sediments. Two types of land subsidence are observed within alluvial sediments: inelastic and elastic. Inelastic land subsidence is a result of the compression of geologic formations and is irreversible. Inelastic land subsidence can be caused by excessive extractions of groundwater, oil, or natural gas. In discussing land subsidence, it is important to note that elastic (reversible) land subsidence is a normal occurrence, whereas inelastic land subsidence has associated negative impacts.

Although there are several causes of inelastic land subsidence, the compression of clay as a result of groundwater extraction is considered the most likely cause of subsidence north of the Sacramento-San Joaquin Delta (Page 1998). Once water is removed (mined) from compressible clay, the clay compresses and cannot accept water again, thus resulting in the permanent lowering of the overlying land surface (inelastic land subsidence). Clay compression has occurred in several locations in California, including the San Joaquin Valley. Compressible clay, such as the Corcoran Clay member of the Tulare Lake Formation, has been mapped over much of the western side of the San Joaquin Valley and can be over 130 feet thick. The subsidence documented in the San Joaquin Valley extends over a very large area, with over 30 feet of subsidence recorded in some areas.

North of the Sacramento-San Joaquin Delta in the Sacramento Valley, inelastic land subsidence, which has been directly related to clay compression as a result of groundwater extraction, has occurred in portions of Solano, Yolo, and Colusa Counties (Page 1998). Recorded land subsidence of more than two feet, and possibly as much as five feet, has occurred in this area. Subsidence in the Sacramento Valley appears to extend from Davis to Arbuckle. The area of subsidence appears to follow a local geologic feature known as the Zamora Syncline. A syncline is a structural fold that is formed by compressional forces which cause the sedimentary layers to have a concave, or a bowl-like geometry. Lakebeds are often associated with structural lows such as synclines. Lakebed deposits typically consist of fine-grained, clayey sediments, which settle out to the bottom of standing bodies of water and of which can include large volumes of freshwater diatoms[5]. Along with sediments, the microscopic diatoms settle and collect on the bottom of a lakebed. In Yolo County, diatomaceous (diatom rich) clay sediments have been identified within the geologic formations of Zamora Syncline. These diatomaceous clay sediments were identified to be

[5] Diatoms are unicellular aquatic algae, typically 20 to 200 microns (Prothero, 1998)

highly compressible (Page 1998). Although diatomaceous clay has been identified in numerous boreholes drilled in Sutter County, there have not been any recorded land subsidence issues.

Elastic land subsidence is observed to be cyclical and does not result in permanent compaction of subsurface materials. One example of elastic land subsidence is seasonal fluctuations in ground surface elevations that coincide with fluctuations in groundwater levels (and associated aquifer pressure). In elastic land subsidence, the subsurface pressures acting on the aquifer do not decrease enough so that subsurface materials permanently compact.

The DWR, in cooperation with federal, state and local agencies, installed and surveyed Global Positioning System (GPS) monuments to be able to measure and monitor ground surface elevations over time in the Sacramento Valley. The project, titled "The Sacramento Height-Modernization Project", consists of 339 monuments, spaced approximately 7 kilometers apart, in 10 counties. There are 32 monuments located in Sutter County. The GPS monuments will augment the existing network of extensometers which DWR currently monitors for land subsidence. In total, there are 13 extensometers located in Glenn, Colusa, Butte, Yolo, and Sutter Counties. The land subsidence monitoring network is shown in Figure 24. Only one of these extensometers, State Well Number 11N/4E-04, is located within Sutter County. It is located in the south-central part of the County along Highway 99, and extends to a depth of 1,003 feet, extending over a large portion of the fresh-water formations. The extensometer is installed in a dedicated monitoring well and is designed to measure any change in distance between the bottom of the well and the ground surface. DWR reports the accuracy of the extensometer to be ±0.001 feet. The extensometer provides for ongoing, real-time data collection, of land surface elevation changes. The Sutter County extensometer has been recording data since early 1994. In the 14 years since it began recording, the extensometer in Sutter County has recorded seasonal (cyclic) elastic land subsidence of approximately 0.03 feet (approximately one-third inch). There has been no indication over the period of record that any inelastic subsidence has occurred.

4.6. Groundwater-Surface Water Interaction

Several clustered monitoring wells located throughout the county adjacent are used to monitor changes in surface flow or quality that directly affect the groundwater system (levels or quality), and/or to monitor changes in surface flow or quality that are caused by groundwater pumping. These monitoring wells are adjacent to surface water bodies, and have a river stage gage located in the immediate vicinity.

Several of the network wells are located along the banks of the Sacramento, Feather, and Bear Rivers, as shown in Figure 25. The relationship between the volume of water flowing in the major rivers/streams and the influence the surface water imparts on groundwater elevation are being monitored with a combination of nested monitoring wells and river stage gages. Four stations exist in the County for observing this interaction: on the Sacramento River below Wilkins Slough (WLK), on the Bear River at Pleasant Grove Road (BPG), on the Sutter Bypass at RD 1500 pump (SBP), and along the Feather River above Star Bend (FSB). Sutter County also monitors a river stage gage at Boyd's Landing (FBL). At stations BPG and FBL, observations of water surface/groundwater elevations trend closely during high flow/stage events in the rivers, suggesting a significant hydrologic connection between the groundwater in the shallow aquifers and the surface water.

4.7. Groundwater Recharge

Groundwater recharge is the process in which groundwater is replenished. The geologic formations that comprise the aquifer system underlying the County extend well beyond the County's jurisdictional boundaries. Several processes are responsible for recharge of the groundwater basin. On a regional scale, surface water flowing over the surface expression of the geologic formations (surface outcrops) allows for direct infiltration into the hydrogeologic system. Figure 26 depicts contours of equal groundwater elevations, superimposed over the surface geology, for the Sacramento Valley Groundwater Basin. Groundwater flow is perpendicular and down gradient to the contour interval. On the east side of the Sacramento Valley Groundwater Basin, the groundwater contours become parallel to and follow the margin of the valley, indicating groundwater is moving through the subsurface from the east to the west. Locally, groundwater recharge occurs where surface water flows over permeable sediments (gravel and sand) in the river channels, allowing for the direct infiltration of surface water. Deep percolation of applied irrigation water also recharges the groundwater basin. Additionally, surface water deliveries have increased the quantity of water flowing down the river, adding available water to recharge the underlying aquifers helping to improve groundwater elevations.

The amount of groundwater recharge is dependent on the available storage space within the aquifer(s). Depending on the degree of separation between the elevation of the bottom of the river or stream and that of the groundwater, streams can either "lose" water into the underlying aquifer(s) or "gain" water. Where groundwater levels are at or above the elevation of surface water, groundwater will discharge into the stream (gaining stream). Where there is a separation between the groundwater and surface water, water flowing downstream will recharge into (losing stream) the groundwater basin (although the contribution has not been

studied). Conversely, if groundwater levels are at land surface, there will be refusal of any "new" water into the subsurface.

The State Water Resources Control Board has identified hydrogeological vulnerable areas, meaning vulnerable to groundwater contamination, where geologic conditions allow recharge to the underlying aquifers. Generally, these areas include the coarse deposits associated with the Feather River.

4.8. Groundwater Infrastructure

According to DWR records, 6,742 well completion reports have been filed for wells constructed in Sutter County. Well completion reports are not always filed with DWR, even though they are required by law, so the number of reports likely under-represent the actual total for the County. Of the wells for which well completion reports have been filed:

- 3,344 are domestic wells
- 1,167 are irrigation wells
- 854 have unknown or other uses
- 308 are monitoring wells
- 75 are municipal wells
- 34 are industrial wells
- 13 are test wells
- Seven (7) are stock-watering wells
- 12 are fire or frost protection wells
- Two (2) are cathodic protection wells

Figure 27 shows the number of DWR well completion reports filed for Sutter County from 1928 through 2007. The figure only illustrates wells that were classified as either: domestic, irrigation, or public supply. Domestic wells were constructed at a rate of approximately five per year from 1941 through 1950, but have been constructed at a rate of approximately 59 per year since then. Irrigation wells tend to be constructed more frequently during drought periods, in the mid-1970's and early 1990's. On average, 16 irrigation wells are constructed per year; however, significantly more wells are constructed during droughts. Municipal well construction has averaged two-and-a-half per year. Of the wells for which records exist, approximately 700 wells are classified as either abandoned or destroyed.

Figure 28 shows the average depth of wells constructed from 1950 through 2005. The average depth of domestic wells has fluctuated since the 1930's, but has generally been about 100 feet deep. The average depth of irrigation wells has fluctuated significantly, but has been about 160 feet deeper than the average depth of domestic wells in any give year, or an average of about 260 feet deep. Municipal well depths are inconsistent and vary widely in

depth, from about 50 to 700 feet deep. Combined with the small number constructed annually, calculation of an average depth of new municipal wells would not be meaningful.

5. GROUNDWATER MANAGEMENT PLAN REQUIRED, VOLUNTARY, AND RECOMMENDED COMPONENTS

California Water Code §10750 et seq., as amended by Senate Bill (SB) 1938, defines the required and voluntary components of a GMP and establishes procedures by which they must be developed. DWR recommends additional elements to include in a GMP in Bulletin 118 Update 2003, Appendix C. The Sutter County GMP includes the components required in the Water Code and has been developed in accordance with the required procedures. This GMP also includes many of the voluntary and recommended GMP components. This GMP also includes components designed to address the requirements of California Water Code §10920 et seq., which establish requirements for groundwater monitoring that affect eligibility for grant funding.

5.1. California Water Code Requirements

Section 10750 et seq. of the California Water Code, as amended by SB 1938, requires GMPs to include six mandatory components to be eligible for the award of funds administered by DWR for the construction of groundwater projects or groundwater quality projects. These components are listed below.

Description	*GMP Section*
Make available to the public a written statement describing the manner in which interested parties would be allowed to participate in the development of the GMP.	1.4
Include Basin Management Objectives (BMOs), including components relating to the monitoring and management of groundwater levels, groundwater quality degradation, inelastic land subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality or are caused by groundwater pumping.	6.2
Prepare a plan that involves other agencies that enables Sutter County to work cooperatively with other public entities whose service area or boundary overlies the groundwater basin.	7.1.5
Prepare a map that details the area of the groundwater basins, Sutter County's boundaries, and other local agencies within the groundwater basins.	Figure 1

Description	*GMP Section*
Adopt monitoring protocols to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence, and flow and quality of surface water that directly affects groundwater levels or quality or are caused by groundwater pumping.	7.1
For areas outside the groundwater basins, use geologic and hydrologic principles appropriate to those areas.	4.2.5;7.1.4

5.2. DWR Bulletin 118 Recommended Components

DWR's Bulletin 118 recommends other components that may voluntarily be included in a GMP. These are listed below.

Description	*GMP Section*
Establish an advisory committee of stakeholders to help guide the development and implementation of the plan and provide a forum for resolution of controversial issues.	1.4
Describe the area to be managed under the GMP.	1.3
Describe how meeting each BMO will contribute to a more reliable long-term groundwater supply, and describe management actions to achieve each BMO.	6.2
Describe GMP monitoring program.	7.1
Describe integrated water management planning efforts.	7.1.5
Periodically report groundwater basin conditions and management activities.	7.1.6
Evaluate GMP periodically.	7.1.6

5.3. California Water Code Voluntary Requirements

California Water Code §10753.8 lists twelve issues of groundwater management which may voluntarily be included in a groundwater management plan.

Description	*GMP Section*
Control of saline water intrusion.	6.1.3
Identification and management of wellhead protection areas and recharge areas.	4.7; 6.1.3
Regulation of the migration of contaminated groundwater.	N/A
Administration of well abandonment and well destruction program.	6.1.3
Mitigation of conditions of overdraft.	4.3
Replenishment of groundwater extracted by water producers.	N/A
Monitoring of groundwater levels and storage.	4.3; 5.4
Facilitating conjunctive use operations.	6.1.3
Identification of well construction policies.	6.1.3
The construction and operation of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.	N/A
The development of relationships with state and federal regulatory agencies.	7.1.5
Review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.	7.1.6

5.4. California Water Code Groundwater Monitoring Components

On November 4, 2009 the State Legislature amended the Water Code with Senate Bill SBx7-6, which mandates a statewide groundwater elevation monitoring program to track seasonal and long-term trends in groundwater elevations in California's groundwater basins. To achieve that goal, the amendment requires collaboration between local monitoring entities

and DWR to collect groundwater elevation data. Collection and evaluation of such data on a statewide scale is an important fundamental step toward improving management of California's groundwater resources.

In accordance with this amendment to the Water Code, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) program. The intent of the CASGEM program is to establish a permanent, locally-managed program of regular and systematic monitoring in all of California's alluvial groundwater basins. The CASGEM program will rely and build on the many, established local long-term groundwater monitoring and management programs. DWR's role is to coordinate the CASGEM program, to work cooperatively with local entities, and to maintain the collected elevation data in a readily and widely available public database. DWR will also continue its current network of groundwater monitoring as funding allows.

The law anticipates that the monitoring of groundwater elevations required by the enacted legislation will be done by local entities. The law requires local entities to notify DWR in writing by January 1, 2011 if the local agency or party seeks to assume groundwater monitoring functions in accordance with the law (Water Code §10928).

Additionally, on or before January 1, 2012, the law requires that Monitoring Entities shall begin reporting seasonal groundwater elevation measurements to DWR (Water Code §10932).

Local entities in Sutter County that have submitted official notifications to DWR to be considered for CASGEM Monitoring Entities include:

- Sutter Extension Water District
- Feather Water District
- Reclamation District 1500 (including RD 1500, Pelger Mutual Water Company and Sutter Mutual Water Company)
- Natomas Central Mutual Water Company
- South Sutter Water District

Garden Highway Mutual Water Company has shown interest in participating in CASGEM but has not yet completed the official notification submittal process include.

Local entities that submit complete Monitoring Entity notifications and adequate groundwater monitoring plans and well networks will be officially designated by DWR to be

the Monitoring Entities for their respective subbasin or portion of a subbasin for the purposes of the CASGEM Program. However, if no local monitoring entity volunteers or is identified for a particular area or groundwater basin, DWR may assume the monitoring and reporting duties and certain entities in the basin may not be eligible for water grants or loans administered by the state.

Sutter County is severely limited in its ability to take a lead in groundwater monitoring because of budget and staff shortages. Furthermore, the County does not own any groundwater monitoring wells and does not conduct any groundwater monitoring on its own. For this reason, Sutter County does not seek to assume groundwater monitoring functions under California Water Code §10920 et seq. However, the County does promote the coordinated collection of groundwater elevation data through its Groundwater Monitoring Program, discussed in Section 7.1 of this GMP.

6. GROUNDWATER MANAGEMENT GOALS AND BASIN MANAGEMENT OBJECTIVES

6.1. Groundwater Management Goals

Sutter County's groundwater management goals represent the overarching intent of the County with regard to groundwater management. Basin Management Objectives (BMOs) and Management Actions must be consistent with these Groundwater Management Goals, and must contribute to achieving the goals. Sutter County's goals for groundwater management (as developed with input from the public through PAG meetings and workshops) are:

- To promote responsible groundwater use in Sutter County so groundwater is available to meet present and future demands.
- To provide groundwater users with information and guidance to help them be responsible stewards of the groundwater resources in Sutter County.
- To discourage activities that could reduce the long-term availability of high-quality groundwater in Sutter County.

Each of the Groundwater Management Goals is discussed below.

6.1.1. To Promote Responsible Groundwater Use in Sutter County So Groundwater is Available to Meet Present and Future Demands.

One of Sutter County's main goals for groundwater management is to ensure that a reliable water supply is available so that water users in the County can be confident that water will be available to meet domestic, irrigation, and other demands on an ongoing basis.

The goal to promote responsible groundwater use in Sutter County is intended to provide the County with useable groundwater resources now and in the future. This is important because the socio-economic well being of the County could be adversely affected if the groundwater supply becomes less useable from a supply or quality standpoint. Ensuring responsible groundwater use will help protect groundwater rights and maintain local control because adjudication of the groundwater basin will not be warranted if long-term groundwater sustainability can be achieved.

6.1.2. To Provide Groundwater Users with Information and Guidance to Help Them Be Responsible Stewards of the Groundwater Resources in Sutter County.

It is important to understand that in order to responsibly manage groundwater to ensure long-term groundwater sustainability, it is necessary to thoroughly understand the groundwater system underlying the County, along with its capabilities and limitations. Sutter County's water resources should be viewed as a dynamic system with the amount of available surface water and groundwater varying over time with fluctuations in hydrologic and climatic conditions. The implementation of a surface/groundwater monitoring program to observe and document the County's resources is essential to provide the community with the necessary information to accomplish this management objective.

6.1.3. To Discourage Activities that Could Reduce Long-Term Availability of High-Quality Groundwater in Sutter County.

It is important to recognize that this management objective is not intended to restrict the users within the community from exercising their legal rights to groundwater. Groundwater is a resource that should remain available for the people of the County to use beneficially on their property. The intent of this objective is for groundwater management to be accomplished in a way that minimizes activities that could potentially reduce the long-term availability of high-quality groundwater in Sutter County. There are a number of management practices that can be utilized to accomplish this goal. Two of the main practices that should be considered are conjunctive use programs and improving County well standards.

The goal of optimizing the conjunctive use of surface water and groundwater will enhance the County's water supply reliability and maximize the available water supply. The term "conjunctive use" basically means using surface water and groundwater together to meet water demands, using different proportions of each depending upon availability. For example, in years of reduced surface water availability, more groundwater would be used and groundwater levels might decline. Conversely, in years of full surface water availability, less groundwater would be used and groundwater levels would be allowed to recover. Optimizing conjunctive use generally means that, whenever possible, surface water is used to the fullest extent with groundwater serving as a "back-up" supply. This maximizes the available water supply because unused surface water generally flows downstream and is lost, but unused groundwater remains in the ground and would be available for later use.

On the other hand, the potential may exist in some areas of the County where groundwater levels are (and have historically been) high, to utilize more groundwater and thus induce more recharge (by creating additional storage space within the aquifer) thereby increasing the total water supply available in the County.

A related goal is to "even out" water availability in the County. There are cases when surplus water is available in some areas of the County, but other areas have inadequate supplies. For example, an area with high groundwater levels may have adequate or excess surface water, while another area may have low groundwater levels and inadequate surface water. In this case, groundwater could be pumped in the area with high groundwater levels, and their surface water could be transferred to the area with low groundwater levels so that area does not have to rely as much on groundwater. If possible, undertaking such projects will help improve the overall water supply reliability in the County.

The goal for updating the County's well standards is to add additional levels of protection to ensure that the design of new well structures prohibit the downward migration of surface/shallow contaminants or cross contamination of aquifers. The County has adopted standards as set forth in Chapter II of the State Department of Water Resources Bulletin 74-81, and as supplemented by Bulletin 74-90, entitled "Water Well Standards: State of California", except as otherwise provided in Section 700, Chapter 765 "Water Wells" of the Sutter County Municipal Code[6]. Some amendments that could be made to the existing well standards are: (1) require the use of geophysical surveys for all new well projects, (2) increase the required minimum sanitary seal depths, (3) institute water quality sampling during cable tool well drilling, (4) institute well restriction zones where poor water quality is known, and (5) improve/implement well destruction programs.

Requiring the use of geophysical surveys (spontaneous potential, 16- and 64-inch resistivity) in all new boreholes can help to enhance groundwater protection by identifying the zone(s) of poor water quality, as well as the depths of confining layers, which can be used to design adequate sanitary/annular seals. With this data, future wells can be designed to effectively seal against poor water quality while providing adequate measures for aquifer protection.

Increasing the minimum sanitary seal depth required for new wells is a proactive measure that can effectively increase aquifer protection. Increasing the required sanitary seal to a minimum depth of 50 feet for all new wells can seal off shallower aquifers with poorer water quality from the deeper aquifers with better water quality, as well as impede the

[6] http://www.co.sutter.ca.us/doc/government/bos/ordinance

downward migration of surface contaminants. Currently, the standards in force require a minimum 50-foot sanitary seal for municipal supply wells and 20-foot sanitary seal for all other wells (Bulletin 74-90).

Many wells in Sutter County have been drilled and constructed utilizing the cable tool drilling method. One of the main troubles with cable tool wells is that they usually are constructed across, and connect, multiple aquifer zones. Some of these well structures likely have become conduits for the downward migration and cross contamination of aquifer zones. Water quality sampling during the drilling of these wells (field tests for TDS or specific conductance) would delineate between problematic and non-problematic aquifer zones. If an existing well is deemed problematic (i.e. poor water quality), corrective measures through well modification or even well destruction could help mitigate the movement of poorer water quality between aquifer zones.

Implementing well restriction zones where water quality contamination is known to exist in specific aquifers can aide in protecting aquifers with acceptable water quality. Restricting the construction of wells or requiring specific seal intervals can provide an additional level of aquifer protection. Certain areas within Sutter County have localities of poorer water quality. It may be beneficial to assess the risk of drilling and constructing new wells within these areas. If adequate aquifer protection can not be achieved during construction activities, it may be warranted to designate well exclusion zones.

Unused, unsecured, abandoned, or improperly destroyed wells can act as a direct conduit for surface water infiltration or degradation of one or more aquifers, if they are connected by the well structure. Well destruction requirements adopted by the County currently require abandoned wells to be destroyed. Currently, these requirements require the uppermost 20 feet of the well/borehole be filled with impervious material. Special situations, in the case where vertical movement of poor water quality could contaminate an aquifer with good water quality, require impervious sealing material to be placed adjacent to confining layers. Increasing oversight of the permitting process during the planning and design of well destruction programs can ensure added protection against the vertical migration of poor water quality.

6.2. Basin Management Objectives

Basin Management Objectives (BMOs) are guidelines established to ensure that the County's basin management goals are being fulfilled. BMOs create a systematic method for collecting and monitoring data for specific components of the groundwater system and to provide for the dissemination of such information to the public. The objective of the BMOs is not to assign a fixed value, or level, to each parameter, but to allow for the early identification of

potential problems with sufficient time for the County and its groundwater users to formulate an action plan to mitigate adverse effects to its groundwater resource.

Sutter County's BMOs address the following parameters:

- Groundwater levels
- Groundwater quality
- Inelastic land subsidence
- Surface water
- Coordination

6.2.1. Groundwater Levels BMO

There are three BMOs for groundwater levels:

- *Avoid ongoing declines in groundwater levels during water year types identified by DWR to be "above normal" or "wet" for the Sacramento Valley.*
- *Avoid problematically high groundwater levels.*
- *Provide assistance with assessing problems and resolve disputes related to groundwater levels.*

Groundwater levels are to be managed to ensure adequate water supplies while avoiding adverse impacts and mitigating them if and when they do occur. Adverse impacts related to groundwater levels can occur from excessively high or low groundwater levels. What constitutes an excessively high or low groundwater level may change over time, and will also vary by land use and hydrologic and climatic conditions.

Excessively high groundwater levels are problematic in some areas of the County. High groundwater levels in Sutter County are often naturally occurring. However, groundwater levels can be raised by application of water to the ground surface through irrigation, surface storage, or recharge projects. When groundwater levels are high, there is no storage capacity available in the underlying aquifer for groundwater recharge from precipitation, stream flow, or excess applied irrigation water. This represents a lost opportunity to capture recharge and increase the overall water supply for the County. Adverse impacts related to high groundwater levels include:

- Damage to foundations, roads, and other infrastructure.

- Water-logging the root zone of certain crops.

Groundwater levels decline when pumping exceeds recharge and rise when recharge exceeds pumping. It is important to note that periodic short-term declines in groundwater levels (during drought periods and/or increased pumping), which are then followed by recovery to at or near historic highs (during wet periods and/or decreased pumping), are normal and do not represent overdraft. Excessively low groundwater levels that are caused by long-term declines without recovery, thus overdraft, can be avoided by reducing pumpage. This can be accomplished by expanding the conjunctive use with surface water. Adverse impacts related to low groundwater levels include:

- Infrastructure problems when lowered groundwater levels dewater pumps or wells, so groundwater cannot be extracted using existing infrastructure even though it is available at greater depths.
- Depleted available groundwater supply.
- Inelastic land subsidence.
- Riparian and/or native vegetation destroyed.
- Reduced surface water flow due to increases in streambed infiltration, or increases in the capture of groundwater that otherwise would have contributed to increasing the base flow of a surface water system.

6.2.2. Groundwater Quality BMO

The BMO for groundwater quality is to:

- *Improve the understanding of groundwater quality in Sutter County.*
- *Maintain or improve groundwater quality.*

Adverse impacts to groundwater quality most commonly occur when degradation of groundwater renders groundwater unsuitable for intended uses. Accordingly, what constitutes a significant adverse impact to groundwater quality is related to the purposes for which groundwater is used, and may change over time as land uses and water quality regulations change. Groundwater quality degradation can occur when groundwater pumping causes poor quality water (surface water or groundwater) to migrate into areas with good quality groundwater. It can also occur when surface contaminants migrate into groundwater. As a consequence, it is important to coordinate land use planning and

resource management activities in order not to create opportunities for water quality deterioration. Adverse impacts related to groundwater quality include:

- Degradation of groundwater quality so that yields are reduced for crops irrigated with groundwater.
- Degradation of groundwater quality so that it does not comply with drinking water quality standards.
- Degradation of groundwater quality so that it is no longer suitable for beneficial uses.

There are some areas in Sutter County that currently have problems with groundwater quality (particularly arsenic and salinity) that appear to be naturally-occurring. The BMO of maintaining or improving groundwater quality reflects the County's desire to improve the quality of naturally-occurring groundwater where possible, so that it is more useful as a water supply.

6.2.3. Inelastic Land Subsidence BMO

The BMO for inelastic land subsidence is to:

- *Avoid inelastic land subsidence that is linked to declines in groundwater levels.*

Inelastic land subsidence is the permanent compaction of the subsurface. In Sutter County, the activities that have the most potential to cause inelastic land subsidence are withdrawals of groundwater or natural gas from the subsurface. Adverse impacts related to inelastic land subsidence include:

- Reduction in the volume of the subsurface that results in a permanent loss in aquifer storage.
- Damage to foundations, roads, bridges, and/or other infrastructure.
- Change in surface topography that reverses the gradients in canals and ditches, and/or changes floodplains.

6.2.4. Surface Water

There are three BMOs for surface water:

- *To improve the understanding of the relationship between surface water and groundwater.*

- *To avoid changes in surface water flow and surface water quality that adversely affect groundwater levels or are caused by groundwater pumping.*
- *Avoid changes in surface water flow and water quality that adversely affect groundwater quality.*

Pumping from very shallow aquifer zones or poorly sealed wells has the potential to affect surface water or wetlands. Adverse impacts related to surface water or wetlands include:

- Depletion of surface flows and/or degradation of water quality.
- Destroying riparian and/or native vegetation and habitat.

6.2.5. Coordination

This BMO for coordination is to:

- *Coordinate County groundwater management efforts with other groundwater management efforts within and surrounding Sutter County.*

This BMO establishes the importance of local coordination of groundwater management and sharing of hydrogeologic data. To make effective and relevant decisions, the County must rely on current data regarding the quality and quantity of the underlying groundwater.

7. PLAN IMPLEMENTATION

Sutter County intends to implement this GMP through a Groundwater Monitoring Program and an Action Plan. In order to recognize and mitigate adverse impacts to the underlying groundwater system, a system is required to collect and disseminate information to the appropriate groundwater users and agencies.

7.1. Groundwater Monitoring Program

The role of monitoring is essential to implementing the BMOs. Monitoring is the process of collecting data that is used to better understand the groundwater basin underlying the County, evaluate groundwater conditions, facilitate groundwater management, and other related activities. In order for the County to promote sustainable groundwater management, as well as for groundwater users to make effective and relevant decisions, the data needs to be made publicly available.

7.1.1. Groundwater Level Monitoring

There is an extensive network of DWR monitored wells, both dedicated monitoring wells and wells with other uses, within Sutter County. Additionally, several water purveyors within the County monitor groundwater levels within their service areas by means of dedicated monitoring wells and production wells. There is an extensive inventory of wells with groundwater measurements within Sutter County. Historically, DWR and its partners have monitored 172 wells in Sutter County, including 15 dedicated monitoring wells. The earliest recorded DWR water level measurement in Sutter County took place in 1929. Wells accessible to DWR are typically agricultural or domestic wells in which the land owners have previous agreements with DWR to allow access for measurements. Overall, the County has adequate spatial distribution of its current network to obtain groundwater level measurements. For this GMP, DWR utilized 122 of the 172 wells to produce groundwater contour maps of equal elevation.

Water level measurements are generally made two times each year, in spring and fall. Measurements have been made at some monitoring wells on an almost-monthly basis. Twice-annual (spring/fall) water level measurements are generally sufficient for the purpose of determining changes in overall groundwater conditions over time. However, these measurements should reflect the annual high (spring) and low (fall) water levels. More frequent (i.e. at most monthly) measurements are necessary to confirm that the months chosen for spring and fall measurements reflect the months with the highest and lowest groundwater elevations, on average. Water level data is currently available from DWR's Water Data Library, at: http://well.water.ca.gov.

7.1.1.1. Vertical Groundwater Gradients – Nested and/or Clustered Monitoring Wells

The vertical gradients between aquifer zones are important because they give an indication of the direction (up or down) that groundwater will migrate if a pathway, such as a well that connects multiple aquifer zones, is present. To evaluate the vertical gradient between aquifer zones, data for the different aquifer zones at a single location is needed. The preferred way to obtain this data is with nested and/or clustered monitoring wells. Nested monitoring wells have multiple wells within a single borehole, with each well isolated from the others by annular seals. Clustered monitoring wells have a single well in each borehole, with the boreholes in close proximity to one another. Figure 19 shows the locations of the 15 nested and/or clustered monitoring wells in Sutter County. Eleven of these wells are in the DWR monitoring network with measurements taken twice a year, in spring and fall. The remaining four nested monitoring wells are pending inclusion into the network because they were constructed by private parties. All of these wells are dedicated monitoring wells.

7.1.1.2. Groundwater Flow Direction – Contour Maps

The direction of groundwater flow is evaluated with groundwater level contour maps. Groundwater contours are created which connect surfaces of equal elevation (or levels). Figure 17 illustrates the contours of equal groundwater elevation for measurements taken in the spring of 2010.

The current water level monitoring network spacing is suitable for contouring groundwater elevations. Additionally, it would be beneficial to include data from nearby monitored wells in Butte, Yolo, Sacramento, and Yuba Counties to better characterize the groundwater flow direction at the County lines.

7.1.2. Water Quality

Water quality samples from wells within the County have, in the past, been obtained either by local water purveyors, the DWR, or the USGS. Currently, the County only samples groundwater in Robbins, its only public water supply system. Groundwater samples have been collected for analysis in a total of 133 wells. The DWR has sampled 34 of these wells in Sutter County, fifteen of which are nested multiple-completion monitoring wells, as shown in Figure 19. The USGS has sampled 94 of these wells, and the remaining wells were sampled by water purveyors which have shared their data. The DWR expects to conduct water quality sampling of these wells every three years, or as funds are available. The water quality data is disseminated on the DWR WDL.

The results for the USGS water quality sampling are available on the National Water Information System (NWIS) website[7]. The USGS sampled these wells as part of a larger investigation to document the condition of the groundwater throughout the valley. It is not expected that the USGS will routinely sample these wells.

The current water quality monitoring network consists of DWR owned multiple-completion monitoring wells with a sparse distribution covering the entire County. Routine sampling of these wells will allow for water quality trends to be identified. As stated within this GMP, the County does not own any dedicated monitoring wells. In conjunction with DWRs efforts to collect and distribute water quality information of the groundwater resource, the County encourages private water purveyors to disseminate their water quality data to aid in documenting depth specific and County-wide water quality trends.

7.1.3. Land Subsidence

Land subsidence has not been historically reported or documented within Sutter County. Nevertheless, DWR installed an extensometer and began monitoring for ground surface displacement in 1994. Measurements are recorded on a daily basis, offering real-time and site specific measurements. On a more regional scale, DWR and its cooperating agencies, have implemented the Sacramento Valley GPS Height Modernization Project which will provide significant enhancements to a Sacramento Valley subsidence monitoring program. It is reported by DWR that the GPS monuments will be re-surveyed approximately every three years. The monitoring of land surface elevations will allow for periodic measurements of permanent land subsidence induced by groundwater pumping and/or natural processes. The surveys will be conducted in accordance with the National Geodetic Survey Standards for two centimeter accuracy.

When used in conjunction with surface subsidence survey data (GPS), the extensometer data could aide in identifying whether subsidence is occurring over the total depth of the monitoring well.

7.1.4. Future Groundwater Monitoring

The County's existing monitoring network is described above. Groundwater monitoring within the County is currently conducted by DWR and local water purveyors. The County will continue to cooperate with DWR and encourage the local water purveyors to continue to monitor groundwater levels. Under the voluntary guidelines of SBx7-6, selected local water purveyors will continue to monitor groundwater elevations for their

[7] http://waterdata.usgs.gov/nwis

respective service area(s), along with the DWR, under protocols established by DWR. The possibility exists that in the future, DWR may cease their monitoring if they lose funding for groundwater level measurements, and the responsibility of groundwater level monitoring will be entirely upon the local water purveyors.

All new wells should be sampled for basic water chemistry (i.e. specific conductance, arsenic, manganese, and nitrate). Although not required, the County may, in the future, consider requesting copies of laboratory reports to be submitted through the permit process. Water quality results from wells sampled by DWR are routinely placed on the WDL, and are often sampled every three years, or as funding allows.

The overall subsidence monitoring program should continue to be monitored by the extensometer and GPS monuments throughout the County. The Sacramento Valley GPS Network incorporates existing GPS networks and monuments to create a regional network that covers part or all of Colusa, Sutter, Glenn, Butte, Yolo, Yuba, Tehama, and Placer Counties.

For the area encompassing the Sutter Buttes, which is outside of a DWR delineated groundwater basin, groundwater is likely contained in the fractures of the volcanic rock as well as in the marine sands that compromise the Sutter Buttes. The area encompassing the Sutter Buttes is primarily privately owned and groundwater use is unknown but is likely limited to domestic wells or stock watering wells. It is suggested that private well owners monitor groundwater levels at least twice a year (fall and spring) in order to realize changing conditions. It is also good practice to test the quality of the groundwater for health based constituents.

7.1.5. Local and Regional Groundwater Management Coordination

Coordinating local and regional groundwater management is important to meeting Sutter County's Groundwater Management Goals because groundwater, like other resources, does not respect administrative/jurisdictional boundaries, and actions outside the County can affect groundwater in the County. Further, in order to achieve the Groundwater Management Goals, the County needs to be an "effective participant" in local and regional management efforts and work cooperatively with water managers to conduct effective groundwater management. To be an "effective participant", the County needs to be informed of its groundwater conditions and activities underway or planned, which may affect the resources positively or negatively. With time and appropriate documentation of water management activities and monitoring, an understanding of the resources can be obtained so that groundwater conditions can be the result of deliberate water management choices.

Coordinating groundwater management across local and regional jurisdictions will contribute to ensuring a reliable water supply by working towards management of entire groundwater basins, not just the portions underlying the County. Involvement in regional activities will help ensure that activities outside of Sutter County that affect the reliability of the groundwater supply in the County can be addressed through regional management actions. This involvement will also help protect water rights because the County's involvement with regional groundwater management will allow it to be part of a larger group that can exert more influence in preserving water rights north of the Delta. Finally, regional coordination will help the County maintain local control by ensuring that the County's interests are represented in regional groundwater management activities.

Sutter County recognizes the importance of regional coordination, collaboration, and communication and is signatory to the "Four-County Group," which has evolved into the "Northern Sacramento Valley – Integrated Regional Water Management Group", consisting of Butte, Glenn, Colusa, Tehama, Shasta, and Sutter Counties.

In addition to the water management coordination addressed above, which is more at a technical and operational level, it is important that coordination occur at the policy level as well. This is especially important for effective and consistent operations within water purveyors whose geographic jurisdiction extends beyond Sutter County. The processes to addressing water transfers, in particular, are different in each of the three counties. It would be important, as the GMP is implemented and the institutional structure and management processes become solidified, that a dialogue be established with the neighboring counties to address the need for developing consistency in processes that affect the management and operation of the respective water purveyors.

7.1.6. State of the Basin Report - Groundwater Condition and Groundwater Management Plan Evaluation

In the future, Sutter County and local water purveyors may benefit from preparing an annual report of the conditions of its groundwater basin. However, the present County staffing and funding levels are unable to accommodate this work effort. Groundwater elevation data for the County will be available through the CASGEM program and continued DWR monitoring. Additionally, new and/or current water quality data is periodically submitted and is available through the DWR Water Data Library. The County encourages cooperation among all groundwater users to share data (groundwater level and/or quality) which is not reported or what is readily available through the Water Data Library. Water quality data is also accessible through the Department of Public Health for permitted public water systems. Through this report, the County will encourage its groundwater users to be responsible stewards of the County's resources.

This GMP prepared by the County is not intended to be a static document. As conditions change, such as population, land uses, or climate, it may be warranted to revisit the County's goals and BMOs to ensure that the overall goals of sustaining its groundwater resources to meet current and future demands for the County are being satisfied. The County encourages cooperation among its groundwater users to keep these goals in mind. It is not Sutter County's intent of this GMP to be an enforcer with regards to groundwater use; however, as climatic and groundwater usage change in the future, it may be necessary to "check in" and adjust or expand this GMP.

7.2. Action Plan

7.2.1. Actions for Groundwater Levels BMO

To avoid ongoing declines in groundwater, to avoid abnormally high groundwater levels, the County has taken and will take the following actions:

Action	*Frequency*	*Status*
Participation in the "Northern Sacramento Valley – Integrated Regional Water Management Group"	As needed	2008 - Present
Maintain relationships with state and federal agencies	Annual	1850 - Present
Promote conjunctive use through public outreach	Annual	2008 - Present
Coordination with local and regional jurisdictions on groundwater.	Annual	2008 - Present
Ensure compliance with adopted policies in 2008 General Plan (Goal ER 6)	Annual	2008 - Present
Review groundwater contour maps prepared by DWR	Annual	2008 - Present
Disseminate groundwater level data on County's website	As needed	2010 - Present

7.2.2. Actions for Groundwater Quality BMO

To improve the understanding of groundwater quality, the County has taken and will take the following actions:

Action	*Frequency*	*Status*
Cooperate with DWR in its monitoring efforts	Annual	2010 - Present
Maintain relationships with neighboring counties	Annual	1850 - Present
Ensure compliance with adopted policies in 2008 General Plan (Goal ER 6)	Annual	2008 - Present
Ongoing coordination with local and regional jurisdictions on groundwater	Annual	unknown - Present

7.2.3. Actions for Inelastic Land Subsidence BMO

To avoid inelastic land subsidence that is linked to declines in groundwater levels, the County has taken and will take the following actions:

Action	*Frequency*	*Status*
Cooperate with DWRs monitoring efforts	Annual	2010 - Present
Participate in the "Northern Sacramento Valley – Integrated Regional Water Management Group"	Annual	2008 - Present
Establish and update a groundwater management plan website	Annual	2008 - Present
Review data from the extensometer installed in Sutter County	6 months	2010 - Present
Maintain relationships with state and federal agencies	Annual	1850 - Present

7.2.4. Actions for Surface Water BMO

To improve the understanding of the relationship between surface water and groundwater; to avoid changes in surface water flow and surface water quality that directly affect groundwater levels or are caused by groundwater pumping; and to avoid changes in surface flow and surface water quality that directly affect groundwater quality, the County has taken and will take the following actions:

Action	*Frequency*	*Status*
Engage in the "Northern Sacramento Valley – Integrated Regional Water Management Group"	Annual	2008 - Present
Establish a groundwater management plan website	Annual	2008 - Present
Maintain relationships with state and federal agencies	Annual	1850 - Present
Ensure compliance with adopted policies in 2008 General Plan (Goal ER 5)	Annual	2008 - Present

7.2.5. Actions for Coordination BMO

To coordinate County groundwater management efforts with other groundwater management efforts within and surrounding Sutter County, the County has taken and will take the following actions:

Action	*Frequency*	*Status*
Engage in the "Northern Sacramento Valley – Integrated Regional Water Management Group"	Annual	2008 - Present
Maintain relationships with state and federal agencies	Annual	1850 - Present
Establish and update a groundwater management plan website	As needed	2008 - Present

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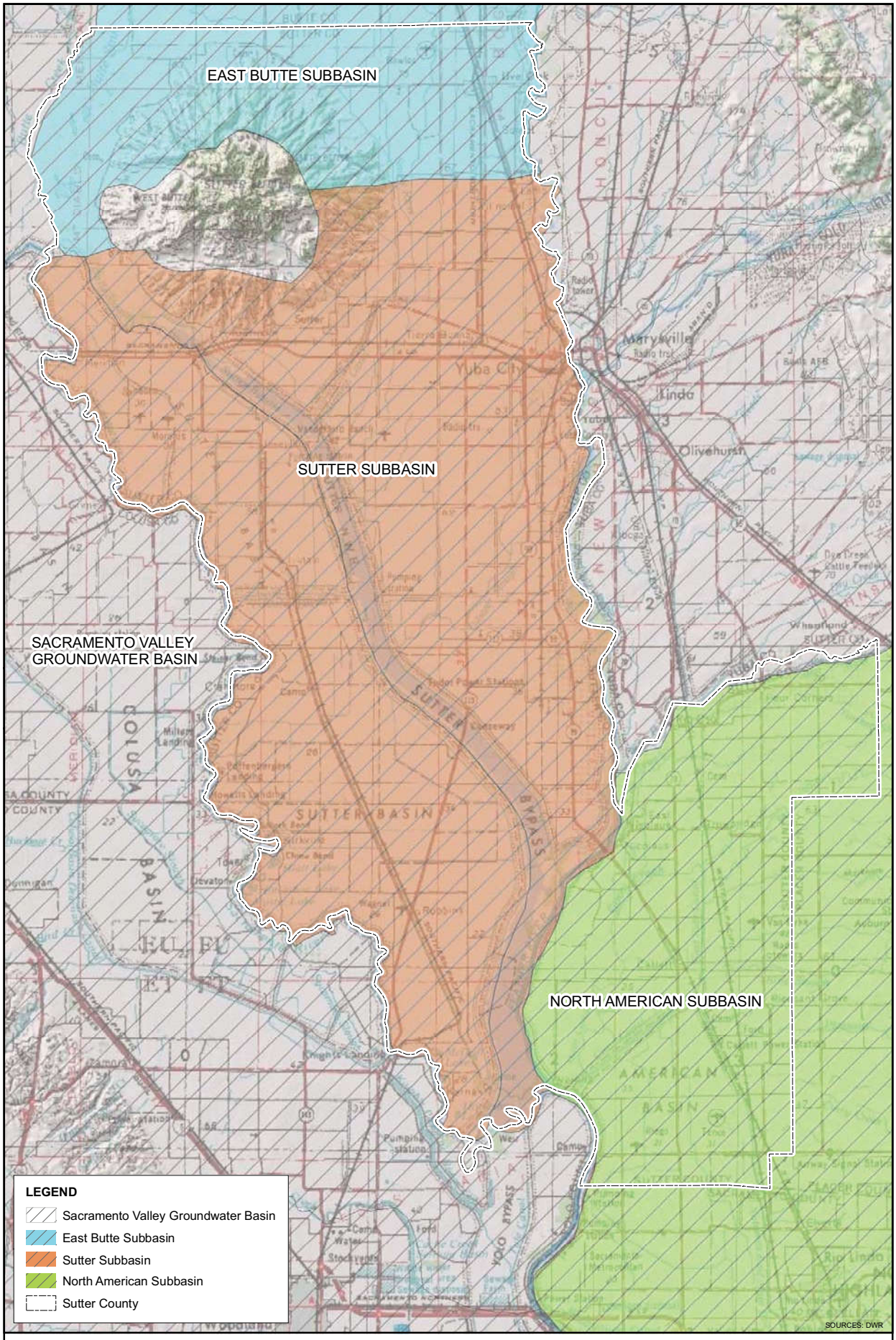

FIGURE 1
GROUNDWATER BASIN AND SUBBASINS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

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DEVELOPING INNOVATIVE DESIGN SOLUTIONS
3301 C Street, Bldg. 100-B Tel: 916.341.7760
Sacramento, CA 95816 Fax: 916.341.7767

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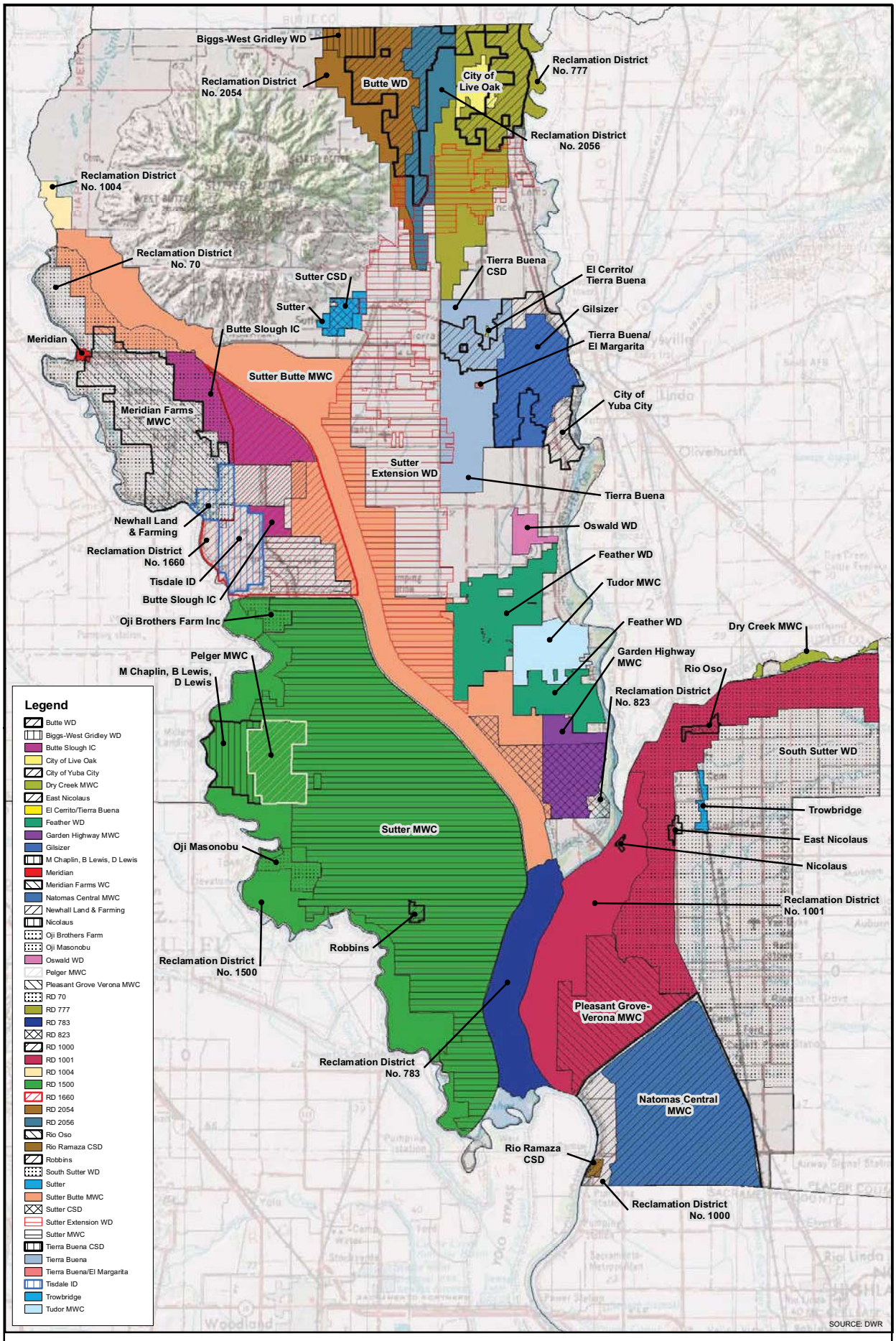

FIGURE 2
WATER DISTRICTS, PURVEYORS, AND WATER COMPANIES
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

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WOOD RODGERS
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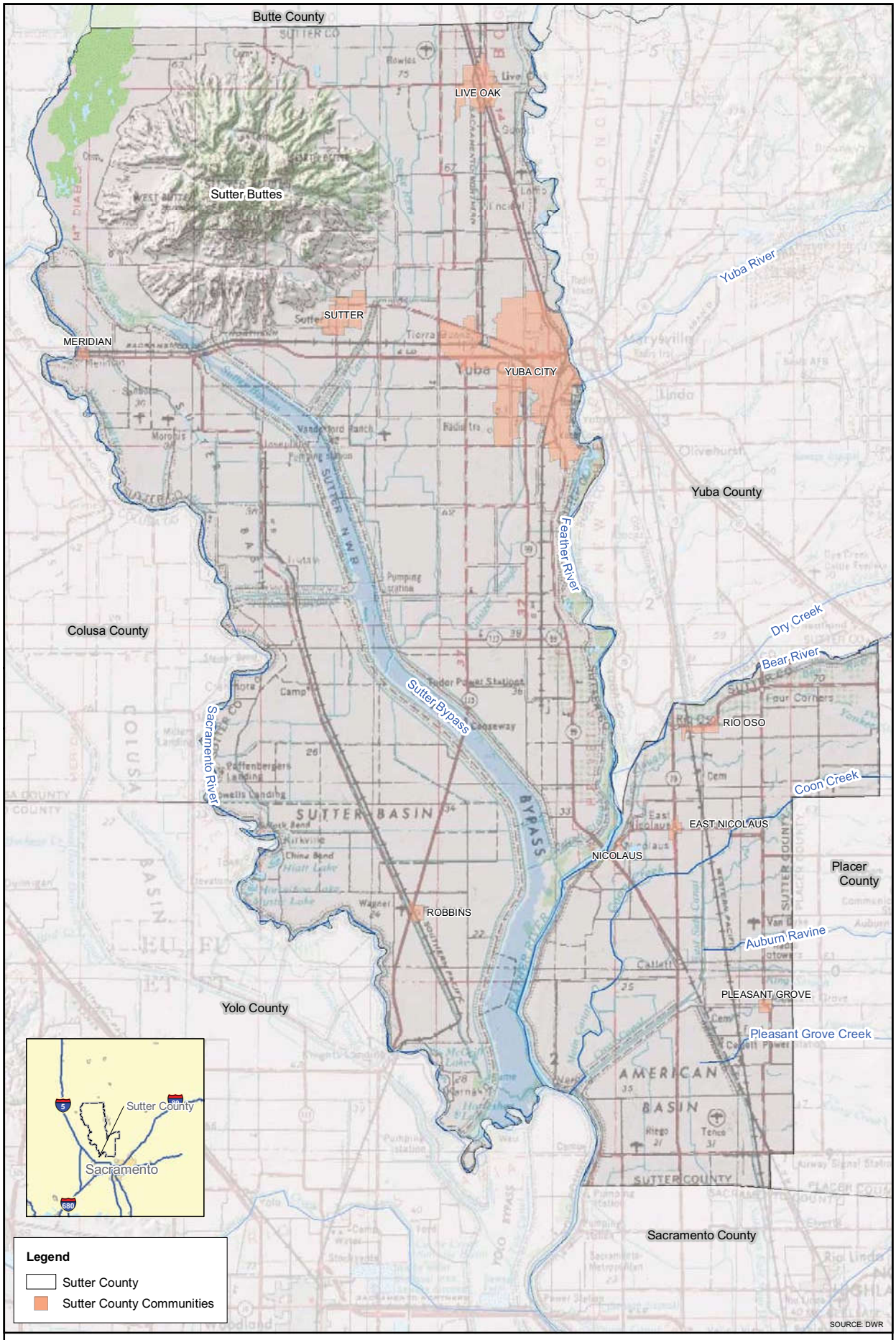

FIGURE 5
PHYSICAL FEATURES
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

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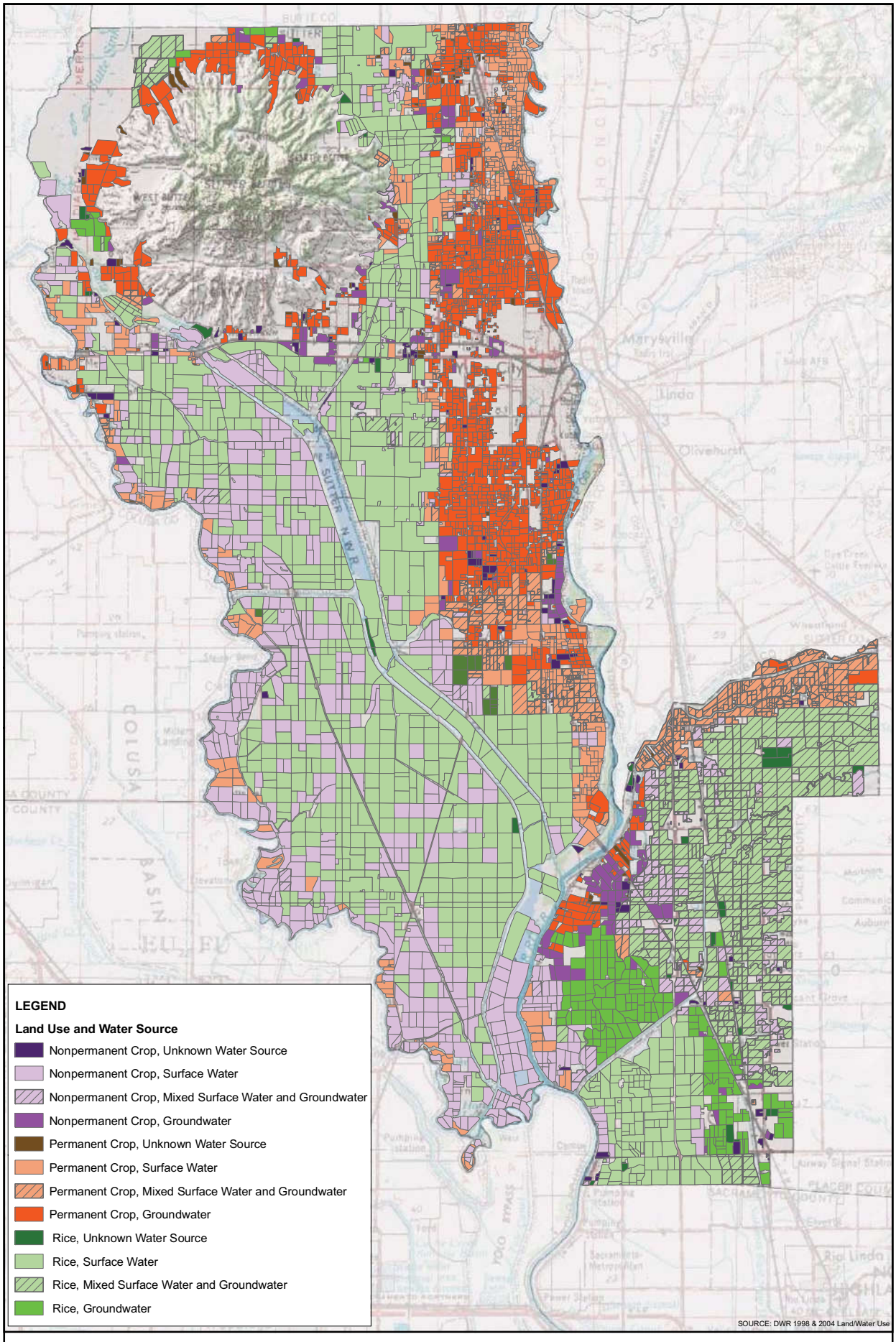

FIGURE 6
WATER SOURCES FOR IRRIGATED CROPS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

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MILES

WOOD RODGERS
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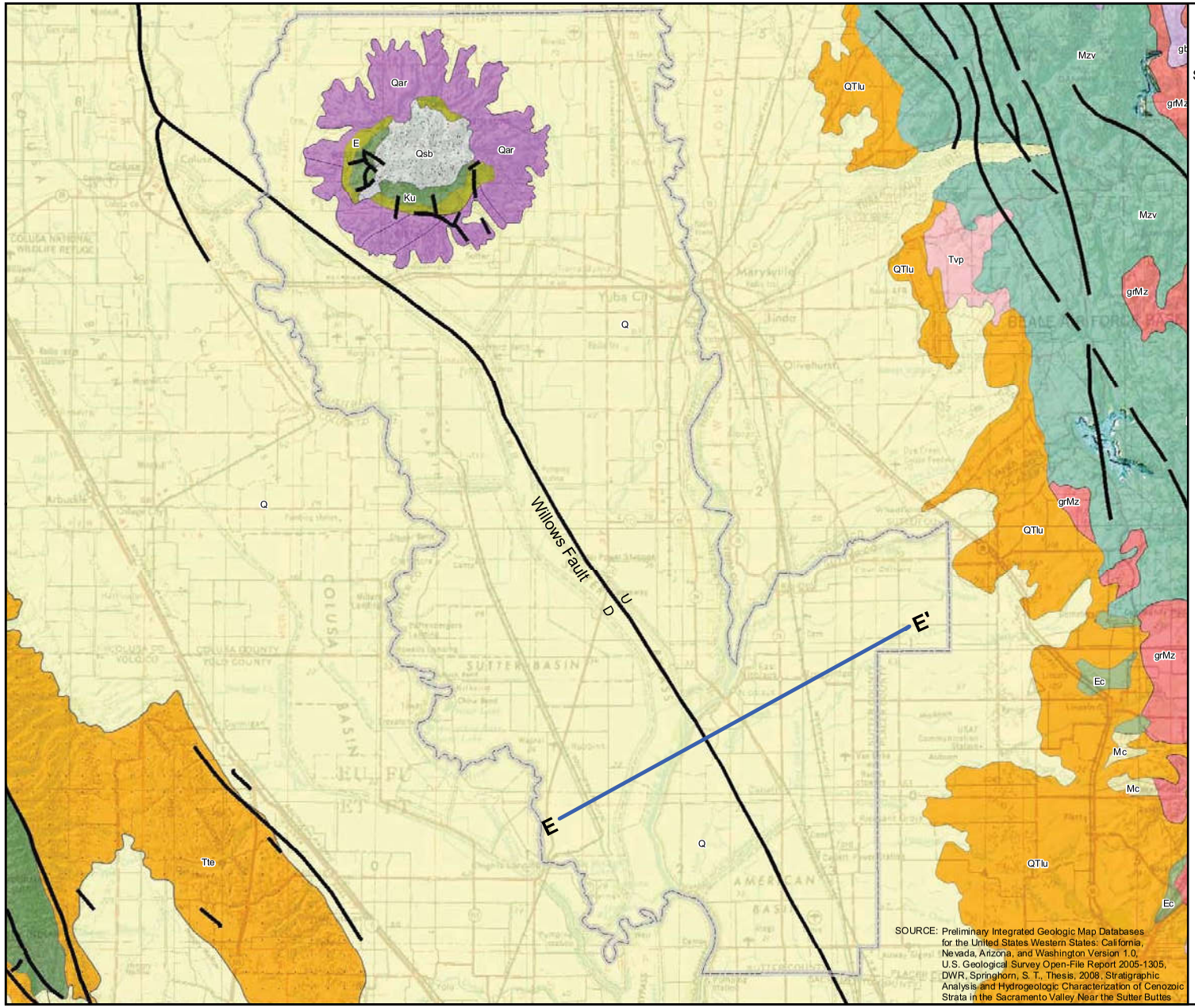
Sacramento, CA 95816 Fax: 916.341.7767

J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 6 Water_Source_IRR_Crops_.mxd 2/7/2012 12:52:19 PM bdemucha

FIGURE 7
SIMPLIFIED SURFACE GEOLOGY AND FAULTS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012



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LEGEND

- Q - Recent Deposits
  - Qb - Basin Deposits
  - Qm - Modesto Formation
  - Qr - Riverbank Formation
- Qsb - Sutter Buttes Igneous Rocks
- Qar - Sutter Buttes Andesitic Rampart
- QTlu - Laguna Formation
- Tte - Tehama Formation
- Tvp - Andesite, Rhyolite
- Mc - Sandstone, Conglomerate
- Ec - Conglomerate, Sandstone
- E - Mudstone, Sandstone
- Ku - Sandstone, Mudstone
- J - Mudstone, Sandstone, & Slate
- um - Serpentinite
- Mzv - Volcanic, Metavolcanic
- gb - Gabbro, Diorite
- grMz - Granodiorite
- Fault
- Fault Displacement - U, upthrown side; D, downthrown side
- Counties
- Simplified Conceptual Geologic Cross Section Line (See Figure 8)

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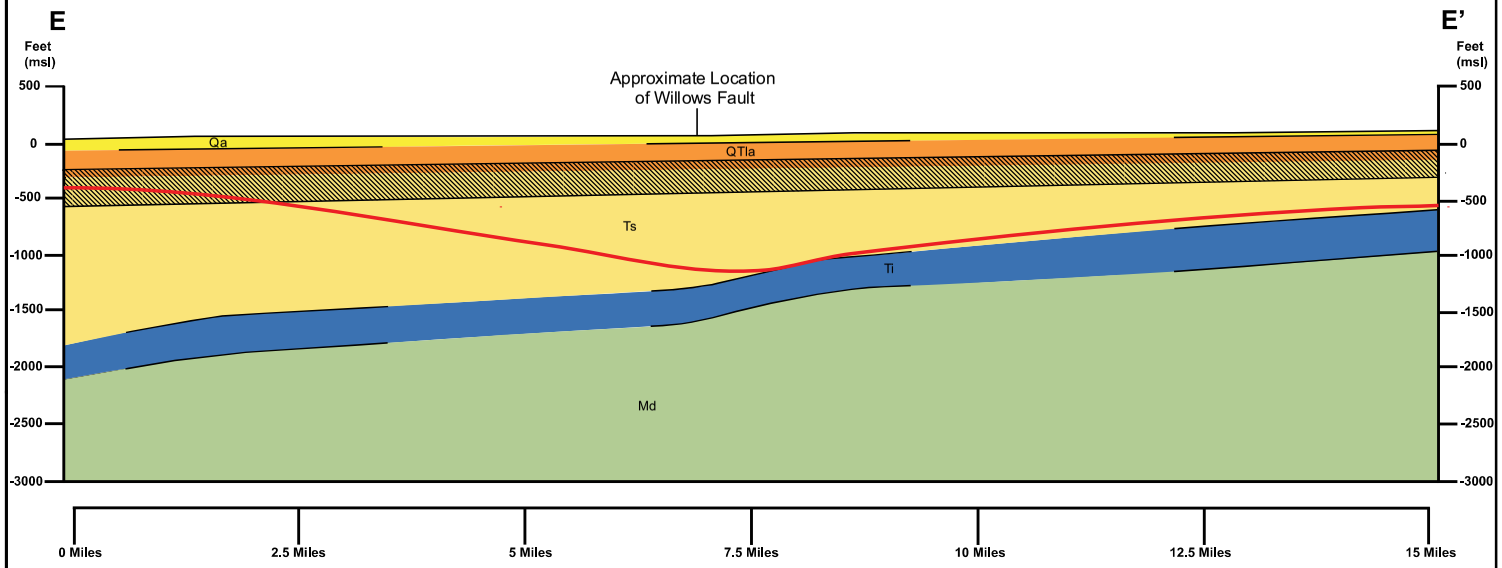
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 7 Simplified Surface Geology and Faults.mxd 2/7/2012 12:54:14 PM bdemucha

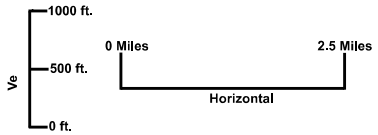
FIGURE 8
SIMPLIFIED CONCEPTUAL GEOLOGIC CROSS SECTION
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012



Explanation

- Qa — Alluvial Deposits
- QTla — Laguna Formation
- Laguna and Sutter Formation Transition (approximate depth)
- Ts — Sutter Formation (map unit, Williams and Curtis, 1977; Helley and Harwood, 1985)
  - Tt — Tuscan Formation (map unit, Helley and Harwood, 1985)
  - Tm — Mehrten Formation (map unit, Helley and Harwood, 1985)
- Ti — Ione Formation (map unit, Helley and Harwood, 1985)
- Md — Marine Deposits
- Inferred Geologic Contact
- Approximate Base of Fresh Water. Line represent depths at which Specific Conductance levels exceed approximately 3,000 umhos/cm

Cross Section Scale



SOURCES: DOGGR; DWR; Springhorn, S. T., Thesis, 2008, Stratigraphic Analysis and Hydrogeologic Characterization of Cenozoic Strata in the Sacramento Valley Near the Sutter Buttes; Berkstresser, C.F. Jr. 1973. Base of Fresh Ground-Water -- Approximately 3,000 micromhos in the Sacramento Valley and Sacramento-San Joaquin Delta, California. U.S. Geological Survey Water-Resource Inv. 40-73; Helley, E. J. and Harwood, D. S., 1985, Geologic Map of Late Cenozoic Deposits of the Sacramento Valley and Northern Sierran Foothills, California.

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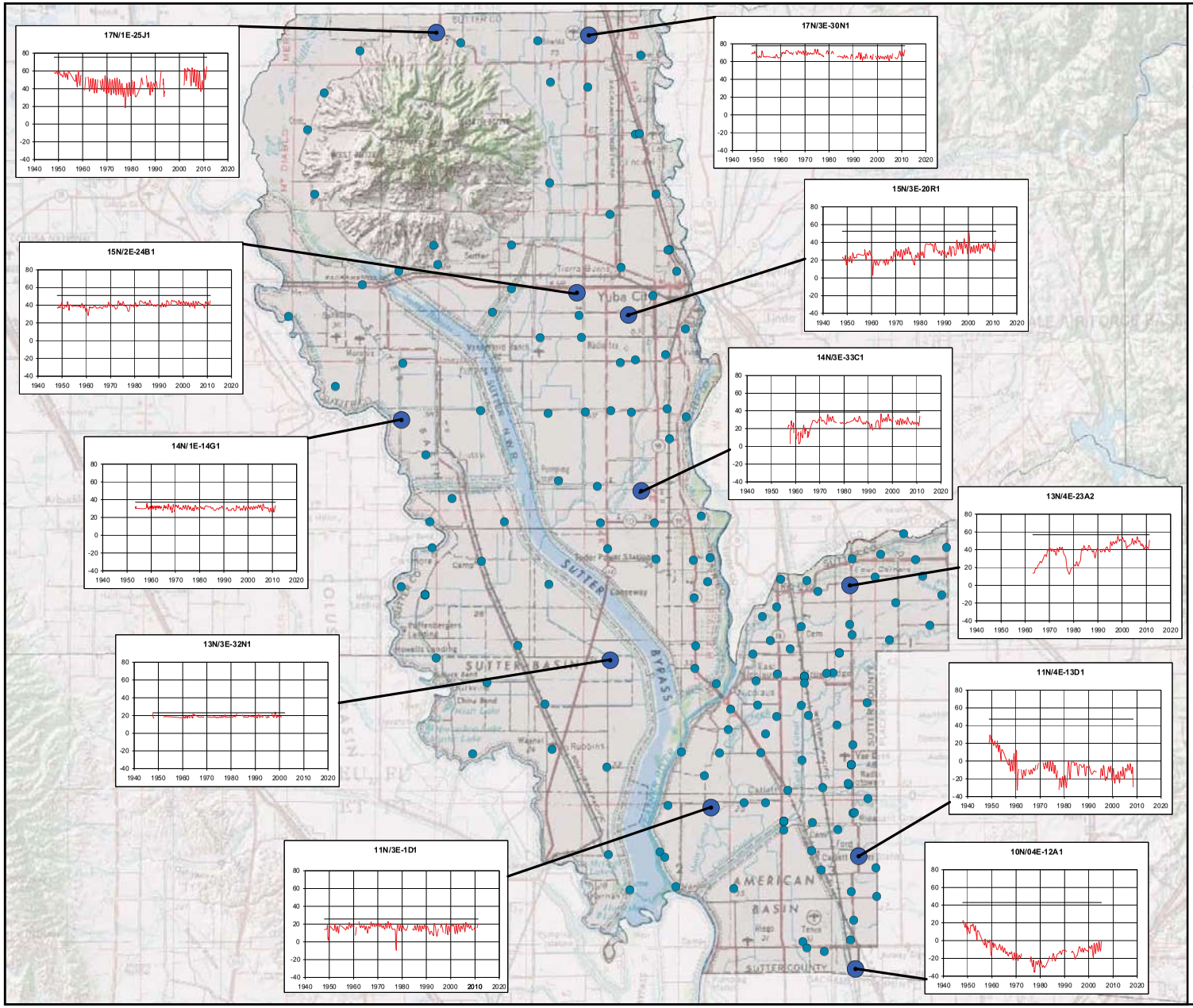

FIGURE 9
HISTORIC GROUNDWATER ELEVATIONS IN SUTTER COUNTY
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH

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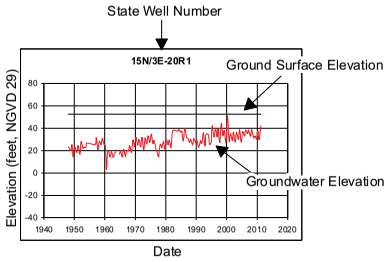
MILES

Legend

- Well with Hydrograph Shown
- Well with Water Level Measurement since 2004

Note: This figure represents wells with historic water level and current measurements either submitted to or obtained by the California Department of Water Resources and may not represent current monitoring activities. Groundwater elevations are in feet above mean sea level.

SOURCE: DWR



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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 9 Historic Groundwater Elevations in Sutter County .mxd 2/7/2012 12:59:56 PM bdemucha

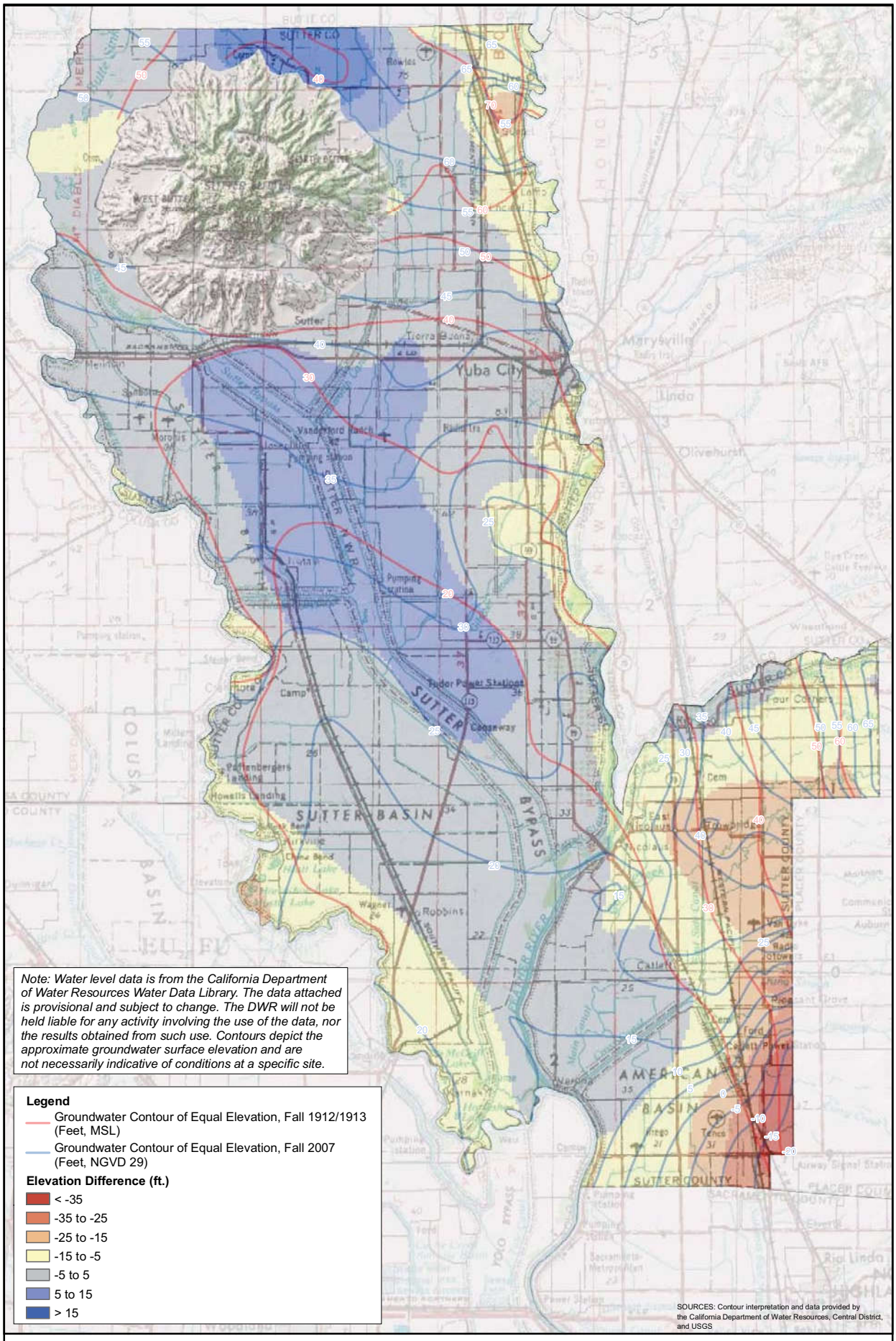

FIGURE 10
GROUNDWATER LEVEL CHANGE MAP
FALL 2007 AND FALL 1912/1913
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120201 Final Draft Figure Comments\Figure 10 Groundwater_elevation_change_map.mxd 2/7/2012 5:35:33 PM bdemucha

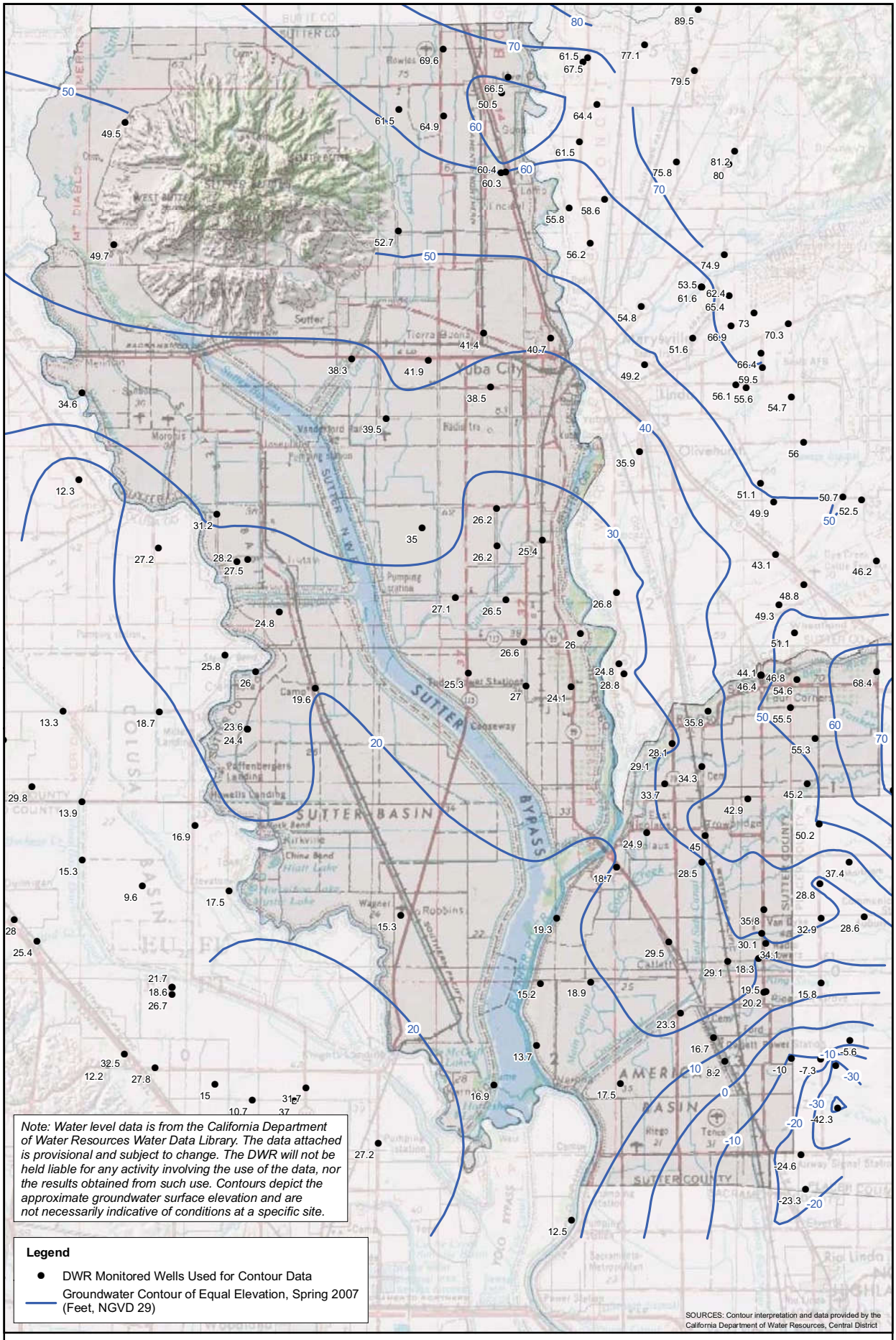

FIGURE 11
GROUNDWATER ELEVATION CONTOUR MAP
SPRING, 2007
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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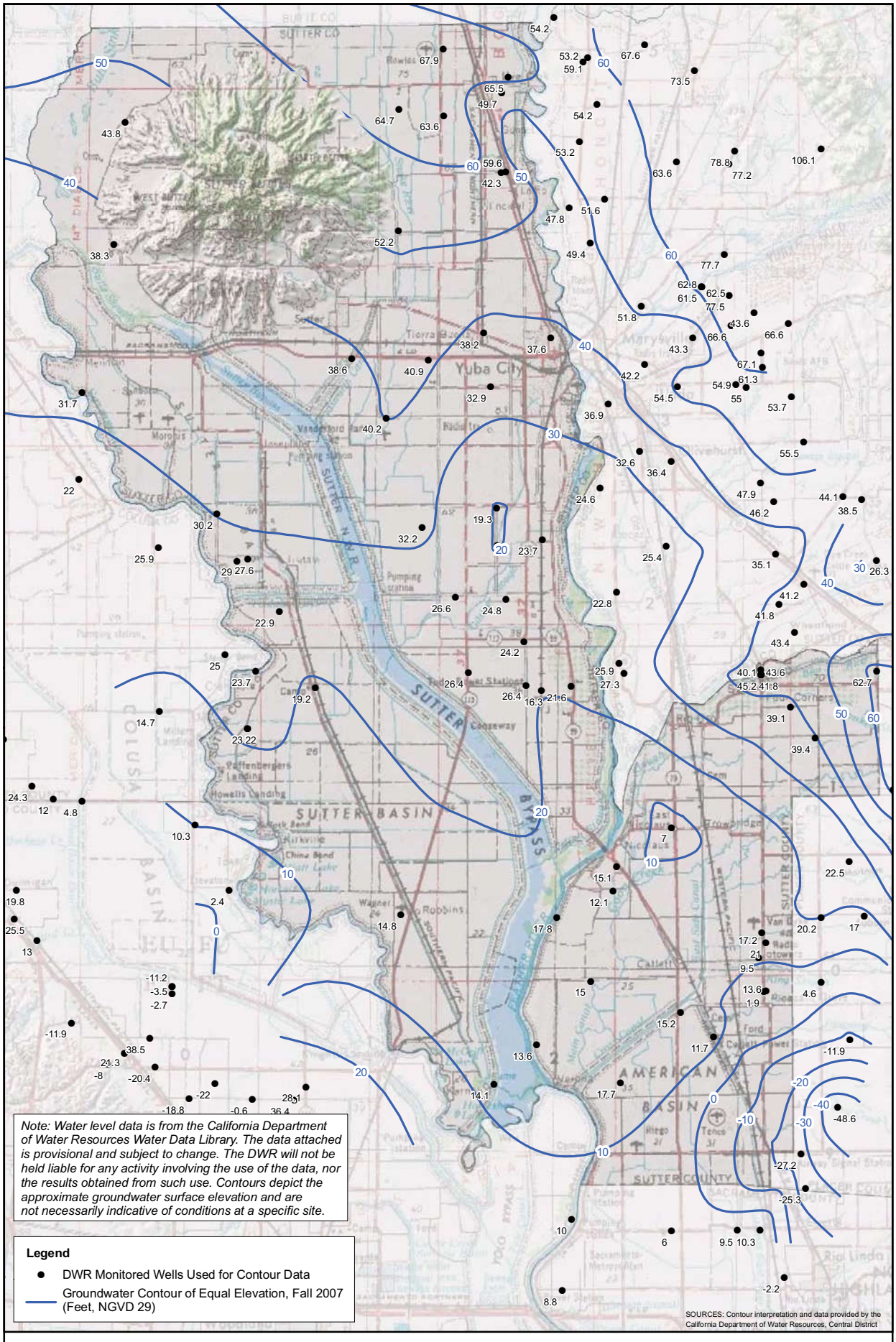

FIGURE 12
GROUNDWATER ELEVATION CONTOUR MAP
FALL, 2007
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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NORTH
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MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 12 Groundwater Elevation Contour Map Fall 2007.mxd 2/7/2012 6:07:59 PM bdemucha

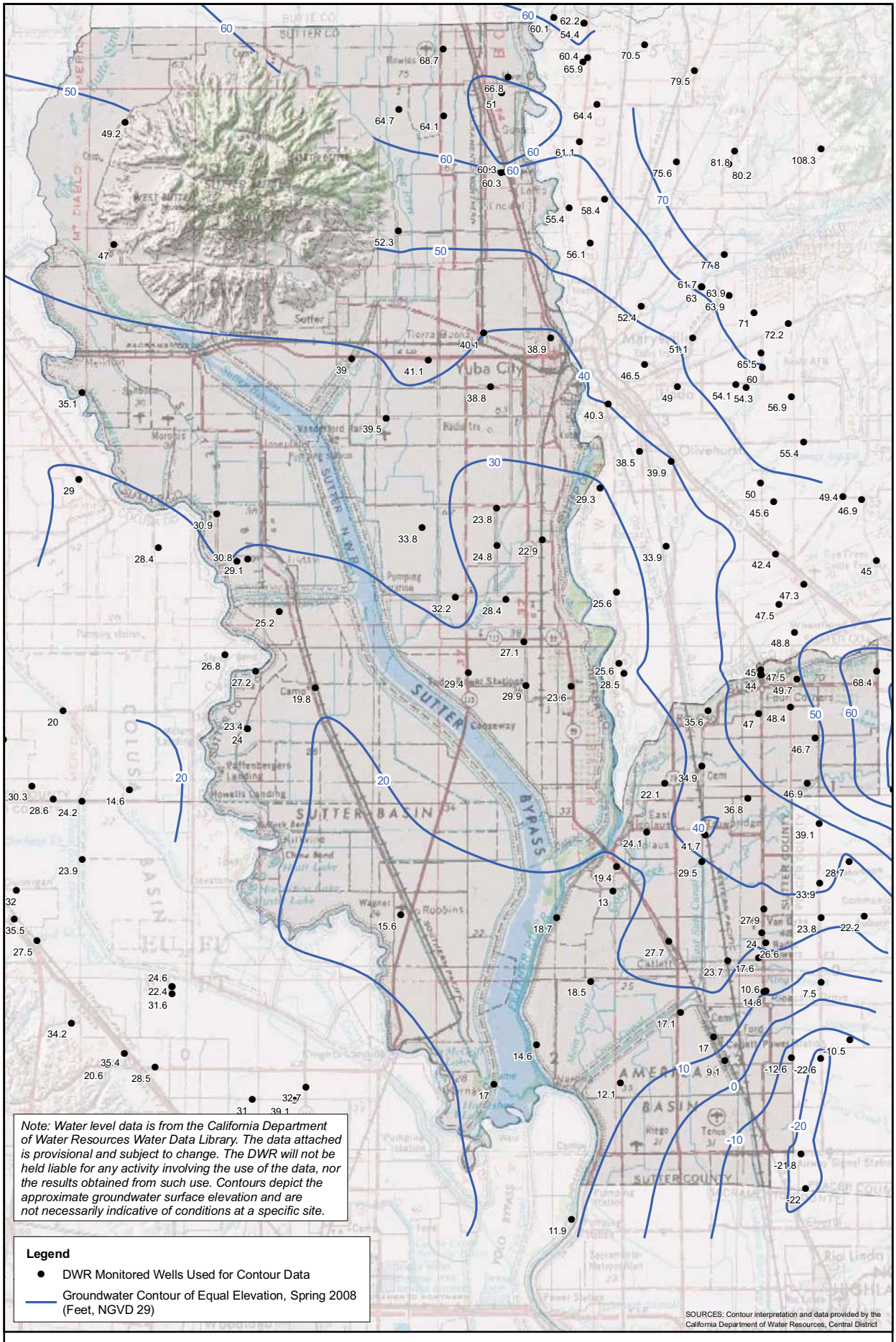

FIGURE 13
GROUNDWATER ELEVATION CONTOUR MAP
SPRING, 2008
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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NORTH
0 1.5 3
MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 13 Groundwater Elevation Contour Map Spring 2008.mxd 2/7/2012 6:20:59 PM bdemucha

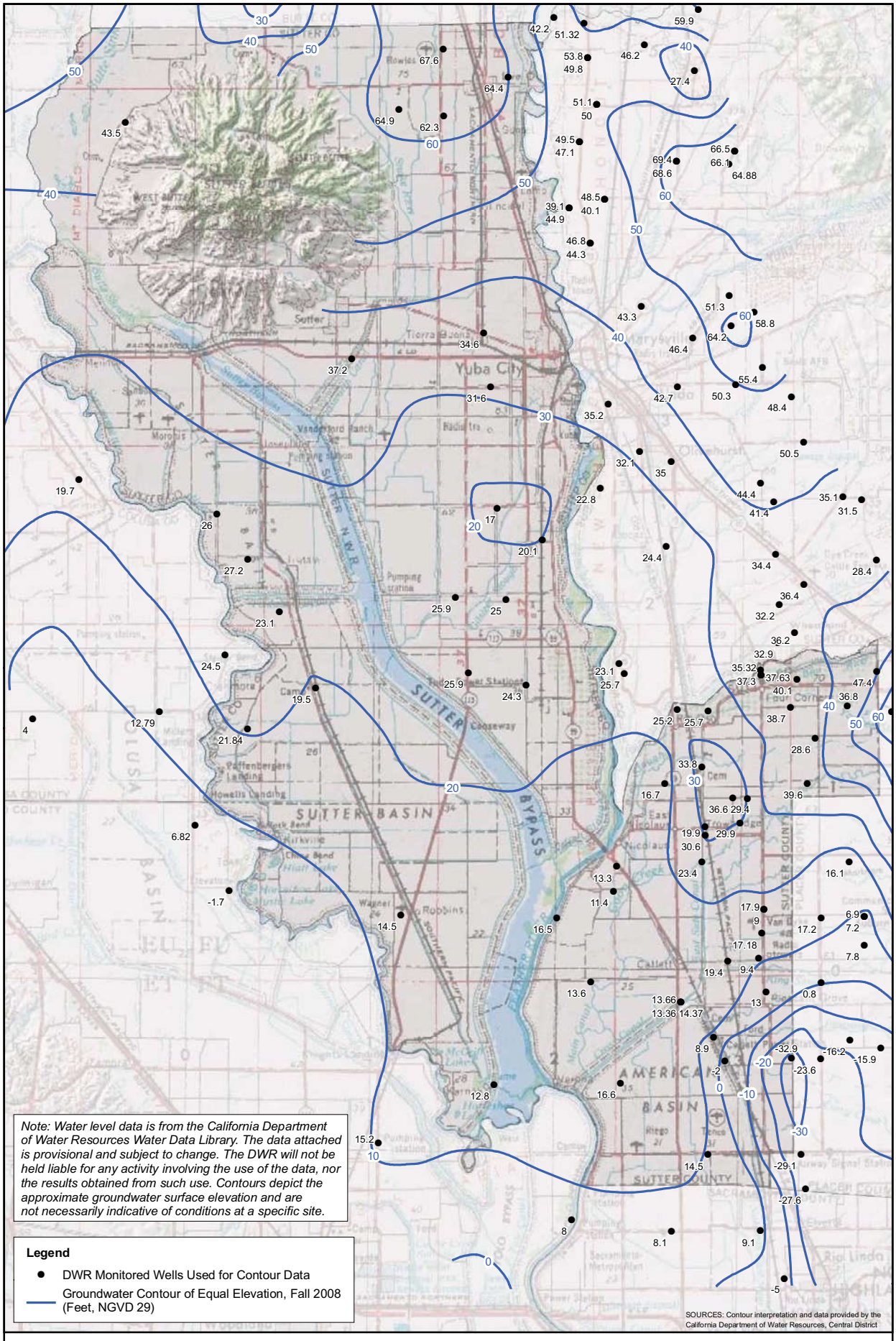

FIGURE 14
GROUNDWATER ELEVATION CONTOUR MAP
FALL, 2008
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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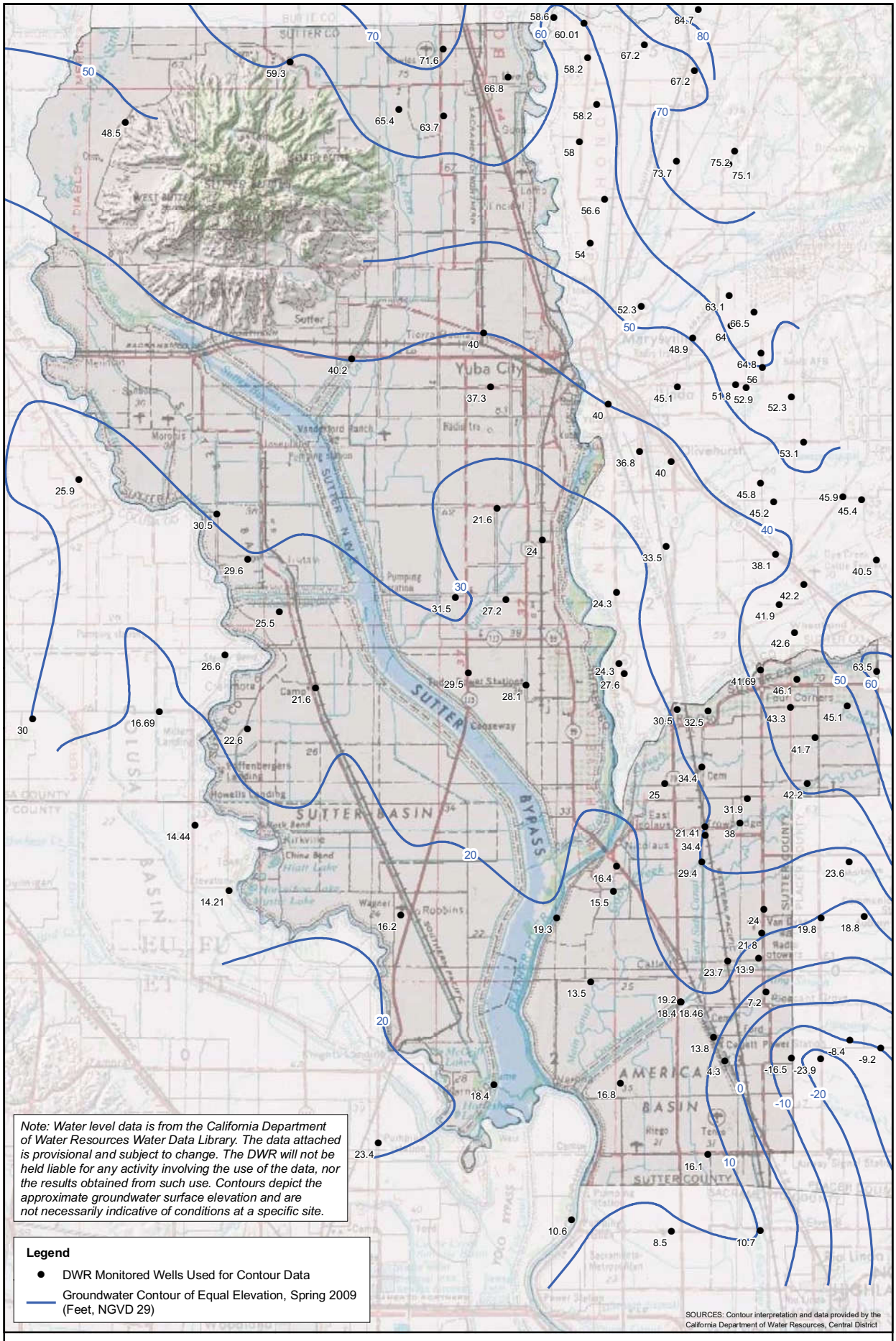
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 14 Groundwater Elevation Contour Map Fall 2008.mxd 2/8/2012 9:20:28 AM bdemucha



Note: Water level data is from the California Department of Water Resources Water Data Library. The data attached is provisional and subject to change. The DWR will not be held liable for any activity involving the use of the data, nor the results obtained from such use. Contours depict the approximate groundwater surface elevation and are not necessarily indicative of conditions at a specific site.

Legend

- DWR Monitored Wells Used for Contour Data
- Groundwater Contour of Equal Elevation, Spring 2009 (Feet, NGVD 29)

SOURCES: Contour interpretation and data provided by the California Department of Water Resources, Central District

FIGURE 15
GROUNDWATER ELEVATION CONTOUR MAP
SPRING, 2009
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MILES

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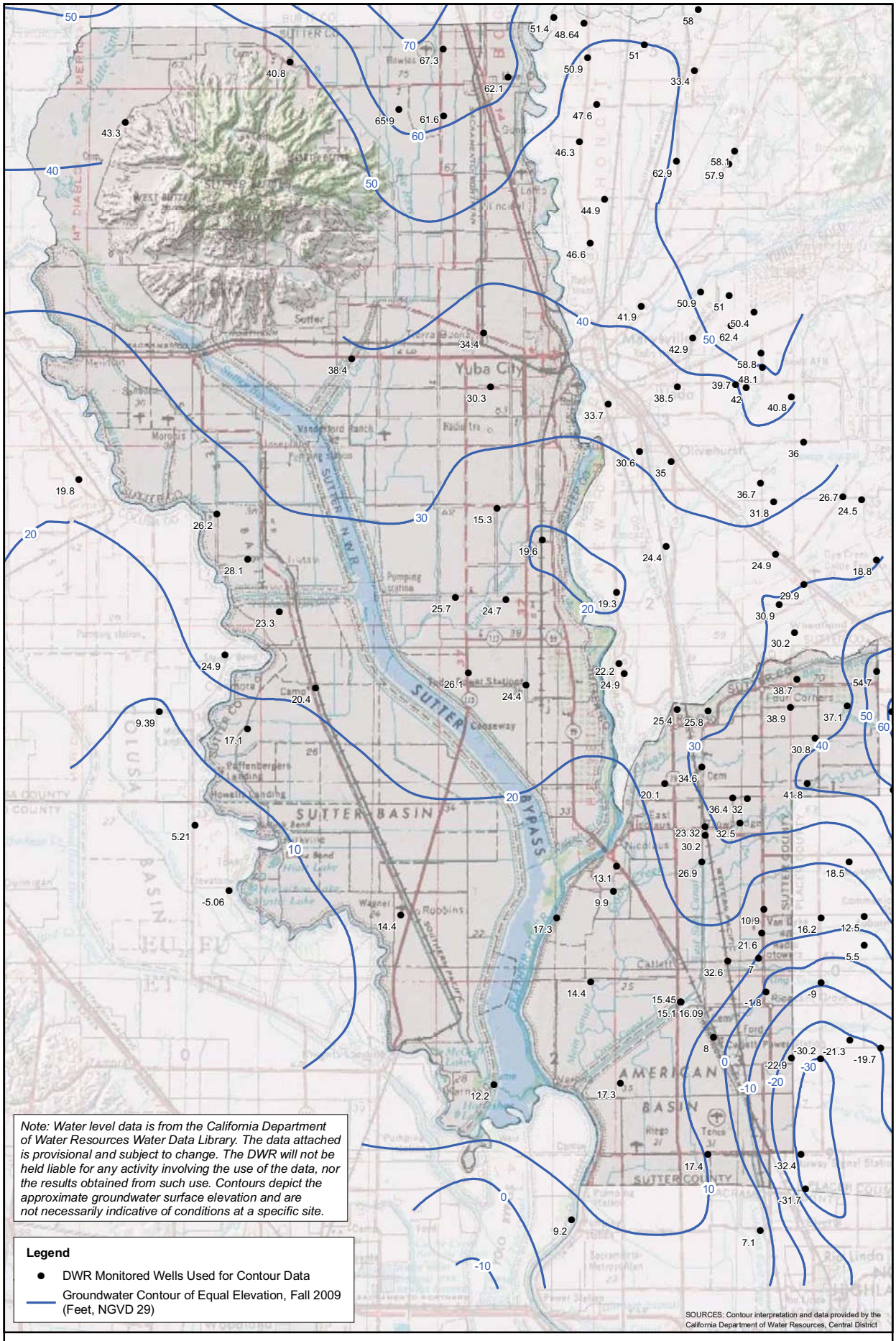

FIGURE 16
GROUNDWATER ELEVATION CONTOUR MAP
FALL, 2009
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

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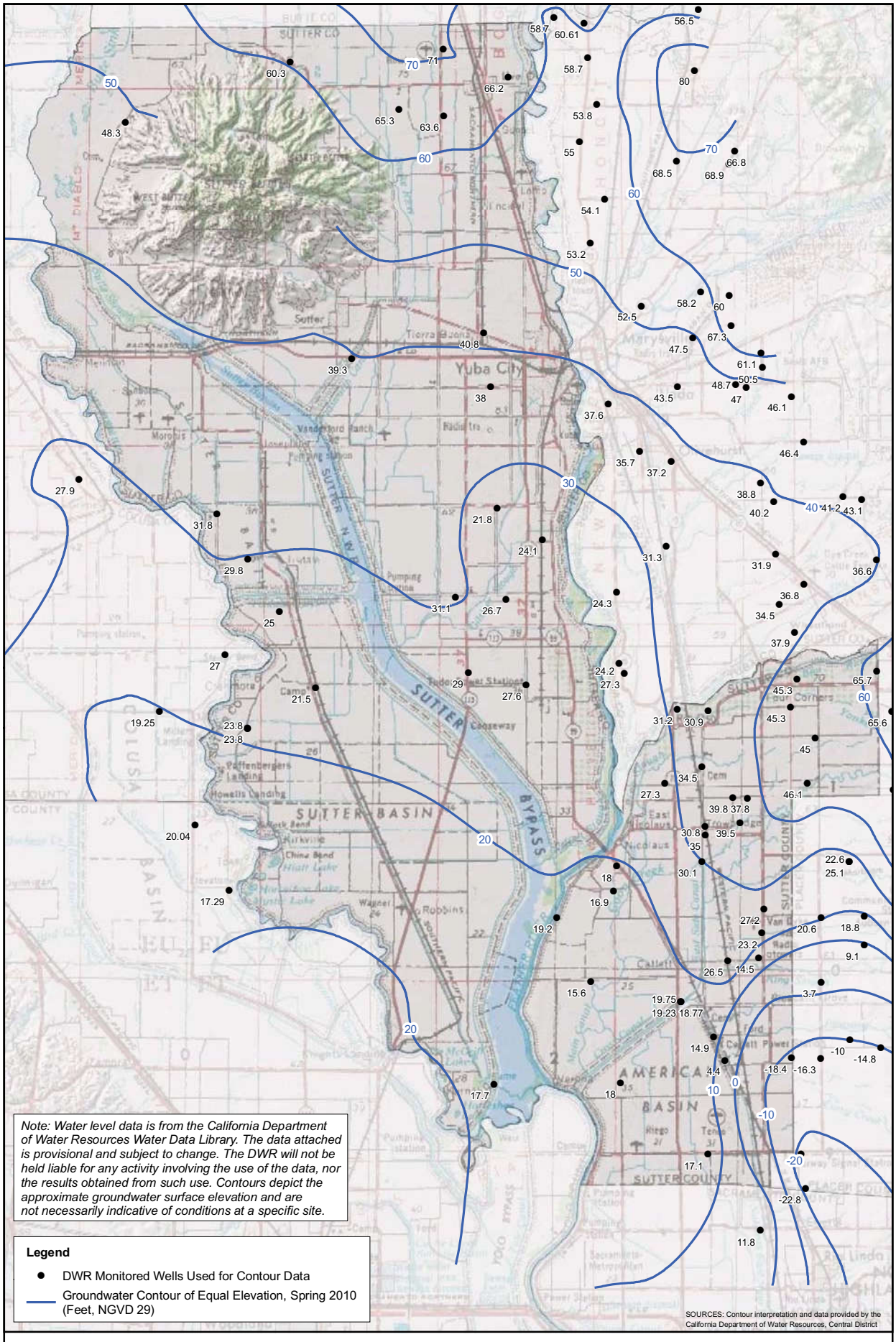
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 16 Groundwater Elevation Contour Map Fall 2009.mxd 2/8/2012 9:44:53 AM bdemucha



Note: Water level data is from the California Department of Water Resources Water Data Library. The data attached is provisional and subject to change. The DWR will not be held liable for any activity involving the use of the data, nor the results obtained from such use. Contours depict the approximate groundwater surface elevation and are not necessarily indicative of conditions at a specific site.

Legend

- DWR Monitored Wells Used for Contour Data
- Groundwater Contour of Equal Elevation, Spring 2010 (Feet, NGVD 29)

SOURCES: Contour interpretation and data provided by the California Department of Water Resources, Central District

FIGURE 17
GROUNDWATER ELEVATION CONTOUR MAP
SPRING, 2010
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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NORTH
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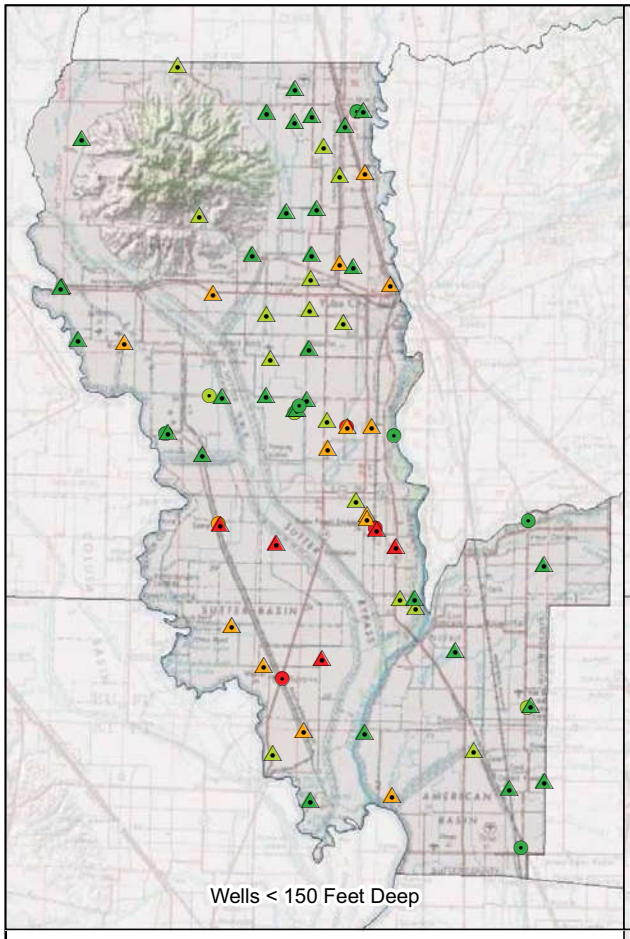
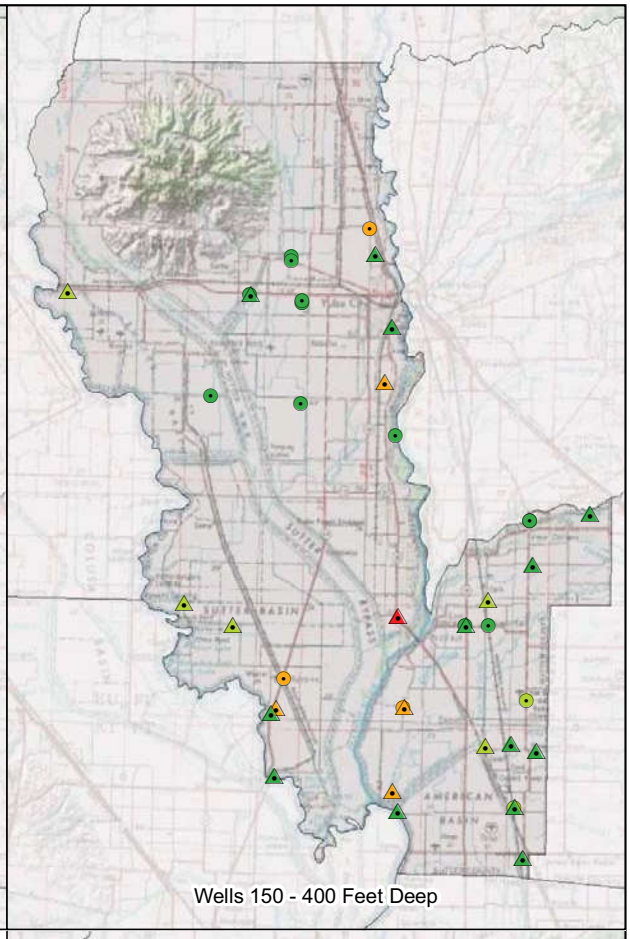




EC in DWR Wells (µmhos/cm)

- < 600
- 600 - 900
- 900 - 1600
- > 1600

EC in USGS Wells (µmhos/cm)

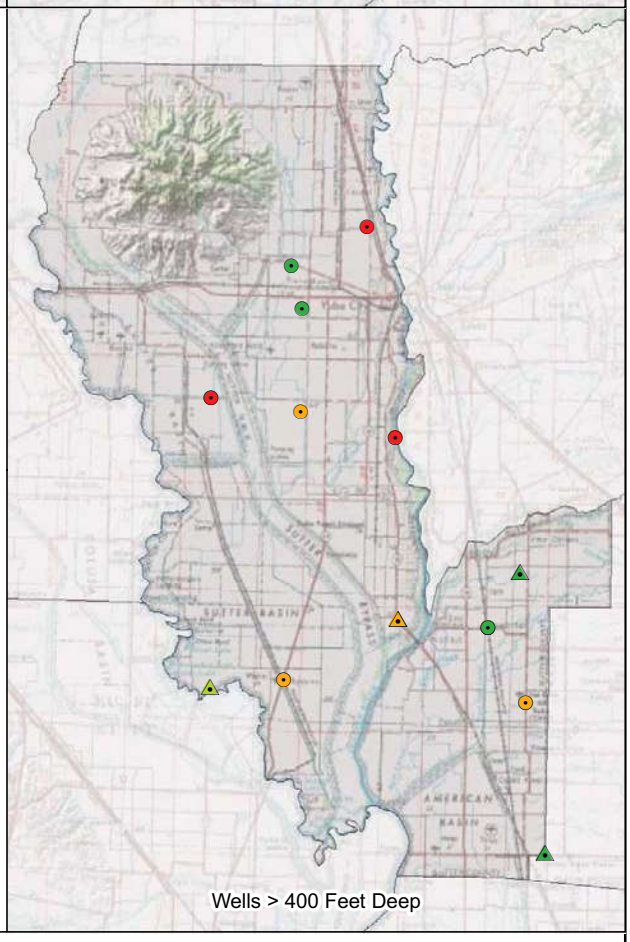
- < 600
- 600 - 900
- 900 - 1600
- > 1600

Note:
"EC" is an abbreviation for specific conductance, which is related to the salt content of a water sample.

For public drinking water systems, the secondary (aesthetic) maximum contaminant levels for EC are 900 micromhos/centimeter (µmhos/cm) (recommended), 1600 µmhos/cm (upper), and 2200 µmhos/cm (short-term).

For irrigation, crop yields decrease above a threshold EC value, which is crop-dependent. Crop yield potential decreases above these threshold levels:

Almonds - 1000 µmhos/cm
Beans - 700 µmhos/cm
Rice - 2000 µmhos/cm
Squash - 2100-3100 µmhos/cm
Tomatoes - 1700 µmhos/cm
Wheat - 4000 µmhos/cm



SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA

FIGURE 18
SPECIFIC CONDUCTANCE BY WELL DEPTH
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
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MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 18 EC_Well Depth.mxd 2/8/2012 10:00:29 AM bdemucha

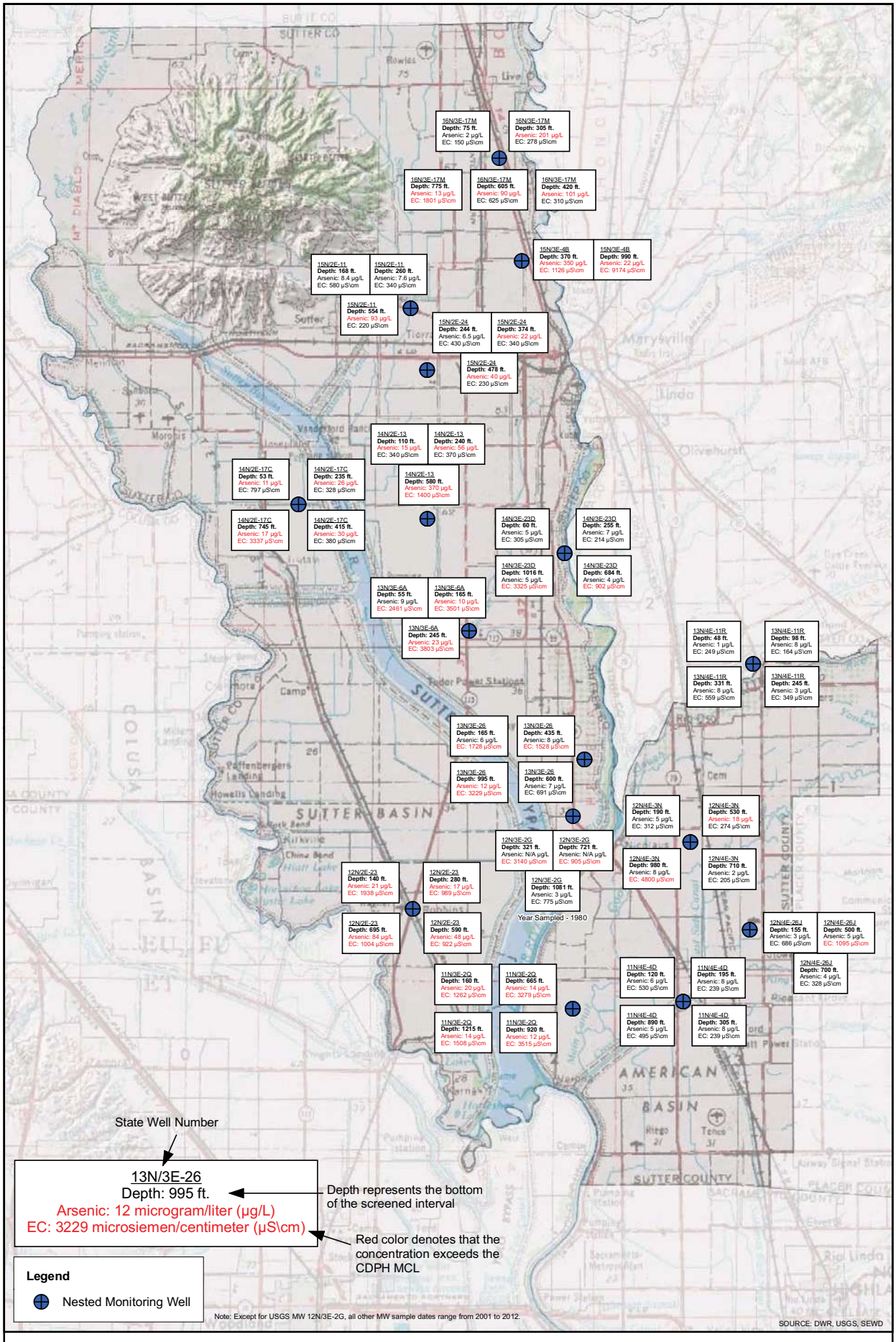

FIGURE 19
DEPTH SPECIFIC ARSENIC AND SPECIFIC CONDUCTANCE CONCENTRATIONS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

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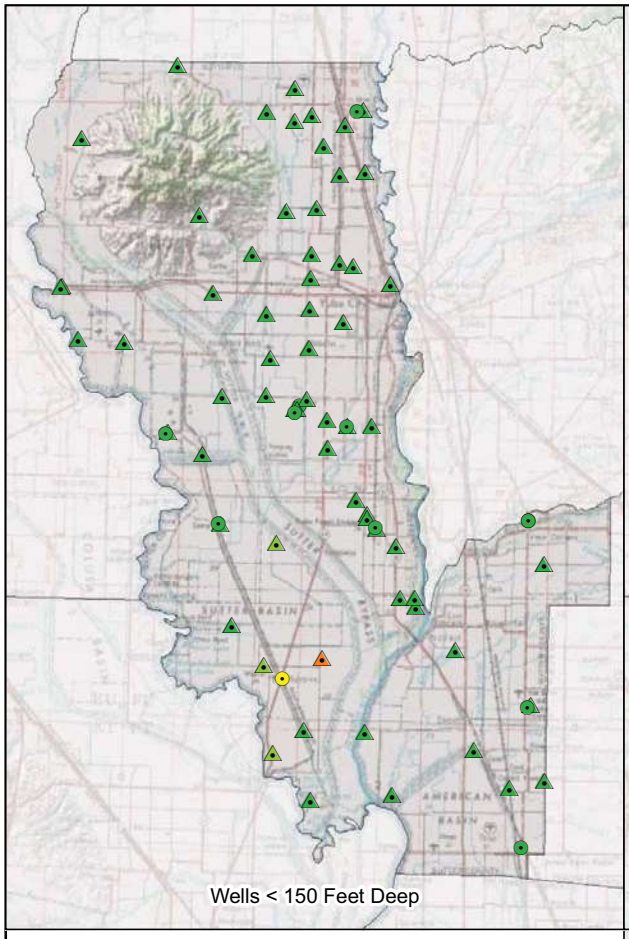
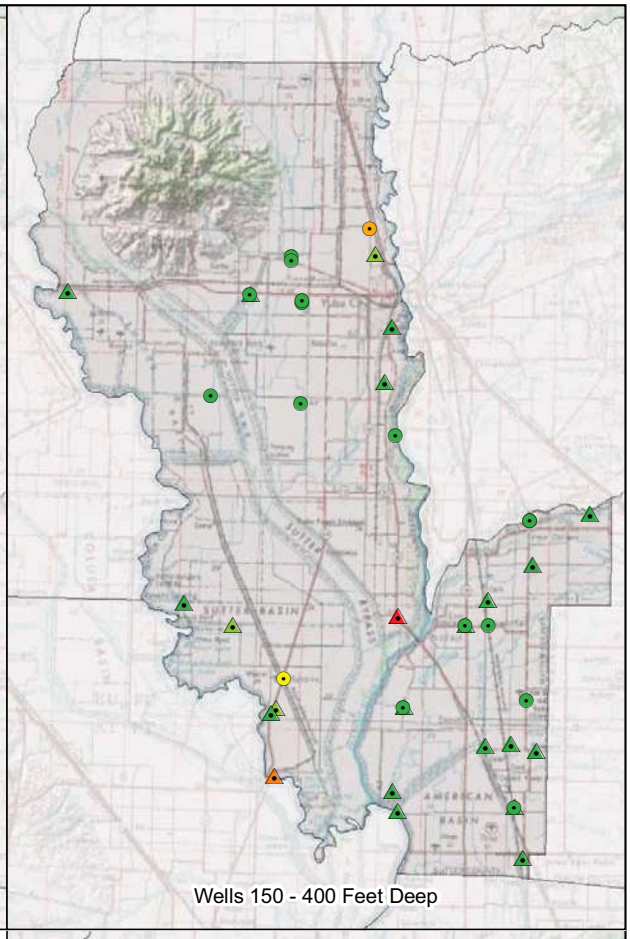
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120201 Final Draft Figure Comments\Figure 19 Depth Specific Arsenic and Specific Conductance.mxd 2/8/2012 11:34:41 AM bdemucha



Wells < 150 Feet Deep



Wells 150 - 400 Feet Deep

Boron in DWR Wells (µg/L)

- < 500
- 500 - 750
- 750 - 1000
- 1000 - 2000
- > 2000

Boron in USGS Wells (µg/L)

- < 500
- 500 - 750
- 750 - 1000
- 1000 - 2000
- > 2000

Note:
Boron is naturally occurring and leaches from aquifer materials into groundwater.

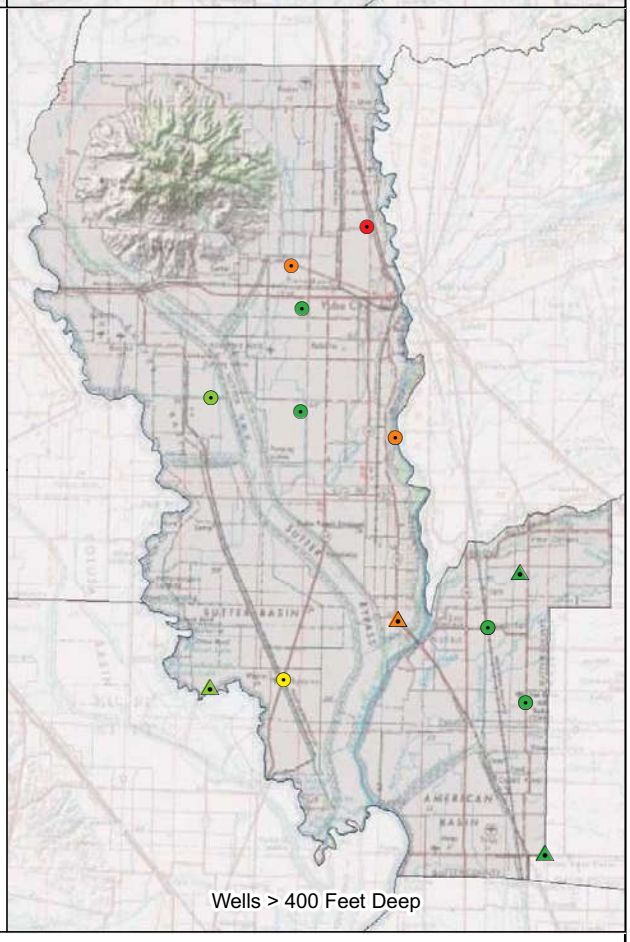
For public drinking water systems, there is a notification level for boron of 1000 micrograms/liter (µg/L).

For irrigation, boron is necessary for crop growth but becomes toxic to the point that yields may decrease above these threshold levels:

Beans - 750 - 1000 µg/L
Grapes - 500 - 750 µg/L
Squash - 2000 - 4000 µg/L
Tomatoes - 4000 - 6000 µg/L
Walnuts - 500 - 750 µg/L
Wheat - 750 - 1000 µg/L

Many other trees are vulnerable to boron toxicity above 500 - 750 µg/L.

SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA



Wells > 400 Feet Deep

FIGURE 20
BORON BY WELL DEPTHS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH

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MILES

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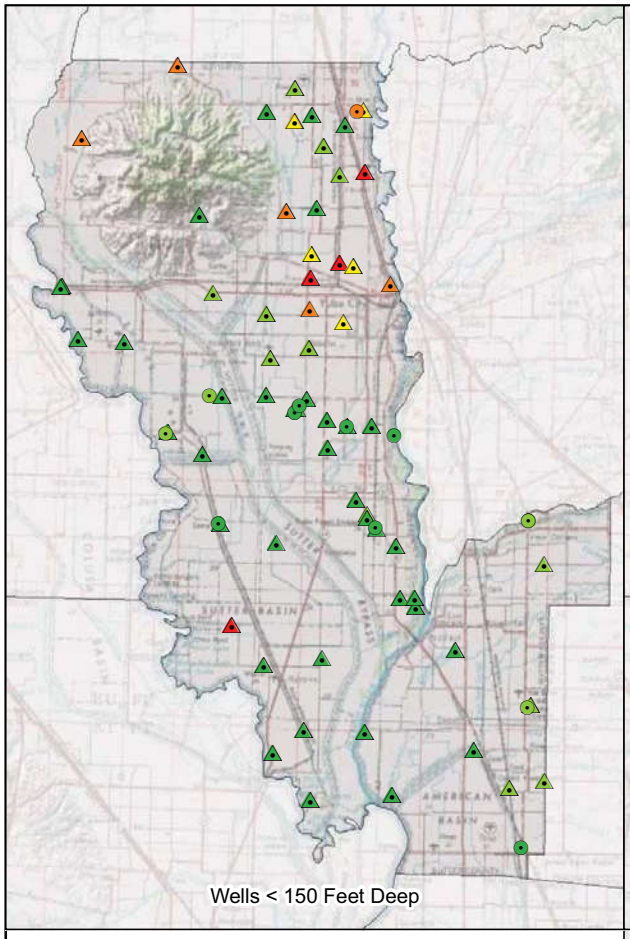
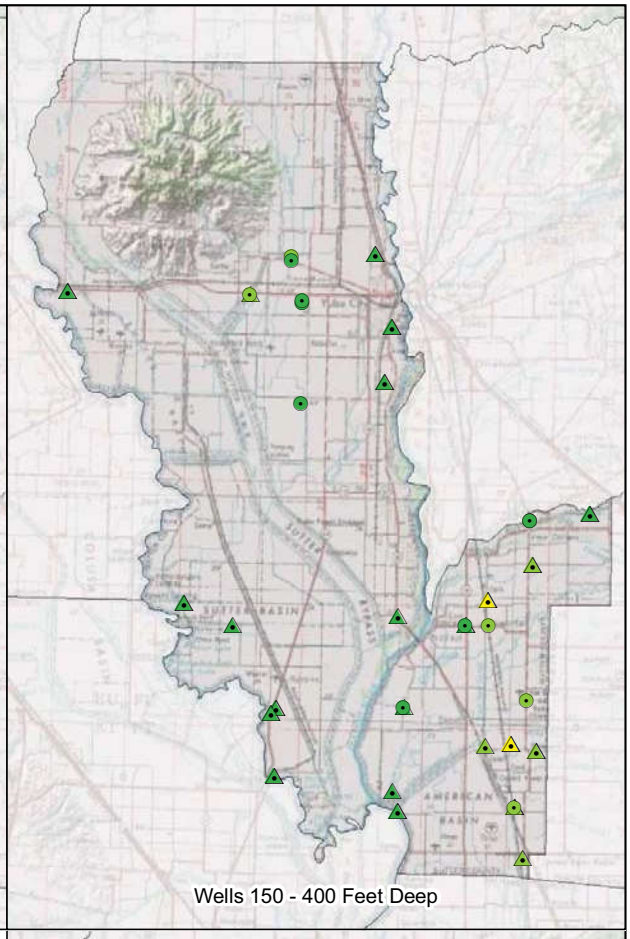




Nitrate in DWR Wells (mg/L)

- < 5
- 5 - 15
- 15 - 30
- 30 - 45
- > 45

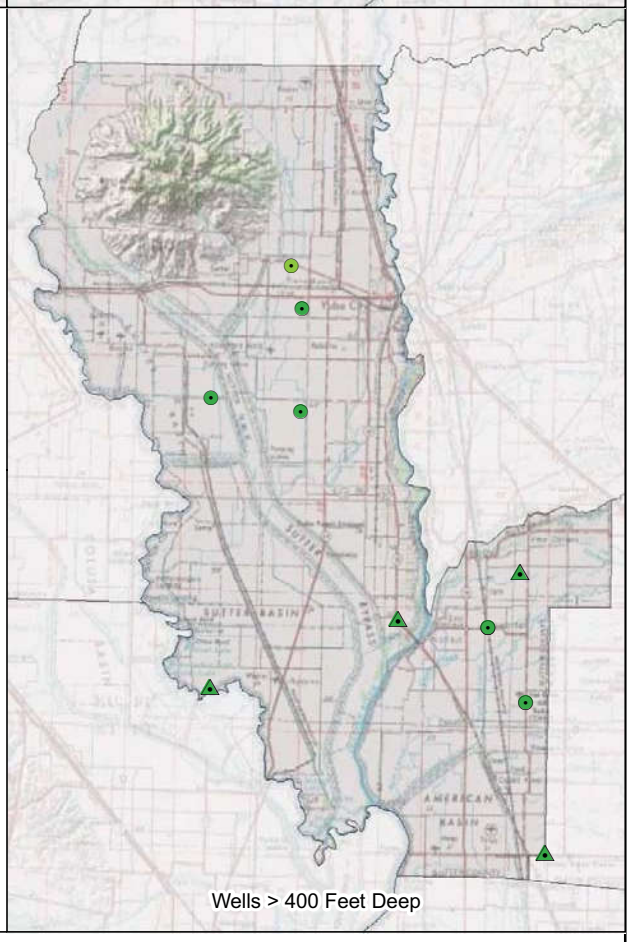
Nitrate in USGS Wells (mg/L)

- < 15
- 5 - 15
- 15 - 30
- 30 - 45
- > 45

Note:
Nitrate is generally introduced into groundwater by septic systems, fertilizers, or confined animal operations.

For public drinking water systems, the primary (health-based) maximum contaminant level for nitrate as NO3 is 45 milligrams/liter (mg/L).

At concentrations exceeding the maximum contaminant level, nitrate can interfere with the blood's ability to carry oxygen. This effect can be especially pronounced in infants, where it is known as "blue baby syndrome".



SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA

FIGURE 21
NITRATE BY WELL DEPTH
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
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MILES

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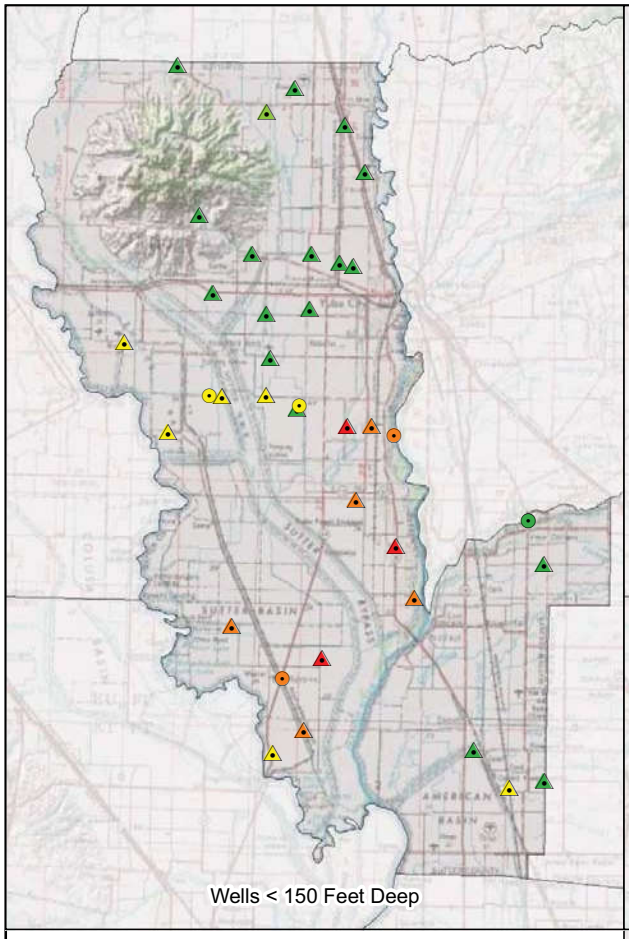
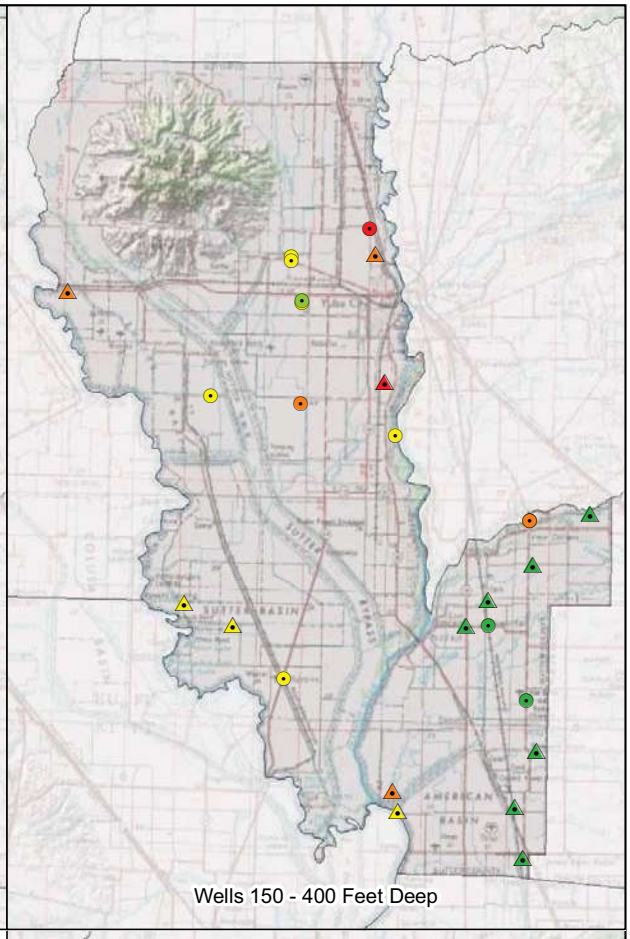
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 21 Nitrates_Well Depth.mxd 2/8/2012 2:10:46 PM bdemucha





Manganese in DWR Wells (µg/L)

- < 25
- 25 - 50
- 50 - 150
- 150 - 500
- > 500

Manganese in USGS Wells (µg/L)

- < 25
- 25 - 50
- 50 - 150
- 150 - 500
- > 500

Note:
Manganese is naturally occurring and leaches from aquifer materials into groundwater.

For public drinking water systems, the secondary (aesthetic) maximum contaminant level for manganese is 50 micrograms/liter (µg/L). There is also a notification level for manganese of 500 µg/L. Notification levels are health-based advisory levels for chemicals that do not have primary maximum contaminant levels.

Manganese can cause staining of plumbing and fixtures, and can contribute a metallic odor to water. At very high concentrations (above the notification level) manganese may cause neurologic problems.

Analysis for manganese is very sensitive to turbidity of samples - turbid samples will often have artificially high results for manganese.

SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA

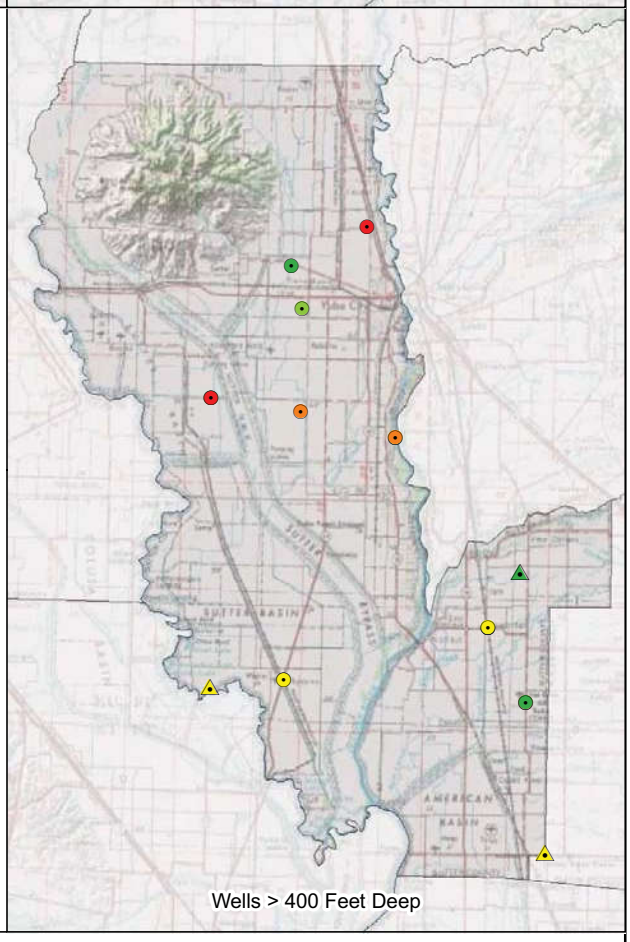


FIGURE 22
MANGANESE BY WELL DEPTHS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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NORTH
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MILES

SUTTER COUNTY CALIFORNIA

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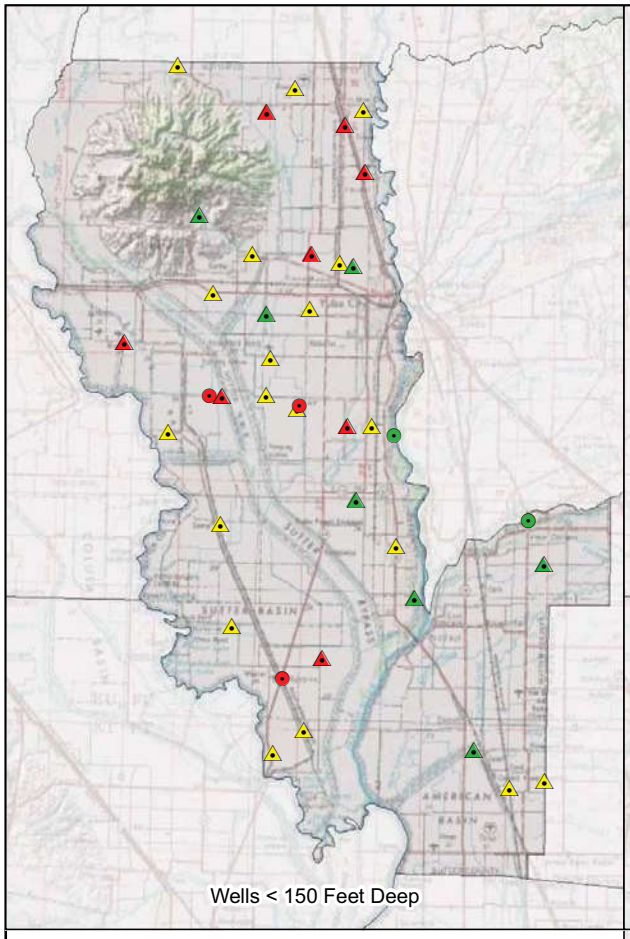
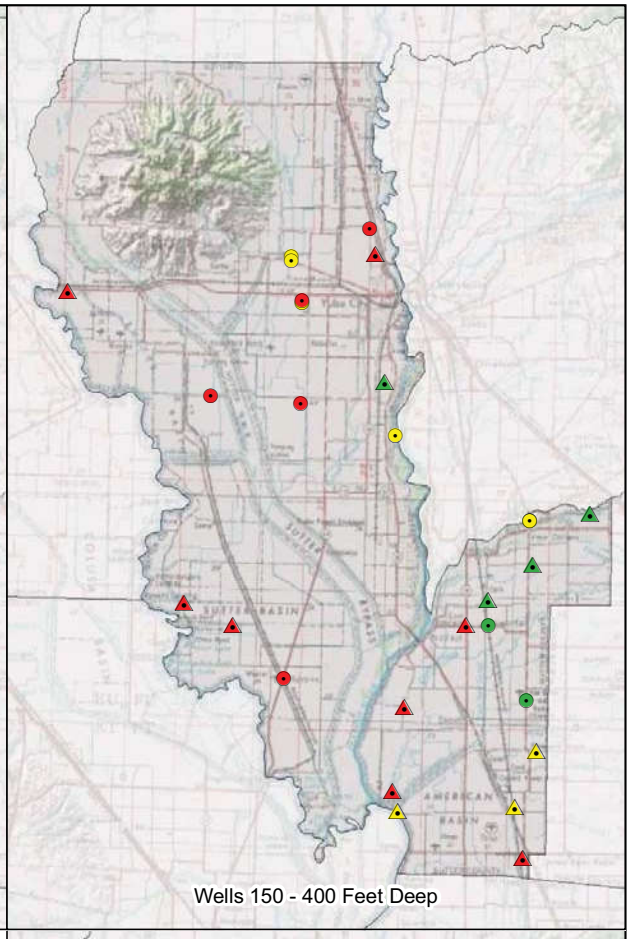




Arsenic in DWR Wells (µg/L)

- < 5
- 5 - 10
- > 10

Arsenic in USGS Wells (µg/L)

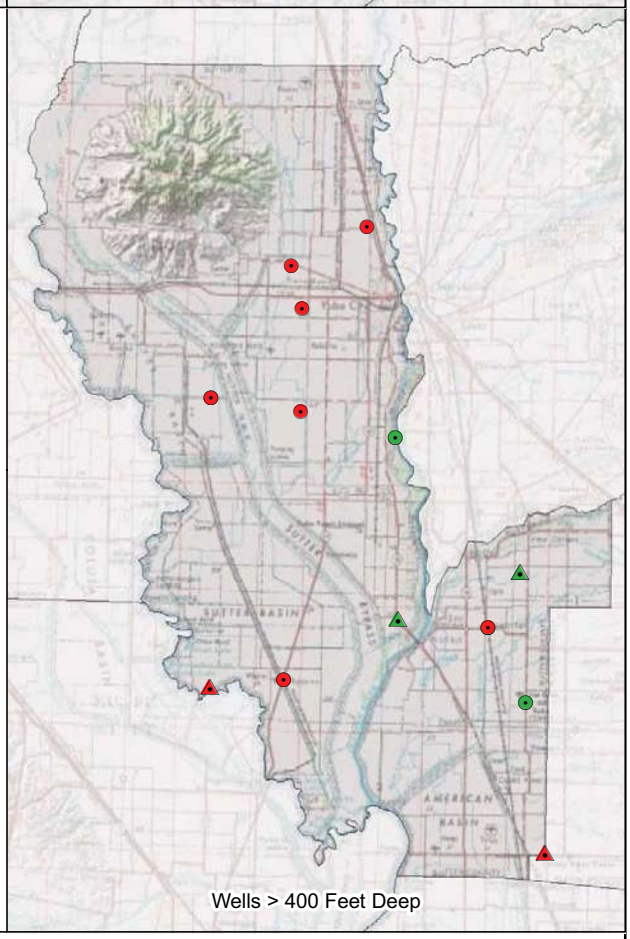
- < 5
- 5 - 10
- > 10

Note:
Arsenic is naturally occurring and leaches from aquifer materials into groundwater.

For public drinking water systems, the primary maximum contaminant level for arsenic is 10 micrograms/liter (µg/L).

Exposure to arsenic can cause both short and long term health effects. Long term exposure to arsenic has been linked to cancer of the bladder, lungs, skin, kidneys, nasal passages, liver and prostate. Short term exposure to high doses of arsenic can cause other adverse health effects.

Analysis for arsenic is very sensitive to turbidity of samples - turbid samples will often have artificially high results for arsenic.



SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA

FIGURE 23
ARSENIC BY WELL DEPTHS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH

0 3 6
MILES

WOOD RODGERS
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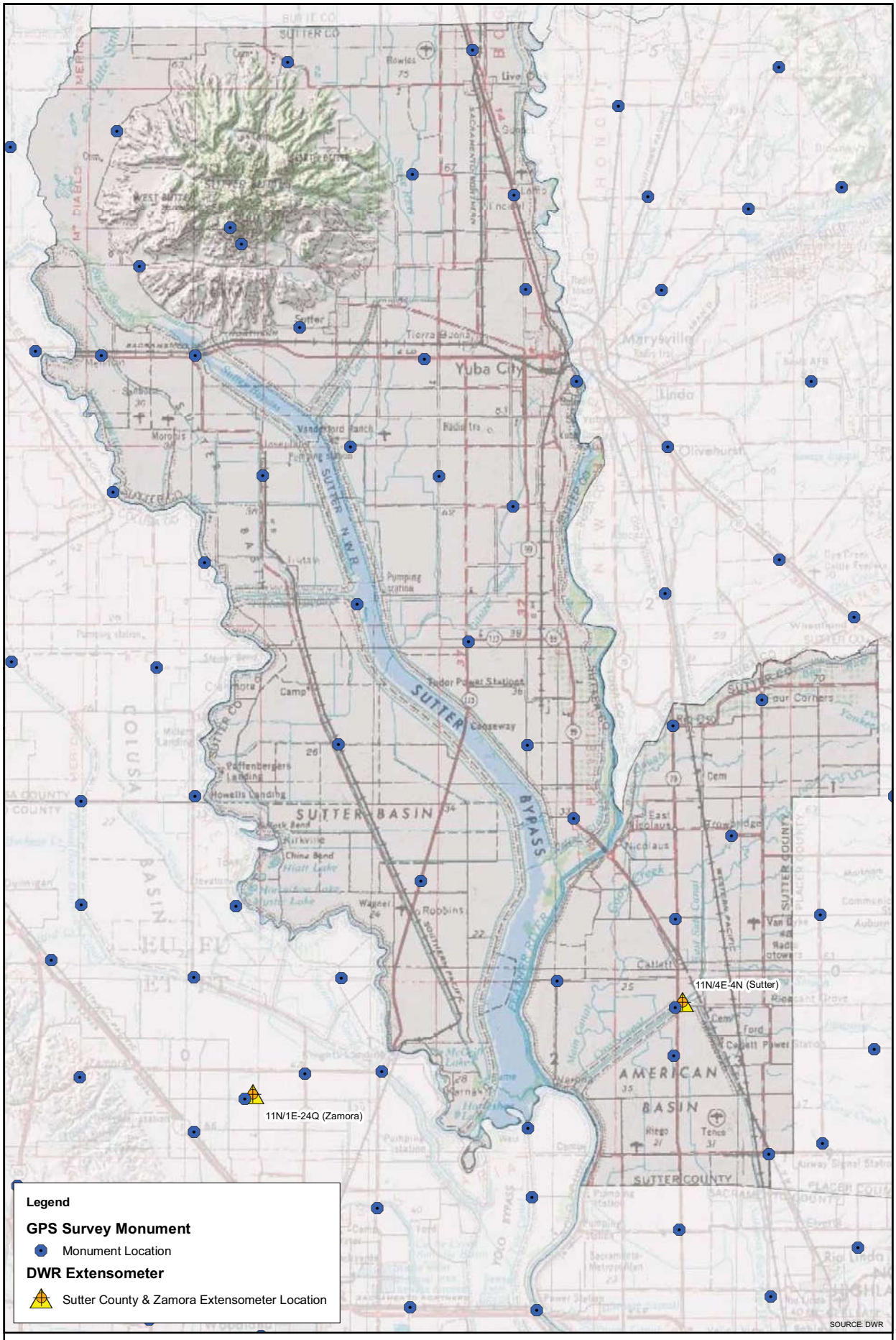

FIGURE 24
LAND SUBSIDENCE NETWORK
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

WOOD RODGERS
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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 24 Land Subsidence Network.mxd 2/8/2012 2:43:42 PM bdemucha

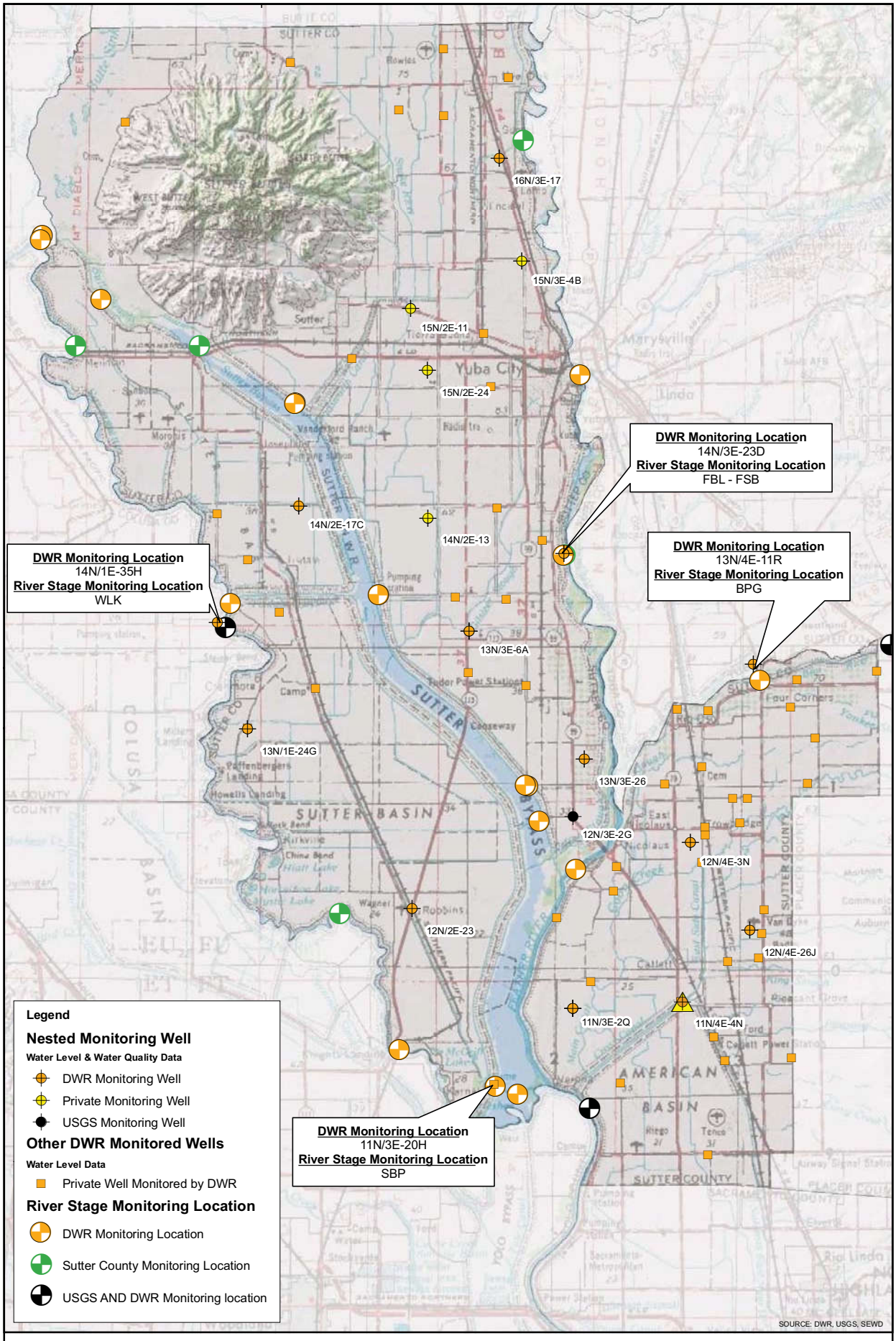

FIGURE 25
GROUNDWATER AND RIVER STAGE MONITORING LOCATIONS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 25 Groundwater and River Stage Monitoring Locations.mxd 2/8/2012 2:46:51 PM bdemucha

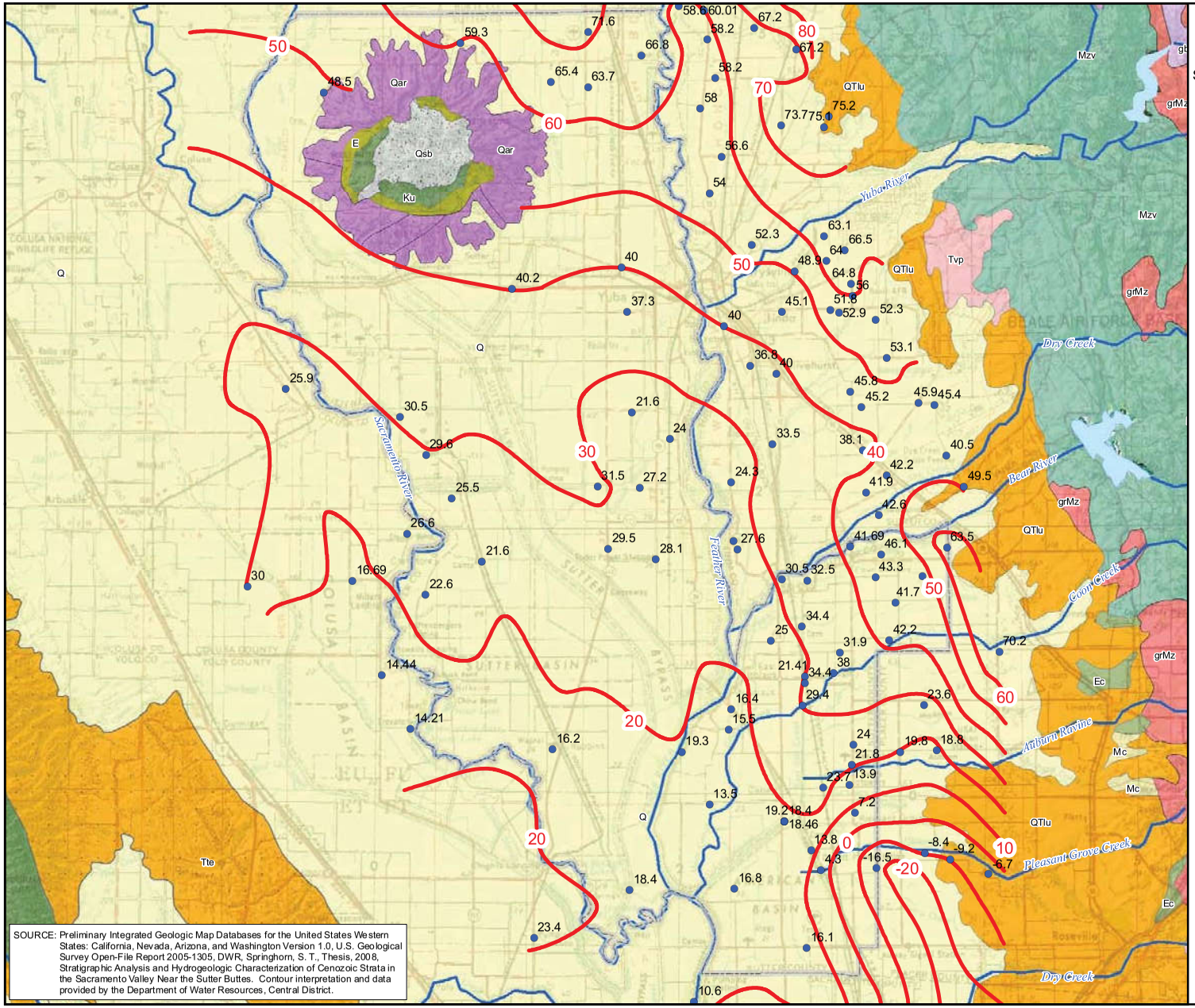

FIGURE 26

RECHARGE AND GROUNDWATER ELEVATION CONTOUR MAP SPRING, 2009

SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN

FEBRUARY 2012

NORTH

0 2 4

MILES

- Q - Recent Deposits
  - Qb - Basin Deposits
  - Qm - Modesto Formation
  - Qr - Riverbank Formation
- Qsb - Sutter Buttes Igneous Rocks
- Qar - Sutter Buttes Andesitic Rampart
- QTlu - Laguna Formation
- Tte - Tehama Formation
- Tvp - Andesite, Rhyolite
- Mc - Sandstone, Conglomerate
- Ec - Conglomerate, Sandstone
- E - Mudstone, Sandstone
- Ku - Sandstone, Mudstone
- J - Mudstone, Sandstone, & Slate
- um - Serpentinite
- Mzv - Volcanic, Metavolcanic
- gb - Gabbro, Diorite
- grMz - Granodiorite
- Sutter County
- DWR Monitored Wells Used for Contours
- Groundwater Contour of Equal Elevation (Feet, NGVD 29)

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 26 Recharge and Groundwater Elevation Contour Map Spring, 2009.mxd 2/8/2012 3:11:15 PM bdemucha

Figure 27
Sutter County
Well Construction By Year

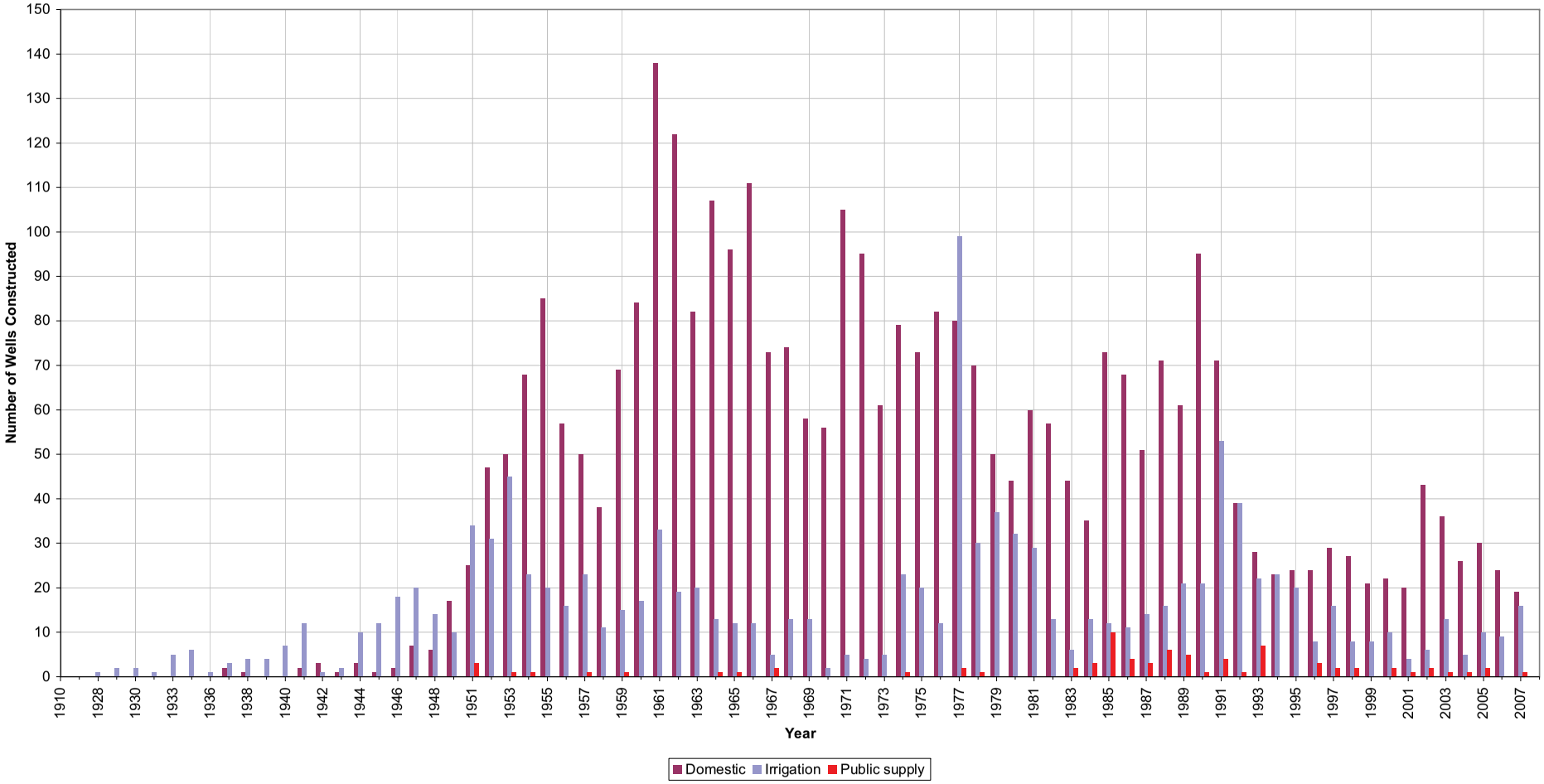
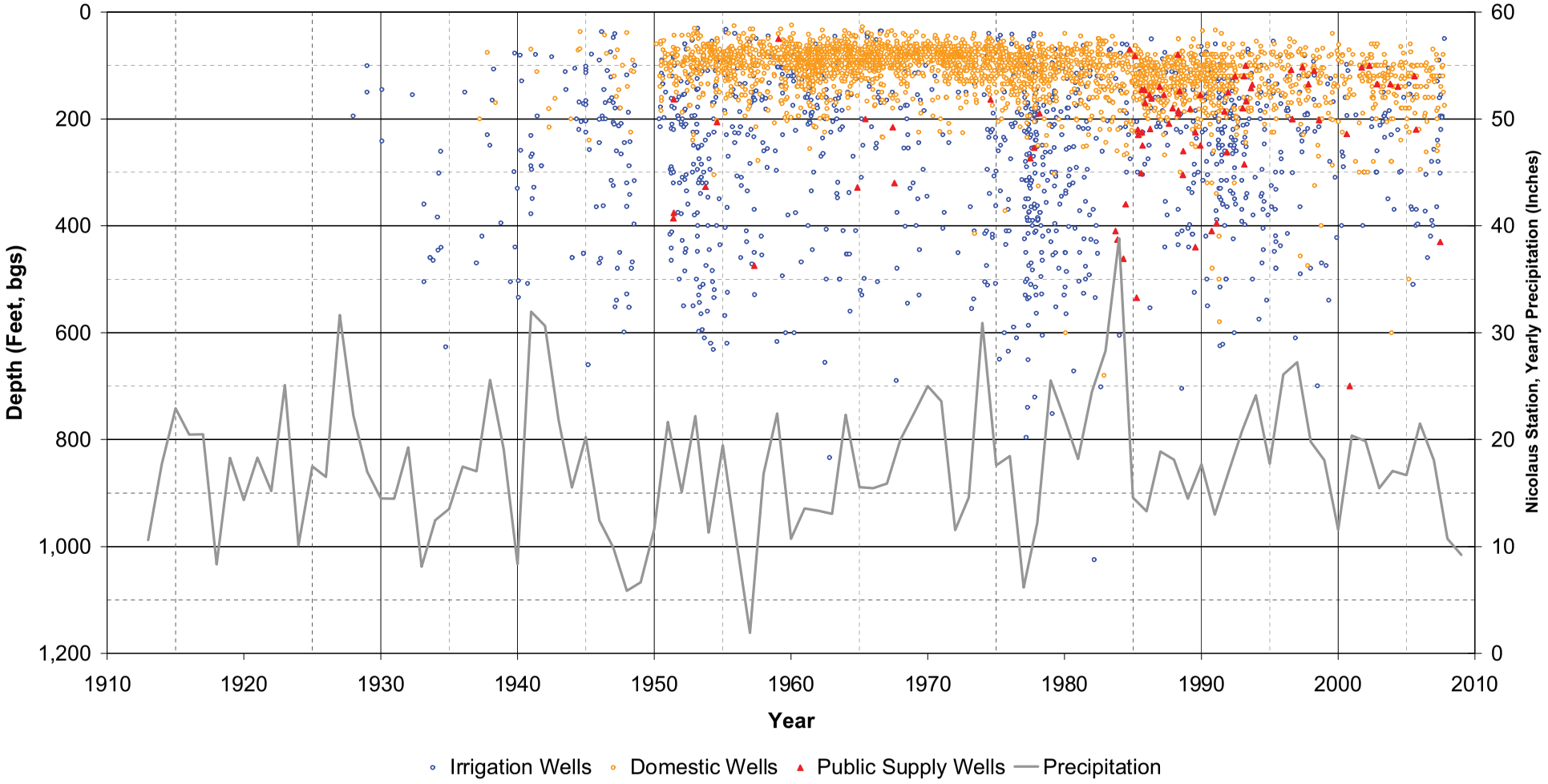
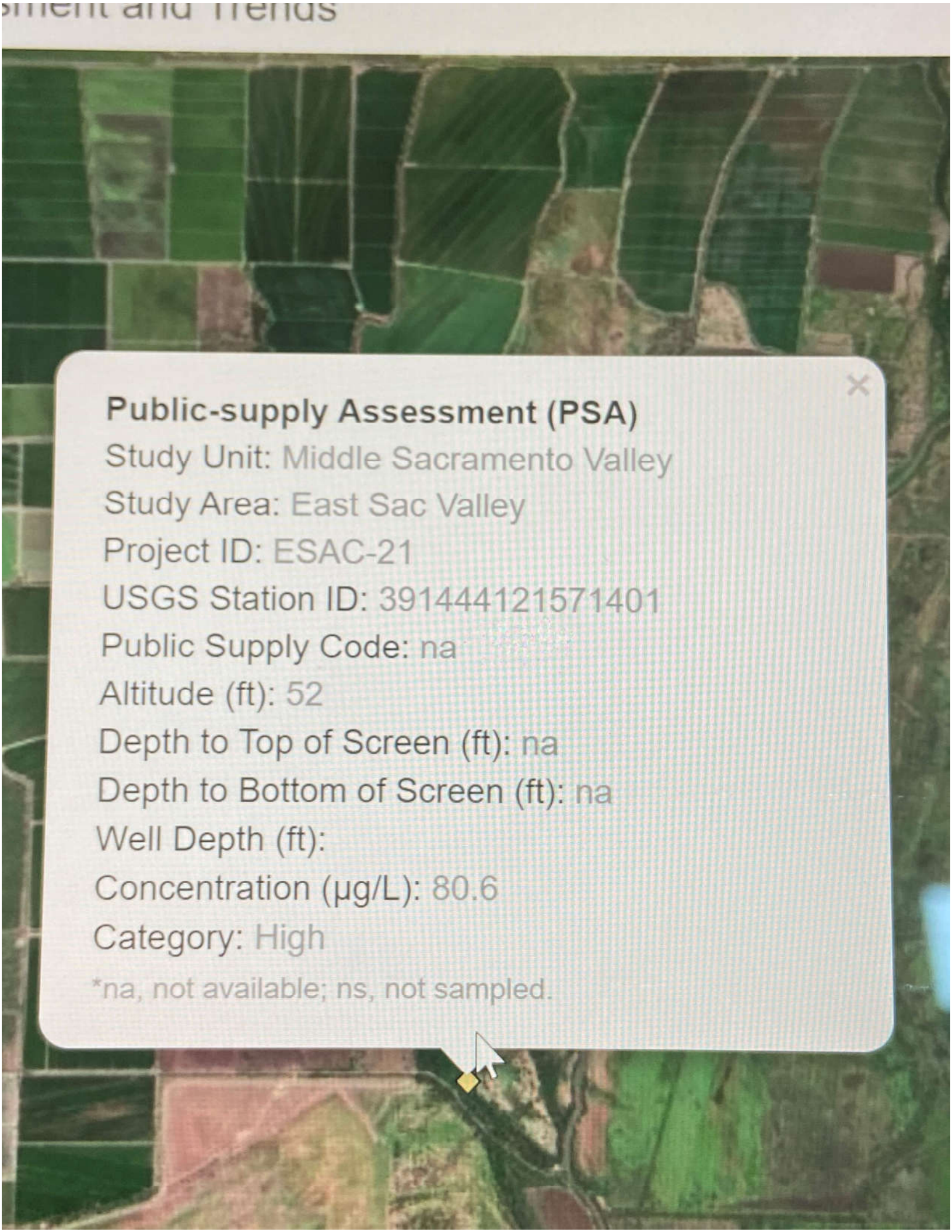


Figure 28
Sutter County
Historic Well Construction by Depth and Annual Precipitation




Public-supply Assessment (PSA)
Study Unit: Middle Sacramento Valley
Study Area: East Sac Valley
Project ID: ESAC-21
USGS Station ID: 391444121571401
Public Supply Code: na
Altitude (ft): 52
Depth to Top of Screen (ft): na
Depth to Bottom of Screen (ft): na
Well Depth (ft):
Concentration (µg/L): 80.6
Category: High
*na, not available; ns, not sampled.

Public-supply Assessment (PSA)

Study Unit: Middle Sacramento Valley

Study Area: East Sac Valley

Project ID: ESAC-11

USGS Station ID: 391900121480001

Public Supply Code: na

Altitude (ft): 66

Depth to Top of Screen (ft): 220

Depth to Bottom of Screen (ft): 510

Well Depth (ft): 520

Concentration (µg/L): 70

Category: High

*na, not available; ns, not sampled.

ARSENIC IN CALIFORNIA DRINKING WATER

Three Years After EPA Notice of Noncompliance to State, Arsenic Levels Still Unsafe in Drinking Water for 55,000 Californians



ENVIRONMENTAL INTEGRITY PROJECT

SEPTEMBER, 2016

ACKNOWLEDGEMENTS

This report was researched and written by Tom Pelton, Courtney Bernhardt, and Eric Schaeffer of the Environmental Integrity Project. The map was created by Kira Burkhart and the graphics by Alana Natke.

THE ENVIRONMENTAL INTEGRITY PROJECT

The Environmental Integrity Project (http://www.environmentalintegrity.org) is a nonpartisan, nonprofit organization established in March of 2002 by former EPA enforcement attorneys to advocate for effective enforcement of environmental laws. EIP has three goals: 1) to provide objective analyses of how the failure to enforce or implement environmental laws increases pollution and affects public health; 2) to hold federal and state agencies, as well as individual corporations, accountable for failing to enforce or comply with environmental laws; and 3) to help local communities obtain the protection of environmental laws.

For questions about this report, please contact EIP Director of Communications
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PHOTO CREDITS

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Arsenic in California Drinking Water

More than three years after the U.S. Environmental Protection Agency found California in noncompliance with the federal Safe Drinking Water Act, 95 community water systems in the state, serving more than 55,000 people, are still providing water with illegal levels of arsenic, according to an examination of state data for the last two years.[1] Arsenic occurs naturally in the soil and groundwater in parts of California and is a known carcinogen that may also damage the developing brains of children and cause other health problems.[2] Many of the people drinking excessive levels of arsenic are poor and/or Latino or African-American, with a cluster in the San Joaquin Valley.[3] Nearly all have been exposed to excessive arsenic levels for at least five years and probably longer.[4]

California requires public water systems to notify their customers when arsenic fails to meet federal health standards. But strangely, the state's language for mailed advisories suggests the water is still safe to drink no matter how high the contimation levels or how long they persist, with the notices telling residents: "You do not need to use an alternative water supply (e.g., bottled water)." [5] That advice conflics with what California tells private well owners (who aren't covered by federal standards) on a state website: "If you suspect that your well may have arsenic, you should not use the water until it is tested, and you take appropriate measures to protect yourself and your family from potential chronic health effects if arsenic is present."[6] Whatever the intention, California's language for people on public water systems is likely to encourage them to drink contaminated water. (For the full text of the California's language, see Appendix A). As the state continues a multi-year effort to solve the contamination problem, it should immediately fix a communications problem so that it clearly warns people not to drink arsenic-tainted tap water.

The highest levels of arsenic in drinking water in California from 2011 through 2015 were in a group home for troubled teenage boys, the Valley Teen Ranch in Madera County. About 50 boys assigned by the courts to the facility have been living in a home with water that has arsenic at concentrations averaging more than 12 times the federal limit (10 parts per billion, or ppb) over these five years, according to state records.[7] "Nobody wants to drink the water because it's brown and nasty,"said Connie R. Clendenan, CEO of the nonprofit organization that runs the group home.[8] "It looks bad."



It is bad. Although California has made substantial progress in addressing

drinking water problems, the state still has 13 school districts, serving a total of 8,822 students, with arsenic in their drinking water that exceeded the federal limit from 2011 to 2015.[9] Twelve mobile home parks in California, serving 889 people, had arsenic in their tap water that averaged up to five times the legal limit. The average annual concentrations of arsenic in the drinking water of 58 residential communities (other than trailer parks) exceeded the legal limit during this time period, as did a military base, three wineries, two food preparation businesses and two campgrounds.

In many of the schools, the group home and military base, administrators say they verbally warn people not to drink tap water. They also provide bottled water as an alternative. But in the residential neighborhoods and trailer parks, it is not clear what warning – if any -- people are receiving. "There is no warning not to drink it. There is no 'non-drink' order out there," said Robert Johnson, President of the Shaver Lake Point 2 Mutual Water Company, which supplies 210 homes in Fresno County with tap water that has seven times the legal limit of arsenic. When asked if these residents should drink bottled water instead of his arsenic-tainted tap water, Johnson said: "It's one of those things, if you want to do it, that's your deal. It's not being recommended. We're not suggesting it. This is per the state of California. We are following their guidance."

The drinking water crisis in Flint, Michigan, was a reminder of how important it is for state governments to issue clear warnings to people with unhealthy tap water. California's mixed message is nearly identical to the one issued by Texas to homeowners with illegal levels of arsenic in their drinking water. Texas also tells consumers with excessive levels of arsenic: "You do not need an alternative water supply."[10] Many other states, however, are more direct in warning people not to drink water with excessive amounts of arsenic, at least for private well owners. Wisconsin, Michigan, Maine, and Washington, for example, simply tell residents not to consume water with more than 10 ppb arsenic (a health standard set by EPA in 2001). Wisconsin advises private well owners: "If your arsenic level is more than 10 ppb, the Wisconsin Department of Health Services recommends that you stop using your water for drinking or food preparation."[11] Florida advises its consumers to avoid water where arsenic contamination persists.[12] The U.S. Department of Health and Human Services makes similar recommendations.[13] If anything, the most recent science suggests that the current 10 ppb arsenic standard is not protective enough and that the IQ of children may be damaged at much lower exposures.[14]

In the wake of a 2013 EPA notice of noncompliance to California over its failure to invest enough money in its drinking water systems, the state has taken several important steps to fix its problems. Over the last three years, the state has more than doubled the amount of funding to build water treatment plants, pipelines, and new wells. The state and counties have filed compliance orders with local utilities to push them to upgrade their systems and are directing small, underfunded water systems to merge with larger utilities. Because of these measures, EPA announced in May 2016 that California was back in compliance with the federal Safe Drinking Water Act.

But in fact, the work is far from done – as witnessed by the 55,985 people in 95 communities across California who still have illegal levels of the carcinogen in their tap water, according to state records.[15] Why the delays? Local officials say that in some cases, bureaucratic

negotiations are holding up projects, which are sometimes stalled because of conflicts between county and state rules. In other cases, local water districts struggle with indecision or a lack of money.

Until these important water system improvements are complete, California and EPA must do a better job of warning consumers to stop drinking water that fails federal health standards. This report recommends:

- California and EPA should revise their regulations and guidance to require that local utilities warn people to stop drinking or cooking with water that fails to meet federal arsenic standards (10 ppb), especially when the contamination persists over several years. The advice should be sensitive to the additional risks posed when children and other sensitive populations drink contaminated water. If there is no reason for consumers to take precautions, there is no reason for Safe Drinking Water Act standards in the first place.

- Public notices mailed to consumers should inform them of options for treating contaminated water at home, e.g., through filtration systems that have proven to be effective. Conversely, the public should be told what doesn't work. For example, boiling water will not reduce arsenic concentrations.

- Federal and state authorities should provide enough money to these 95 California communities to allow them to install water filtration systems or take other steps to eliminate contamination problems. Although the state has already boosted its funding, it still faces a projected $30 billion plus in needed capital improvement projects to help its inadequate systems provide safe drinking water trough 2026.[16]

The big picture is that stepped-up investment in crumbling public infrastructure is sorely needed across the U.S., and it should be regarded as a top priority for both Congress and California lawmakers. But the state also needs to improve its efforts to better inform consumers so people can protect their own health. California does not have to wait for EPA action to strengthen its warnings because the state is already empowered to act independently of EPA.

Public health advisories that are contradictory and confusing – as they are in California -- are as bad as no warnings at all, because they undermine action and weaken public confidence in government.

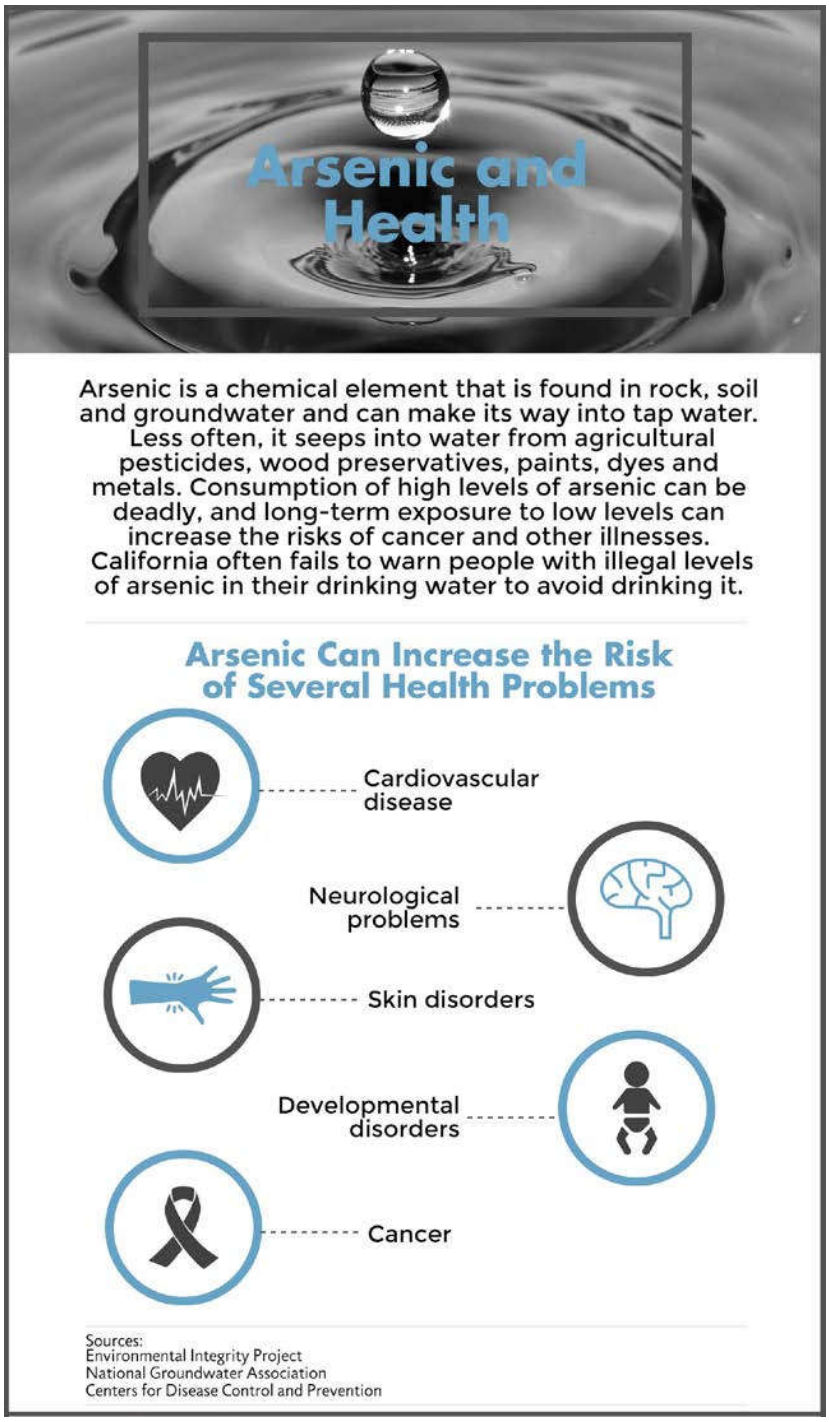
Table 1. Top 20 Arsenic Concentrations in California Public Water Systems

Water System (in Order of Arsenic Levels)	County	Pop. Served	2014-2015 avg (ppb)	2011-2015 avg (ppb)
Lakeview Improvement Association #1	Fresno	160	86.88	86.88*
Fountain Trailer Park Water	Kern	68	85.75	83.90
Hungry Gulch Water System	Kern	33	72.56	70.04
Corral De Tierra Estates WC	Monterey	45	72.50	78.40
Keeler Community Service District	Inyo	50	71.25	75.63
Quail Valley Water District- Eastside System	Kern	60	70.06	69.11
CSA 70 W-4 Pioneertown	San Bernardino	625	64.52	61.55
MD #06 Lake Shore Park	Madera	130	64.25	71.94
Valley Teen Ranch	Madera	50	62.00	120.80
Sierra East Mobile Home Community	Mono	50	54.63	47.03*
Shaver Lake Point #2	Fresno	210	52.31	42.88*
Winterhaven Mobile Estates	Los Angeles	40	52.13	53.35
Olam Spices And Vegetables Inc.	Kings	75	48.38	46.70
The Village Mobile Home Park	Los Angeles	70	45.05	47.04
Callier Water System	San Bernardino	1000	42.13	49.21*
Black Stallion Winery	Napa	25	41.75*	41.75*
Ironwood Camp	San Bernardino	1000	38.38	38.55
Boron CSD	Kern	2500	38.07	37.98
Edgewater Mobile Home Park	Sacramento	40	38.00	37.59
Prunedale MWC	Monterey	252	35.7	32.0

Note: The federal limit for arsenic is 10 ppb. * Average concentrations do not include concentrations from every year. For example, Lakeview Improvement Assn. #1 changed from a non-community water system to a community water system in 2013, and sampling data was only available from 2014 and 2015. Sampling results for Black Stallion Winery were only available for 2015. See Appendix B for annual concentrations in all systems that averaged above 10 ppb.

Health Risks Posed by Arsenic

Arsenic is a chemical element that occurs naturally in geological formations in California and elsewhere, and is also used in a variety of industrial products, including pesticides, paint, and wood preservatives.[17] It is a well-known poison at high doses. At lower doses, researchers have concluded it can cause cancers of the lung, kidney, bladder, skin, and other



organs with prolonged exposure. Any level of exposure, however, carries some risk.[18] According to EPA, the risk of developing cancer after drinking water containing 10 ppb arsenic over a lifetime is 1 in 2,000.[19] This level of risk is almost never 'acceptable' from a regulatory perspective. The agency usually tries to limit lifetime cancer risk to no more than 1 in 10,000, at most. EPA's risk estimate assumes that the cancer risk is linear, meaning if water contains 20 ppb arsenic, those who drink it over a long period of time have a 1 in 1,000 chance of developing cancer. People exposed over shorter periods of time have lower risks, but exposure during childhood may have a greater impact than exposure during adulthood.[20]

Morever, these risk calculations reflected the old thinking. New evidence suggests that the actual cancer risk may be much higher. EPA is currently revising its assessment of cancer risks from arsenic to incorporate more recent science. A 2010 draft of the assessment indicated that the risk of getting cancer from drinking water containing 10 ppb of arsenic is closer to 1 in 136, more than 17 times higher than current assumptions.[21] In addition to causing cancer, arsenic is also a neurotoxin that can harm developing brains at levels at or below the allowable limit.[22] One recent study in Maine, for example, found significant reductions in IQ and other problems in children exposed to arsenic concentrations of 5 to 10 ppb.[23] Specifically, children in homes with more than 5 ppb arsenic in the tap water tested roughly 6 points lower on a full-scale IQ test.[24] While EPA's

Scientific Advisory Board and the most recent studies suggest that the 'safe' level of arsenic is likely much lower than 10 ppb, any concentration higher than 10 is clearly unsafe.

Background on California's Problem

On April 19, 2013, EPA sent a letter to the California Department of Public Health notifying the state that it was out of compliance with the federal Safe Drinking Water Act.[25] The reason was that California's drinking water system was inadequate – providing contaminated water in many poor, rural communities – and the state was not investing enough money to fix the problem. A state investigation that year revealed that 680 community water systems serving 21 million people relied on groundwater that was compromised by one or more contaminants, with the most common being arsenic.[26]

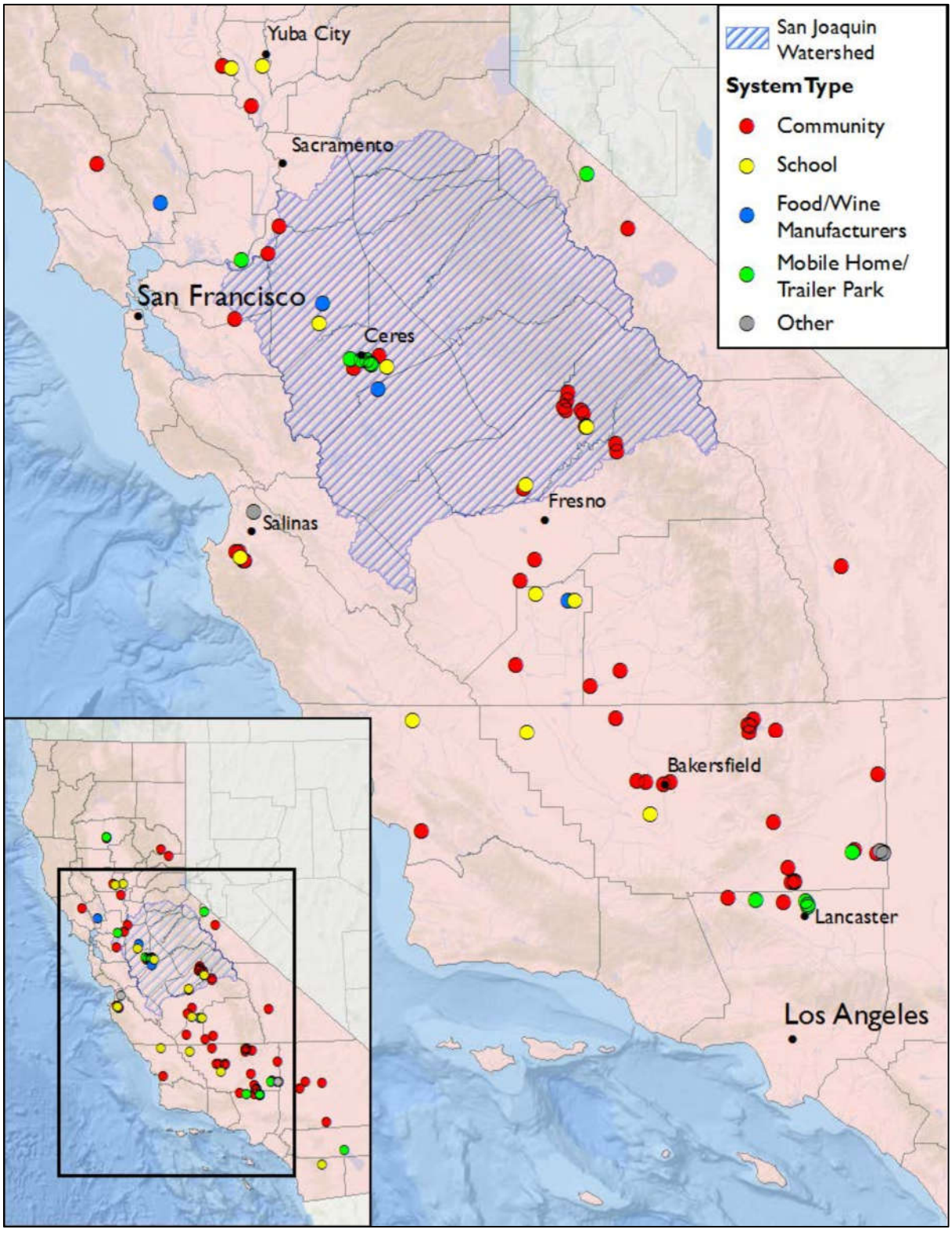
Not all of these 680 water systems provided tap water that had levels of contaminants in excess of federal health standards. In most wealthier and urban communities, the local water utilities treated the groundwater or diluted it with clean water from other wells so that it met the requirements of the federal Safe Drinking Water Act. But in 265 of these communities – often with small populations in rural, isolated areas – the tap water provided to customers had at least one violation of federal standards from 2002 to 2010 for a variety of contaminants, including nitrates from farm fertilizer, according to a 2013 report by the California Department of Health.[27]

In a separate study, researchers at the University of California, Berkeley, examined 464 community water systems serving 1.1 million people in California's San Joaquin Valley, one of the poorest regions in the state, and found that 15 percent of the systems and 14 percent of the people had tap water with arsenic above the federal limit.[28] Of the people exposed, 61 percent were either Latino or African-American. "Community water systems serving higher percentages of people of color had a 260 percent higher chance of having at least one (arsenic) violation," researcher Dr. Carolina L. Balazs and colleagues wrote.[29]

In response to the chronic drinking water problem, Congress had approved $1.5 billion to California over a decade to upgrade its water systems through a program called the Safe Drinking Water State Revolving Fund.[30] Yet because of bureaucratic obstacles and inefficiencies, the state by 2013 had not spent $455 million of those funds – the largest unspent balance of any state. According to EPA's 2013 letter of noncompliance to the California Department of Health, this violated a federal requirement that the state "make *timely* loan or grants using *all available* drinking water funds."[31]

EPA ordered the state to accelerate its efforts to fix public water systems. California Governor Jerry Brown's administration took action in several steps. These included switching control of the state's drinking water program from the Department of Health (where policy focus was dispersed among numerous problems, including drug abuse and AIDS), to the California State Water Resources Control Board (whose only focus is water) under the California Environmental Protection Agency. Since the EPA issued its

Map 1. Public Water Systems with Illegal Levels of Arsenic, 2014-2015



2013 letter of noncompliance, the state has more than doubled the amount of money it is distributing for water system upgrade projects, to an average of $738 million per year, compared to $366 million per year in the period of 2008 to 2012.[32] The unspent balance in the drinking water fund dropped to about $100 million.[33] As a result, EPA in May 2016 decided that California's system was back in compliance.[34]

Recent Analysis of California Records

The problem, however, is still far from fixed. An examination of California's online records by the Environmental Integrity Project (EIP) in May 2016 revealed that there were still 95 community water systems in the state, serving 55,985 people, providing drinking water with levels of arsenic that exceed the federal standard of 10 ppb in 2014 and 2015, according to two-year averages over those years. [35]

Over a longer period of time, 2011 through 2015, state records show 70 systems serving 46,772 residents, that each year have averaged higher than the limit in the Safe Drinking Water Act. These do not include homes on individual private wells, which are not covered by the federal Safe Drinking Water Act.

For a detailed discussion of the methods used to arrive at these numbers, please see Appendix C.

Examples of Drinking Water Contamination

Some of the worst water in community systems in California can be found in the Lakeview Community Association, which serves 160 residents in Shaver Lake (northeast of Fresno, in Fresno County). This community had an average arsenic concentration of nearly nine times the federal limit – 87 ppb – in 2014 and 2015, according to state data.[36]

Four water systems in the unincorporated community of Boron, in San Bernardino County, provided water to about 5,200 residents that had at least three times the safe limit of arsenic in 2014 and 2015.[37] In the city of Keyes in Stanislaus County, 4,891 people have tap water with arsenic concentrations that averaged above the federal limit each year for the last five years. The Pixley Public Utilities District, serving 3,310 residents, had arsenic levels in its drinking water that averaged 50 percent higher than health standards in 2011-2014.

Twelve school districts, serving a combined total of 5,462 students, had arsenic levels that averaged from 30 percent higher to three times the federal limit over the last five years. (See Table 4. Some of these school districts provided explanations, which will be discussed on pages 15 and 16 of this report).

Across California, there were 12 mobile home parks serving 889 people that had average arsenic levels ranging from 20 percent over legal limits to five times the federal standards from 2011 through 2015.[38]

Table 2: Top 10 Mobile Home Parks for Arsenic Contamination

Water System	County	People Served	2014-2015 Avg. (ppb)	2011-2015 Avg. (ppb)
Fountain Trailer Park Water	Kern	68	85.8	83.9
Sierra East Mobile Home Community	Mono	50	54.6	47.0*
Winterhaven Mobile Estates	Los Angeles	40	52.1	53.4
The Village Mobile Home Park	Los Angeles	70	45.1	47.0
Edgewater Mobile Home Park	Sacramento	40	38.0	37.6
Mitchell's Avenue E Mobile Home Park	Los Angeles	26	21.3	21.0
Millstream Mobile Home Park	Tehama	80	20.5	20.0
Country Western Mobile Home Park	Stanislaus	120	20.4	22.2
Saint Anthony Trailer Park	Riverside	300	19.7	21.5
New Orchard Mobile Home Park LLC	Tehama	125	19.6	19.0

Note: federal limit is 10 ppb arsenic. The 2011-2015 average for Sierra East Mobile Home Community reflects fewer than 5 years.

Response from California Officials

The Environmental Integrity Project asked the California State Water Resources Control Board why so many people are still exposed to contaminated drinking water after the state supposedly returned its system to compliance. Officials at the state agency replied in an interview and emails that they had issued orders to nearly all of the local utilities to fix the arsenic problem, but that some local government still need more time to upgrade their systems. In some cases, local utilities are building water filtration systems to remove arsenic, or digging new wells in an effort to extract cleaner water.

"The State Water Board Division of Drinking Water is working with each of these communities to return them to compliance," said Cindy Forbes, Deputy Director of the Division of Drinking Water at the Water Resources Board.[39] "District Office staff are working with these communities to evaluate alternative solutions, including new treatment options, new wells or modification of existing wells, and in some instances consolidation with larger water systems that can provide drinking water that meets all standards. The State Water Board is also helping communities that are struggling financially to reach compliance by offering financial assistance to solutions through low-interest loans and grants."

Public Notification of Drinking Water Violations

As the work continues to upgrade the drinking water systems, however, many citizens of California have not been given warnings to avoid drinking contaminated water.

The background is this: As part of the federal Safe Drinking Water Act, local water utilities are required to periodically test public drinking water systems that serve at least 25 people. When those results show more than 10 ppb arsenic (a standard imposed by EPA in 2001), the utilities must notify residents of the violation in writing by mail "as soon as practical, but within 30 days."[40] In California, however, the warning notices provide a mixed message, stating: "Our water system recently violated a drinking water standard," but also, "you do not need to use an alternative water supply (e.g., bottled water). This is not an emergency…. However, some people who drink water containing arsenic in excess of the (federal limit) over many years may experience skin damage or circulatory system problems, and may have an increased risk to getting cancer."[41] (For the full text of California's notice template for local utilities to use, see Appendix A)

This advisory says two contradictory things: Warning, you have a problem with your water. But don't worry – keep drinking it. If consumers are being told to ignore the federal health standards and keep drinking the contaminated water, there is no reason for the federal Safe Drinking Water standards for arsenic to exist. As stated previously in this report, California is much more clear about warning private well owners to "protect yourself and your family" from arsenic-tainted tap water. And other states – including Wisconsin, Michigan, Maine, and Washington – bluntly advise people not to drink private well water with more than 10 ppb arsenic.

In addition to receiving advisories about violations when they occur, customers also receive annual reports from their local water utilities called "Consumer Confidence Reports." These reports list the levels of more than a dozen different potential contaminants, including bacteria, lead, copper, nitrates and arsenic. When arsenic levels exceed the limit of 10 ppb, these reports provide the numbers and say: "Some people who drink water containing arsenic in excess of the MCL (maximum contaminant level) over many years may experience skin damage or circulatory system problems, and may have an increased risk of getting cancer."[42] But the reports do not tell consumers to stop drinking water with excessive levels of arsenic, and instead hint that it might not be a problem, saying: "Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants."

We asked the California State Water Resources Control Board why the agency doesn't tell people to avoid drinking water with illegal levels of arsenic. In response, Forbes, the deputy director for water, said that the state does provide this kind of blunt and immediate warning for other contaminants that can make consumers sick immediately, such as fecal bacteria. But for arsenic, she said, the threat is more long term. "Arsenic is categorized as a chronic contaminant that poses possible health risks after long-term exposure – 70-plus years of drinking two liters of arsenic-contaminated water a day above the maximum contaminant level," Forbes said. "There are no known acute/immediate health effects that would cause consumers to immediately stop drinking the water."

This answer, however, ignores the fact that many of these California residents have been drinking arsenic-contaminated water for decades. For example, Drs. Carolina Balazs and Isha Ray in 2014 published a study in the American Journal of Public Health in which they interviewed residents with contaminated tap water and found that the current notification requirements are poorly serving people with long-term exposure to pollutants.[43] "A resident from the community of Cutler explained that for years she had received Consumer Confidence Reports indicating that dibromochloropropane levels in the water exceeded the MCL (maximum contaminant level)," Balazs and Ray wrote. "These reports noted that residents should not worry because health impacts were not based on immediate exposure, but rather on lifetime exposure... She had lived in her community for nearly 30 years—so, she asked, should she worry or not? In these situations, water systems simply leave residents to cope with contaminated drinking water as best they can….In these instances, Safe Drinking Water Act regulations ultimately fail the (low-income) household."[44]

California's records identify more than 46,772 people whose tap water has had average levels of arsenic that have exceeded the federal standards for at least five years, from 2011 to 2015. But there is no reason to believe that these people received cleaner water before this. The longer a person drinks water contaminated with excessive levels of arsenic, the higher the increased risk of cancer. In much the same way, smoking a single cigarette is not an immediate health threat, in that it will instantly kill a person. But the longer a person smokes, the worse the health threat. For this reason, California would better protect public health if it told people to stop drinking arsenic-tainted water now, just as health warnings on tobacco required by the U.S. Food and Drug Administration advise, "WARNING: Quitting smoking now greatly reduces serious risks to your health." These advisories do not state, "WARNING: You do not need to change your smoking habits."

Evolution of the Science on Arsenic

One reason for stronger warning language is that scientific research continues to show that arsenic causes health problems – including brain damage in children -- at lower levels than previously thought.

The history of EPA's arsenic rule reflects the continuing evolution of scientific knowledge about the harms that even low levels of the element can cause. Back in 1996, Congress amended the Safe Drinking Water Act and directed EPA to establish new limits for arsenic to replace the old standard of 50 ppb. Based on the best available research, EPA proposed a limit of 5 ppb in 2000. Because arsenic is a carcinogen, some public health experts consider any level above zero to pose some risk. EPA then revised its proposal, based in part on cost considerations, and finalized a new arsenic standard of 10 ppb in 2001.

The EPA Administrator at the time, Christine Todd Whitman, explained that "the 10 ppb protects public health based on the best available science and ensures that the cost of the standard is achievable."[45] The new regulations required that public water systems across the U.S. meet the new standard by January 23, 2006.[46] The law allowed states to grant exemptions until January 23, 2015, for some small community water systems that had trouble complying.[47]

The 2014 Maine study discussed earlier in this report found found significant reductions in IQ in children exposed to arsenic concentrations of 5 to 10 ppb.[48] With this new information, EPA should change its own guidance for notification language so that people – especially parents of young children -- receive a clearer warning not to drink contaminated water. A template for warning language on the federal agency's website for drinking water systems with chemical contaminants such as arsenic advises utilities to tell their customers: "Some people who drink water containing arsenic in excess of the MCL (maxiumum contaminant level) over many years may have an increased risk of getting cancer." But the notices also say: "There is nothing you need to do….If you have specific health concerns, consult your doctor."[49] This is a problem, because many lower-income people do not have doctors with whom they can regularly consult about questions like water quality.

Responses from Local Drinking Water Systems

When asked about their drinking water violations by EIP, some of the utilities in California with illegal levels of arsenic replied that their attempts to fix the problem have been hindered by bureaucratic obstacles at the local level. Others indicated they are taking steps to solve the problem, but simply need more time or money. Not all public systems were contacted by EIP or provided answers.

Table 3. Top 10 Residential Water Systems for Arsenic Contamination (Excluding Mobile Home Parks)

System	County	Population Served	2014-2015 avg (ppb)	2011-2015 avg. (ppb)
Lakeview Improvement Association #1	Fresno	160	86.9	86.9*
Corral De Tierra Estates WC	Monterey	45	72.5	78.4
Keeler Community Service District	Inyo	50	71.3	75.6
Quail Valley Water District-Eastside System	Kern	60	70.1	69.1
MD #06 Lake Shore Park	Madera	130	64.3	71.9
Valley Teen Ranch	Madera	50	62.0	120.8
Shaver Lake Point #2	Fresno	210	52.3	42.9
Boron Community Service District	Kern	2500	38.1	38.0
Monterey Park Tract Comm. Service District	Stanislaus	186	31.9	34.3
North Edwards Water District	Kern	600	31.5	31.6

Note: The federal limit is 10 ppb arsenic. Lakeview had fewer than five years of data available.

At the **Lakeview Improvement Association** in Fresno County, 160 people have been receiving drinking water with more than eight times the legal limit of arsenic on average for

at least the last five years, according to state data. State records show that on May 16, 2016, the California Water Resources Control Board issued a citation to the association's water system, imposing a fine of $1,000 for its failure to follow the directives of two earlier compliance orders, in 2014 and 2015. "The water system continues to violate the arsenic maximum contaminant level (MCL) and does not appear to be making progress toward the compliance deadline," says the most recent letter from the state. "Additionally, the water system has failed to routinely conduct the public notification of the arsenic MCL violation, as required."

Philip Dutton, an engineer for surrounding Fresno County, said that the Lakeview Association's plan, as expressed verbally, is to test some in-home water filtration systems and see how well they perform.[50] "They've got a few of these (filtration systems) installed in homes, but they are sampling from different technologies to try and identify what is going to be the best long-term alternative," Dutton said. The California State Water Resources Control Board's website already lists which types of filtration technologies work well to remove arsenic.[51]

In **Kettleman City**, in Kings County, 1,450 residents have had tap water with excessive levels of arsenic for decades. The average from 2011 to 2015 was 20 percent above the legal limit, according to state data. "I have a daughter, a little one, who's still brushing her teeth with contaminated water, taking a bath in contaminated water," said Maricela Mares-Alatorre, a city resident, during a recent public hearing of the state water board.[52] The Kettleman City Community Services District has promised local residents that it will build a $9 million water treatment plant, but the project has been repeatedly delayed – with a target to open in the fall of 2016 recently pushed back to 2018.[53]

At the **Corral De Tierra Estates** subdivision in Monterey County, 45 people have been exposed to drinking water with arsenic levels almost eight times the legal limit from at least 2011 through 2016, state records indicate. This small water system has received 10 violations notices from the state for excessive levels of arsenic over the last decade, with the most recent in the first quarter of 2016, when it had 77 ppb of the contaminant (compared to the 10 ppb limit).

The manager of Monterey County's drinking water program, Cheryl Sandoval, said Corral De Tierra Estates is among at least five privately-owned water systems that have been issued corrective orders by the county because they are in violation of the arsenic standard. Solving the problem is taking longer than expected, Sandoval said, and some of the local water utilities are still debating the best path forward. "Dealing with the problem is very complicated," Sandoval said.[54] "They haven't made a lot of progress toward compliance, but they are going to have to." One challenge is that a water treatment plant for even a small system can cost hundreds of thousands of dollars and cause new waste disposal problems, because the plants produce concentrated arsenic sludge that must be handled carefully as a hazardous material. Corral De Tierra Estates and other subdivisions want to try in-home water treatment systems as a systemic solution, but county rules don't allow that, Sandoval said. However, debate over this in-home option continues, because new state regulations may open the door for in-home filtration as a systemic solution in the future.

Meanwhile, as the bureaucratic discussions continue, residents are receiving confusing advice about whether they should drink the water pouring from their taps with illegal levels of arsenic. One recent report from Corral de Tierra Estates to local water consumers, displayed on the state website and sent to homeowners in July 2014, advised people that arsenic levels were eight times above the legal limit.[55] But that fact was buried in the middle of a dense report with lots of numbers that also gave the impression that the exceedance was not a problem. The report told homeowners: "The presence of contaminants does not necessarily indicate that the water poses a health risk."[56]

At the **Quail Valley Water District-Eastside System** in Kern County, 60 residents have been receiving drinking water with seven times the legal limit of arsenic over the last five years, state records show. In April 2015, the state issued a compliance order to the local utility and mandated that it fix the problem by April 2018.

Randy Hardenbrook, Director of the Quail Valley Water District, said the problem should be solved within the next two years because a $5.8 million grant from the state is allowing the district to build a new pipeline. The pipe will be about 8.5 miles long and will connect a part of the system with arsenic-tainted water to a well that has good water.[57] In the interim, local residents receive quarterly letters with data on the arsenic exceedances but are not being provided with bottled water. More importantly, they are not being told to refrain from consuming the contaminated water. "We're not telling them not to drink it," Hardenbrook said, "but we are telling them there are long-term health effects."[58]

At the **Shaver Lake Point #2** subdivision in Fresno County, 210 people have been receiving tap water with more than four times legal levels of arsenic for at least the last five years, according to state data. In January 2015, the state wrote to the water system's administrators and ordered them to come into compliance with the federal and state arsenic limits by December 31, 2016.

With only four months left until the deadline, the arsenic levels remain illegally high and Robert Johnson, President of the Shaver Lake Point Mutual Water Company, said he is still thinking about what to do about the problem.[59] "Currently, it's being researched. We have engineers involved. We have water experts involved, and we are trying to figure it out," Johnson said. He added that building a water filtration system could cost as much as $250,000, so the subdivision is considering trying to blend water from its arsenic-tainted wells with cleaner water from different wells.

Meanwhile, nobody in the community is being warned to avoid the contaminated water. "There is no warning not to drink it. There is no 'non-drink' order out there," said Johnson.[60] When asked if his customers should drink bottled water as a precaution instead of the arsenic-tainted tap water, Johnson said: "It's one of those things, if you want to do it, that's your deal. It's not being recommended. We're not suggesting it. This is per the state of California."

Group Home for Troubled Children

The **Valley Teen Ranch**, a Christian residential treatment group home for 32 court-referred abused and neglected boys in Madera County, has arsenic in its tap water that averaged more than 12 times the federal limit from 2011 through 2015, according to state records.[61] "We've been out of compliance, but no children have gotten sick, no adults have gotten sick," said Connie R. Clendenan, CEO of the nonprofit organization that runs the group home. "Nobody wants to drink the water here because it's brown and nasty."[62]

About five years ago, the state approved a $5 million grant to help the group home solve the problem by linking its small water system to a larger one run by the county. But the work has not started yet. Because of ongoing negotiations at the county level, the fix could still be three years or more away, Clendanan said. Meanwhile, children are being given bottled water and are verbally warned not to drink tap water, although there are no warning signs posted above sinks.

"I want to get out of the water business. I'm in the kid business," Clendenan said. Of the continuing delays in fixing the problem with contaminated water, she said: "Nobody's mad. But it's government, and it takes a lot of time. It's just the stupid county."

Table 4. Schools with Excessive Arsenic in Drinking Water

System	County	Population Served	2014-2015 avg. (ppb)	2011-2015 avg. (ppb)
Kit Carson Elem. School	Kings	510	34.7	34.7*
Washington School WS	Monterey	250	26.1	27.7
MUSD-Nile Garden School	San Joaquin	804	20.9	22.8
Liberty High School	Madera	1340	17.9	20.5*
Island Union School	Kings	300	11.9	18.8
Winship Elementary School	Sutter	38	16.4	17.3*
Lakeside School	Kern	800	16.3	16.9
Barry Elementary School	Sutter	650	15.2	15.3
Pleasant Valley Elementary	San Luis Obispo	100	13.8	14.1
Gratton School	Stanislaus	110	13.5	13.5
North Fork Union School	Madera	350	12.9	12.4
Warner Unified School District	San Diego	250	10.9	11.4
Central Union Elementary	Kings	320	10.1	13.5

*Note: federal limit is10 ppb arsenic. *Indicates systems with monitoring gaps (less than five years available data)*

Arsenic in School Drinking Water

At the **Washington School in Salinas,** California, the tap water serving about 250 students has had almost three times the federal limit of arsenic for the last five years, 28 ppb on average over this time period, compared to the limit of 10 ppb.[63] School Principal Whitney Meyer said that the local school district has been discussing the problem for several years but does not yet have a solution. Meanwhile, students are given bottled water, she said.

"We remind them over and over that they cannot drink the water," Meyer said.[64] "Many of the students live out in this area and their homes are similarly impacted (with arsenic), so they also hear the message at home. We have drinking stations with clean water in every classroom, teaching space, and hallway. The fountains have all been shut down."

At the **Barry Elementary School in Yuba City**, California, the arsenic levels have averaged 50 percent above the federal limit for arsenic over the last five years. Because of the violations, the state issued a compliance order to the school in May 2015. Tom Butcher, Director of Maintenance and Facilities for the school system, said that the school has not yet solved the problem, but is giving bottled water to students as officials try to figure out a solution.[65] Adminstrators of the water system are discussing a consolidation with a larger neighboring system that has better water. "The (state) Water Board indicates a best case scenario of a consolidation in approximately 1.5 years," Butcher said. "Until the consolidation is completed (the school district) will continue to provide bottled drinking water."

At the **Kit Carson Elementary School**, in Hanford, Ca., arsenic levels in drinking water averaged more than three times the legal limit in 2011 through 2014, according to state records. In January 2015, the school solved the problem by connecting its pipes to the water system of the surrounding city,[66] whose arsenic levels are below the federal limits.

At the **Lakeside School in Bakersfield,** California, the arsenic levels in the drinking water averaged more than 70 percent above the federal limit for arsenic over the last five years, 17 ppb compared to the limit of 10 ppb. Ty Bryson, District Superintendent, said that the school notified all families by sending home notice letters with the students and by posting warnings in the office. "We provide bottled drinking water for students and staff," Bryson said. "We drilled an alternate well, but that also had unacceptable levels of contaminant. We are now pursuing an alternative source of drinking water by connecting to a local municipal water source via pipeline."

At the **Gratton School in Denair,** California, the drinking water system has had arsenic levels that averaged 40 percent above the federal limit for arsenic over the last five years, state records indicate. The school's superintendent, Shannon Sanford, said that students have been provided bottled water for the last two years. "Students were initially warned (not to drink the water) and signs were used until fountains were disabled," Sanford said. More recently, the school drilled a new well that will be used for the 2016-2017 school year that should solve the problem.

At the **Island Union School in Lemoore,** California, arsenic levels in the drinking water were nearly twice the federal limit from 2011 to 2015, averaging 18.8 ppb compared to

federal limit of 10 ppb, according to state records. Superintendent Charlotte Hines said the school dug a new well in 2015, and provided students and warnings and bottled water in the interim. "We know that bottled water is only a temporary solution," Hines said. "And in an effort to find a permanent solution, the school requested -- and was awarded -- state funding to drill a new well that would meet all primary drinking water standards."[67]

Military Base with Contaminated Water

At the **U.S. Army Base Fort Irwin** in San Bernardino County, 16,000 soldiers live in facilities that have had arsenic in some tap water at levels 50 percent higher than the federal limit from 2011 through 2015, state records indicate. For the last three years, the Army Corps of Engineers has been building a new $100 million water treatment plant at the base to solve the problem. The plant is now undergoing testing and is scheduled to go online in October 2016, base officials indicate.

"The new plant will treat all Fort Irwin water to comply with Safe Drinking Water act Standards for ALL pollutants of concern including …arsenic," said Muhammad A. Bari, Director Public Works at Fort Irwin.[68]

In the interim, soldiers have been provided with bottled water and warned which faucets to avoid, according to base managers.

Vineyards with High Arsenic Levels

In San Joaquin County, the **Delicato Family Vineyards** had arsenic levels in the tap water that averaged 18 ppb from 2011 through 2014, which was 80 percent higher than the federal limits, state records indicate. Kylie Barnett, a spokeswoman for the company, said that the vineyards worked with county officials in 2014 to build a new drinking water system, including by digging two new wells, which brought the arsenic levels down below the federal standard in 2015 and 2016.[69] "The drinking water is not used in production of our wine," Barnett noted. Before the repair, people working at the vineyards and visiting were provided bottled water, she said.

In Napa County, the **Larkmead Vineyards** had drinking water with six times more arsenic than allowed from 2011 through 2013, according to state records. No results were listed for 2014 or 2015, and it is unclear if the drinking water system, which serves 25 people, is used for workers or guests. (Wine making does not generally use tap water.) Emails sent to managers of the vineyard asking about the water were not returned. The researchers of this report also received no response from the **Black Stallion Winery** in Napa County, whose tap water had four times legal limits of arsenic from 2011 through 2015, according to state records.

Conclusion

California is making progress toward solving its drinking water contamination problem. The state has reorganized its drinking water agency, and increased its financial assistance to local utilities to build water treatment systems, dig new wells, and take other steps to resolve the issue. The work, however, is expected to take many more years. In the meantime, tens of thousands of people continue to be exposed to drinking water with illegal levels of arsenic, a carcinogen that could damage the developing brains of children and cause other health problems. And yet, the warnings that some of these residents receive from the government are contradictory and confusing.

Both California and the federal government need to do more to protect consumers, especially the young. This report recommends:

1) California and EPA should both revise the language for written notifications of violations of arsenic standards, so that people are clearly advised to stop drinking contaminated water. If the violations are in schools or group homes, warning signs should also be posted over all sinks and drinking fountains. The state should help provide bottled water as an interim solution.

2) Consumers should be provided more information through the mail about what works and what does not work to remove arsenic from tap water. Residents need to know, for example, that boiling water will not help, but that certain filtration systems can remove the carcinogen. In some cases, residents may need technical help from the state in understanding how to use filtration systems properly.

3) Both Congress and the state government should increase investments in upgrades to California's drinking water systems. This is not only an environmental justice issue, but also a sensible strategy to boost the local economy through the hiring of engineers, construction workers and others to improve local infrastructure.

Counter arguments made by California officials – that the state is already taking action, and that arsenic is not an immediate threat to public health – do not hold water. Although the state has issued enforcement orders to local utilities, some local officials clearly still need more prodding and money to upgrade their water systems. A growing amount of scientific research suggests that arsenic increases the risk of cancer and other diseases and may do so at a lower level than expressed in current federal regulations. Years more of exposure to arsenic-tainted water will only raise the risk of cancer or neurological damage for California residents.

The state and federal governments should advise people to stop drinking contaminated water immediately, just as public health experts urge smokers to change their habits sooner rather than later because it will increase their odds of survival.

With public health warnings, simple and direct is better than bureaucratic and complex, because safe is better than sorry when people's lives and minds are at risk.

APPENDIX A: California's Language for Public Notices about Arsenic Violations

IMPORTANT INFORMATION ABOUT YOUR DRINKING WATER

Este informe contiene información muy importante sobre su agua potable.
Tradúzcalo o hable con alguien que lo entienda bien.

[System] Has Levels of Arsenic Above the Drinking Water Standard

Our water system recently violated a drinking water standard. Although this is not an emergency, as our customers, you have a right to know what you should do, what happened, and what we are doing to correct this situation.

We routinely monitor for the presence of drinking water contaminants. Water sample results received on [date] showed arsenic levels of [level and units]. This is above the standard, or maximum contaminant level (MCL), of 0.010 milligrams per liter.

What should I do?

- **You do not need to use an alternative water supply (e.g., bottled water).**
- This is not an emergency. If it had been, you would have been notified immediately. However, *some people who drink water containing arsenic in excess of the MCL over many years may experience skin damage or circulatory system problems, and may have an increased risk to getting cancer.*
- If you have other health issues concerning the consumption of this water, you may wish to consult your doctor.

What happened? What is being done?

[Describe corrective action]. We anticipate resolving the problem within [estimated time frame].

For more information, please contact [name of contact] at [phone number] or [mailing address].

Please share this information with all the other people who drink this water, especially those who may not have received this notice directly (for example, people in apartments,

nursing homes, schools, and businesses). You can do this by posting this public notice in a public place or distributing copies by hand or mail.

Secondary Notification Requirements

Upon receipt of notification from a person operating a public water system, the following notification must be given within 10 days [Health and Safety Code Section 116450(g)]:

- SCHOOLS: Must notify school employees, students, and parents (if the students are minors).
- RESIDENTIAL RENTAL PROPERTY OWNERS OR MANAGERS (including nursing homes and care facilities): Must notify tenants.
- BUSINESS PROPERTY OWNERS, MANAGERS, OR OPERATORS: Must notify employees of businesses located on the property.

This notice is being sent to you by [system].

State Water System ID#: _____. Date distributed: _____.

APPENDIX B: Listing of All California Public Drinking Water Systems with Arsenic Levels that Averaged Over the Federal Limit over the Last Five Years

System Name	County	Pop. Served	2014-2015 Avg (ppb)	2011-2015 Avg (ppb)	
Lakeview Improvement Association #1	Fresno	160	86.9	86.9	^
Fountain Trailer Park Water	Kern	68	85.8	83.9	*
Hungry Gulch Water System	Kern	33	72.6	70.0	*
Corral De Tierra Estates WC	Monterey	45	72.5	78.4	*
Keeler Community Service District	Inyo	50	71.3	75.6	*
Quail Valley Water District-Eastside System	Kern	60	70.1	69.1	*
CSA 70 W-4 Pioneertown	San Bernardino	625	64.5	61.6	*
MD #06 Lake Shore Park	Madera	130	64.3	71.9	*
Valley Teen Ranch	Madera	50	62.0	120.8	*
Sierra East Mobile Home Community	Mono	50	54.6	47.0	^
Shaver Lake Point #2	Fresno	210	52.3	42.9	^
Winterhaven Mobile Estates	Los Angeles	40	52.1	53.4	*
Olam Spices And Vegetables Inc.	Kings	75	48.4	46.7	*

System Name	County	Pop. Served	2014-2015 Avg (ppb)	2011-2015 Avg (ppb)	
The Village Mobile Home Park	Los Angeles	70	45.1	47.0	*
Callier Water System	San Bernardino	1000	42.1	49.2	^
Black Stallion Winery	Napa	25	41.8	41.8	^
Ironwood Camp	San Bernardino	1000	38.4	38.6	*
Boron CSD	Kern	2500	38.1	38.0	*
Edgewater Mobile Home Park	Sacramento	40	38.0	37.6	*
Prunedale MWC	Monterey	252	35.7	32.0	
Kit Carson Elem. School	Kings	510	34.7	34.7	^
Darr Water Co.	San Bernardino	1000	34.3	36.0	*
Monterey Park Tract Community Service District	Stanislaus	186	31.9	34.3	*
North Edwards WD	Kern	600	31.5	31.6	*
Desert Lake Community Service District	Kern	700	31.0	32.5	*
Locke Water Works Co [SWS]	Sacramento	80	29.5	29.1	*
Lucky 18 On Rosamond, LLC.	Kern	73	28.0	24.3	*
Washington School WS	Monterey	250	26.1	27.7	*
Rancho Marina	Sacramento	250	24.0	30.1	*
Colusa Co. WWD #1 - Grimes	Colusa	500	23.9	24.7	*
Bridgeport PUD	Mono	850	23.3	24.0	*
Country Hills Estates	San Luis Obispo	60	23.0	26.8	^
Doubletree Ranch Water System	Contra Costa	49	21.6	22.4	*
Mitchell's Avenue E Mobile Home Park	Los Angeles	26	21.3	21.0	*
Vista Del Toro WS	Monterey	87	21.0	20.4	*
MUSD-Nile Garden School	San Joaquin	804	20.9	22.8	*
Country Villa Apts.	Stanislaus	30	20.8	21.1	*
Millstream Mobile Home Park	Tehama	80	20.5	20.0	*
Country Western Mobile Home Park	Stanislaus	120	20.4	22.2	*
Saint Anthony Trailer Park	Riverside	300	19.7	21.5	*
New Orchard Mobile Home Park LLC	Tehama	125	19.6	19.0	*
MD #24 Teaford Meadow Lakes	Madera	150	19.0	12.5	
William Fisher Memorial Water Company	Kern	53	19.0	18.4	*
Ceres West Mobile Home Park	Stanislaus	161	18.9	18.0	*
Boulder Canyon Water Association	Kern	28	18.4	17.9	*
Lakeview Ranchos Mutual Water Company	Kern	120	18.1	22.4	*
Liberty High School	Madera	1340	17.9	20.5	^
Sutter Co. WWD #1 (Robbins)	Sutter	350	17.9	18.1	*
MD #42 Still Meadow	Madera	100	17.7	17.7	^
Maher Mutual Water Company	Kern	150	17.7	20.8	*
Cedar Valley Mutual Water Co.	Madera	137	17.6	18.6	^
First Mutual Water System	Kern	35	17.5	15.1	*
Sierra Co. W.W.D #1 Calpine	Sierra	225	17.0	14.1	*
Bar-Len MWC	San Bernardino	124	16.6	16.2	*

System Name	County	Pop. Served	2014-2015 Avg (ppb)	2011-2015 Avg (ppb)	
Winship Elementary School	Sutter	38	16.4	17.3	^
Lakeside School	Kern	800	16.3	16.9	*
Lanare Community Services Dist	Fresno	660	16.2	17.3	*
Delicato Vineyards	San Joaquin	25	15.6	18.3	^
Fourth Street Water System	Kern	56	15.6	14.0	*
Barry Elementary School	Sutter	650	15.2	15.3	*
Rand Communities Water District	Kern	450	15.1	15.3	*
US Army Fort Irwin	San Bernardino	16000	14.9	15.4	*
Pond Mutual Water Company	Kern	48	14.7	14.4	^
Alpaugh Community Services District	Tulare	1026	14.5	17.8	
Lands Of Promise Mutual Water Associatio	Kern	190	14.4	15.0	*
Pixley Public Util Dist	Tulare	3310	14.4	15.0	*
Caruthers Comm Serv District	Fresno	2497	14.3	15.4	*
Nord Road Water Association	Kern	32	14.2	15.0	*
Lancaster Park Mobile Home Park	Los Angeles	53	14.2	15.0	*
Mesa Del Toro MWC	Monterey	90	14.2	13.1	*
Green Run Mobile Estates	Stanislaus	100	14.0	15.1	*
Pleasant Valley Elementary	San Luis Obispo	100	13.8	14.1	*
Loch Haven Mutual Water Company	Sonoma	50	13.8	13.1	*
Gratton School	Stanislaus	110	13.5	13.5	*
Hillview Water Co-Raymond	Madera	290	13.4	17.8	
Mettler Valley Mutual	Los Angeles	100	13.0	13.1	*
Mobile Plaza Park	Stanislaus	125	13.0	12.7	*
Hilmar Cheese Company	Merced	1000	13.0	13.3	
North Fork Union School	Madera	350	12.9	12.4	*
Yosemite Forks Est Mutual	Madera	110	12.8	11.6	
MD #08 North Fork Water System	Madera	264	12.8	13.9	^
Keyes Community Services Dist.	Stanislaus	4891	12.3	12.8	*
Countryside Mobile Home Park	Stanislaus	60	12.1	12.5	*
Land Project Mutual Water Co.	Los Angeles	1500	12.1	13.5	*
El Adobe POA, Inc.	Kern	200	12.1	12.1	*
Island Union School	Kings	300	11.9	18.8	
Plumas Eureka CSD	Plumas	325	11.6	11.4	*
Kettleman City CSD	Kings	1450	11.4	12.0	*
Laguna Seca WC	Monterey	162	11.1	11.7	*
Los Molinos Comm. Services Dist.	Tehama	1500	11.1	9.0	
R.S. Mutual Water Company	Kern	67	11.0	11.1	*
Oasis Property Owners Association	Kern	100	10.9	10.8	^
Warner Unified School District	San Diego	250	10.9	11.4	^
MD #07 Marina View Heights	Madera	200	10.5	9.3	
Central Union Elementary	Kings	320	10.1	13.5	^

Note: Click on the hyperlink in the name of the system to view the state records for each water system.

** Indicates a system that has had annual concentrations averaging over the federal limit (10 ppb) each year 2011-2015*

^ Indicates that the 2011-2015 average includes years for which data was not available.

APPENDIX C:

Methods

This report is based on public data available from the California Environmental Protection Agency's State Water Resources Control Board (SWRCB) as of May 2016. We downloaded the SWRCB's Water Quality Analyses Database Files for 2011-2016 and identified public water systems that had arsenic concentrations that exceeded the 10 ppb Maximum Contaminant Level, targeting the systems with frequent exceedances between 2011 and 2015. The SWRCB database contained results for each water source used by a drinking water system, such as wells, treated or blended water, and standby wells that are only allowed to be used for a few days during a year. SWRCB warns users of its database that results in the database may not reflect the quality of water that systems actually served their customers.

Calculating average arsenic concentrations

- We calculated the average arsenic concentration from each individual water source at each water system using the sampling results available in SWRCB's database as of May 2016. Some sampling results from the end of 2015 may not have been available in the database at the time we downloaded the data in May.

- We reviewed each water system's source descriptions to determine which sources represented water served to consumers and whether the source should be included in the system-wide average arsenic concentration. For example, if the database showed that a system had two groundwater wells and a 'treated' source, we assumed that consumers would be served the treated source if results for that treated source were available each year. If the database listed a treated source in 2011, for example, but contained no data from that source for the following years, we excluded that source from the average because it was not clear if the system continued treating water for arsenic. If a system listed a source as inactive or as a 'standby' option, we excluded that source from the analysis because we could not determine when or if the water was used. We compared the selected sources with available Consumer Confidence Reports available through California's Drinking Water Watch system and narrative information in public SWRCB enforcement action documents to verify, to the extent possible, that the sources we selected represented water that was provided to consumers. If no information was available for a particular system, we relied on the

assumptions described above (i.e. inactive and standby sources were not used, treated sources were used instead of untreated sources when concentrations were available for each year). We did not include purchased water sources.

- After identifying individual sources, we calculated the system's annual average arsenic concentration using the annual average concentrations from each source. The average concentrations during the two-year period between 2014 and 2015 and the five year period between 2011 and 2015 are time-weighted average concentrations (i.e. we averaged the annual average concentrations from each year). This method is similar to how the California EPA's Office of Environmental Health Hazard Assessment calculated average concentrations at drinking water systems for use in it's 2014 CalEnviroScreen 2.0 tool, except we focused on annual average concentrations from 2011-2015, rather than a single average concentration from 2005-2013.

- We excluded entire systems from the analysis if a) they were inactive, b) the available data and source descriptions did not allow us to confidently assume that customers received the sampled water at their taps, and c) the average concentration over the most recent two years (2014-2015) fell below the MCL.

Mapping Public Water Systems

To map water system locations, we found the centroids of public water system boundaries from the California Environmental Health Tracking Program's Water Systems Geographic Reporting Tool, or Water Boundary Tool (WBT). For systems without boundaries in the WBT, we determined coordinates from the addresses in the SWRCB Water Quality Analysis database files and the California Drinking Water Watch system.

Notes

[1] Based on averages for 2014-2015. Numbers in this report from the California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed May, 2016.
[2] U.S. EPA (1998), Integrated Risk Information System, Inorganic Arsenic, available at http://www.epa.gov/iris/subst/0278.htm.
[3] Carolina L. Balazs, Rachel Morello-Frosch, Alan E. Hubbard and Isha Ray, "Environmental justice implications of arsenic contamination in California's San Joaquin Valley: a cross-sectional, cluster-design examining exposure and compliance in community drinking water systems," Environmental Health, 2012. Link: https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-11-84
[4] California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed May. Records show 51,306 residents receiving drinking water from 2011-2015 with annual averages of more than 10 ppb.

[5] California Code of Regulations Title 22, Chapter 15, Section 64463.4(b)] reglations require notifications for arsenic exceedances. The California State Water Resources Board template for the language in notifications to be sent out by local water utilities is available on state agency's website at: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Notices.shtml.

[6] California State Water Resources Control Board website, link: http://www.waterboards.ca.gov/drinking_water/certlic/device/watertreatmentdevices.shtml
[7] Ibid.
[8] Telephone interview with Connie R. Clendenan, CEO of the Valley Teen Ranch nonprofit organization, on August 1, 2016.
[9] Ibid.
[10] Texas Commission on Environmental Quality Notice of Drinking Water Arsenic Violation. Available at https://www.tceq.texas.gov/assets/public/permitting/watersupply/pdw/notices/chemical/arsenic.pdf
[11] Wisconsin Department of Natural Resources, Arsenic, Available at: http://dnr.wi.gov/topic/groundwater/arsenic/, accessed 3/7/2016.
[12] Florida Department of health, Brueau of Environmental Health, "Chemicals in Private Drinking Water Wells Fact Sheet- Arsenic," Available at: http://www.floridahealth.gov/environmental-health/drinking-water/_documents/arsenic-fs.pdf. Accessed 3/7/2016.
[13] See e.g. U.S. Department of Health and Human Services, (2004), "Health Consultation: Arsenic in Private Drinking Water Wells, Cornville, Yavapai County, Arizona," available at: http://www.atsdr.cdc.gov/HAC/pha/ArsenicInPrivate061504-AZ/ArsenicInPrivateHC061504.pdf, accessed 3/8/2016.
[14] Wasserman et al. (2014), A Cross-Sectional Study of Well Water Arsenic and Child IQ in Maine Schoolchildren, Environ Health 13:23-32.
[15] Based on averages for 2014-2015. Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016.
[16] Letter from Jared Blumenfeld, Director of EPA's Region 9 office, to California Department of Public Health Director Dr. Ron Chapman, April 19, 2013. Link: https://www3.epa.gov/region9/water/grants/pdf/CDPHNoticeofNonCompliance.pdf
[17] U.S. Centers for Disease Control, fact sheet on arsenic. Available at http://www.cdc.gov/biomonitoring/pdf/Arsenic_FactSheet.pdf
[18] U.S. EPA (1998), Integrated Risk Information System, Inorganic Arsenic, available at http://www.epa.gov/iris/subst/0278.htm.

[19] The EPA describes arsenic's cancer-causing potency with a 'slope factor' (because it describes the slope of the dose-response curve). The current EPA slope factor for arsenic is 1.5 per mg/kg-d. This number represents the risk that can be expected from consuming one milligram of arsenic per kilogram of body weight per day. The EPA also translates the slope factor into a 'drinking water unit risk' of 5×10^{-5} per µg/L. For carcinogens, the formal MCL Goal is always zero. Zero is an unattainable goal, so in most cases the EPA will reduce exposure to carcinogens to a level of 'acceptable risk,' something between 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000).[19] One way of looking at this range is to assume that risks less than 1 in 1,000,000 are always 'acceptable,' while risks greater than 1 in 10,000 never are. The risks of drinking arsenic at the MCL of 10 µg /L are much higher than 1 in 10,000.

[20] See, e.g., National Research Council, Critical Aspects of EPA's IRIS Assessment of Inorganic Arsenic – Interim Report, 82 – 83 (2013). For health endpoints like childhood IQ, the critical window of exposure is obviously much less, encompassing in utero development and childhood.

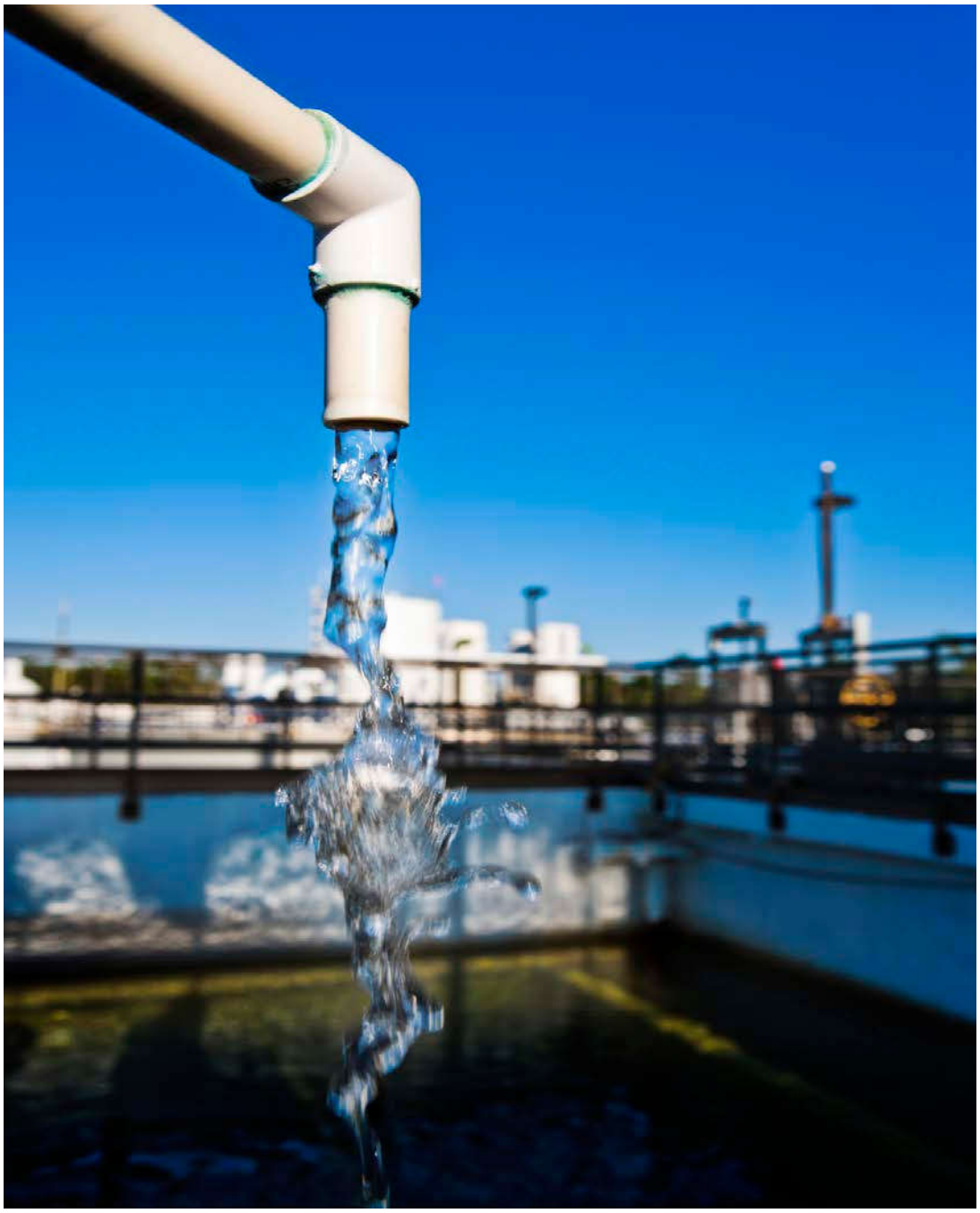
[21] EPA web page, "Drinking Water Arsenic Rule History," available at: https://www.epa.gov/dwreginfo/drinking-water-arsenic-rule-history.
[22] ATSDR (2007), Toxicological Profile for Arsenic; Grandjean and Landrigan (2014), Neurobehavioural Effects of Developmental Toxicity, *Lancet Neurol* 13:330-338.

[23] Wasserman et al. (2014), A Cross-Sectional Study of Well Water Arsenic and Child IQ in Maine Schoolchildren, *Environ Health* 13:23-32.

[24] Ibid.

[25] Ibid.
[26] California Water Resources Board report to the California legislature, "Communities that Rely on a Contaminated Groundwater Source for Drinking Water," January 2013. Link: http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/docs/ab2222.pdf
[27] California Water Resources Board report to the California legislature, "Communities that Rely on a Contaminated Groundwater Source for Drinking Water," January 2013. Link: http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/docs/ab2222.pdf
[28] Carolina L. Balazs and colleagues, "Environmental Justice Implications of Arsenic Contamination In California's San Joaquin Valley: a Cross-Sectional, Cluster-Design Examining Exposure and Compliance in Community Drinking Water Systems," Environmental Health, November 14, 2012. Link: https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-11-84
[29] Ibid.
[30] Letter from Jared Blumenfeld, Director of EPA's Region 9 office, to California Department of Public Health Director Dr. Ron Chapman, April 19, 2013. Link: https://www3.epa.gov/region9/water/grants/pdf/CDPHNoticeofNonCompliance.pdf
[31] Ibid.
[32] California Water Boards press release, "State Water Board, Drinking Water Revolving Fund Return to Safe Drinking Water Act Compliance," May 26, 2016. Link: http://www.waterboards.ca.gov/press_room/press_releases/2016/pr052616_cap_release.pdf
[33] Ibid.
[34] Ibid.
[35] Based on averages for 2014-2015. Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016.
[36] Ibid.
[37] Ibid.
[38] Ibid.
[39] Email from Andrew DiLuccia, Public Information Officer for the California State Water Resources Control Board, containing quote from Cindy Forbes, Deputy Director of the Division of Drinking Water, on August 8, 2016. Telephone interview with Forbes on August 4, 2016.
[40] California State Water Resources Board, template for public notification of Arsenic MCL Exceedance, Link: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Notices.shtml
[41] Ibid.
[42] Example of Consumer Confidence Report for a California system can be found on the state website: https://sdwis.waterboards.ca.gov/PDWW/JSP/WaterSystemDetail.jsp?tinwsys_is_number=370&tinwsys_st_code=CA&wsnumber=CA1000071#
[43] Carolina L. Balazs and Isha Ray, "The Drinking Water Disparities Framework: On the Origins and Persistence of Inequities in Exposure," American Journal of Public Health, April 2014, Vol 104, No. 4. Link: http://www.ncbi.nlm.nih.gov/pubmed/24524500.
[44] Ibid.
[45] Ibid.
[46] Ibid.
[47] 40 CFR 142.20(a)(2)
[48] Wasserman et al. (2014), A Cross-Sectional Study of Well Water Arsenic and Child IQ in Maine Schoolchildren, Environ Health 13:23-32.
[49] U.S. EPA public notification template on EPA website: https://www.epa.gov/dwreginfo/public-notification-templates-community-and-non-transient-non-community-water-systems
[50] Telephone interview on August 25, 2016 with Philip Dutton, engineer for Fresno County.
[51] California State Water Resources Control Board website, http://www.waterboards.ca.gov/drinking_water/certlic/device/watertreatmentdevices.shtml
[52] KFSN-TV, ABC-30 in Fresno, report "Kettleman City Residents Get Answers to Questions about Construction of Water Treatment Plant," August 31, 2016. Link: http://abc30.com/society/kettleman-city-residents-get-answers-to-questions-about-construction-of-water-treatment-plant/1493726/
[53] Ibid.

[54] Telephone interview on August 26, 2016, with Cheryl Sandoval, Supervising Environmental Health Specialist and Manager of Monterey County's drinking water program.
[55] Corral de Tierra Water Company 2013 Consumer Confidence Report, dated July 11, 2014.
[56] Ibid.
[57] Telephone interview on August 26, 2016, with Randy Hardenbrook, Director of the Quail Valley Water District.
[58] Ibid.
[59] Telephone interview on August 25, 2016, with Robert Johnson, President of the Shaver Lake Point 2 Mutual Water Company.
[60] Ibid.
[61] Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016.
[62] Telephone interview with Connie R. Clendenan, CEO of the Valley Teen Ranch nonprofit organization, on August 1, 2016.
[63] Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016
[64] Email from Whitney Meyer, Principal of the Washington School in Salinas, California, on August 1, 2016.
[65] Email from Robert Shemwell, Assistant Superintendent of Business Services of the Yuba City Unified School District, containing quote from Tom Butcher,Director of Maintenance and Facilities, on August 12, 2016.
[66] Email on August 24, 2016, from Liliana Stransky of the Kings County Department of Public Health.
[67] Email from Superintendent Charlotte Hines of the Island Union School in Lemoore, California, August 4, 2016.
[68] Email from Kenneth Drylie, Public Affairs Specialist at Fort Irwin, containing quotes from Muhammad A. Bari, Director Public Works at the forst, on August 11, 2016.
[69] Email from Kylie Barnett, Director Public Relations at Delicato Family Vineyards, August 10, 2016.



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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

May 28, 2004

Mike Paulucci
Treatment Plants Chemist
City of Yuba City
302 Burns Drive
Yuba City, California 95991

Re: 2004 Pretreatment Evaluation

Dear Mr. Paulucci:

Enclosed is the April 30, 2004 report for our pretreatment evaluation of Yuba City. We ask that the City provide short written responses to each of the findings in Sections 2.0 to 8.0 of this inspection report by **July 30, 2003.** We expect to follow this inspection report with an Administrative Order that establishes a 12-month schedule for upgrading the pretreatment program, starting with the budget cycle on July 1.

The new NPDES permit incorporates a number of permit limits for pollutants that were unregulated in the past. There are now many pollutants of concern for which the City must develop and implement a source control program. One noteworthy finding of this inspection is that for most of the new pollutants of concern, the effluent levels for Yuba City exceed those for sewer districts representative of the industrialized Central Valley. Yuba City=s levels are partly explained by the ground water supply (*arsenic, barium*), water delivery system (*copper*), and the fact that the other districts perform advanced treatment, either nutrient removal or tertiary filtration, and thus have higher removal rates (*chromium, manganese, iron, silver*). Nevertheless, for a number of metals, non-domestic contributions appear to be the primary or at least a significant source in the Yuba City effluent (*aluminum, arsenic, copper, iron, manganese, mercury, molybdenum, selenium, and zinc*).

Otherwise, the most significant findings involve the unrepresentative self-monitoring by the industrial users over their reporting periods, the under-developed industrial user inventory, the incorrectly permitted significant industrial users, the lack of an updated sewer use ordinance as approved in 1995, and outdated local limits. Some of these issues were advanced in the EPA inspection reports and follow-up Administrative Orders to three significant industrial users in Yuba City. It is expected that their efforts to meet the requirements of their Administrative Orders will partly address the issues in this report.

Much of the City=s past efforts to regulate non-domestic contributions to the sewers will not have to be reconsidered or redone. In particular, the work done by the City to identify pollutant sources can be built upon, and the annual reports are informative. But the City will have to provide resources to do a number of required functions to address the deficiencies found in this inspection. Local limits will have to be redetermined. The ordinance will have to be

updated and adopted. Permits will have to be reissued to most significant industrial users. Self-monitoring requirements will have to be re-evaluated. Fact sheets will have to be prepared. All of these requirements are outlined in the enclosed inspection report.

Thank you for your cooperation during and after this inspection. Please do not hesitate to call (415) 972-3504 or e-mail arthur.greg@epa.gov.

Sincerely,

Original signed by:
Greg V. Arthur

Greg V. Arthur
Clean Water Act Compliance Office

cc: Melissa Hall, RWQCB

U.S. ENVIRONMENTAL PROTECTION AGENCY

REGION 9

CLEAN WATER ACT COMPLIANCE OFFICE

PRETREATMENT PERFORMANCE EVALUATION INSPECTION REPORT

NPDES Permittee:	City of Yuba City 302 Burns Drive, Yuba City, California 95991 Wastewater Treatment Plant (NPDES CA0079260) WDRs Orders R5-2003-0085
Dates of Inspection:	August 5, August 20-21, August 27, 2003
Data Review:	Influent and Effluent Conventional: 2003 – 2004 Influent and Effluent Toxics: 2000 – 2004 Sludge toxics: 2000 – 2004

Inspection Participants:

US EPA:	Greg V. Arthur, CWA Compliance Office, (415) 972-3504 Meg Masquelier, CWA Compliance Office, (415) 972-3536
RWQCB:	No Representative
Yuba City:	Mike Paulucci, Chemist, (530) 822-7695 Al Butterfield, Chief Plant Operator
Industrial Users:	Sunsweet Growers, Jerry Ramsey, Engr Mgr, (530) 751-5278 Greenleaf Unit 2, Diane Tullos, Compliance Mgr, (530) 821-2074 Custom Chrome, Gene Hutchinson, Owner, (530) 673-2360

Report Prepared By:	Greg V. Arthur, Environmental Engineer April 30, 2004

Section 1

Introduction and Background

1.0 Scope and Purpose

In April 2004, EPA completed a performance evaluation of the regulatory control of non-domestic wastewaters discharged into the City of Yuba City wastewater treatment plant ("WWTP"). This performance evaluation was one of a series of reviews of small publicly-owned treatment works that accept non-domestic contributions, many of which are not large enough to be mandated to operate EPA-approved pretreatment programs. Yuba City is large enough and has operated an EPA-approved pretreatment program since 1982.

The scope of this performance evaluation comprised:

- Sampling inspection of the Yuba City wastewater treatment plant on August 27, 2003;
- Review of the 2003-2004 Yuba City self-monitoring reports;
- Review of the 2000-2004 influent and effluent sampling records for toxic pollutants;
- Inspections of three significant industrial users including the sampling of two of them;
- Review of the 2000-2003 sampling records for the significant industrial users inspected;
- Interviews with City representatives on August 5, August 20-21, and August 27, 2003;
- Review of the industrial responses to their inspection reports and enforcement actions.

The purpose of this evaluation was to determine if non-domestic discharges into the Yuba City sewer system are properly controlled. The evaluation findings were measured against two fundamental performance objectives. The first is the prevention of sewage treatment works pass-through, interference and sludge contamination as shown by compliance with the Federal sludge limits, the discharge permit limits, and any expected future Clean Water Act requirements. The second is the consistent compliance by the industrial users with their own Clean Water Act requirements, in particular with the Federal best-available-technology standards that apply to certain industrial categories, and any national prohibitions and local limits for pollutants associated with treatment works non-compliance.

This report covers the performance of the pretreatment program as it currently exists in Yuba City. Some pertinent findings from the industrial user inspections are also incorporated. The significant industrial users received individual reports and enforcement actions. Arthur collected samples on August 20, 21, and 27, 2003 for delivery to the EPA Richmond Lab.

1.1 Yuba City Wastewater Treatment Plant

The Yuba City WWTP is a pure-oxygen activated sludge plant that discharges either by diffuser to the Feather River in the winter wet-season or to 120 acres of percolation ponds

Section 1 – Introduction and Background

located alongside the river in the summer dry-season. The wastewater treatment plant provides high-rate treatment of higher-than-typical-strength wastewaters. It has a dry-weather design capacity of 7.0 million gallons per day ("mgd") and a wet-weather design capacity of 11.0 mgd. The average and calculated peak flows were 6.60 and 8.05 mgd in 2003. See Figure 1.

- Primary and Secondary Treatment - The headworks, which provide grinding and aerated grit removal, is followed by primary sedimentation. Ammonia and phosphates are added, usually in the summer, in order to precondition the high-strength and nutrient-poor contributions from Sunsweet Growers. Primary effluent is then aerobically biodegraded in three treatment trains each with four compressed-gas pure-oxygen aeration cells followed by three secondary clarifiers. Activated sludge returns without re-aeration in order to strip carbon dioxide, and does so at rates to support a mean cell residence time of around 3 days. Real-time metering for dissolved oxygen, solids, and redox potential are used to better ensure the treatment plant can respond to the contributions from Sunsweet.

- Advanced Treatment - There is no capability to provide nitrification or denitrification. There is also no tertiary polishing of secondary effluent and, as a result, no capability to reuse treated wastewater off-site.

- Solids Handling - Waste secondary activated sludge and primary sludge are digested in two anaerobic digestors each with detention times of 25 days and operated in series. Digested sludge dosed with anionic polymer is dewatered through belt pressing, with the cake further dewatered in on-site sludge drying beds for off-site disposal as landfill cover. Grit is hauled off-site to a landfill. The waste activated sludge is first thickened in two polymer-aided dissolved air flotation units. Belt press filtrate returns to the lateral leading into the headworks. Dissolved air flotation subnatant returns to the aeration cells.

- WWTP Sampling - The influent sampling point, located upstream of the headworks is designated as IWD-YC1 for the purposes of this report. All return flows except the belt press filtrate rejoin treatment downstream of influent sampling. The effluent compliance sample point, sited immediately after final dechlorination, is designated as IWD-YC2. The accumulation of filter cake for hauling off-site is designated as the sludge sampling point, IWD-YC3. The receiving water sampling point downstream of the Yuba City outfall is designated in the permit as R-1.

- Water Supply - For most of its sewered users, Yuba City provides surface water drawn from the Feather River and treated through its water treatment plant. Some sewered customers located outside of the city limits receive untreated ground water from the former Hillcrest Water Company system. According to the City's Urban Water Management Plan, an estimated 1,000 of the 9,020 water users receive the more mineralized ground water. For the purposes of this report, a ratio of 1:9 ground to surface water was used in estimating the flow-weighted average concentrations for the water supply.

- Receiving Water Hardness - The USGS maintains a station on the Feather River at Nicolaus, approximately 13 miles downstream from the Yuba City outfall. This station and six others in Sacramento River basin were extensively sampled under a full range of conditions for conventional, toxic, and pesticide-related pollutants, as part of the 1995-1998 National Water Quality Assessment Program. The calculated 99th% minimum hardness and the minimum sample result for the Feather River station was 22.6 mg/l and 22 mg/l as CaCO3. The lowest minimum sample result recorded for all seven stations both upstream and downstream of the Feather River station was 16 mg/l. For the purposes of this report, a hardness of 22.6 mg/l is used in the calculations of the permit limits for metals to be in effect in 2007. By then, Yuba City will have a better data set of hardness values for the Feather River near the outfall, as required by the NPDES permit.

1.2 Sewer Service Area

The Yuba City sewer service area comprises the incorporated area of the city that receives city supplied surface water as well as the unincorporated county lands southwest of the city limits that receive ground water. The WWTP also serves as a regional disposal point for septage collected from septic tanks in unsewered areas within both the city limits and in the outlying county land. According to the City's Urban Water Management Plant, the service area has a population in 2004 estimated to be 60,000, and 950 commercial and four industrial users, who together contribute 35-40% of the sewered wastewater. The inventory of industrial users includes at least seven considered to be significant industrial users who together discharged an average of 930,000 gallons per day into the sewers in 2003 (14% of total flows).

1.3 Discharge Requirements

Yuba City is authorized by the June 6, 2003 RWQCB Waste Discharge Requirements, Order R5-2003-0085, ("WDRs"), and a concurrent Cease and Desist Order, Order No. R5-2003-0086, ("CDO"), to discharge treated sewage from the Yuba City WWTP either to the Feather River or to percolation ponds sited along the river or from the percolation ponds to the Feather River. The WDRs also function as National Pollutant Discharge Elimination System ("NPDES") permit CA0079260. The WDRs contain narrative prohibitions, effluent limits that implement the California Toxics Rule, receiving water limitations, monitoring requirements, pretreatment provisions, and sludge disposal requirements. In essence, the WDRs and CDO together require Yuba City to comply with effluent limits for conventional pollutants, disinfection, and pH upon issuance of the permit and for pesticides, metals, surfactants, toxic organics, ammonia, and nitrates by November 2007.

The effluent limitations for a discharge to the Feather River are for conventional pollutants, total coliform, ammonia based on temperature and pH, nitrites and nitrates, surfactants, residual chlorine, pH, acute biotoxicity, and various pesticides, metals, and toxic organics. The effluent limits that take effect on November 1, 2007 are for additional metals based on

the hardness in the river, and for additional toxic organics. The CDO required the completion of the corrective steps necessary to meet the WDRs for organochlorine pesticides, thiobencarb, aluminum, ammonia, arsenic, chloroform, diazinon, cis-1,2-dichloroethene, ethion, iron, manganese, MTBE, surfactants, molybdenum, and nitrates also by November 1, 2007.

The limitations for a discharge to percolation ponds are limited to narrative prohibitions against public contact, objectionable odors, anoxic conditions, the proliferation of mosquitoes, inadequate freeboard, degraded ground waters, and exceeding numerical limitations for pH. The receiving water limitations include narrative provisions against causing a visible film, discoloration, objectionable growths, nuisance conditions, the bioaccumulation of toxics, bad tasting fish, increased temperatures over 5°F, increased turbidity, increased specific conductivity, high or low pH's, and any adverse effect on the beneficial uses of the receiving waters.

1.4 Legal Authorities

Yuba City obtained approval of its pretreatment program in 1982. Yuba City operates under the authority of Public Works Title 6, Wastewater Collection and Treatment Chapter 5 of its municipal code as adopted in 1976. Yuba City began the process of revising its ordinance to be in accord-ance with the requirements of 40 CFR 403 in the late 1980's and submitted a draft ordinance for review in 1990. EPA and the RWQCB provided numerous and extensive reviews of the ordinance culminating in an approval letter from the RWQCB issued on November 29, 1995. Yuba City has not readopted the revised ordinance. As a result, the local limits and the regulatory provisions in effect are those in the 1976 ordinance. The WDRs since 1990 have imposed pretreatment provisions that require implementation of the regulatory controls necessary to enact all of 40 CFR 403. The current WDRs issued in June 2003, require Yuba City to resubmit pretreatment program for approval. Requirements to obtain and implement an approved pretreatment program would include the following:

- The implementation of the general and specific national prohibitions in 40 CFR 403.5 for industrial users against the introduction of incompatible wastewaters;
- The requirement in 40 CFR 403.5 to develop locally-determined limits necessary to protect the treatment works from potential adverse impacts, such as operational interference, worker health and safety risks, the pass-through of pollutants to the receiving waters, and sludge contamination;
- The performance of the program functions set forth in 40 CFR 403.8, such as identifying industrial users, issuing permits, inspecting and sampling industrial users, providing adequate funding, and enforcing against violators;
- The implementation of an industrial users self-monitoring program under 40 CFR 403.12;
- The implementation of Federal categorical standards under 40 CFR 403.6; and
- The enacting of the local legal authorities necessary to operate an approved pretreatment program under 40 CFR 403.8.

Section 1 – Introduction and Background

This evaluation did not involve a review of the 1976 ordinance because the proposed 1990 revised ordinance has not been adopted. As a result, the administrative record since the late 1980's stands as the determination that Yuba City does not have the legal authority to implement all aspects of an approved pretreatment program.

Section 2

Wastewater Treatment Plant Performance

The Yuba City WWTP must meet permit effluent limits for conventional pollutants, nutrients, pesticides, metals, toxic organics, pH, surfactants, and biotoxicity. 40 CFR 403.5(a,b,c) and 403.6.

Non-domestic wastewaters may not result in unpermitted releases, hazardous or explosive conditions with the sewers, or operational interferences in the collection system. 40 CFR 403.5(b).

2.0 Summary

The WWTP has the capacity and capability to handle the domestic wastewaters in the Yuba City service area as well as the high-strength wastes generated by Sunsweet. However, without a change in the influent loadings, removal rates, or disinfection methods, the WWTP is expected to experience the pass-through of a number of metals, chlorination byproducts, toxic organics, and pesticides once their NPDES permit limits take full effect in 2007. Moreover, without nitrification and denitrification, the WWTP is also expected to experience the pass-through of ammonia and the toxicity associated with ammonia. Finally, the nutrient-poor nature of Sunsweet's contributions caused operational interferences related to WWTP responses, however, better metering has lessened those risks.

See Tables 1 - 3 for wastewater and sludge summaries, Table 4 for statistical probabilities of violation, Table 5 for a comparison of Yuba City with representative Central Valley sewer districts, Table 6 for the EPA sampling results, and Table 8 for the definitions of 'pass-through' and 'interference'.

Requirements

- The domestic, non-domestic, and water supply sources of aluminum, arsenic, copper, iron, manganese, molybdenum, and zinc must be identified and quantified.

Recommendations

- The wastewater treatment plant influent should be monitored for aluminum, arsenic, copper, iron, manganese, mercury, molybdenum, selenium, and zinc.
- The receiving waters should be monitored for hardness, pH, and temperature.
- The cause of the instances of low pH in the influent should be determined.

Section 2 – Wastewater Treatment Plant Performance

Recommendations – continued

- Corrosion controls of the water delivery system should be implemented in order to reduce the leaching of copper, thereby reducing the copper discharged from the treatment plant.
- Sunsweet and septage deliveries should be monitored for the farm-related contaminants such as arsenic and selenium.
- Sunsweet and the power plants should be monitored for the corrosion-related contaminants associated with circulating water systems such as iron, molybdenum, and zinc.
- A specific prohibition against abrupt changes in organic loads, such as a restriction in the percentage change in mass loads per day, should be considered for Sunsweet.
- The water service newsletter should be supplemented to also inform rate payers of the wastewater compliance status and the on-going need to fund the capital improvements, pretreatment, and operations to protect and maintain the public wastewater investment.

2.1 Conventional Pollutants

The WWTP produces high-quality secondary-treated wastewaters. As a result, it consistently complies with its permit limits for conventional pollutants. The average and calculated 99th% peaks are less than 11 and 22 mg/l BOD and 9 and 16 mg/l TSS even through Sunsweet's contributions elevate the average influent BOD to 339 mg/l. The WWTP discharged to the percolation basins May 1 through October 31, and to the river otherwise.

There were four instances of the effluent pH below the lower 6.5 limit and one above the upper 8.5 limit. There were also two unrelated instances of low influent pH, (2.62 on 11/14/03 and 4.99 on 11/22/03). The national prohibitions not only prohibit discharges that cause structural damage to the sewerage works but also specifically prohibit discharges below 5.0 s.u. because pHs below that level are known to cause concrete degradation.

2.2 Ammonia Toxicity

The permit sets sliding-scale effluent limits for ammonia which are most stringent when pH and temperature are high. During the winter wet-season when the WWTP discharges to the Feather River, the monthly-average and sample-maximum ammonia limits bottom out at 3.56 and 19.7 mg/l based on and assumed maximums for pH and temperature of 7.2 s.u and 70ºF. Sampling required by the permit would result in actual values for maximum pH and temperature in the Feather River and better establish the ammonia limits. Against these preliminary sliding-scale ammonia limits, the WWTP inconsistently complies when it discharges to the river, with the average and calculated 99th% peak ammonia concentrations

of 12.9 and 36.9 mg/l. As a result, there is a >20% chance of violating the lowest expected maximum limit and 99%+ chance of violating the lowest expected monthly-average limit.

2.3 Nitrates Plus Nitrites

The WWTP complies with the permit limits for nitrite plus nitrate of 10 mg/l primarily because it does not nitrify by design. The WWTP would be expected to comply with the permit limits upon the 2007 compliance deadline only upon completion of upgrades for both full nitrification and denitrification.

2.4 Salts

The permit does not limit salts but requires monitoring for total dissolved solids, hardness, and electrical conductivity. The monitoring results for salts are all well below what could adversely impact reuse, or in the case of sulfate, impart an acute toxicity.

2.5 Toxic Metals

Without decreased loadings, corrosion controls, or increased removals, the WWTP would be expected to exceed the permit limits for aluminum, arsenic, copper, iron, lead, manganese, molybdenum, and zinc. See Table 2 for a summary of toxics in the influent, effluent, and water supply, Table 4 for statistical probabilities of exceeding limits, and Table 5 for comparisons with representative of Central Valley sewer districts with industrial contributions. (The sewer districts selected for comparison were Deer Creek, El Dorado Hills, Grass Valley, Nevada City, Placer County No.1, Red Bluff, and Stockton.)

For most metals, the effluent concentration averages for Yuba City exceed the averages for sewer districts representative of the industrialized Central Valley. Elevated levels for Yuba City are partly explained by the water supply (*arsenic, barium*), water delivery (*copper*), and the fact that the other districts perform advanced treatment of some sort, either nutrient removal or tertiary filtration, and thus have higher removal rates (*chromium, manganese, iron, silver*). Nevertheless, for a number of metals, unidentified non-domestic contributions appear to be the primary or at least a significant cause of the elevated levels in the Yuba City effluent *(aluminum, iron, manganese, mercury, molybdenum, selenium, zinc*).

Aluminum - Influent concentrations are significantly higher than can be explained by the water supply or known non-domestic sources. In fact, the influent levels are so high, up to 6,225 µg/l, that the sources are likely limited to utilities' use of alum for water, wastewater, or sludge conditioning or water conditioning at industries that discharge the generated sludges or backwashes. A sample of 3,600 µg/l from Greenleaf Unit 2 partly bears this out. Since the 85%+ removal rate is typical for secondary wastewater treatment, not only the influent but also effluent concentrations far exceed the averages for representative Central

Section 2 – Wastewater Treatment Plant Performance

Valley sewer districts. The effluent average and calculated 99th% peaks are 256 and 571 µg/l resulting in a >80% chance of a sample violating the 120 µg/l maximum limit.

Arsenic - Influent concentrations are higher than can be explained by known sources. The ground water used in part of the city accounts for nearly half of the elevated influent levels. However, for the remainder, arsenic in fruit pesticides makes it possible that fruit washing at Sunsweet and farm-related run-off or septage are likely sources that account for the increases from 2.5 µg/l in the water supply to 6.1 µg/l in the influent. Both the average influent and effluent concentrations are >400% higher for Yuba City than for representative Central Valley sewer districts. The effluent average and calculated 99% peaks are 7.8 and 33.5 µg/l which result in a >40% chance of samples violating the 10 µg/l monthly limit.

Barium - The permit does not set effluent limits for barium. Average effluent concentrations are >400% higher than representative Central Valley sewer districts, and ground water may account for nearly half of the elevated levels. Potential non-domestic sources might include the removal of barium sulfate deposits from circulating cooling water circuits.

Cadmium - The industrial discharge from Custom Chrome is the likely source of the small concentrations of cadmium found in the influent and effluent. No cadmium was detected in the water supply and the WWTP levels are consistent with those for representative Central Valley sewer districts. The effluent average and calculated 99% peaks are 0.17 and 0.31 µg/l which result in far less than a 1% chance of a sample exceeding the calculated 0.85 µg/l maximum limit.

Chromium - The industrial discharge from Custom Chrome is the likely source of the small concentrations of chromium found in the influent and effluent. No chromium was detected in the water supply and the WWTP levels are consistent with those for representative Central Valley sewer districts. The effluent average and calculated 99% peaks are 0.94 and 1.14 µg/l which result in far less than a 1% chance of a sample exceeding the calculated 106 µg/l maximum limit.

Copper – Corrosion of household plumbing appears to be the principal source. Surveys conducted by Yuba City found 10% of the households with copper concentrations at their taps over 199 µg/l if served by surface water and 459 µg/l if served by ground water. These concentrations are high enough to account for the significant increases from 1.3 µg/l in the surface water supply to 50.1 µg/l in the WWTP influent. The removal rate of 80%+ is in the typical range for secondary wastewater treatment. As a result, the effluent average and calculated 99th% peaks are 8.5 and 18.7 µg/l which result in a >90% chance of a sample violating the 2.65 µg/l maximum limit. This means Yuba City is likely to nearly always exceed permit limits without preconditioning the water supply to inhibit corrosion.

Section 2 – Wastewater Treatment Plant Performance

The principal corrosion control methods in use by other water suppliers include the following:

- carbonate passivation of copper pipes through the increase of both pH and alkalinity,
- silicate passivation of copper pipes through the application of sodium silicates and sodium carbonate, and
- precipitation of scale within the pipes through the supersaturation of calcium.

(EPA publication EPA-811-B-92-002, September 1992, "Lead and Copper Rule Guidance Manual, Vol. II: Corrosion Control Treatment).

Iron - Lone samples of 15,000 and 9,800 µg/l from Sunsweet and Greenleaf Unit 2, respectively, could easily account for the significant increase between the flow-weighted average of 25.3 µg/l for the water supply and the average WWTP influent of 960 µg/l. The removal rate of 80%+ is typical for secondary wastewater treatment. The effluent concentrations exceed the averages for repre-sentative Central Valley sewer districts. The effluent average and calculated 99th% peaks are 164 and 309 µg/l which result in a slight >1% chance of a sample violating the 300 µg/l maximum limit.

Lead - There is not enough data to make conclusions regarding future compliance with the 0.83 µg/l maximum or 0.38 µg/l monthly-average limits. All water supply samples were below detection, but the 1 µg/l detection limit is over the limits.

Manganese - Effluent concentrations are far higher than typical for representative Central Valley sewer districts because treatment plant removals are essentially 0% in Yuba City but between 60% and 97% at the representative Central Valley sewer districts. The effluent average and calculated 99th% peaks are 53 and 156 µg/l which result in a >50% chance of a sample violating the 50 µg/l maximum limit. Influent concentrations are typical for representative sewer districts, although there are no sources identified at this time that could account for the increase between the flow-weighted average for the water supply of 11.5 µg/l and the WWTP influent of 49.8 µg/l.

Mercury – There is a negligible chance of even a single sample violating the 0.05 µg/l monthly-average limit, even though both influent and effluent concentrations exceed the averages for representative Central Valley sewer districts. The removal rate of 95%+ is typical for secondary wastewater treatment. Effluent average and calculated 99th% peaks are 0.017 and 0.048 µg/l.

Molybdenum - Molybdate is a corrosion inhibitor in widespread use in circulating cooling water circuits, which account for a significant fraction of the non-domestic contributions into the Yuba City sewers. As a result, circulated cooling at Sunsweet and the power plants are likely sources of the significant increase in the average concentration from less than 1.0 µg/l in the water supply to 10.3 µg/l in the influent. Both influent and effluent concentrations exceed the averages for the representative Central Valley sewer district with molybdenum

samples. The effluent average and calculated 99th% peaks for Yuba City are 11.0 and 31.6 µg/l which result in a >50% chance of a sample violating the 10 µg/l maximum limit.

Nickel - The industrial discharge from Custom Chrome is the likely source of the small concentrations of nickel found in the influent and effluent. No nickel was detected in the water supply and the WWTP levels are consistent with representative Central Valley sewer districts. The effluent average and calculated 99th% peak concentrations are 1.78 and 3.96 µg/l, which result in less than a 1% chance of a sample violating the 23.6 µg/l maximum limits.

Selenium - The permit does not set effluent limits. Selenium has farm-related uses in veterinary medicine, fungicides, and insecticides. As a result, fruit washing at Sunsweet and farm related run-off or septage are likely sources of the increase in the average concentration from less than 1.0 µg/l in the water supply to 7.1 µg/l in the influent. Both influent and effluent concentrations far exceed the averages for the representative Central Valley sewer district. The effluent average and calculated 99th% peaks for Yuba City are 7.1 and 44.7 µg/l.

Silver - There is not enough data to make conclusions regarding future compliance with the 0.31 µg/l maximum limits, even though the single effluent sample exceeded the limit. All water supply samples were below detection, but the 1 µg/l detection limit is over the limit.

Zinc - Zinc phosphates are corrosion inhibitors in widespread use in circulating cooling water circuits, which account for a significant fraction of the non-domestic contributions into the Yuba City sewers. As a result, the circulated cooling at Sunsweet and the power plants are likely sources of the huge increase in the average concentration from less than 1.0 µg/l in the water supply to 157 µg/l in the influent. The influent and effluent concentrations are within the ranges at the representative Central Valley sewer districts. The effluent average and calculated 99th% peaks for Yuba City are 51.8 and 86.7 µg/l which result in a >80% chance of a sample violating the 34.0 µg/l maximum limit.

2.6 Toxic Organics and Pesticides

A number of other toxic pollutants were detected but most of them did not or will not exceed the permit limits. Those detected but not exceeding permit limits include MTBE (*methyl-tert-butyl ether*). The principle exceptions were the permit limits for two chlorination byproducts (*dichloro-bromomethane, dibromochromomethane*), a pesticide (*diazinon*), and two chlorinated solvents (*chloroform, tetrachloroethylene*). However, no definitive conclusions regarding any of these pollutants can be made at this time because there are only three samples for each and the permit limits are not much higher than the detection limits.

Section 2 – Wastewater Treatment Plant Performance

2.7 Federal Sludge Limits

The WWTP sludges consistently comply with the Federal sludge limits for disposal as landfill cover. The WWTP sludges also would likely consistently comply with the Federal clean sludge limits suitable for any reuse in Table 3 of 40 CFR 503.13 although the more stringent limits do not apply as long as the Yuba City disposes of sludge as landfill cover.

2.8 WWTP Interference

Sunsweet poses two operational risks to the Yuba City treatment works. First, sharp drops in loadings have in the past resulted in operational interferences at the WWTP related to the treatability of the nutrient-deficient discharges from Sunsweet and the responsive dosing of nutrients by Yuba City. Second, the high-strength organic discharges could cause sulfide degradation of concrete sewers if they become anoxic.

Yuba City has instituted permit requirements to Sunsweet to keep the pH above 8.5 and to provide 48-hour prior notification for impending shutdowns of more than 24 hours. Yuba City also has real-time probes with automatic alarms for dissolved oxygen, solids, and redox potential at various locations in the WWTP. Nevertheless, within the permit requirements, the variabilities in the organics, suspended solids, and hydraulic loadings from Sunsweet still have the potential to be large enough to adversely effect the operation of the WWTP because the mitigating actions rely solely on operators and procedures. It would be better for the City if Sunsweet installed some form of built-in load equalization that does not rely on operating procedures. See the February 20, 2004 EPA report of the inspection of Sunsweet and Sunsweet's May 26, 2004 response for a larger discussion.

Section 3

Local Limits

Pretreatment programs are required to develop local limits to prevent pass-through, interference, sludge contamination or other adverse effects upon the treatment works. 40 CFR 403.5(c).

3.0 Summary

Yuba City has an ordinance to prohibit discharges that exceed local limits or could harm the treatment works. However, the technical basis of the local limits is questionable since they are not based on the current conditions or permit. Furthermore, Yuba City did not adopt an updated sewer ordinance reviewed by EPA and approved by the RWQCB to reflect changes in the Federal pretreatment rule promulgated after 1982. Sampling has indicated that without a change in the influent loadings, or removal rates, the WWTP would be expected to experience the pass-through of a number of metals, toxic organics, and pesticides once the permit limits take full effect in 2007. See Table 7 for a definition of 'local limits'. Also see Item 1.4 of this report for more detail regarding Yuba City's legal authority.

Requirements

- Yuba City must determine the maximum allowable headworks loadings for aluminum, arsenic, copper, iron, manganese, molybdenum, and zinc, and enact new local limits, prohibitions or control strategies.
- The sewer use ordinance must be updated to reflect the changes in the Federal rules.

Recommendations

- The WWTP influent and effluent should be sampled to determine whether diazinon, chloroform, tetrachloroethylene are pollutants of concern present at levels above their detection limits.

3.1 Sewer Use Ordinance

This pretreatment program evaluation did not include a new review of the sewer use ordinance. However, the ordinance has not be updated to reflect the changes in the Federal pretreatment rules in the ways outlined in the reviews by EPA of the ordinance and culminating in the approval letter issued by the RWQCB on November 29, 1985.

Section 3 – Local Limits

3.2 National Prohibitions

The national prohibitions apply to every non-domestic discharge into the sewers nationwide to prevent harm to the treatment works. They consist of the general prohibitions in 40 CFR 403.5(a) against harm and the specific prohibitions in 40 CFR 403.5(b). In practice, local limits, covering a range of pollutants, and developed in accordance with 40 CFR 403.5(c), replace most of the effective span of the national prohibitions.

3.3 Pollutants of Concern

The pollutants of concern are those related to non-domestic sources with a statistical chance of over 1% to cause a violation of the WDRs or the Federal sludge limits. The pollutants with a statistical chance over 1% are aluminum, ammonia, arsenic, chloroform, copper, diazinon, dibromochloro-methane, dichlorobromomethane, iron, lead, manganese, molybdenum, tetrachloroethylene, and zinc. Of these, dibromochloromethane and dichromobromomethane would not be pollutants of concern because they are chlorination by-product unrelated to influent quality. Ammonia and nitrates also would not be pollutants of concern because their effluent concentrations are a function of the treatment plant operations. It cannot be determined without further monitoring of both the influent and effluent whether diazinon, chloroform, and tetrachloroethylene are pollutants of concern.

A number of other pollutants with a statistical chance below 1% to cause a violation, nevertheless, should be pollutants of concern because of discernible sources. Cadmium, chromium, and nickel are entrained in solution and rinse tanks at metal finishers (*Custom Chrome*). Selenium is associated with farm-related uses (*Sunsweet, septage*). Lead and barium are scoured from boilers (*Sunsweet, power plant*). Mercury has non-domestic commercial sources (*dentists*). MTBE at aquifer clean-up sites are pollutants of site-specific concern. And oil & grease is a concern in every sewer district.

3.4 Maximum Allowable Headworks Loadings

Every sewer district must determine the maximum loading of pollutants it can accept and still comply with the permit requirements and Federal sludge limits. The maximum allowable headworks loadings ("MAHLs") form the technical basis for determining local limits. All this requires influent, effluent, and sludge monitoring under the range of conditions expected during the year, in order to determine the WWTP removal efficiencies. EPA has a free spread sheet program called Prelim to assist in the calculations. WEF also has a fate and transport model available for purchase on its web-site.

Section 3 – Local Limits

3.5 Allocation Method

The MAHLs for each of the pollutants of concern must be allocated between uncontrollable and controllable sources. The uncontrollable sources comprise domestic sewage, and infiltration and inflow. The controllable sources are those that could be regulated under permits or best-management practices. This will require background monitoring of domestic sewage, and infiltration and inflow, in order to determine the pollutant loadings that cannot be allocated to the controllable sources. The remaining loadings can then be allocated in any fashion to the individual industrial and commercial sources. For example, Yuba City could set different local limits by individual industrial discharge, or by flow-weighted average, or uniformily across the entire service area for some pollutants but differentially set for others. The allocation method does not matter as long as the total allocation out to the domestic and non-domestic users does not exceed the calculated MAHLs.

It is possible that the main sources of certain pollutants are domestic in nature and largely uncontrollable by ordinance through permitting or best-management practices. For example, significant loadings of copper likely come from the delivery pipes and pesticides may come primarily from infiltration and inflow off of nearby fields, or household use. In these cases, Yuba City would have to redetermine the MAHLs after the sources are mitigated through some other means.

3.6 Industrial User Compliance with Local Limits

The Federal regulations do not define how to determine regulatory success. Moreover, any conclusion regarding industrial user compliance with the local limits would be premature since they are not technically-based to protect the Yuba City treatment works from adverse impacts, and the sources of the pollutants of concern are not yet identified. Once the local limits are sound and implemented through industrial user permits, however, the following performance measures determine regulatory success in achieving industrial user compliance.

- Treatment Plant Performance - EPA Region 9 bases its primary determinations on the purpose of local limits and the national prohibitions to prevent pass-through, interference, sludge con-tamination, or potential worker safety risks. As a result, the best measure of a program's effectiveness is consistent compliance with the NPDES permit and sludge limits. By this measure, Yuba City would not be successful if the pass-through of aluminum, arsenic, chloro-form, copper, diazinon, iron, lead, manganese, molybdenum, tetrechloroethylene, and zinc continues to persist.

- Cost Effective On-Site Treatment - Conventional pollutants can be treated at the sources and the sewage treatment plant. In general, primary treatment for solids and organics, pH adjustment, and gravity oil-water separation, are cost effective at the sources, while secondary treatment for dissolved organics, nitrification and denitrification are much more cost effective at the sewage treatment plant. On the other hand, toxics must be entirely controlled by the sources since sewage treatment plants are not designed to for

Section 3 – Local Limits

toxics. By this measure, Yuba City would not be successful in ensuring all non-domestic dischargers of acidic and alkaline wastewaters provide final pH adjustment.

- Significant Non-Compliance - Significant non-compliance will be based on industrial user compliance rates once the local limits are re-developed and implemented into the permits.

Section 4

Industrial User Compliance with Federal Standards

Pretreatment programs are required to be administered to ensure industrial user compliance with Federal categorical pretreatment standards. 40 CFR 403.8(b).

4.0 Summary

Best-available-technology ("BAT") treatment or its equivalent was not applied and in place at the identified Federally-regulated industrial process within the Yuba City service area.

Requirements

- Compliance sampling points, monitoring requirements, and on-demand rinsing practices must be established and implemented in order to determine whether treatment is necessary at Custom Chrome.

Recommendations

- The operational and disposal procedures to ensure compliance with Federal categorical pretreatment standards through the achievement of zero-discharge should be determined.

4.1 Treatment In-Place

EPA Region 9 uses two performance measures that together reflect the purpose of the various Federal categorical pretreatment standards to bring about the nationwide use of model BAT treat-ment. The first measure is BAT treatment across the industrial inventory. The Federal standards for each Federally-regulated industrial category were based on the statistical performance of model BAT treatment as it is separately defined for each category. For job-shop electroplating, BAT treatment is metals precipitation, settling and solids removal, and if necessary, cyanide destruction and chromium reduction.

The lone industrial user identified during this evaluation by EPA as a Federally-regulated user, was not found to comply with its Federal standards either through BAT treatment or through facility configurations and practices to keep from discharging to the sewers.

Custom Chrome - This metal finishing job-shop is required to comply with either the expanded list of pollutants in the Federal job-shop electroplating for dischargers over 10,000 gpd, or the abbreviated list of standards for dischargers under 10,000 gpd. Compliance cannot be determined at this time with either set of standards because the rinses discharge continuously irrespective metal finishing work and the spent solutions

are not specifically monitored. This constitutes "dilution as a substitute for treatment" since the Federally-regulated wastewaters discharge without treatment for metals or cyanide. None of the previous samples are usable for the determination of compliance.

- Power Plants - No Federal categorical standards apply (*Calpine Greenleaf Unit 2, Calpine Feather River Energy Center, Calpine Yuba City Energy Center, and Yuba City Cogeneration*).

4.2 Comparison with Model IU Performance

The second measure, derived from statistical comparisons with the performance of model categorical industrial users, only applies to larger industrial user inventories.

Section 5

Industrial User Inventory

Pretreatment programs are required to develop a complete inventory of industrial users, as part of ensuring industrial user compliance. 40 CFR 403.8(b,f1iii,f2i).

5.0 Summary

Yuba City has identified for regulation its significant industrial users ("SIUs"). However it has misclassified the SIUs qualifying as either categorical industrial users. Yuba City does not have a current inventory of non-significant industrial users nor of any zero-discharge categorical industrial users who would be subject to Federal standards if they discharged. Yuba City does have an unverified business list. See Table 7 for a list of identified SIUs and Table 8 for a definition of SIU.

Requirements

- Yuba City must field verify its industrial user inventory and institute formal documented procedures to continually identify additions, deletions and changes.
- Yuba City must re-identify the SIUs in its inventory as categorical, non-categorical, and zero-discharging categorical.

Recommendations

- Yuba City should maintain its industrial user inventory by non-domestic wastewater discharge point, with each discharge point characterized by Federal point source category, annual average flow rate, type of wastewater, and owner or operator.

5.1 Inventory Completeness

Yuba City has identified SIUs but has not identified, visited, or permitted all of its commercial and industrial users in its sewer service area. As a result, EPA could not produce a completed inventory during this performance evaluation and cannot verify that all SIUs are identified. The following four characteristics would be considered by EPA as good indications of a complete inventory. First, the inventory should include commercial sources, such as dentist, supermarkets, restaurants, and automobile repair shops, none of which would be expected to pose a significant risk to the treatment works. Second, the inventory should include commercial and industrial dischargers of less than 25,000 gpd designated by SIC code. Third, the inventory should include "zero-dischargers" that would be categorical if they discharged. Fourth, the industrial users with multiple non-domestic discharges to the

sewers should be identified and permitted by separate discharge points. All of these modifications to the basic definition in 40 CFR 403.3(t) of an SIU are good indications of the successful identification of the potential threats to its treatment works. EPA found none of these modifications to the basic definitions in effect in Yuba City, however, the inventory would include two non-categorical power plants with discharges averaging less than 25,000 gpd once they are reclassified.

5.2 Inventory Classifications

The Yuba City must re-determine which industries qualify as SIUs and re-classify the five of SIUs identified by Yuba City that were found to be misclassified.

- Custom Chrome - Job-shop electroplaters subject to the Federal standards in 40 CFR 413 qualify for regulation under either a full set of regulated pollutants or an abbreviated set depending on the discharge flow rate. If every day of discharge to the sewers is under 10,000 gpd, then the abbreviated set of standards apply for cadmium, lead, cyanide, and toxic organics. If any one day exceeds 10,000 gpd, then the full set of standards apply for cadmium, lead, cyanide, and toxic organics, as well as chromium copper, nickel, silver, and zinc. Yuba City classified Custom Chrome as a job-shop electroplater discharging more than 10,000 gpd. Custom Chrome has show that its average discharges are less than 10,000 gpd. It is not clear that there is not any one day exceeding 10,000 gpd. EPA expects Custom Chrome to qualify as a job-shop electroplater that always discharges less than 10,000 gpd once it documents its daily discharges and reduces flow by instituting on-demand rinsing in response to an EPA Order.

- Calpine Greenleaf Unit 2 - This industry qualifies as an SIU because the highly mineralized nature of its wastewater discharges poses the risks of sewer line disintegration and the pass-through of toxics. Furthermore, its discharges average more than 25,000 gpd. It was misclassified as a steam electric power generating station subject to the Federal standards in 40 CFR 423. It does not qualify because it does not generate any power through steam-driven turbines. The steam electric rule would cover combined-cycle cogeneration plants that use steam-driven turbines to generate power from exhaust heat.

- Calpine Feather River Energy Center - This industry qualifies as an SIU and was misclassified as a steam electric power generating station for the same reasons stated above for Calpine Greenleaf Unit 2.

- Calpine Yuba City Energy Center - This industry qualifies as an SIU and was misclassified as a steam electric power generating station for the same reasons stated above for Calpine Greenleaf Unit 2, except its discharges do not average more than 25,000 gpd.

Section 5 – Industrial User Inventory

- Yuba City Cogeneration - This industry qualifies as an SIU and was misclassified as a steam electric power generating station for the same reasons stated above for Calpine Greenleaf Unit 2, except its discharges do not average more than 25,000 gpd.

- Sunsweet and Franklin Circle K - These are properly classified as non-categorical SIUs.

- Metal-Bearing Discharges - These might include glass polishers, metal finishers, metals formers, radiator shops, water purification facilities, and agricultural-chemical sources. See the discussion in item 2.5 of this report for sources of aluminum, arsenic, copper, iron, manganese, molybdenum, and zinc. Possibles: Chipco Mfg., Transitional Systems Mfg., Cal Classic Custom Trim.

- Other Possibles - These would include any other large dischargers, categoricals, or toxic loaders. Possibles: Paperboard Packaging Corp.

5.3 Zero-Discharging Categorical Industrial Users

Yuba City should institute the good practice of identifying and permitting industrial users that would qualify as categoricals if they discharged their Federally-regulated process-related wastewaters to the sewers. In essence these are the industrial users that comply with their Federal standards by maintaining the steps necessary to prevent the discharge of process-related wastewaters to the sewers. Including zero-discharging CIUs in the inventory ensures the local regulatory control over industrial users who would violate their Clean Water Act requirements and could endanger the operations of the treatment works if they discharged to the sewers.

Section 6

Industrial User Permits

Pretreatment programs are required to issue permits with standards and limits, sampling locations, self-monitoring requirements, and a 5-year or less expiration, as part of ensuring industrial user compliance. 40 CFR 403.8(b,f1iii,f2i).

6.0 Summary

Yuba City has a good permit program and has successfully issued valid permits to all of its identified SIUs. The permits all have standards and limits, self-monitoring requirements, and a 2-year expira-tion, but they do not specify sampling locations nor define what constitutes representative sampling. Permits will have to be re-issued once the local limits are re-determined, the SIU inventory is re-determined, and the Federal standards are re-applied. See item 7.0 for this report for a discussion on representative sampling.

Requirements

- Each permit issued to an SIU must explicitly state all applicable Federal standards, national prohibitions, and local limits, as well as the self-monitoring and reporting requirements, and sampling locations.

Recommendations

- Permits should be issued with the applicable Federal standards and national prohibitions, and then reissued to include the local limits once they are re-determined.
- Each permit issued to an SIU should list all standards, limits, self-monitoring and analytical requirements on one page, and the sampling location(s) on a site map.
- The information in the permit applications as well as any other information gathered to issue the permits, such as statistical analyses of sample representativeness, should be field verified and documented in fact sheets prepared for each SIU.

6.1 Permit Accuracy and Fact Sheets

Yuba City will have to reissue permits with the applicable Federal standards and national prohibit-tions to all of its SIUs, and then reissue them again with local limits once they are re-determined. Fact sheets should be prepared to document the information and decisions behind the permit provisions, such as Federal category, sample point, pollutants of concern, representative sampling, and self-certifications in lieu of self-monitoring.

Section 6 – Industrial User Permits

- Sunsweet - A permit must be reissued to apply the national prohibitions and the local limits, once they are re-determined. The permit should require self-monitoring for all of the local limits as well as any other toxics that identified by Sunsweet under the EPA Order, with a provision to re-open the self-monitoring requirements depending on the results. The national prohibitions should be restated to explicitly prohibit the identified discharges and conditions from Sunsweet that have or could have adversely effected the sewers or the WWTP. See items 2.0 and 2.8 of this report. Sampling protocols set in the permit should reflect the variabilities from plant operations and treatment associated with the defined sample point not only over the sampling day but also over the reporting period.

- Power Plants - The permits for the power plants must be reissued to apply the national prohibitions, to remove the Federal standards for steam electric power stations, and add the local limits, once they are re-determined. The permits should require self-monitoring for all of the local limits, with a provision to re-open the self-monitoring requirements depending on the results. The national prohibitions should be restated to explicitly prohibit the discharges and conditions that could adversely affect the sewers or the WWTP. Sampling protocols set in the permit should reflect the variabilities from plant operations and treatment associated with the defined sample points not only over the sampling day but also over the reporting period. In particular, the permit should address the entire schedule of batch, slug, blowdown, or continuous discharges through the sample point.

- Zero-Discharging CIUs - Zero-discharge permits should be issued to any industries found to comply with Federal categorical pretreatment standards by not discharging Federally-regulated process-related wastewaters. A zero-discharge permit should explicitly prohibit the discharge of the Federally-regulated wastewaters and require the industry to certify every six months to not discharging in lieu of self-monitoring. A zero-discharge permit would strengthen enforcement efforts against the illegal dumping to the sewer because the establishment of violation depends only on whether a discharge occurred and not on surveillance sampling and the difficult arguments surround the representativeness of sampling.

6.2 Permit Clarity

All of the permits issued to the SIUs should clearly communicate the applicable Federal standards, national prohibitions, local limits, sample type, sampling frequency, self-certifications in lieu of self-monitoring, analytical test methods and the associated detection limits, and, if necessary, the flow and production rates behind the Federal standards. All of this information can be presented in table form on a single page of the permit with one line per pollutant. The compliance sampling locations also could be clearly delineated on a site map annotated with a description of the location. Each permit should clearly state the effective duration and the procedures for re-applying.

Section 7

Monitoring, Self-Monitoring and Inspections

Pretreatment programs, as part of ensuring industrial user compliance [40 CFR 403.8(b)], are required to:

- Cause industrial users to self-monitoring at least twice per year unless the program samples for them [40 CFR 403.8(f1iii), 403.12(e1,g10)];
- Inspect industrial users at least once per year;
- Sample industrial users at least once per year if they self-monitor or twice per year if they are not required to self-monitor [40 CFR 403.8(f2v), 403.12(i2,e1,g10)];
- Ensure that all sampling and self-monitoring is representative of the reporting period [40 CFR 403.12(g3)].

7.0 Summary

For the most part, Yuba City successfully obtains self-monitoring as well as performs the inspections and city sampling necessary to determine compliance independent of the information submitted by the SIUs. However, the self-monitoring is not representative over the reporting periods and the sample records do not cover all of the pollutants of concern.

Requirements

- The self-monitoring records for each SIU must be complete in the number and type of

- Yuba City must sample each SIU, including Franklin Circle K, at least once per year.

Recommendations

- Inspection reports should include an analysis that the sampling is representative of both the sampling day and reporting period.

- Inspection reports should document the findings that establish the sewer discharge permit conditions and prompt any necessary revisions or enforcement actions.

- All self-certifications in lieu of self-monitoring should be explicitly stated in the permit.

Section 7 – Monitoring, Self-Monitoring and Inspections

7.1 City Inspections and Sampling

Yuba City performs routine inspections of each SIU once per year and samples them at least once per year since its permits require self-monitoring. Sunsweet is sampled each weekday and the power plants are sampled once per week. The one exception is the contaminated groundwater clean-up site, Franklin Circle K, which is not sampled by the City.

7.2 Self-Monitoring

Frequency and Coverage - The permits require daily self-monitoring for Sunsweet and quarterly self-monitoring for the others. However, the self-monitoring and city monitoring do not cover all of the pollutants of concern (aluminum, arsenic, chloroform, copper, diazinon, iron, lead, manganese, molybdenum, tetrachloroethylene, and zinc), nor the potential pollutants of concern (barium, cadmium, chromium, mercury, nickel, oil & grease, selenium, and MTBE).

Sampling Representativeness - Representative sampling points have been established and known even though they are not specified in the permits. However, the self-monitoring frequencies do not ensure representative sampling over the reporting period because the significant slug, batch and variable discharges, such as spent solutions, blowdowns and regenerants, are not specifically required by the permits to be self-monitored. Both of these findings regarding the representative-ness of sampling were illustrated at each of the SIUs inspected during this inspection.

7.3 Self-Certifications

Self-certifications in lieu of any required self-monitoring for Federal standards or local limits should be explicitly stated in the permits. In particular, the Custom Chrome permit should explicitly state which toxic organic pollutants do not have to be self-monitored if Custom Chrome self-certifies to following a previously submitted and approved toxic organics management plan, as allowed under the Federal job-shop electroplating standards in 40 CFR 413.

Section 8

Enforcement and Compliance Assistance

Pretreatment programs, as part of ensuring industrial user compliance are required to enforce their permits following an enforcement response plan, and to publish annual significant non-compliance lists [40 CFR 403.8(b,f1ii,f2vii,f5)].

8.0 Summary

The Federal regulations do not define how to determine a program's success in enforcing permit limits. However, an evaluation of enforcement and the City's enforcement response plan is premature since the SIU permits need to be revised to include updated local limits, result in representative sampling records, and apply the proper Federal standards.

Requirements

- Approved pretreatment programs are required to develop and follow an enforcement response plan that specifies the actions, and their time frames, that the City will take in response to each type of industrial user permit.

Recommendations

- None.

Figure 1

Yuba City Water Pollution Control Facility
Schematic of the Wastewater Treatment

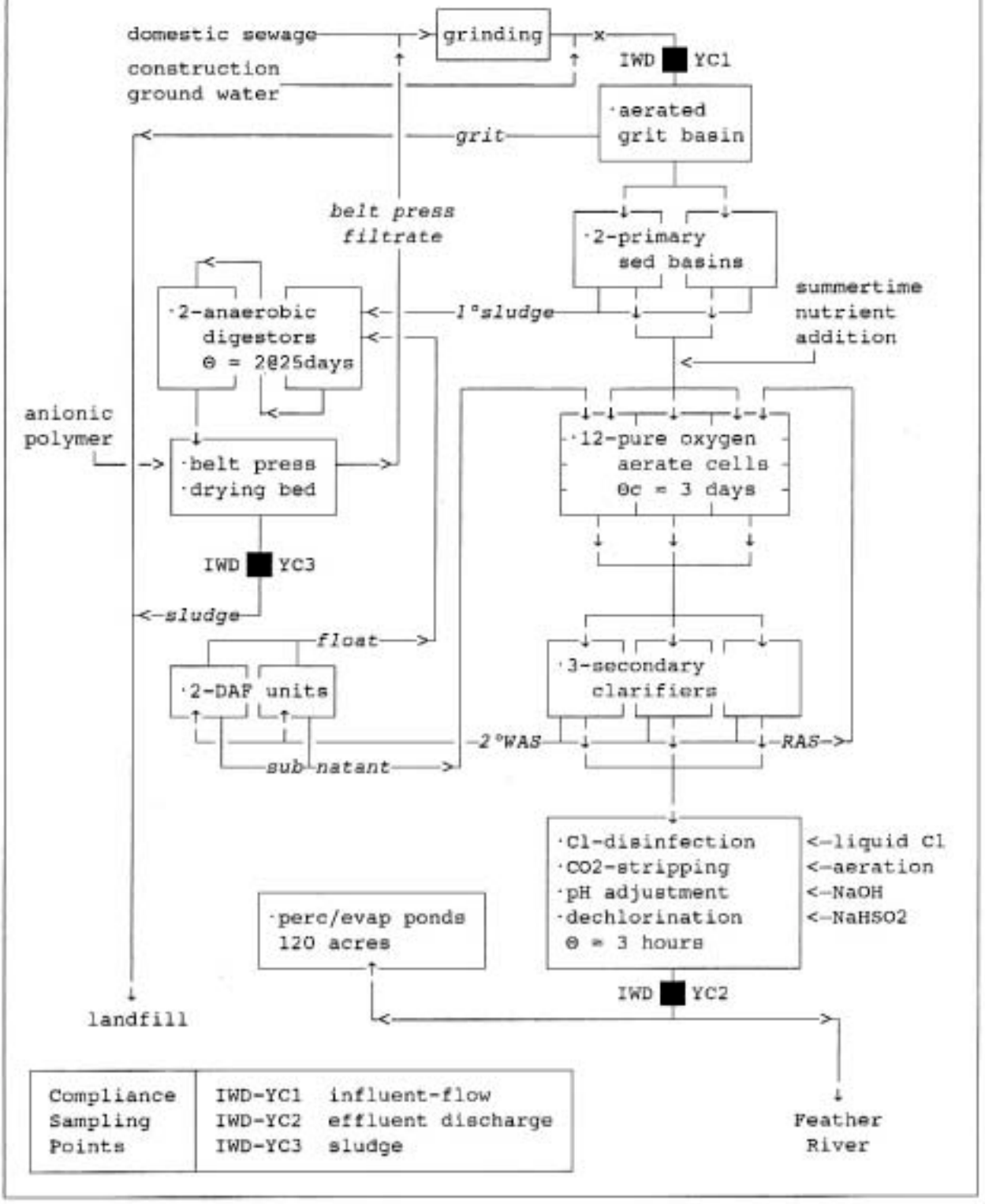

Table 1

Yuba City WWTP Wastewater Quality
Conventionals Pollutants, Nutrients, Other Non-Toxics
Jan-2003 to Jan-2004

Pollutants (mg/l)	influent mean	5th%	99th%	effluent mean	99th%	sample viol rate d-max	avgs	count
flow (mgd)	6.60	5.57	8.05	5.98	-	nr	nr	365
BOD	339.	182.	560.	10.5	21.6	0/101	0/12	101
TSS	190.	103.	312.	8.7	15.4	0/261	0/12	261
*ammonia-N	28.8	12.3	52.1	12.9	36.9	8/34 b/	3/3	34
*nitrates-N	0.28		0.51	0.77	2.00	0/11	nr	11
*phosphates-P	4.73		14.6	3.03	5.02	nr	nr	5
MBAS-surfactants			-	0.25	0.45	0/3	nr	3
TDS			465.	370.	457.	nr	nr	11
alkalinity			-	145.	164.	nr	nr	3
*hardness			92.	119.	78.	nr	nr	7
*hardness @ R-1				15.2	8.78	nr	nr	5
hardness @ FR c/				34.9	22.6	nr	nr	27
*sulfates			15.	22.	44.	nr	nr	4
*chlorides			66.	82.	116.	nr	nr	4
sodium			61.		76.	nr	nr	1
EC (µmhos/cm2)			600.	728.	827.	nr	nr	10

Stat Measures	Median	95%th	99th%	Max	maxs	avgs	count
acute toxicity	pass	pass	pass	pass	0/12	nr	12
pH-min (s.u.)	<6.5 at least 4 times			5.8	≥4	-	cont
pH-max (s.u.)	>8.5 at least once			9.0	≥1	-	cont

* effluent results for salts/nutrients include data from 2000-2002 DMRs
b/ minimum ammonia based on maximum pH of discharges to the river of 7.2 and average temperature during the wet-season of 70°F.
c/ USGS Feather River station at Nicolaus from the 1996-1998 National Water Quality Assessment Program - Sacramento River Basin Study (single sample minimum hardness in entire basin was 18.0 mg/l)
nr no required permit limits
cont continuous pH meter reading

Table 2

Yuba City WWTP Wastewater Quality
Inorganic Toxic Pollutants, Toxic Organics, and Pesticides - Compliance Deadlines Nov 2007
Jan-2000 to Jan-2004

Pollutants (µg/l)	surface a/ mean	99th%	grnd mean	est avgs	influent mean	99th%	effluent b/ mean	99th%	remo vals	sampl viol rate d-max	avgs	count
aluminum	11.6	38.3		11.6	1965	6225	256.	571.	87%	4/4 c/	4/4	10 d/
arsenic	<1.0	<1.0	15.8	2.5	6.1	34.0	7.8	33.5	~0%	-	0/4	14
barium	13.7	18.2	292.	41.5	98.6	257.	19.5	24.1	80%	-	-	6
beryllium	<1.0	<1.0		<1.0	0.3	1.5	0.4	1.7	~0%	-	-	10
cadmium	<1.0	<1.0		<1.0	0.5	1.7	0.2	0.3	68%	0/3 c/	0/3	10
chromium	<1.0	1.1		<1.0	1.2	3.1	0.9	1.1	-	0/1 c/	0/1	11
copper	1.1	2.2		1.1	50.1	90.2	8.5	18.7	83%	4/4 c/	4/4	14 d/
iron	23.6	63.1	40.8	25.3	960.	1476	164.	309.	83%	0/4	-	10 d/
lead	<1.0	<1.0	4.7	1.4		2.7		0.75	-	1/1 c/	1/1	1 d/
manganese	4.8	13.4	71.5	11.5	49.8	130.	53.0	135.4	~0%	3/4	-	5 d/
mercury	0.008	0.030		0.008	0.50	1.37	0.017	0.048	96%	0/4	-	10
molybdenum	<1.0	<1.0		<1.0	10.3	30.8	11.0	31.6	~0%	0/3	-	13 d/
nickel	<1.0	1.0		<1.0	3.7	10.3	1.8	4.0	51%	0/1 c/	0/1	7
selenium	<1.0	<1.0		<1.0	7.2	45.1	7.1	44.7	~0%	-	-	11
silver	<1.0	<1.0		<1.0		0.90		0.32	-	0/1 c/	nr	1
zinc	<1.0	1.9		<1.0	157.	329.	51.8	86.7	67%	4/4 c/	4/4	14 d/
chloroform					9.7	18.5	3.7	18.5	-	1/3	-	3 d/
diazinon							0.12	0.57		1/3	1/3	3 d/
dibromochlorometh							0.21	1.02		0/3	1/3	3 d/
dichlorobromometh							1.62	6.22		1/3	1/3	3 d/
MTBE							0.32	1.24		0/3	-	7
tetrachloroethyle							0.64	1.00		0/3	0/3	3 d/
other tox organx							<0.02	<0.02		0/4	0/4	4

a/ Surface water supply data from USGS Feather River station at Nicolaus - 13 miles downstream.
Ground water supply data from Yuba City water quality report for Hillcrest water users.
Estimated water supply flow-weighted averages based on estimated mix of 1:9 ground to surface water.
b/ Effluent results for toxics include data from 2000-2002 DMRs.
c/ Metals limits based on a calculated 22.6 mg/l minimum hardness at Feather River station at Nicolaus.
d/ See Table 4 for computed statistical probabilities of exceeding limits - otherwise viols no expected.

Table 3

Yuba City WWTP Sludge Quality
Jan-2000 to Jan-2004

Pollutants (mg/kg)	Federal Standards ceiling	reuse	landfill	sample results mean a/b/ 99th%	sample viol d-max	count
arsenic	75	41	73	14.0	nr	1
cadmium	85	39	-	<10.9	nr	2
chromium	-	-	600	28.5	nr	2
copper	4300	1500	-	237.7	nr	2
lead	840	300	-	31.0	nr	1
mercury	57	17	-	1.4	nr	2
molybdenum	75	-	-	<77.0	nr	1
nickel	420	420	420	<59.6	nr	2
selenium	100	100	-	<15.0	nr	1
silver	-	-	-	8.5	nr	2
zinc	7500	2800	-	507.9	nr	2
total toxic metals				829.0		

a/ self-monitoring in 2000-2002 not reported in mg/kg dry-weight nor with moisture content
b/ detection limits in 2003 for arsenic and selenium over standards
nr no requirements because sludge is not land applied or monofilled

Table 4

Yuba City WWTP Wastewater Quality
Computed Statisitcal Probabilties of Exceeding Limits
Jan 2004

daily-max limits (µg/l)	mean	std dev	probability		percent
aluminum	µ = 256.2	σ = 135.1	α(120)	= 0.8433	84%
ammonia (mg/l)	µ = 12.87	σ = 10.32	α(19.7)	= 0.2231	22%
chloroform	µ = 3.670	σ = 6.355	α(1.1)	= 0.6569	66%
#copper	µ = 8.486	σ = 4.395	α(2.65)	= 0.9078	91%
diazinon	µ = 0.120	σ = 0.191	α(0.08)	= 0.5829	58%
#dibromochloromethane	µ = 0.210	σ = 0.347	α(1.1)	= 0.0051	<1%
#dichromobromomethane	µ = 1.620	σ = 1.976	α(1.5)	= 0.5242	52%
iron	µ = 163.8	σ = 62.37	α(300)	= 0.0145	1%
#lead	µ = na	σ = na	α(0.375)	> 0.5000	>50%
manganese	µ = 53.01	σ = 35.36	α(50)	= 0.5339	53%
molybdenum	µ = 11.05	σ = 8.816	α(10)	= 0.5474	55%
pH-lower limit (su.)	µ = na	σ = na	α(6.5)	= 0.0110	1%
pH-upper limit (su.)	µ = na	σ = na	α(8.5)	= 0.0027	<1%
#zinc	µ = 51.77	σ = 14.97	α(34.0)	= 0.8683	87%

month-avg limits (µg/l)	mean	std dev	probability		percent
aluminum	µ = 205.0	σ = 58.02	α(78)	= 0.9857	99%
ammonia (mg/l)	µ = 13.07	σ = 3.912	α(3.56)	= 0.9925	99%
arsenic	µ = 8.870	σ = 9.002	α(10)	= 0.4540	45%
#copper	µ = 7.900	σ = 2.252	α(1.38)	= 0.9980	>99%
diazinon	µ = 0.120	σ = 0.191	α(0.04)	= 0.6623	66%
#dibromochloromethane	µ = 0.210	σ = 0.347	α(0.41)	= 0.2816	28%
#dichromobromomethane	µ = 1.620	σ = 1.976	α(0.56)	= 0.7041	70%
#lead	µ = na	σ = na	α(0.829)	< 0.5000	<50%
#tetrachloroethylene	µ = 0.640	σ = 0.155	α(0.8)	= 0.1510	15%
#zinc	µ = 40.50	σ = 3.786	α(22.3)	= 0.9999	>99%

expected permit limits to be in effect in Nov 2007
minimum hardness of 22.6 mg/l CaCO3 used in metals limits calculations

Table 5

Comparison of Wastewater Quality
Average Concentrations of Toxics Jan-00 to Jan-2004

Influent (µg/l)	Yuba City	Deer Creek	ElDor Hills	Grass Vally	Nevad City	Placr Co#1	Red Bluff	Stock -ton	norm a/
aluminum	**1965**					820.			+0.7
arsenic	**6.1**	<1.0	1.4	<1.0	1.1	<1.0	1.33	4.4	+2.0
barium	98.6								
beryllium	0.3							<0.5	
cadmium	**0.5**	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.4	
chromium	1.2	<5.0	5.5	<1.0	<5.0	<5.0	7.6	**8.0**	-1.4
copper	50.1	83.0	**110.**	45.5	20.0	22.5	26.0	39.0	+0.0
iron	960.	430.	**1600**	510.	1500	1425			-0.2
lead	2.7	<5.0	<5.0	<5.0	5.8	10.4	<5.0	**10.9**	-0.6
manganese	49.8	24.0	**200.**	98.0	46.0	87.0			-0.5
mercury	**0.50**	0.26	0.43	0.26	0.21	<0.2	<0.2	0.30	+1.7
molybdenum	**10.3**							4.6	+0.7
nickel	3.7	3.3	5.5	4.6	3.1	5.1	5.0	**9.1**	-0.6
selenium	**7.2**	1.1	1.4	<1.0	<1.0	<1.0	<1.0	<0.5	+2.4
silver	0.90	1.1	2.5	**3.7**	1.0	1.3	2.86	1.8	-1.0
zinc	157.	120.	160.	**225.**	91.0	110.	77.5	138.	+0.5

Effluent (µg/l)	Yuba City	Deer Creek	ElDora Hills	Grass Valley	Nevada City	Placer Co#1	Red Bluff	Stock -ton	norm a/
aluminum	**256.**	39.0	36.4	26.8	47.1	101.			+2.0
arsenic	**7.75**	0.4	0.50	1.29	1.5	0.43	1.44	3.6	+2.3
barium	**19.5**	4.05	2.02	4.04	9.2	4.82			+1.9
beryllium	**0.44**	0.022	<0.003	<0.1	<0.1	<0.02	<1.0	<0.5	+2.1
cadmium	0.17	<1.0	0.071	0.05	<1.0	0.05	**0.39**	<0.1	+0.2
chromium	0.94	0.34	0.48	0.30	0.30	0.25	1.13	**1.6**	+0.6
copper	8.49	**20.4**	13.7	4.03	2.4	2.00	7.62	5.6	+0.1
iron	**164.**	31.4	8.40	87.1	44.0	79.2			+1.7
lead	**0.75**	0.50	0.061	0.41	0.33	0.73	0.45	<1.0	+0.9
manganese	**53.0**	1.58	2.57	35.9	10.8	34.7			+1.4
mercury	**0.017**	<2.0	0.002	0.005	0.013	0.004	<0.2	<0.2	+1.4
molybdenum	**10.5**							5.1	+0.7
nickel	1.78	**24.0**	3.28	4.15	1.8	2.62	1.55	7.1	-0.5
selenium	**7.10**	<1.0	0.28	0.45	0.3	0.15	0.57	<0.5	+2.5
silver	**0.76**	<1.0	0.006	<0.08	<1.0	0.07	0.34	<0.4	+1.7
zinc	51.8	36.5	22.9	**60.7**	34.5	27.3	53.0	14.8	+0.9

Flow (mgd)	6.60	2.94	1.94	1.75	0.42	1.95	1.35	32.4	

bold highest sampling averages highlighted in bold

a/ calculated norm for Yuba City versus 8-city averages

$$\text{norm} = \frac{(x - \mu)}{\sigma}$$

x = Yuba City average
μ = 8-city averages
σ = 8-city std deviation

Table 6

Sampling Results
City of Yuba City Wastewater Treatment Plant

Sample Number	YC001	YC002	YC003	YC009	YC004
Date	08/27/03	08/27/03	08/27/03	08/27/03	08/27/03
Type	24-hr	24-hr	24-hr	grab	grab
Location	WWTP	WWTP	WWTP	Field	WWTP
Point	Influent	Influent	Effluent	Blank	Sludge
Units	mg/l	mg/l	mg/l	mg/l	mg/kg *
aluminum	1.40	1.40	0.240	<0.010	13000
arsenic	0.0026	0.0028	0.0026	<0.0005	14
cadmium	<0.0010	<0.0010	<0.0010	<0.0010	<7.7
chromium	0.0041	0.0034	0.0012	<0.0010	38
copper	0.028	0.024	0.0056	<0.0020	320
cyanide-total	<0.010	0.020	<0.010	<0.010	
iron	0.76	0.73	0.18	<0.10	8200
lead	0.0026	0.0028	0.0008	<0.0010	31
manganese	0.024	0.023	0.068	<0.0010	940
mercury	0.00032	0.00041	0.00004	<0.00003	2.0
molybdenum	0.010	0.010	0.018	<0.0005	<77
nickel	0.0039	0.0036	0.0039	<0.0010	<77
selenium	0.0007	0.0007	0.0006	<0.0010	<15
silver	0.0009	0.0009	0.0003	<0.0005	12
zinc	0.095	0.094	0.046	<0.005	700
ammonia-N	10	10	5.30	<0.30	
boron	0.170	0.170	0.180	<0.100	
chloride	66	65	99	<1.0	
hardness	92	92	110	<2.3	
nitrate-N	0.51	0.28	1.6	<0.10	
total phosphate-P	3.5 o/	3.5 o/	1.4 o/	<1.0 o/	
sodium	61	61	76	<0.5	
sulfate	14	15	21	<0.5	
TDS	470	460	360	<20	
EC (umohs/cm)	610	590	630	3	
moisture (%)					87%

All samples collected, kept in custody, and delivered to the laboratory by Greg V. Arthur. Samples analyzed by EPA's Richmond Laboratory. Documentation including chain of custody and quality control results are attached.

* dry-weight o/ ortho-phosphate as P

Table 6 (continued)

Sampling Results
City of Yuba City Wastewater Treatment Plant

Sample Number	YC005	YC006	YC008	YC007	
Date	08/20/03	08/20/03	08/20/03	08/21/03	
Type	grab	grab	24-hr	grab	
Location	CustChrm	CustChrm	Greenleaf	Field	
Point	Tank-3	Tank-26	Unit2	Blank	
Units	mg/l	mg/l	mg/l	mg/l	
aluminum	0.032	0.130	3.60	<0.010	
arsenic	0.0003	0.0006	0.0087	<0.0005	
cadmium	<0.0010	0.033	0.0016	<0.0010	
chromium	0.032	0.019	0.047	<0.0010	
copper	0.057	0.063	0.300	<0.0020	
cyanide-total	<0.010	<0.010		<0.010	
iron	0.72	1.70	9.80	<0.100	
lead	0.0006	0.021	0.0044	<0.0010	
manganese	0.001	0.009	0.190	0.0018	
mercury	<0.00003	<0.00003	0.00006	<0.00002	
molybdenum	0.0003	0.0004	2.00	<0.0005	
nickel	2.70	0.080	0.064	<0.0010	
selenium	<0.0010	<0.0010	0.0070	<0.0010	
silver	<0.0005	<0.0005	<0.0005	<0.0005	
zinc	0.023	0.140	0.870	<0.0050	
ammonia-N	<0.30	<0.30	<0.30	<0.30	
boron	0.240	<0.100	0.098	<0.100	
chloride	4.0	5.7		<1.0	
hardness	46	46		<2.3	
nitrate-N	<0.10	0.06		<0.10	
ortho phosphate-P	<1.0 o/	<1.0 o/		<1.0 o/	
sodium	6.9	9.9	1700	<0.500	
sulfate	19	7.9		<0.50	
TDS	93	85		<20	
EC (umohs/cm)	150	140		3	

All samples collected, kept in custody, and delivered to the laboratory by Greg V. Arthur. Samples analyzed by EPA's Richmond Laboratory. Documentation including chain of custody and quality control results are attached.

() invalid result o/ ortho-phosphate as P

Table 7

City of Yuba City Service Area 2004 Inventory
(based solely on EPA observations)

SIGNIFICANT INDUSTRIAL USERS ("SIUs")	FLOW in gpd	PRETREATMENT-IN-PLACE	FEDERAL CATEGORY	BAT
Sunsweet Growers	764485	SCRN PH	non-cat	n/a
Custom Chrome & Bumper	15000	-	413	BAT-
Calpine-Greenleaf #2	47600	PH	non-cat	n/a
Calpine-Feather River EC	50000	PH	non-cat	n/a
Calpine-Yuba City EC	20000	PH	non-cat	n/a
Calpine-Yuba City Cogen	5000	PH	non-cat	n/a
Franklin Circle K	25000	CARBON	non-cat	n/a

Federal Category and Best Available Technology

413	Job-shop Electroplating >10,000 gpd
non-cat	Non-Categorical SIU
BAT	Best-Available-Technology treatment (equivalent to the model treatment used in setting the Federal standards)
BAT+	Exceeds BAT treatment
BAT-	Falls short of BAT treatment
n/a	No applicable Fed standards that are that are based on model treatment

Treatment-In-Place

CARBON	Activated Carbon
PH	pH Adjustment
SCRN	Screening

Table 8

Pretreatment Program Definitions

Pass-Through: A non-domestic discharge which exits the treatment works in quantities or concentrations which, alone or in conjunction with other non-domestic discharges, *is a cause of violation* of any requirement of the NPDES permit, 40 CFR 403.3(n).

Interference: A non-domestic discharge, including excessive or slug loads of conventional pollutants, which inhibits or disrupts the treatment with other non-domestic discharges, inhibits or disrupts the treatment works, its treatment processes or operations, or its sludge processes, use or disposal, *thereby causing a violation* of any requirement of the NPDES permit or any Federal, state or local sludge regulation, 40 CFR 403.3(i).

Local Limits: Specific limits developed and enacted by the local authority, designed to prevent pass-through, interference, sludge contamination, and potential threats to worker health and safety, and to ensure renewed and continued compliance with the NPDES permit or sludge use or disposal practices, 40 CFR 403.5(c).

Significant Industrial User: A non-domestic source that either (1) is subject to Federal categorical pretreatment standards, or (2) discharges an average of more than 25,000 gpd of process wastewater, or (3) makes up more than 5% of the flow or organic capacity of the treatment plant, or (4) is determined by the local authority or State to have a reasonable potential to adversely effect the treatment works, 40 CFR 403.3(t).

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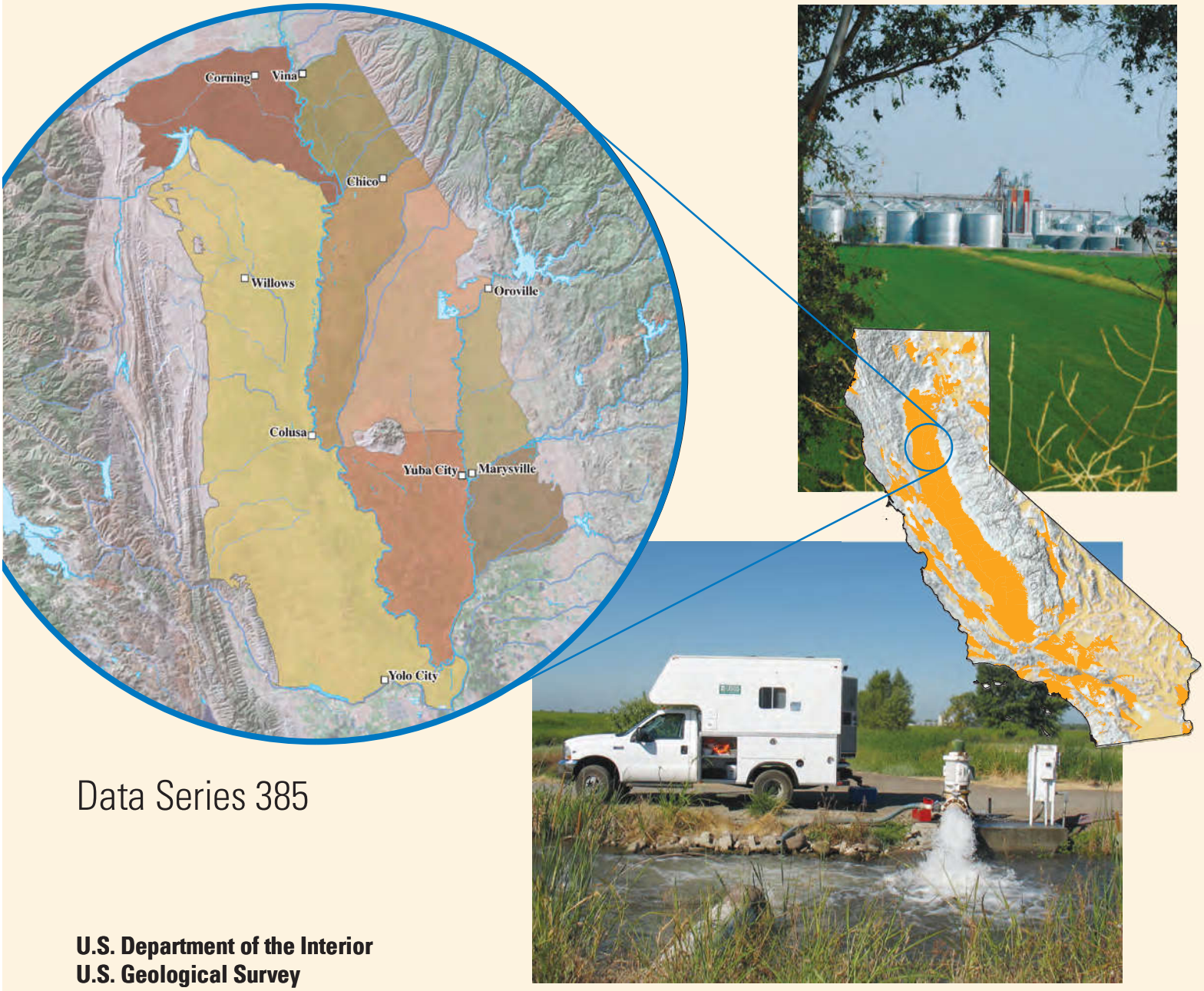
Ground-Water Quality Data in the Middle Sacramento Valley Study Unit, 2006—Results from the California GAMA Program



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Cover Photographs:
Top: Rice field and grain silos in Colusa County, California, July 2008. (Photograph taken by Cathy Munday, U.S. Geological Survey.)
Bottom: Irrigation well in Butte County, California, July 2008. (Photograph taken by Michael Judd, U.S. Geological Survey.)

Ground-Water Quality Data in the Middle Sacramento Valley Study Unit, 2006—Results from the California GAMA Program

By Stephen J. Schmitt, Miranda S. Fram, Barbara J. Milby Dawson, and Kenneth Belitz

Prepared in cooperation with the California State Water Resources Control Board

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Abbreviations and Acronyms

(Additional information or clarification given in parentheses)

AB	Assembly Bill (through the California State Assembly)
AL	action level
AL-US	action level (USEPA)
CAS	Chemical Abstracts Service (American Chemical Society)
CSU	combined standard uncertainty
D	detected
DLR	detection level for the purpose of reporting (CDPH)
E	estimated or having a higher degree of uncertainty
ESAC	East study area of the Middle Sacramento Valley study unit
FP	flow path
GAMA	Groundwater Ambient Monitoring and Assessment (program)
GPS	global positioning system
HAL-US	Lifetime Health Advisory Level (USEPA)
HPLC	high-performance liquid chromatography
IBW	inorganic blank water
LRL	laboratory reporting level
LSD	land-surface datum
LT-MDL	long-term method detection level
MCL	maximum contaminant level
MCL-CA	maximum contaminant level (CDPH)
MCL-US	maximum contaminant level (USEPA)
MDL	method detection limit
MRL	minimum reporting level
MSACV	Middle Sacramento Valley study unit
MU	method uncertainty
N	normal (1-gram-equivalent per liter of solution)
na	not available
NAWQA	National Water Quality Assessment (USGS)
nc	sample not collected
NL	notification level
NL-CA	California notification level (CDPH)
NRP	National Research Program (USGS)
NWIS	National Water Information System (USGS)
P	probability
PCFF-GAMA	Personal Computer Field Forms program designed for GAMA sampling
pK	logarithm of the reciprocal of the equilibrium constant for a specified reaction under specific conditions
QC	quality control
RICE	rice agriculture
RPD	relative percent difference
RSD	relative standard deviation
RSD5	risk-specific dose at 10^{-5}

Abbreviations and Acronyms—Continued

RSD5-US	risk-specific dose at 10^{-5} (USEPA)
SMCL	secondary maximum contaminant level
SMCL-CA	secondary maximum contaminant level (CDPH)
SMCL-US	secondary maximum contaminant level (USEPA)
SSMDC	sample-specific minimum detectable concentration
TT	treatment technique
TT-US	treatment technique (USEPA)
U.S.	United States
V	analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results
VBW	VOC-free (nitrogen-purged) blank water
VPDB	Vienna Peedee Belemnite (the international reference standard for carbon isotopes)
VSMOW	Vienna Standard Mean Ocean Water (an isotopic water standard defined in 1968 by the International Atomic Energy Agency)
WSAC	West study area of the Middle Sacramento Valley study unit

Organizations

CDPH	California Department of Public Health (formerly the California Department of Health Services until July 1, 2007)
LLNL	Lawrence Livermore National Laboratory
MWH	Montgomery Watson Harza (laboratory)
NELAP	National Environmental Laboratory Accreditation Program
NWQL	National Water Quality Laboratory (USGS)
SWRCB	State Water Resources Control Board (California)
TML	Trace Metal Laboratory (USGS)
USEPA	U.S. Environmental Protection Agency
USGS	U. S. Geological Survey

Selected Chemical Names

$CaCO_3$	calcium carbonate
CO_3^{-2}	carbonate
DOC	dissolved organic carbon
HCl	hydrochloric acid
HCO_3^-	bicarbonate
MTBE	methyl *tert*-butyl ether
NDMA	*N*-Nitrosodimethylamine
1,2,3-TCP	1,2,3-trichloropropane
TDS	total dissolved solids
THM	trihalomethane
VOC	volatile organic compound

Abbreviations and Acronyms—Continued

Units of Measurement

ft	foot (feet)
in.	inch
L	liter
mg	milligram
mg/L	milligrams per liter (parts per million)
mi	mile
mL	milliliter
mm of Hg	millimeters of mercury
µg/L	micrograms per liter (parts per billion)
µL	microliter
µm	micrometer
NTU	nephelometric turbidity units
pCi/L	picocuries per liter
per mil	parts per thousand
$\delta^{i}E$	standard delta notation, the ratio of a heavier isotope of an element (^{i}E) to the more common lighter isotope of that element, relative to a standard reference material, expressed in per mil

Notes

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is equivalent to parts per million (ppm) and micrograms per liter is equivalent to parts per billion (ppb).

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Ground-Water Quality Data in the Middle Sacramento Valley Study Unit, 2006—Results from the California GAMA Program

By Stephen J. Schmitt, Miranda S. Fram, Barbara J. Milby Dawson, and Kenneth Belitz

Abstract

Ground-water quality in the approximately 3,340 mi^2 Middle Sacramento Valley study unit (MSACV) was investigated from June through September, 2006, as part of the California Groundwater Ambient Monitoring and Assessment (GAMA) program. The GAMA Priority Basin Assessment project was developed in response to the Groundwater Quality Monitoring Act of 2001 and is being conducted by the U.S. Geological Survey (USGS) in cooperation with the California State Water Resources Control Board (SWRCB).

The Middle Sacramento Valley study was designed to provide a spatially unbiased assessment of raw ground-water quality within MSACV, as well as a statistically consistent basis for comparing water quality throughout California. Samples were collected from 108 wells in Butte, Colusa, Glenn, Sutter, Tehama, Yolo, and Yuba Counties. Seventy-one wells were selected using a randomized grid-based method to provide statistical representation of the study unit (grid wells), 15 wells were selected to evaluate changes in water chemistry along ground-water flow paths (flow-path wells), and 22 were shallow monitoring wells selected to assess the effects of rice agriculture, a major land use in the study unit, on ground-water chemistry (RICE wells).

The ground-water samples were analyzed for a large number of synthetic organic constituents (volatile organic compounds [VOCs], gasoline oxygenates and degradates, pesticides and pesticide degradates, and pharmaceutical compounds), constituents of special interest (perchlorate, *N*-nitrosodimethylamine [NDMA], and 1,2,3-trichloropropane [1,2,3-TCP]), inorganic constituents (nutrients, major and minor ions, and trace elements), radioactive constituents, and microbial indicators. Naturally occurring isotopes (tritium, and carbon-14, and stable isotopes of hydrogen, oxygen, nitrogen, and carbon), and dissolved noble gases also were measured to help identify the sources and ages of the sampled ground water.

Quality-control samples (blanks, replicates, laboratory matrix spikes) were collected at approximately 10 percent of the wells, and the results for these samples were used to evaluate the quality of the data for the ground-water samples. Field blanks rarely contained detectable concentrations of any constituent, suggesting that contamination was not a noticeable source of bias in the data for the ground-water samples. Differences between replicate samples were within acceptable ranges, indicating acceptably low variability. Matrix spike recoveries were within acceptable ranges for most constituents.

This study did not attempt to evaluate the quality of water delivered to consumers; after withdrawal from the ground, water typically is treated, disinfected, or blended with other waters to maintain acceptable water quality. Regulatory thresholds apply to treated water that is served to the consumer, not to raw ground water. However, to provide some context for the results, concentrations of constituents measured in the raw ground water were compared with health-based thresholds established by the U.S. Environmental Protection Agency (USEPA) and California Department of Public Health (CDPH) and thresholds established for aesthetic concerns (secondary maximum contaminant levels, SMCL-CA) by CDPH. Comparisons between data collected for this study and drinking-water thresholds are for illustrative purposes only and are not indicative of compliance or noncompliance with regulatory thresholds.

Most constituents that were detected in ground-water samples were found at concentrations below drinking-water thresholds. VOCs were detected in less than one-third and pesticides and pesticide degradates in just over one-half of the grid wells, and all detections of these constituents in samples from all wells of the MSACV study unit were below health-based thresholds. All detections of trace elements in samples from MSACV grid wells were below health-based thresholds, with the exceptions of arsenic and boron.

Arsenic concentrations were above the USEPA maximum contaminant level (MCL-US) threshold in eight grid wells, and boron concentrations were above the CDPH notification level (NL-CA) in two grid wells. Arsenic was detected above the MCL-US in two flow-path wells. Arsenic, barium, boron, molybdenum, strontium, and vanadium were detected above health-based thresholds in a few of the RICE wells; these wells are not used to supply drinking water. All detections of radioactive constituents were below health-based thresholds, although six samples had activities of radon-222 above the lower proposed MCL-US threshold. Most of the samples from the MSACV wells had concentrations of major elements, total dissolved solids, and trace elements below the non-enforceable thresholds set for aesthetic concerns. Chloride and sulfate concentrations exceeded SMCL-CA thresholds in two and one grid well, respectively. Iron, manganese, and total dissolved solids concentrations were above the SMCL-CA thresholds in 1, 12, and 6 grid wells, respectively. Nitrate (nitrite plus nitrate, as dissolved nitrogen) concentrations from two grid wells were above the MCL-US threshold. There were no detections of microbial indicators in MSACV.

Introduction

Ground water comprises nearly half of the public water supply used in California (Hutson and others, 2004). To assess the quality of ground water from public-supply wells and establish a program for monitoring trends in ground-water quality, the California State Water Resource Control Board (SWRCB), in collaboration with the U.S. Geological Survey (USGS) and Lawrence Livermore National Laboratory (LLNL), implemented a statewide Groundwater Ambient and Monitoring and Assessment (GAMA) program (http://www.waterboards.ca.gov/gama). The GAMA program consists of three projects: Priority Basin Assessment, conducted by the USGS (http://ca.water.usgs.gov/gama/); Voluntary Domestic Well Assessment, conducted by the SWRCB; and Special Studies, conducted by LLNL.

The SWRCB initiated the GAMA Priority Basin Assessment project in response to the Ground-Water Quality Monitoring Act of 2001 (Sections 10780–10782.3 of the California Water Code, Assembly Bill 599). AB 599 is a public mandate to assess and monitor the quality of ground water used as public supply for municipalities in California. The project is a comprehensive assessment of statewide ground-water quality designed to help better understand and identify risks to ground-water resources and to increase the availability of information about ground-water quality to the public. As part of the AB 599 process, the USGS, in collaboration with the SWRCB, developed the monitoring plan for the project (Belitz and others, 2003; State Water Resources Control Board, 2003). Key aspects of the project are interagency collaboration and cooperation with local water agencies and well owners. Local participation in the project is entirely voluntary.

The GAMA Priority Basin Assessment project is unique in California because the data collected during the study include analyses for an extensive number of chemical constituents at very low concentrations—analyses that are not normally available. A broader understanding of ground-water composition will be especially useful for providing an early indication of changes in water quality and for identifying the natural and human factors affecting water quality. Additionally, the GAMA Priority Basin Assessment project will analyze a broader suite of constituents than required by the California Department of Public Health (CDPH, formerly the California Department of Health Services). An understanding of the occurrence and distribution of these constituents is important for the long-term management and protection of ground-water resources.

The range of hydrologic, geologic, and climatic conditions that exist in California must be considered in an assessment of ground-water quality. Belitz, and others (2003) partitioned the state into 10 hydrogeologic provinces, each with distinctive hydrologic, geologic, and climatic characteristics (fig. 1), and representative regions in all 10 provinces were included in the project design. Eighty percent of California's approximately 16,000 public-supply wells are located in ground-water basins within these hydrologic provinces. These ground-water basins, defined by the California Department of Water Resources, generally consist of relatively permeable, unconsolidated deposits of alluvial or volcanic origin (California Department of Water Resources, 2003). Ground-water basins were prioritized for sampling on the basis of the number of public-supply wells in the basin, with secondary consideration given to municipal ground-water use, agricultural pumping, the number of leaking underground fuel tanks, and pesticide applications within the basins (Belitz, and others, 2003). In addition, some ground-water basins or groups of adjacent similar basins with relatively few public-supply wells were assigned high priority so that all hydrogeologic provinces would be represented in the subset of basins sampled. The 116 priority basins were grouped into 35 study units. Some areas not in the defined ground-water basins were included in several of the study units to achieve representation of the 20 percent of public-supply wells not located in the ground-water basins.



Figure 1. The hydrogeologic provinces of California and the location of the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study unit (black area).

Three types of water-quality assessments are being conducted with the data collected in each study unit: (1) Status: assessment of the current quality of the ground-water resource, (2) Trends: detection of changes in ground-water quality, and (3) Understanding: identification of the natural and human factors affecting ground-water quality (Kulongoski and Belitz, 2004). This report is one of a series of status reports presenting water-quality data collected in each study unit; previous reports in this series include Wright and others (2005), Kulongoski and others (2006), Bennett and others (2006), Fram and Belitz (2007), Dawson and others (2008), and Kulongoski and Belitz (2007). Subsequent GAMA reports will address the trends and understanding aspects of the water-quality assessments.

The Middle Sacramento Valley GAMA study unit, hereinafter referred to as "MSACV," lies in the Central Valley hydrogeologic province (Belitz and others, 2003). MSACV contains eight subbasins of the Sacramento Valley ground-water basin (California Department of Water Resources, 2003) (fig. 2). MSACV was considered high priority for sampling because of the number of public-supply wells, basin area, number of sections with pesticide applications, and the amount of agricultural pumping (Belitz and others, 2003).

Purpose and Scope

The purposes of this report are: (1) to describe the study design and study methods; (2) to present the sampling, analytical, and quality assurance methods used during the study; (3) to present the results of quality-control (QC) tests; and (4) to present the analytical results for ground-water samples collected in MSACV.

Ground-water samples were analyzed for organic, inorganic, and microbial constituents, field parameters, and chemical tracers. The chemical and microbial data presented in this report were evaluated by comparison with state and federal drinking-water regulatory thresholds and other health-based standards that are applied to treated drinking water. Regulatory thresholds considered for this report are those established by the U.S. Environmental Protection Agency (USEPA) and the California Department of Public Health (CDPH) (U.S. Environmental Protection Agency, 2008a, 2008b, 2008c; California Department of Public Health, 2008a, 2008b).

The data presented in this report are intended to characterize the quality of untreated ground-water resources within the study unit, not the treated drinking water delivered to consumers by water purveyors. Discussions of the factors that influence the distribution and occurrence of the constituents detected in ground-water samples will be the subject of subsequent publications.

Acknowledgments

The authors thank the following cooperating agencies for their support: the State Water Resources Control Board (SWRCB), California Department of Public Health, California Department of Water Resources, and Lawrence Livermore National Laboratory. We especially thank the well owners and water purveyors for their generosity in allowing the U.S. Geological Survey (USGS) to collect samples from their wells. Three reviewers, Jan Stepek (SWRCB), George Bennett (USGS), and Jacob Fleck (USGS) provided comments to improve this report. Funding for this work was provided by state bonds authorized by Proposition 50 and administered by the SWRCB.

Hydrogeologic Setting

Knowledge of the hydrogeologic setting is important in the design of a ground-water-quality investigation. MSACV lies within the Central Valley hydrogeologic province of California and covers approximately 3,340 mi^2 in Butte, Colusa, Glenn, Sutter, Tehama, Yolo, and Yuba Counties (fig. 2). The long axis of the study unit trends north-south for a distance of approximately 90 mi along the Sacramento River, and the short axis is approximately 40 mi long and corresponds to the width of the Central Valley between the Coast Ranges to the west and the Sierra Nevada to the east (fig. 2). MSACV contains eight subbasins of the Sacramento Valley ground-water basin (California Department of Water Resources, 2003) (fig. 2). For the purposes of this study, these eight subbasins were grouped into the East and West study areas, separated by the Sacramento River (fig. 3). The East study area includes the subbasins of Vina, West Butte, East Butte, North Yuba, South Yuba, and Sutter, whereas the West study area includes the Colusa and Corning subbasins.

The main water-bearing deposits of MSACV are primarily composed of continental and marine sediments overlying the consolidated Sierra Nevada block (California Department of Water Resources, 2003). These recent Quaternary (Holocene) to Late Tertiary (Miocene) deposits have a cumulative thickness of several hundred feet near the foothills of the Coast Ranges and Sierra Nevada and deepen to approximately 2,000 ft near the valley center. Sources of ground-water recharge include deep infiltration of precipitation, river and stream flow, and agricultural irrigation return flow.

The primary surface-water features of MSACV include the Sacramento River and smaller rivers and their principal tributaries. The rivers and tributaries include Stony Creek and Cache Creek in the West study area, and Butte Creek, the Feather, Yuba, and Bear Rivers in the East study area (fig. 2).

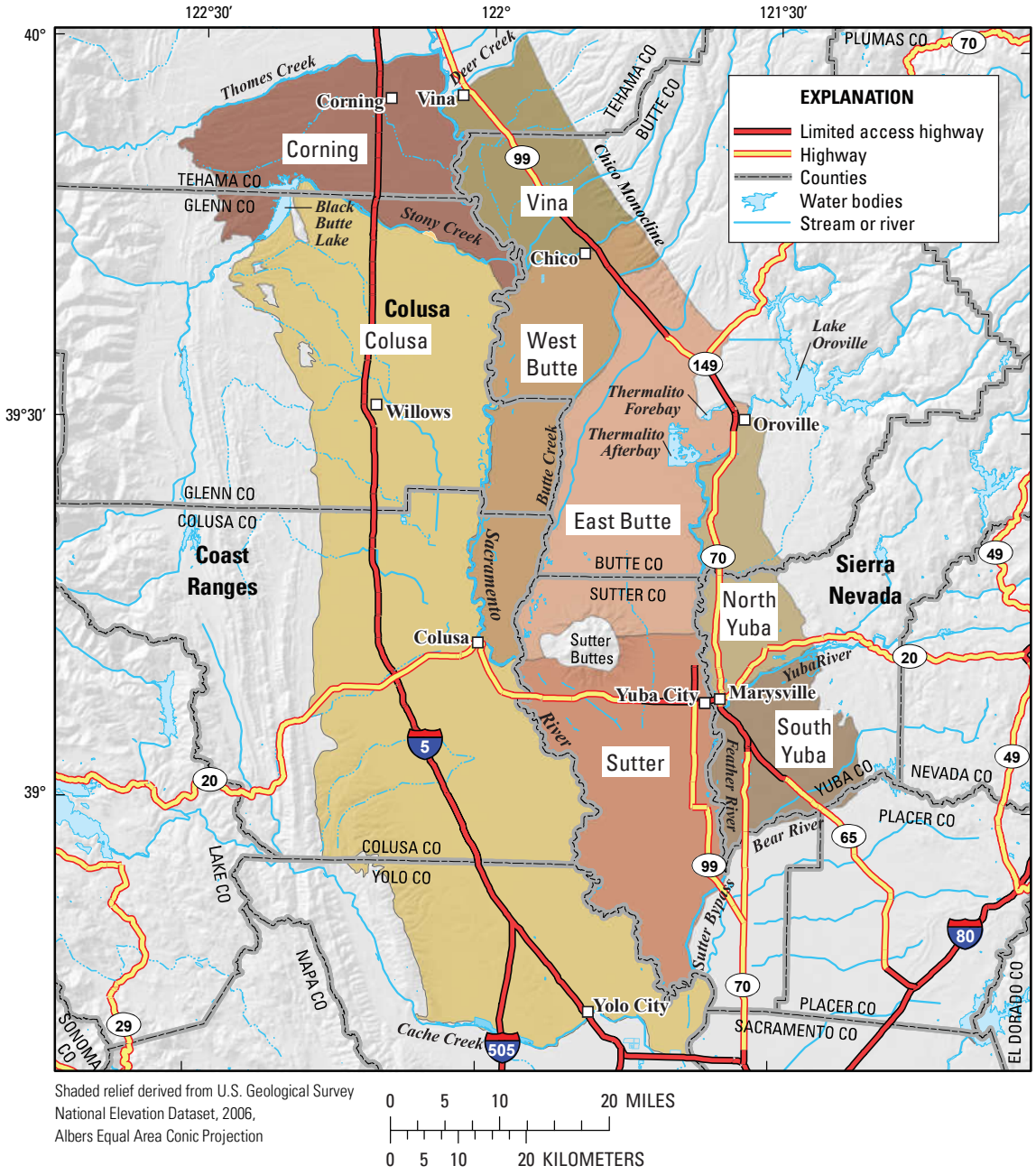

Figure 2. The Middle Sacramento Groundwater Ambient Monitoring and Assessment (GAMA) study unit showing the California Department of Water Resources defined ground-water basins and major hydrologic features within the study unit.

West Study Area—Corning and Colusa Subbasins

The West study area is bounded to the north by Thomes Creek, to the south by Cache Creek, to the west by the Coastal Ranges, and to the east by the Sacramento River (fig. 3). It covers an area of approximately 1,756 mi^2 and includes parts of Colusa, Glenn, Tehama, and Yolo Counties (California Department of Water Resources, 2003). The average annual precipitation ranges from 17 to 27 in., increasing to the north and west. The main water-bearing aquifer within this study area is the Tehama formation (Pliocene). The formation consists of unconsolidated to moderately consolidated coarse- and fine-grained sediments, indicative of floodplain deposits. The Tehama formation is up to 2,000 ft thick and varies in depth from a few feet to several hundred feet below the land surface with depth generally increasing to the east. The Tehama formation is confined by the Tertiary-age Tuscan formation, which contains low permeability lahar layers (California Department of Water Resources, 2003).

East Study Area—Vina, W. Butte, E. Butte, N. Yuba, S. Yuba, and Sutter Subbasins

The East study area is bounded to the north by Deer Creek, to the south by Sutter Bypass and Bear River, to the west by the Sacramento River, and to the east by the Chico Monocline and the Sierra Nevada (fig. 3). It covers an area of approximately 1,584 mi^2 and includes parts of Butte, Colusa, Glenn, Sutter, Tehama and Yuba Counties (California Department of Water Resources, 2003). The average annual precipitation is 17 to 32 in., with increasing rainfall to the north and east. Aquifers within this study area are composed of Tertiary to late Quaternary age deposits, with the younger Quaternary deposits typically representing the unconfined portion of the aquifer system. The Quaternary portion of the aquifer system is largely composed of unconsolidated gravel, sand, silt, and clay stream channel and alluvial fan deposits. South and east of the Sutter Buttes, the deposits contain Pleistocene alluvium, which is composed of loosely compacted silts, sands, and gravels that are moderately permeable; however, nearly impermeable hardpans and claypans do exist in this deposit, which restrict the vertical movement of ground water. The confined portion of the aquifer system includes the Tertiary-age Tuscan and Laguna formations. The Tuscan formation consists of volcanic mudflows, tuff breccia, tuffaceous sandstone, and volcanic ash deposits up to 1,250 ft thick. The Laguna formation consists of moderately consolidated and poorly to well cemented interbedded alluvial sand, gravel, and silt with a low permeability, overall (California Department of Water Resources, 2003).

Methods

The methods used for the GAMA program were selected to achieve the following objectives: (1) design a sampling plan suitable for statistical analysis, (2) collect samples in a consistent manner, (3) analyze samples using proven and reliable laboratory methods, (4) assure the quality of the ground-water data, and (5) maintain data securely and with relevant documentation.

Study Design

The wells selected for sampling in this study reflect the combination of two well selection strategies. Seventy-one wells were selected to provide a statistically unbiased, spatially distributed assessment of the quality of ground-water resources used for public drinking-water supply (fig. 3), and 37 additional wells were selected to provide greater sampling density in several areas to address specific ground-water quality issues in the study unit (fig. 4).

The spatially distributed wells were selected using a randomized grid-based method (Scott, 1990). Each of the study areas was subdivided into grid cells that were 38.6 mi^2 (100 km^2) in area. This grid-cell size met GAMA objectives for the Central Valley hydrogeologic province of a sampling density of at least one well per 38.6 mi^2 and having at least 10 grid cells per study area. For this assessment, the East study area was divided into 41 grid cells and the West study area into 46 grid cells.

Seventy-one of the 87 grid cells in MSACV contained wells that could be sampled; the other 16 grid cells did not contain accessible wells. If a grid cell contained more than one public-supply well, each well was randomly assigned a rank. The highest ranking well that met basic sampling criteria (for example, sampling point prior to treatment, capability to pump for several hours, and available well-construction information), and for which permission to sample could be obtained was then sampled. If a grid cell contained no accessible public-supply wells, domestic and irrigation wells were considered for sampling. An attempt was made to select domestic and irrigation wells with depths and screened intervals similar to those in public-supply wells in the area. Wells sampled as part of the randomized grid-cell network are hereinafter referred to as “grid wells.” Grid wells sampled in MSACV were numbered in the order of sample collection, with the following prefixes that are based on study area: “ESAC” for the East study area of the Middle Sacramento Valley study unit, and “WSAC” for the West study area of the Middle Sacramento Valley study unit.

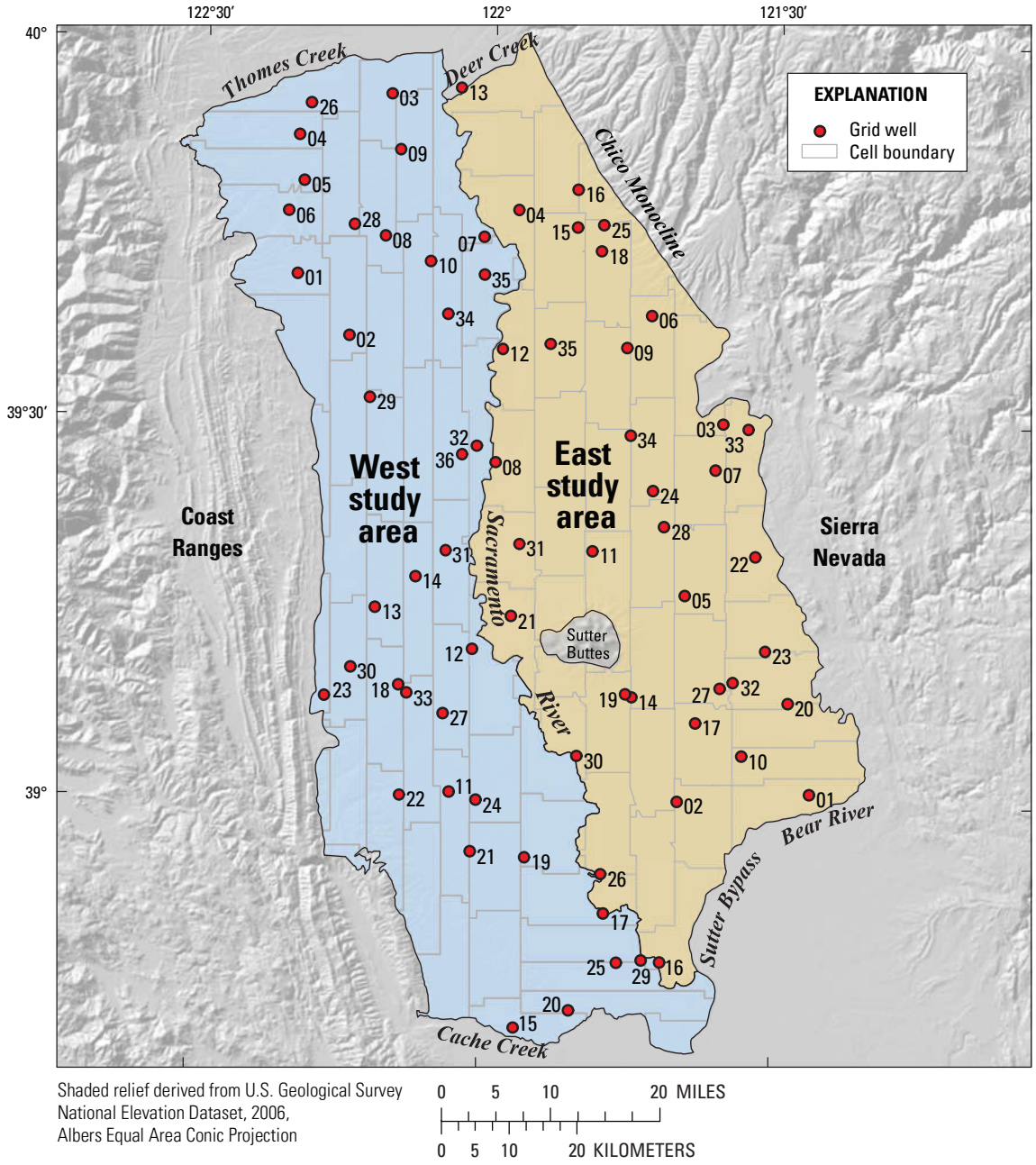

Figure 3. The East and West study areas of the Middle Sacramento Groundwater Ambient Monitoring and Assessment (GAMA) study unit showing the distribution of study area grids cells, the locations of sampled grid cell wells, and the study area boundaries.

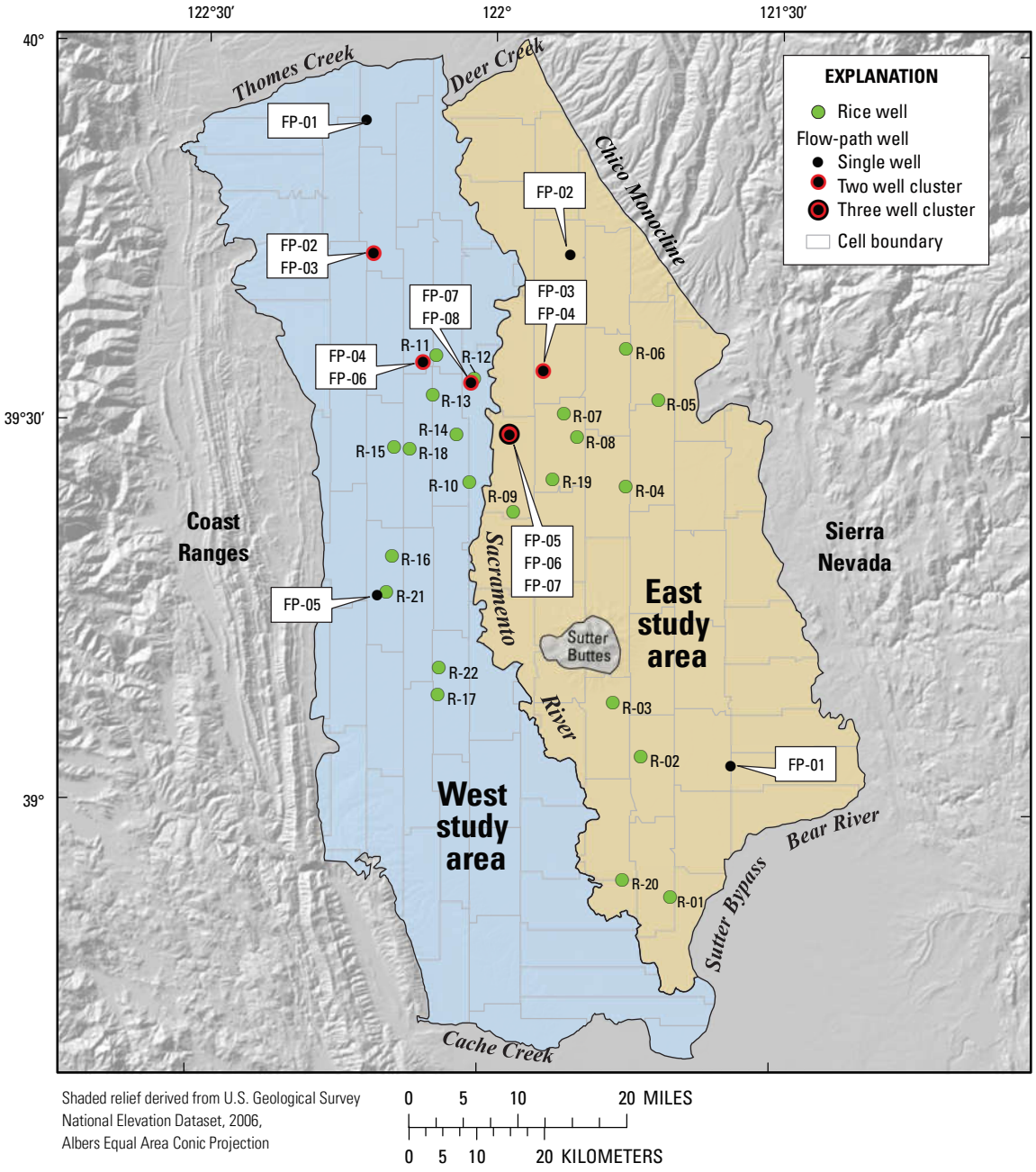

Figure 4. The East and West study areas of the Middle Sacramento Groundwater Ambient Monitoring and Assessment (GAMA) study unit showing the distribution of study area grid cells, the locations of sampled flow-path (FP) and RICE (R) wells (RICE wells are part of a well network monitoring the shallow ground-water quality associated with rice agriculture), and the study area boundaries.

In addition to the 71 grid wells, two types of nonrandomized wells were sampled in the East and West study areas. The first type of nonrandomized wells included 15 wells to evaluate changes in water chemistry along ground-water flow paths; these wells are referred to as "flow-path wells." Flow-path wells were numbered in the order of sample collection, with the prefixes ESAC-FP for wells in the East Sacramento Valley study area and WSAC-FP for wells in the West Sacramento Valley study area. The second type of nonrandomized wells consisted of 22 shallow monitoring wells selected to assess the effects of rice agriculture, a major land-use in the study unit, on shallow ground-water chemistry. In 1997, the USGS installed and sampled a set of monitoring wells in rice-growing areas of the Sacramento Valley as part of the National Water-Quality Assessment Program (Milby Dawson, 2001). Many of those monitoring wells are in the MSACV area and were resampled as part of this study. The monitoring wells are numbered in the order of sample collection with the prefix "RICE." Flow-path wells and RICE wells sampled as part of this study for better understanding were not included in the statistical characterization of water quality in MSACV, as the inclusion of these wells would have caused overrepresentation of certain grid wells and of shallow ground water.

Table 1 provides the GAMA alphanumeric identification number for each well, along with the date sampled, sampling schedule, well elevation, and well-construction information.

Well locations and identifications were verified using a global positioning system (GPS) receiver, 1:24,000 scale USGS topographic maps, comparison with existing well information in USGS and CDPH databases, and information provided by well owners. Drillers' logs for wells were obtained when available. Well information was recorded by hand on field sheets and electronically using specialized software on field laptop computers. All information was verified and then uploaded into the USGS's National Water Information System (NWIS). Well owner information is confidential. Well location information and all chemical data are currently inaccessible from NWIS's public website.

The wells in MSACV were sampled using a tiered analytical approach. All wells were sampled for a standard set of constituents, including field water-quality indicators, volatile organic compounds (VOCs), pesticides and pesticide degradates, perchlorate, stable isotopes of water, and dissolved noble gases and tritium and helium age dates. The standard set of constituents was termed the fast schedule (table 2). Wells on the intermediate schedule were sampled for all the constituents on the fast schedule, plus pharmaceuticals, *N*-nitrosodimethylamine (NDMA), 1,2,3-trichloropropane (1,2,3-TCP), nutrients, stable isotopes of oxygen and nitrogen in nitrate, major and minor ions, trace elements, species of arsenic, iron, and chromium, and carbon isotopes. Wells on the slow schedule were sampled for all the constituents on the intermediate schedule, plus dissolved organic carbon, radium 226/228, radon-222, gross alpha and beta radiation, coliform, coliphage, alkalinity, and turbidity (table 2). Fast, intermediate, and slow refer to the time required to sample the well for all the analytes on the schedule. Generally, one slow, two intermediate, or three fast wells could be sampled in one day. RICE wells were sampled on a modified intermediate schedule. In MSACV, 26 wells were sampled on the fast schedule, 52 were sampled on the intermediate schedule, 8 on the slow schedule, and 22 on the RICE monitoring-well schedule (table 2).

Sample Collection and Analysis

Samples were collected in accordance with the protocols established by the USGS's National Water Quality Assessment (NAWQA) program (Koterba and others, 1995) and the National Field Manual (U.S. Geological Survey, variously dated). These sampling protocols ensure that a representative sample of ground water is collected at each site, and that the samples are collected and handled in a way that minimizes the potential for contamination. The methods used for sample collection are described in the Appendix section "Sample Collection and Analysis."

Tables 3A–L list the compounds analyzed in each constituent class. Raw (untreated) ground-water samples were analyzed for 85 VOCs (table 3A) and 8 gasoline additives (table 3B), 135 pesticide and pesticide degradates (tables 3C, 3D), 14 pharmaceutical compounds (table 3E), 3 constituents of special interest (table 3F), 5 nutrients and dissolved organic carbon (table 3G), 10 major and minor ions and total dissolved solids (table 3H), 25 trace elements (table 3H), 6 species of arsenic, iron, and chromium (table 3I), 5 stable isotope ratios and 7 radioactive constituents, tritium, and carbon-14 (table 3J), 5 dissolved noble gases, helium stable isotope ratios, and tritium (table 3K), and 4 microbial constituents (table 3L). The methods used for sample analysis are described in the Appendix section "Sample Collection and Analysis."

Data Reporting

The methods and conventions used for reporting the data are described in the Appendix. Thirteen constituents analyzed in this study were measured by more than one method at the USGS's National Water Quality Laboratory (NWQL), but only the results from the preferred method for each of the constituents are reported. Arsenic, iron, and chromium concentrations, and tritium activities were analyzed by more than one laboratory, and both sets of results are reported.

Quality Assurance

The protocols used for this study are those used by the NAWQA program (U.S. Geological Survey, variously dated; Koterba and others, 1995), and the quality assurance protocols are described in the NWQL quality assurance plan (Maloney, 2005; Pirkey and Glodt, 1998). QC samples collected in the MSACV study include source-solution blanks, field blanks, replicates, and matrix and surrogate spikes. QC samples were collected to evaluate contamination, bias, and variability of the water-quality data that may have resulted from sample collection, processing, storage, transportation, and laboratory analysis. Quality-assurance methods and results are described in the Appendix section "Quality Assurance."

Water-Quality Results

Quality-Control Sample Results

Results of QC analyses (blanks, replicates, matrix spikes, and surrogates) were used to evaluate the quality of the data for the ground-water samples (see Appendix). Assessment of the QC data from blanks resulted in some ground-water samples being censored, as indicated with "V" codes in tables 5–14. Of the 300 constituents analyzed, 35 were detected in at least one field blank. For 15 of these constituents, concentrations detected in the field blanks were below the lowest concentration detected in ground-water samples, or the constituent was not detected in ground-water samples; thus, no data were affected. Some reported detections for five organic constituents in ground-water samples were flagged as potentially contaminated, and, therefore, were not considered as detections for ground-water quality assessment. Some low concentration detections of 12 inorganic constituents were flagged because contamination may have raised the concentrations sufficiently to have changed a nondetection into a low-level detection relative to the stated reporting limit.

Data from replicates indicate that variability between measurements generally was low, with relative standard deviations (RSD) below 5 percent for most replicate pairs for most constituents. Of the 30 pairs with RSDs above the acceptable limit of 20 percent, 29 had data that were estimated concentrations at or below the laboratory reporting level (LRL) for the constituent analyzed. At these low concentrations, small differences in the measured values in the replicate pairs account for the large RSDs. These results from the replicates confirm that the procedures used to collect and analyze the samples were consistent.

Median matrix-spike recoveries for 35 of the 232 constituents analyzed were lower than the acceptable limits, which may indicate that these constituents might not have been detected in some samples if they were present at very low concentrations.

More than 90 percent of the samples analyzed with surrogates had surrogate recoveries within acceptable limits. The QC results are described in the Appendix section "Quality-Control Sample Results."

Comparison Thresholds

Concentrations in ground-water samples were compared with CDPH and USEPA drinking-water health-based thresholds. Concentrations were also compared with thresholds established for aesthetics—secondary maximum contaminant levels (SMCLs) (California Department of Health Services, 2007a; California Department of Public Health, 2008a, 2008b; U.S. Environmental Protection Agency, 2006, 2008a, 2008b, 2008c). CDPH became the California Department of Health Services (CDHS) on July 1, 2007. The chemical and microbial data presented in this report are meant to characterize the quality of the untreated ground-water resources within MSACV, and are not intended to represent the treated drinking water delivered to consumers by water purveyors. The chemical and microbial composition of treated drinking water may differ from untreated ground water because treated drinking water may be subjected to disinfection, filtration, mixing with other waters, and exposure to the atmosphere prior to its delivery to consumers.

The following thresholds were used for comparisons:

MCL—Maximum Contaminant Level. Legally enforceable standards that apply to public-water systems and are designed to protect public health by limiting the levels of contaminants in drinking water. National MCLs established by the USEPA are the minimum standards with which states are required to comply, and individual states may choose to set more stringent standards. CDPH has established MCLs for additional constituents not regulated by the USEPA, as well as lowered the threshold concentration for a number of constituents with MCLs established by the USEPA. In this report, a threshold set by the USEPA is labeled "MCL-US," and one set by CDPH that is different from the MCL-US is labeled "MCL-CA." CDPH is notified when constituents are detected at concentrations exceeding MCL-US or MCL-CA thresholds in samples collected for the GAMA Priority Basin Assessment, but these detections do not constitute violations of CDPH regulations

AL—Action Level. Legally enforceable standards that apply to public-water systems and are designed to protect public health by limiting the levels of copper and lead in drinking water. Detections of copper or lead above the action-level thresholds trigger requirements for mandatory water treatment to reduce the corrosiveness of water to water pipes. The action levels established by the USEPA and CDPH are the same, thus these thresholds are labeled "AL-US" in this report.

TT—Treatment Technique. Legally enforceable standards that apply to public-water systems and are designed to protect public health by limiting the levels of microbial constituents in drinking water. Detections of microbial

constituents above the treatment-technique thresholds trigger requirements for mandatory additional disinfection during water treatment. The action levels established by the USEPA and CDPH are the same, thus these thresholds are labeled "TT-US" in this report.

SMCL—Secondary Maximum Contaminant Level. Non-enforceable standards applied to constituents that affect the aesthetic qualities of drinking water, such as taste, odor, and color, or technical qualities of drinking water, such as scaling and staining. Both the USEPA and CDPH define SMCLs, but unlike MCLs, SMCLs established by CDPH are not required to be at least as stringent as those established by USEPA. SMCLs established by CDPH are used in this report (SMCL-CA) for all constituents that have SMCL-CA values. The SMCL-US is used for pH because no SMCL-CA has been defined.

NL—Notification Level. Health-based notification levels established by CDPH for some of the constituents in drinking water that lack MCLs (NL-CA). If a constituent is detected above its NL-CA, California state law requires timely notification of local governing bodies and recommends consumer notification.

HAL—Lifetime Health Advisory Level. The maximum concentration of a constituent at which its presence in drinking water is not expected to cause any adverse carcinogenic effects for a lifetime of exposure. HALs are established by the USEPA (HAL-US) and are calculated assuming consumption of two liters of water per day over a 70-year lifetime by a 70-kilogram adult and that 20 percent of a person's exposure comes from drinking water.

RSD5—Risk-Specific Dose. The concentration of a constituent in drinking water corresponding to an excess estimated lifetime cancer risk of 1 in 100,000. RSD5 is an acronym for risk-specific dose at 10^{-5}. RSD5s are calculated by dividing the 10^{-4} cancer risk concentrations established by the USEPA by ten (RSD5-US).

For constituents with MCLs, detections in ground-water samples were compared with the MCL-US or MCL-CA. Constituents with SMCLs were compared with the SMCL-CA. For chloride, sulfate, specific conductance, and total dissolved solids, CDPH defines a "recommended" and an "upper" SMCL-CA; detections of these constituents in ground-water samples were compared with both levels. The SMCL-US for these constituents corresponds to the recommended SMCL-CA. Detected concentrations of constituents that lack MCLs and SMCLs were compared with NL-CAs. For constituents that lack an MCL, SMCL, or NL-CA, detected concentrations were compared with the HAL-US. For constituents that lack an MCL, SMCL, NL-CA, or HAL-CA, detected concentrations were compared with the RSD5-US. Note this hierarchy of selection of comparison thresholds means that for constituents with multiple types of established thresholds, the threshold used for comparison purposes may not be the one with the lowest concentration. The comparison thresholds used in this report are listed in tables 3A–L for all constituents and in tables 4–14 for constituents detected in ground-water samples from the MSACV. Not all constituents analyzed for this study have established thresholds. Concentrations greater than the selected comparison threshold are marked with asterisks in tables 4–14.

Ground-Water-Quality Data

Results from analyses of raw (untreated) ground-water samples from MSACV are presented in tables 4–14. Ground-water samples collected in MSACV were analyzed for up to 280 constituents, and 195 of those constituents were not detected in any of the samples (tables 3A–L). The results tables present only the constituents that were detected and list only samples that had at least one constituent detected. For constituent classes that were analyzed at all of the grid wells, the tables include the number of wells at which each analyte was detected, the frequency at which it was detected (in relation to the number of grid wells), and the total number of constituents detected at each well. Results from the flow-path and RICE wells are presented in the tables, but these results were excluded from the detection frequency calculations to avoid statistically over-representing the areas in the vicinity of these wells.

Table 4 includes water-quality indicators measured in the field and at NWQL. Tables 5–14 present the results of ground-water laboratory analyses organized by compound classes:

- Organic constituents
  - VOCs and gasoline oxygenates and degradates (table 5)
  - Pesticides and pesticide degradates (table 6)
- Constituents of special interest (table 7)
- Inorganic constituents
  - Nutrients and dissolved organic carbon (table 8)
  - Major and minor ions (table 9)
  - Trace elements (table 10)
  - Species of inorganic arsenic, iron, and chromium (table 11)
- Inorganic tracer constituents
  - Hydrogen and oxygen isotopes and tritium (table 12)
  - Stable isotopes of nitrogen and carbon and carbon-14 (table 13)
- Radioactive constituents (table 14)

Results for pharmaceutical compounds, dissolved noble gases, and tritium/helium age dates are not presented in this report; they will be included in subsequent GAMA

publications. No summary table is presented for microbial constituents because none were detected in any of the samples analyzed.

Water-Quality Indicators

Field and laboratory measurements of water-quality indicators, including dissolved oxygen, pH, specific conductance, alkalinity, and associated parameters (turbidity and water temperature) are presented in table 4. Dissolved oxygen and alkalinity are used as indicators of natural processes that control water chemistry. Specific conductance is the unit electrical conductivity of the water and is proportional to the amount of total dissolved solids (TDS) in the water. The pH value indicates the acidity or basicity of the water. Six wells (3 grid wells, 2 flow-path wells, and 1 RICE well) had pH values outside of the SMCL-CA range for pH. Laboratory pH values may be higher than field pH values because the pH of ground water often increases upon exposure to the atmosphere (see Appendix). Twenty-two wells (11 grid, 1 flow-path well, and 10 RICE wells) had specific conductance values above the recommended SMCL-CA, with 9 of those wells (4 grid wells and 5 RICE wells) above the upper threshold.

Organic Constituents

VOCs are widely used and can be found in paints, solvents, fuels, fuel additives, refrigerants, fumigants, and disinfected water and are characterized by their tendency to evaporate. VOCs generally persist longer in ground water than in surface water because ground water is isolated from the atmosphere.

Of the 85 VOCs analyzed, 24 were detected in ground-water samples; all detections were below health-based thresholds and most were less than one-hundredth of the threshold values (table 5). The only VOC detected in more than 10 percent of the grid wells was chloroform, a byproduct of drinking-water disinfection. Chloroform was the most frequently detected VOC in ground water nationally (Zogorski and others, 2006).

Pesticides include herbicides, insecticides, and fungicides, and are used to control weeds, insects, fungi, and other pests in agricultural, urban, and suburban settings. Of the 135 pesticides and pesticide degradates analyzed, 30 were detected in ground-water samples; all detections were below health-based thresholds and all were less than one-hundredth of the threshold values (table 6). The only pesticides detected in more than 10 percent of the grid wells were the herbicides bentazon, simazine, atrazine, and deethylatrazine, a degradate of atrazine. Simazine, atrazine, and deethlyatrazine are among the most commonly detected pesticide compounds in ground water nationally (Gilliom and others, 2006). Bentazon is primarily used in rice agriculture.

Constituents of Special Interest

Perchlorate, 1,2,3-TCP, and NDMA are constituents of special interest in California because they may adversely affect water quality and recently have been found in water supplies (California Department of Health Services, 2007b). Perchlorate is used as an oxidizer in rocket fuel and explosives, 1,2,3-TCP is used as a chemical synthesis product, and NDMA is an industrial by-product. Perchlorate was detected in approximately 6 percent of the grid wells, and all concentrations measured in the MSACV wells were less than one-third of the NL-CA (table 7). 1,2,3-TCP and NDMA were not detected in any samples.

Inorganic Constituents

Unlike the organic constituents and the constituents of special interest, most of the inorganic constituents are naturally present in ground water, although their concentrations may be influenced by human activities.

The nutrients, nitrogen and phosphorus, and dissolved organic carbon present in ground water can affect biological activity in aquifers and in surface water bodies that receive ground-water discharge. Nitrogen may be present in the form of ammonia, nitrite, or nitrate depending on the oxidation–reduction state of the ground water. High concentrations of nitrate can adversely affect human health, particularly the health of infants. Ground-water samples from two grid wells in MSACV had concentrations of nitrate (nitrite plus nitrate, dissolved as nitrogen) above the health-based threshold (table 8). All concentrations of nitrite and ammonia measured in ground-water samples were below health-based thresholds. Concentrations of orthophosphate (as phosphorus) and dissolved organic carbon were also low.

The major-ion composition, total dissolved solids (TDS) content, and levels of certain trace elements in ground water may produce undesirable effects on the aesthetic and technical properties of the water. Undesirable aesthetic properties include poor taste, color, or odor, and staining. Undesirable technical properties include scaling, and reduced effectiveness of treatment for other contaminants. CDPH has established non-enforceable thresholds (SMCL-CAs) that are based on aesthetic or technical properties rather than on health-based concerns for the major ions chloride and sulfate, TDS, and several trace elements. Chloride was detected in two grid wells above the recommended SMCL-CA, with one of those detections above the upper SMCL-CA. Sulfate was detected in one grid well above the lower SMCL-CA. Samples from six grid wells contained TDS above the recommended SMCL-CA, although only two of these samples were also above the upper SMCL-CA for TDS (table 9).

Iron and manganese are trace elements whose concentrations are affected by the oxidation–reduction state of the ground water. Precipitation of minerals containing iron or manganese may cause orange or black staining of surfaces. Samples from 12 grid wells had manganese concentrations above the SMCL-CA, and one of these samples also had an iron concentration above the MCL-CA (table 10).

Eighteen of the 25 trace elements analyzed in this study have health-based thresholds. Of the 18 trace elements with health-based thresholds, 2 were not detected in any samples, and all detections of 16 trace elements were below health-based thresholds (table 10). Samples from eight grid wells had arsenic concentrations above the MCL-US and samples from two grid wells had concentrations of boron above the NL-CA.

Arsenic, iron, and chromium occur in different species depending on the oxidation–reduction state of the ground water. The oxidized and reduced species have different solubilities in ground water and may have different effects on human health. The relative proportions of the oxidized and reduced species of each element can be used to aid in interpretation of the oxidation–reduction state of the aquifer. Table 11 reports measured concentrations of total arsenic, iron, and chromium, and the concentrations of the oxidized or the reduced species of each element. The concentration of the other species can be calculated by difference. For example, chromium(III) is equal to chromium(total) minus chromium(VI). The concentrations of arsenic, iron, and chromium reported in table 11 may be different than those reported in table 10 because different analytical methods were used (see Appendix). The concentrations reported in table 10 are considered more accurate.

Inorganic Tracer Constituents

Stable isotope ratios, tritium and carbon-14 activities, and noble gas concentrations are used as tracers of natural processes affecting ground-water composition. The stable isotope ratios of oxygen and hydrogen in water (table 12) may aid in interpretation of ground-water recharge sources. These stable isotope ratios reflect the altitude, latitude, and temperature of precipitation and the extent of evaporation of surface water or soil water. The nitrogen and oxygen stable isotope ratios in nitrate (table 13) may aid in interpretation of sources and processes affecting nitrate concentrations in ground water. Concentrations of dissolved noble gases are used to estimate the conditions of ground-water recharge, particularly the temperature of the recharge water. Noble gases from air dissolve in water that is in contact with the atmosphere, and the solubilities of the different noble gases vary with temperature. Results of noble gas analyses were not available in time for inclusion in this report; they will be presented in a subsequent GAMA report.

Tritium activities (table 12), carbon-14 activities (table 13), and helium isotope ratios provide information about the age of the ground water. Tritium is a short-lived radioactive isotope of hydrogen that is incorporated into the water molecule. Low levels of tritium are continuously produced by interaction of cosmic radiation with the earth's atmosphere, and a large amount of tritium was produced by atmospheric testing of nuclear weapons between 1952 and 1963. Thus, concentrations of tritium above background levels generally indicate the presence of water recharged since the early 1950s (Thatcher and others, 1977). Helium isotope ratios are used in conjunction with tritium concentrations to estimate ages for young ground water. Helium isotope analyses were not completed in time for inclusion in this report; they will be presented in a subsequent GAMA report.

Carbon-14 (table 13) is a radioactive isotope of carbon. Low levels of carbon-14 are continuously produced by interaction of cosmic radiation with the earth's atmosphere and incorporated into atmospheric carbon dioxide. The carbon dioxide dissolves in precipitation and water that is in contact with the atmosphere. Because carbon-14 decays with a half-life of approximately 5,700 years, low activities of carbon-14 relative to modern values generally indicate presence of ground water that is several thousand years old.

Of the inorganic tracer constituents analyzed for this study, the only one with a health-based threshold is tritium. All measured tritium activities in samples from MSACV wells were less than one-thousandth of the MCL-CA (table 12).

Radioactive Constituents

Radioactivity is the release of energy or energetic particles during changes in the structure of the nucleus of an atom. Most of the radioactivity in ground water comes from decay of naturally occurring isotopes of uranium and thorium that are present in minerals in the sediments or fractured rocks of an aquifer. Both uranium and thorium decay in a series of steps, eventually forming stable isotopes of lead. Radium-226, radium-228, and radon-222 are radioactive isotopes formed during the uranium and thorium decay series. In each step of the decay series, one radioactive element turns into a different radioactive element by emitting an alpha or a beta particle from its nucleus. For example, radium-226 emits an alpha particle and, therefore, turns into radon-222. Radium-228 decays to form actinium-228 by emission of a beta particle. The alpha and beta particles emitted during radioactive decay are hazardous to human health because these energetic particles may damage cells. Radiation damage to cell DNA may increase the cancer risk in humans.

Activity is often used instead of concentration for reporting the presence of radioactive constituents. Activity of radioactive constituents in ground water is measured in units of picocuries per liter (pCi/L), and one picocurie is approximately equal to two atoms decaying per minute. The number of atoms decaying is equal to the number of alpha or beta particles emitted.

The eight MSACV samples analyzed for radioactive constituents had activities of radium and of gross alpha and beta emitters less than established health-based thresholds (table 14). Activities of radon-222 in samples from six grid wells were above the proposed MCL-US of 300 pCi/L, but all were below the proposed alternative MCL-US of 4,000 pCi/L. The alternative MCL-US will apply if the state or local water agency has an approved multimedia mitigation program to address radon levels in indoor air (U.S. Environmental Protection Agency, 1999a).

Microbial Indicators

Water is disinfected during drinking-water treatment to prevent diseases that may be spread by water-borne microbial constituents derived from human or animal wastes. The specific viruses and bacteria responsible for diseases generally are not measured because routine analytical methods are not available. Measurements are made of more easily analyzed microbial constituents that serve as indicators of the presence of human or animal waste in water. Drinking-water purveyors respond to detections of microbial indicators by applying additional disinfection techniques to the water.

Samples from eight MSACV wells were analyzed for microbial indicators. None of the samples contained viral indicators F-specific and somatic coliphage, and none contained the bacterial indicator *Escherichia* coliform (*E. coli*) or total coliforms.

Future Work

Subsequent reports will focus on assessment of the data presented in this report using a variety of statistical, qualitative, and quantitative approaches to evaluate the natural and human factors affecting ground-water quality. Water-quality data contained in the CDPH and NWIS databases, and water-quality data available from other state and local water agencies, will be compiled, evaluated, and used in combination with the data presented in this report.

Summary

Ground-water quality in the approximately 3,340 mi^2 Middle Sacramento Valley study unit (MSACV) was investigated from June to September, 2006, as part of the Priority Basin Assessment project of Ground-Water Ambient Monitoring and Assessment (GAMA) program. The California State Water Resources Control Board (SWRCB), in collaboration with the U.S. Geological Survey and the Lawrence Livermore National Laboratory, is implementing the GAMA program (http://www.waterboards.ca.gov/gama/). The Priority Basin Assessment project was designed by the SWRCB and the USGS in response to the Ground-Water Quality Monitoring Act of 2001 (Belitz and others, 2003; State Water Resources Control Board, 2003). The project is a comprehensive assessment of statewide ground-water quality designed to identify and characterize risks to ground-water resources and to increase the availability of information about ground-water quality to the public. MSACV was the twelfth study unit sampled as part of the project.

MSACV is in the Central Valley hydrogeologic province, and includes within it eight ground-water basins, as defined by the California Department of Water Resources (California Department of Water Resources, 2003). The MSACV study included assessment of ground-water quality from 108 wells in Butte, Colusa, Glenn, Sutter, Tehama, Yolo, and Yuba Counties. Seventy-one of the wells (grid wells) were selected using a spatially distributed, randomized grid-based method to achieve statistically unbiased representation of the portion of the ground-water resource used for public drinking-water supplies. Fifteen of the wells (flow-path wells) were selected to provide additional sampling density to aid in understanding processes affecting ground-water quality. Twenty-two of the wells (RICE wells) were sampled for better understanding of the contribution of rice agriculture land use to ground-water conditions.

Ground-water samples were analyzed for volatile organic compounds (VOCs), pesticides and pesticide degradates, constituents of special interest, pharmaceutical compounds, nutrients, major and minor ions, trace elements, radioactivity, and microbial indicators. Naturally occurring isotopes (stable isotopes of hydrogen, oxygen, nitrogen, and carbon, and activities of tritium and carbon-14) and dissolved noble gases also were measured to provide a dataset that will be used to help interpret the source and age of the sampled ground water. This report describes the hydrogeologic setting of the MSACV region, details the sampling, analytical, and quality-assurance methods used in the study, and presents the results of the chemical and microbial analyses made of the ground-water samples collected during June to September, 2006.

QC samples (blanks, replicates, samples for matrix spikes) were collected at approximately 10 percent of the wells, and the results for these samples were used to evaluate the quality of the data for the ground-water samples. Field blanks rarely contained detectable concentrations of any constituent, suggesting that contamination was not a noticeable source of bias in the data for the ground-water samples. Most of the differences between replicate samples were within acceptable ranges, indicating acceptably low variability. Matrix spike recoveries were within acceptable ranges for most compounds.

This study did not attempt to evaluate the quality of water delivered to consumers; after withdrawal from the ground, water typically is treated, disinfected, and blended with other waters to maintain acceptable water quality. Regulatory

thresholds apply to treated water that is served to the consumer, not to raw ground water. However, to provide some context for the results, concentrations of constituents measured in the raw ground water were compared with health-based thresholds established by the U.S. Environmental Protection Agency (USEPA) and the California Department of Public Health (CDPH).

All detections of VOCs, pesticides, and pesticide degradates were below health-based thresholds, and most were less than one-hundredth of the threshold values. All detections of perchlorate, and radioactive constituents were below established thresholds. Arsenic, nitrate, and boron were the only constituents detected at concentrations above health-based thresholds in samples from the grid wells. Total dissolved solids, specific conductance, pH, iron, chloride, sulfate, and manganese were detected at concentrations above the SMCL-CA, a non-enforceable threshold set for aesthetic concerns, in samples from several of the grid wells.

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Table 1. Identification, sampling, and construction information for wells sampled for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; ft, foot (feet); LSD, land surface datum; mm/dd/yy, month/day/year; na, not available; no., number; RICE, rice agriculture; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path]

GAMA identification no.	Sampling information		Well type	Construction information			
	Date (mm/dd/yy)	Sampling schedule[1]		Elevation of LSD (ft above NAVD88)[2]	Well depth (ft below LSD)	Top perforation (ft below LSD)	Bottom perforation (ft below LSD)
Grid wells							
ESAC-01	6/29/06	Fast	Production	76	278	150	252
ESAC-02	6/29/06	Fast	Production	38	160	140	160
ESAC-03	7/10/06	Intermediate	Production	176	272	110	150
ESAC-04	7/10/06	Fast	Production	154	200	140	200
ESAC-05	7/10/06	Intermediate	Production	77	410	207	395
ESAC-06	7/12/06	Intermediate	Production	182	260	148	260
ESAC-07	7/12/06	Fast	Production	153	220	80	220
ESAC-08	7/12/06	Fast	Production	89	108	68	108
ESAC-09	7/13/06	Fast	Production	129	554	140	554
ESAC-10	7/13/06	Intermediate	Production	60	316	96	303
ESAC-11	7/13/06	Intermediate	Production	68	520	220	510
ESAC-12	7/17/06	Intermediate	Production	107	375	0	370
ESAC-13	7/17/06	Fast	Production	207	355	na	na
ESAC-14	7/17/06	Fast	Production	47	280	140	280
ESAC-15	7/20/06	Intermediate	Production	197	500	200	480
ESAC-16	7/20/06	Intermediate	Production	297	560	240	540
ESAC-17	7/20/06	Intermediate	Production	52	200	150	na
ESAC-18	7/20/06	Intermediate	Production	220	560	240	540
ESAC-19	7/20/06	Intermediate	Production	48	265	185	265
ESAC-20	7/25/06	Fast	Production	84	354	212	354
ESAC-21	7/25/06	Intermediate	Production	53	na	na	na
ESAC-22	7/26/06	Intermediate	Production	105	90	na	na
ESAC-23	7/26/06	Fast	Production	93	72	na	na
ESAC-24	7/26/06	Fast	Production	94	327	84	318
ESAC-25	7/27/06	Slow	Production	264	570	290	550
ESAC-26	7/31/06	Slow	Production	37	200	160	200
ESAC-27	8/2/06	Slow	Production	54	135	65	125
ESAC-28	8/3/06	Slow	Production	92	360	102	360
ESAC-29	8/3/06	Intermediate	Production	31	223	199	215
ESAC-30	8/7/06	Intermediate	Production	43	na	na	na
ESAC-31	8/7/06	Intermediate	Production	62	235	48	235
ESAC-32	8/17/06	Intermediate	Production	66	140	64	124
ESAC-33	8/17/06	Fast	Production	212	335	na	na
ESAC-34	8/17/06	Intermediate	Production	102	60	na	na
ESAC-35	8/24/06	Intermediate	Production	114	558	74	558
WSAC-01	7/10/06	Fast	Production	446	na	na	na
WSAC-02	7/11/06	Fast	Production	179	na	na	na
WSAC-03	7/11/06	Slow	Production	274	na	115.5	253
WSAC-04	7/11/06	Intermediate	Production	452	880	320	880
WSAC-05	7/12/06	Fast	Production	367	236	136	236
WSAC-06	7/12/06	Intermediate	Production	485	na	na	na
WSAC-07[3]	7/18/06, 8/10/06	Fast	Production	152	220	71	200
WSAC-08	7/18/06	Slow	Production	248	180	56	170
WSAC-09[3]	7/18/06, 8/10/06	Fast	Production	222	na	na	na
WSAC-10[3]	7/18/06, 8/10/06	Intermediate	Production	187	225	145	225
WSAC-11[3]	7/19/06, 8/9/06	Intermediate	Production	142	570	240	561
WSAC-12	7/19/06	Slow	Production	52	490	na	na
WSAC-13	7/24/06	Fast	Production	87	na	na	na

Table 1. Identification, sampling, and construction information for wells sampled for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; ft, foot (feet); LSD, land surface datum; mm/dd/yy, month/day/year; na, not available; no., number; RICE, rice agriculture; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path]

GAMA identification no.	Sampling information		Well type	Construction information			
	Date (mm/dd/yy)	Sampling schedule[1]		Elevation of LSD (ft above NAVD88)[2]	Well depth (ft below LSD)	Top perforation (ft below LSD)	Bottom perforation (ft below LSD)
WSAC-14	7/24/06	Intermediate	Production	62	159	157	159
WSAC-15	7/31/06	Intermediate	Production	147	610	280	610
WSAC-16	7/31/06	Fast	Production	30	332	313	na
WSAC-17	8/1/06	Intermediate	Production	32	260	230	260
WSAC-18	8/1/06	Slow	Production	85	402	160	380
WSAC-19	8/1/06	Fast	Production	37	364	348	356
WSAC-20	8/2/06	Fast	Production	81	340	253	340
WSAC-21	8/2/06	Intermediate	Production	168	369	237	256
WSAC-22	8/8/06	Intermediate	Production	358	870	408	870
WSAC-23	8/8/06	Fast	Production	43	56	31	56
WSAC-24	8/9/06	Fast	Production	75	185	165	185
WSAC-25	8/9/06	Intermediate	Production	45	na	na	na
WSAC-26	8/14/06	Intermediate	Production	413	330	110	330
WSAC-27	8/15/06	Fast	Production	65	300	140	300
WSAC-28	8/15/06	Intermediate	Production	292	165	145	165
WSAC-29	8/16/06	Intermediate	Production	142	759	173	651
WSAC-30	8/16/06	Intermediate	Production	121	na	na	na
WSAC-31	8/21/06	Intermediate	Production	60	260	145	245
WSAC-32	8/21/06	Fast	Production	93	180	110	180
WSAC-33	8/22/06	Fast	Production	88	205	na	na
WSAC-34	8/22/06	Intermediate	Production	144	197	60	180
WSAC-35	8/23/06	Intermediate	Production	143	410	100	410
WSAC-36	8/23/06	Intermediate	Production	82	260	160	260
Flow-path wells							
ESAC-FP-01	7/13/06	Intermediate	Production	51	750	580	720
ESAC-FP-02	8/21/06	Intermediate	Monitoring	181	na	na	na
ESAC-FP-03	8/23/06	Intermediate	Monitoring	105	130	98.8	109
ESAC-FP-04	8/23/06	Intermediate	Monitoring	107	583	509	562
ESAC-FP-05	8/24/06	Intermediate	Monitoring	105	100	80	90
ESAC-FP-06	8/24/06	Intermediate	Monitoring	105	380	340	350
ESAC-FP-07	8/25/06	Intermediate	Monitoring	105	555	520	530
WSAC-FP-01	8/14/06	Intermediate	Monitoring	312	na	na	na
WSAC-FP-02	8/15/06	Intermediate	Monitoring	257	421	390	400
WSAC-FP-03	8/15/06	Intermediate	Monitoring	257	310	270	290
WSAC-FP-04	8/16/06	Intermediate	Monitoring	131	200	138	180
WSAC-FP-05	8/16/06	Intermediate	Production	94	625	540	625
WSAC-FP-06	8/16/06	Intermediate	Monitoring	131	540	445	525
WSAC-FP-07	8/17/06	Intermediate	Monitoring	99	490	415	470
WSAC-FP-08	8/17/06	Intermediate	Monitoring	99	280	190	260
RICE wells							
RICE-01	7/17/06	RICE	Monitoring	24	50	40	45
RICE-02	7/18/06	RICE	Monitoring	38	44	34	39
RICE-03	7/18/06	RICE	Monitoring	43	35	25	30
RICE-04	7/18/06	RICE	Monitoring	88	35	25	30
RICE-05	7/19/06	RICE	Monitoring	126	35	25	30
RICE-06	7/19/06	RICE	Monitoring	138	35	25	30
RICE-07	7/20/06	RICE	Monitoring	91	45	35	40
RICE-08	7/20/06	RICE	Monitoring	88	35	25	30
RICE-09	7/24/06	RICE	Monitoring	70	34	24	28

Table 1. Identification, sampling, and construction information for wells sampled for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; ft, foot (feet); LSD, land surface datum; mm/dd/yy, month/day/year; na, not available; no., number; RICE, rice agriculture; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path]

GAMA identification no.	Sampling information		Well type	Construction information			
	Date (mm/dd/yy)	Sampling schedule[1]		Elevation of LSD (ft above NAVD88)[2]	Well depth (ft below LSD)	Top perforation (ft below LSD)	Bottom perforation (ft below LSD)
RICE-10	7/24/06	RICE	Monitoring	80	35	25	30
RICE-11	7/25/06	RICE	Monitoring	127	35	25	30
RICE-12	7/25/06	RICE	Monitoring	98	35	25	30
RICE-13	7/26/06	RICE	Monitoring	110	35	25	30
RICE-14	7/26/06	RICE	Monitoring	82	36	26	30
RICE-15	7/27/06	RICE	Monitoring	100	35	25	30
RICE-16	7/27/06	RICE	Monitoring	82	35	25	30
RICE-17	8/15/06	RICE	Monitoring	57	35	25	30
RICE-18	8/16/06	RICE	Monitoring	99	38	28	34
RICE-19	8/16/06	RICE	Monitoring	74	38	28	34
RICE-20	8/17/06	RICE	Monitoring	24	29	19	24
RICE-21	9/12/06	RICE	Monitoring	76	35	25	30
RICE-22	9/13/06	RICE	Monitoring	51	35	25	30

[1] Sampling schedules are described in table 2.

[2] Land-surface datum (LSD) is a datum plane that is approximately at land surface at each well. The elevation of the LSD is described in feet above the North American Vertical Datum 1988.

[3] Well sampled twice (well was partially resampled to replace some sample containers lost in shipping prior to analysis).

Table 2. Classes of water-quality indicators, chemical constituents, and microbial constituents collected for the slow, intermediate, fast, and RICE well sampling schedules in the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[DO, dissolved oxygen; NDMA, *N*-nitrosodimethylamine; SC, specific conductance]

Analyte classes	Analyte list table	Slow schedule	Intermediate schedule	Fast schedule	RICE schedule
Water-quality indicators					
DO, SC, pH, temperature		X	X	X	X
Alkalinity, turbidity		X			X
Organic constituents					
Volatile organic compounds	3A	X	X	X	X
Gasoline additives and oxygenates	3B	X			
Pesticides and pesticide degradates	3C, 3D	X	X	X	X
Pharmaceutical compounds	3E	X	X		X
Constituents of special interest					
Perchlorate	3F	X	X	X	X
N-Nitrosodimethylamine (NDMA)	3F	X	X		
1,2,3-Trichloropropane (1,2,3-TCP)	3F	X	X		
Inorganic constituents					
Nutrients	3G	X	X		X
Dissolved organic carbon (DOC)	3G	X			X
Major and minor ions and trace elements	3H	X	X		X
Arsenic, iron, and chromium speciation	3I	X	X		X
Stable isotopes					
Stable isotopes of hydrogen and oxygen in water	3J	X	X	X	X
Stable isotopes of nitrogen and oxygen in nitrate	3J	X	X		
Stable isotopes of carbon and carbon-14 abundance	3J	X	X		
Radioactivity and gases					
Tritium	3J	X	X	X	
Tritium and noble gases	3K	X	X	X	X
Radium isotopes	3J	X			
Radon-222	3J	X			
Gross alpha and beta radiation	3J	X			
Microbial constituents					
Escherichia coliform and total coliform	3L	X			
F-specific and somatic coliphage	3L	X			

Table 3A. Volatile organic compounds, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 2020.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); THM, trihalomethane; USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type	Threshold value (µg/L)	Detection
Acetone	Solvent	81552	67-64-1	6	na	na	D
Acrylonitrile	Organic synthesis	34215	107-13-1	0.8	RSD5-US	0.6	—
Benzene	Gasoline hydrocarbon	34030	71-43-2	0.021	MCL-CA	1	D
Bromobenzene	Solvent	81555	108-86-1	0.028	na	na	—
Bromochloromethane	Fire retardant	77297	74-97-5	0.12	HAL-US	90	—
Bromodichloromethane	Disinfection by-product (THM)	32101	75-27-4	0.028	MCL-US[1]	80	D
Bromoform (Tribromomethane)	Disinfection by-product (THM)	32104	75-25-2	0.10	MCL-US[1]	80	D
2-Butanone (MEK, Methyl ethyl ketone)	Solvent	81595	78-93-3	2	HAL-US	4,000	D
n-Butylbenzene	Gasoline hydrocarbon	77342	104-51-8	0.12	NL-CA	260	—
sec-Butylbenzene	Gasoline hydrocarbon	77350	135-98-8	0.06	NL-CA	260	—
tert-Butylbenzene	Gasoline hydrocarbon	77353	98-06-6	0.06	NL-CA	260	—
Carbon disulfide	Organic synthesis	77041	75-15-0	0.038	NL-CA	160	D
Carbon tetrachloride (Tetrachloromethane)	Solvent	32102	56-23-5	0.06	MCL-CA	0.5	D
Chlorobenzene	Solvent	34301	108-90-7	0.028	MCL-CA	70	—
Chloroethane	Solvent	34311	75-00-3	0.12	na	na	—
Chloroform (Trichloromethane)	Disinfection by-product (THM)	32106	67-66-3	0.024	MCL-US[1]	80	D
Chloromethane	Refrigerant/organic synthesis	34418	74-87-3	0.17	HAL-US	30	D
3-Chloro-1-propene	Organic synthesis	78109	107-05-1	0.5	na	na	—
2-Chlorotoluene	Solvent	77275	95-49-8	0.04	NL-CA	140	—
4-Chlorotoluene	Solvent	77277	106-43-4	0.05	NL-CA	140	—
Dibromochloromethane	Disinfection by-product (THM)	32105	124-48-1	0.10	MCL-US[1]	80	D
1,2-Dibromo-3-chloropropane (DBCP)	Fumigant	82625	96-12-8	0.51	MCL-US	0.2	—
1,2-Dibromoethane (EDB)	Fumigant	77651	106-93-4	0.036	MCL-US	0.05	—
Dibromomethane	Solvent	30217	74-95-3	0.050	na	na	—
1,2-Dichlorobenzene	Solvent	34536	95-50-1	0.048	MCL-CA	600	—
1,3-Dichlorobenzene	Solvent	34566	541-73-1	0.03	HAL-US	600	—
1,4-Dichlorobenzene	Fumigant	34571	106-46-7	0.034	MCL-CA	5	—
trans-1,4-Dichloro-2-butene	Organic synthesis	73547	110-57-6	0.70	na	na	—
Dichlorodifluoromethane (CFC-12)	Refrigerant	34668	75-71-8	0.18	NL-CA	1,000	—
1,1-Dichloroethane	Solvent	34496	75-34-3	0.035	MCL-CA	5	D
1,2-Dichloroethane	Solvent	32103	107-06-2	0.13	MCL-CA	0.5	—
1,1-Dichloroethene (DCE)	Organic synthesis	34501	75-35-4	0.024	MCL-CA	6	—
cis-1,2-Dichloroethene	Solvent	77093	156-59-2	0.024	MCL-CA	6	D
trans-1,2-Dichloroethene	Solvent	34546	156-60-5	0.032	MCL-CA	10	D
Dichloromethane (Methylene chloride)	Solvent	34423	75-09-2	0.06	MCL-US	5	—
1,2-Dichloropropane	Fumigant	34541	78-87-5	0.029	MCL-US	5	—
1,3-Dichloropropane	Fumigant	77173	142-28-9	0.06	na	na	—
2,2-Dichloropropane	Fumigant	77170	594-20-7	0.05	na	na	—
1,1-Dichloropropene	Organic synthesis	77168	563-58-6	0.026	na	na	—
cis-1,3-Dichloropropene	Fumigant	34704	10061-01-5	0.05	RSD5-US[2]	4	—
trans-1,3-Dichloropropene	Fumigant	34699	10061-02-6	0.09	RSD5-US[2]	4	—
Diethyl ether	Solvent	81576	60-29-7	0.08	na	na	—
Diisopropyl ether (DIPE)	Gasoline oxygenate	81577	108-20-3	0.10	na	na	—
Ethylbenzene	Gasoline hydrocarbon	34371	100-41-4	0.030	MCL-CA	300	—
Ethyl *tert*-butyl ether (ETBE)	Gasoline oxygenate	50004	637-92-3	0.030	na	na	—

Table 3A. Volatile organic compounds, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 2020.—Continued

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); THM, trihalomethane; USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type	Threshold value (µg/L)	Detection
Ethyl methacrylate	Organic synthesis	73570	97-63-2	0.18	na	na	—
1-Ethyl-2-methylbenzene (*o*-Ethyl toluene)	Gasoline hydrocarbon	77220	611-14-3	0.06	na	na	D
Hexachlorobutadiene	Organic synthesis	39702	87-68-3	0.14	RSD5-US	90	—
Hexachloroethane	Solvent	34396	67-72-1	0.14	HAL-US	1	—
2-Hexanone (*n*-Butyl methyl ketone)	Solvent	77103	591-78-6	0.4	na	na	—
Isopropylbenzene (Cumene)	Gasoline hydrocarbon	77223	98-82-8	0.038	NL-CA	770	—
4-Isopropyl-1-methylbenzene	Gasoline hydrocarbon	77356	99-87-6	0.08	na	na	D
Methyl acrylate	Organic synthesis	49991	96-33-3	1.0	na	na	—
Methyl acrylonitrile	Organic synthesis	81593	126-98-7	0.40	na	na	—
Methyl bromide (Bromomethane)	Fumigant	34413	74-83-9	0.33	HAL-US	10	—
Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	78032	1634-04-4	0.10	MCL-CA	13	D
Methyl iodide (Iodomethane)	Organic synthesis	77424	74-88-4	0.50	na	na	—
Methyl isobutyl ketone (MIBK)	Solvent	78133	108-10-1	0.37	NL-CA	120	—
Methyl methacrylate	Organic synthesis	81597	80-62-6	0.20	na	na	—
Methyl *tert*-pentyl ether (*tert*-Amyl methyl ether, TAME)	Gasoline oxygenate	50005	994-05-8	0.04	na	na	—
Naphthalene	Gasoline hydrocarbon	34696	91-20-3	0.52	NL-CA	17	—
n-Propylbenzene	Solvent	77224	103-65-1	0.042	NL-CA	260	—
Styrene	Gasoline hydrocarbon	77128	100-42-5	0.042	MCL-US	100	—
1,1,1,2-Tetrachloroethane	Solvent	77562	630-20-6	0.03	HAL-US	70	—
1,1,2,2-Tetrachloroethane	Solvent	34516	79-34-5	0.08	MCL-CA	1	—
Tetrachloroethene (PCE)	Solvent	34475	127-18-4	0.030	MCL-US	5	D
Tetrahydrofuran	Solvent	81607	109-99-9	1.2	na	na	—
1,2,3,4-Tetramethylbenzene	Gasoline hydrocarbon	49999	488-23-3	0.14	na	na	D
1,2,3,5-Tetramethylbenzene	Gasoline hydrocarbon	50000	527-53-7	0.18	na	na	D
Toluene	Gasoline hydrocarbon	34010	108-88-3	0.02	MCL-CA	150	D
1,2,3-Trichlorobenzene	Organic synthesis	77613	87-61-6	0.18	na	na	—
1,2,4-Trichlorobenzene	Solvent	34551	120-82-1	0.12	MCL-CA	5	—
1,1,1-Trichloroethane (TCA)	Solvent	34506	71-55-6	0.032	MCL-US	200	—
1,1,2-Trichloroethane	Solvent	34511	79-00-5	0.04	MCL-US	5	—
Trichloroethene (TCE)	Solvent	39180	79-01-6	0.038	MCL-US	5	D
Trichlorofluoromethane (CFC-11)	Refrigerant	34488	75-69-4	0.08	MCL-CA	150	D
1,2,3-Trichloropropane (1,2,3-TCP)	Solvent/organic synthesis	77443	96-18-4	0.18	NL-CA	0.005	—
1,1,2-Trichloro-1,2,2-trifluoroethane (CFC-113)	Refrigerant	77652	76-13-1	0.038	MCL-CA	1,200	—
1,2,3-Trimethylbenzene	Gasoline hydrocarbon	77221	526-73-8	0.09	na	na	—
1,2,4-Trimethylbenzene	Gasoline hydrocarbon	77222	95-63-6	0.056	NL-CA	330	D
1,3,5-Trimethylbenzene	Organic synthesis	77226	108-67-8	0.044	NL-CA	330	D
Vinyl bromide (Bromoethene)	Fire retardant	50002	593-60-2	0.10	na	na	—
Vinyl chloride (Chloroethene)	Organic synthesis	39175	75-01-4	0.08	MCL-CA	0.5	—
m- and *p*-Xylene	Gasoline hydrocarbon	85795	108-38-3 / 106-42-3	0.06	MCL-CA	1,750	D
o-Xylene	Gasoline hydrocarbon	77135	95-47-6	0.038	MCL-CA	1,750	—

[1] The MCL-US and MCL-CA thresholds for trihalomethanes are the sum of chloroform, bromoform, bromodichloromethane, and dibromochloromethane.

[2] The RSD5 threshold for 1,3-dichloropropene is the sum of its isomers (*cis* and *trans*).

Table 3B. Gasoline oxygenates and their degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 4024.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; DLR-CA, detection level for the purpose of reporting (CDPH); LRL, laboratory reporting level; MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Threshold type	Threshold value (µg/L)	Detection
Acetone	Degradate	81552	67-64-1	1.8	na	na	D
tert-Amyl alcohol	Gasoline oxygenate	77073	75-85-4	1	na	na	—
tert-Butyl alcohol (TBA)	Oxygenate/degradate	77035	75-65-0	1	NL-CA	12	—
Diisopropyl ether	Gasoline oxygenate	81577	108-20-3	0.04	na	na	—
Ethyl *tert*-butyl ether (ETBE)	Gasoline oxygenate	50004	637-92-3	0.06	DLR-CA	3	—
Methyl acetate	Degradate	77032	79-20-9	0.43	na	na	—
Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	78032	1634-04-4	0.05	MCL-US	13	D
Methyl *tert*-pentyl ether	Gasoline oxygenate	50005	994-05-8	0.05	DLR-CA	3	—

Table 3C. Pesticides and pesticide degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032 and 2033.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Rice wells were sampled for Schedule 2033, whereas all other wells were sampled for Schedule 2032. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent[1]	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Type of comparison threshold	Threshold (µg/L)	Detection
Acetochlor	Herbicide	49260	34256-82-1	0.006	na	na	D
Alachlor	Herbicide	46342	15972-60-8	0.005	MCL-US	2	—
Atrazine	Herbicide	39632	1912-24-9	0.007	MCL-CA	1	D
Azinphos-methyl	Insecticide	82686	86-50-0	0.05	na	na	—
Azinphos-methyl-oxon	Degradate	61635	961-22-8	0.042	na	na	—
Benfluralin	Herbicide	82673	1861-40-1	0.01	na	na	—
Carbaryl	Insecticide	82680	63-25-2	0.041	RSD5	400	D
Carbofuran	Herbicide	82674	1563-66-2	0.02	MCL-CA	18	—
2-Chloro-2,6-diethylacetanilide	Degradate	61618	6967-29-9	0.0065	na	na	—
2-Chloro-4-isopropylamino-6-amino-s-triazine (deethylatrazine)	Degradate	04040	6190-65-4	0.014	na	na	D
4-Chloro-2-methylphenol	Degradate	61633	1570-64-5	0.005	na	na	—
Chlorpyrifos	Insecticide	38933	2921-88-2	0.005	HAL-US	2	D
Chlorpyrofos, oxygen analog	Degradate	61636	5598-15-2	0.0562	na	na	—
Cyanazine[2]	Herbicide	04041	21725-46-2	0.018	HAL-US	1	—
Cyfluthrin	Insecticide	61585	68359-37-5	0.053	na	na	—
λ-Cyhalothrin	Insecticide	61595	91465-08-6	0.014	na	na	—
Cypermethrin	Insecticide	61586	52315-07-8	0.046	na	na	—
DCPA (Dacthal) monoacid	Herbicide	82682	1861-32-1	0.003	HAL-US	70	—
Desulfinylfipronil	Degradate	62170	na	0.012	na	na	D
Desulfinylfipronil amide	Degradate	62169	na	0.029	na	na	—
Diazinon	Insecticide	39572	333-41-5	0.005	HAL-US	1	—
3,4-Dichloroaniline	Degradate	61625	95-76-1	0.0045	na	na	D
3,5-Dichloroaniline[2]	Degradate	61627	626-43-7	0.012	na	na	—
Dichlorvos	Fumigant	38775	62-73-7	0.013	na	na	—
Dicrotophos	Insecticide	38454	141-66-2	0.0843	na	na	—
Dieldrin	Insecticide	39381	60-57-1	0.009	RSD5	0.2	—
2,6-Diethylaniline	Degradate	82660	579-66-8	0.006	na	na	—
Dimethoate	Insecticide	82662	60-51-5	0.0061	na	na	—
Disulfoton[2]	Insecticide	82677	298-04-4	0.021	HAL-US	0.7	—
Disulfoton sulfone[2]	Degradate	61640	218208	0.014	na	na	—
α-Endosulfan[2]	Insecticide	34362	959-98-8	0.011	na	na	—
Endosulfan sulfate[2]	Degradate	61590	1031-07-8	0.022	na	na	—
EPTC[2]	Herbicide	82668	759-94-4	0.004	na	na	—
Ethion	Insecticide	82346	563-12-2	0.016	na	na	—
Ethion monoxon	Degradate	61644	17356-42-2	0.021	na	na	—
Ethoprophos[2]	Insecticide	82672	13194-48-4	0.012	na	na	—
2-Ethyl-6-methylaniline	Degradate	61620	24549-06-2	0.01	na	na	—
Fenamiphos	Insecticide	61591	22224-92-6	0.029	HAL-US	0.7	—
Fenamiphos sulfone	Degradate	61645	31972-44-8	0.053	na	na	—
Fenamiphos sulfoxide	Degradate	61646	31972-43-7	0.04	na	na	—
Fipronil	Insecticide	62166	120068-37-3	0.016	na	na	D
Fipronil sulfide	Degradate	62167	120067-83-6	0.013	na	na	D
Fipronil sulfone	Degradate	62168	120068-36-2	0.024	na	na	D
Fonofos	Insecticide	04095	944-22-9	0.0053	HAL-US	10	—
Hexazinone	Herbicide	04025	51235-04-2	0.026	HAL-US	400	D
Isofenphos	Insecticide	61594	25311-71-1	0.011	na	na	—
Malaoxon	Degradate	61652	1634-78-2	0.039	na	na	—

Table 3C. Pesticides and pesticide degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032 and 2033.—Continued

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Rice wells were sampled for Schedule 2033, whereas all other wells were sampled for Schedule 2032. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent[1]	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Type of comparison threshold	Threshold (µg/L)	Detection
Malathion	Insecticide	39532	121-75-5	0.027	HAL-US	100	—
Metalaxyl	Fungicide	61596	57837-19-1	0.0069	na	na	—
Methidathion	Insecticide	61598	950-37-8	0.0087	na	na	—
Methyl paraoxon[2]	Degradate	61664	950-35-6	0.019	na	na	—
Methyl parathion	Insecticide	82667	298-00-0	0.015	HAL-US	1	—
Metolachlor	Herbicide	39415	51218-45-2	0.006	HAL-US	700	D
Metribuzin	Herbicide	82630	21087-64-9	0.028	HAL-US	70	—
Molinate	Herbicide	82671	2212-67-1	0.003	MCL-CA	20	D
Myclobutanil	Fungicide	61599	88671-89-0	0.033	na	na	—
1-Naphthol	Degradate	49295	90-15-3	0.0882	na	na	—
Oxyfluorfen[2]	Herbicide	61600	42874-03-3	0.017	na	na	—
Pendimethalin	Herbicide	82683	40487-42-1	0.022	na	na	—
cis-Permethrin	Insecticide	82687	54774-45-7	0.006	na	na	—
Phorate	Insecticide	82664	298-02-2	0.055	na	na	—
Phorate oxygen analog	Degradate	61666	2600-69-3	0.027	na	na	—
Phosmet	Insecticide	61601	732-11-6	0.0079	na	na	D
Phosmet oxon	Degradate	61668	3735-33-9	0.0511	na	na	D
Prometon	Herbicide	04037	1610-18-0	0.01	HAL-US	100	—
Prometryn	Herbicide	04036	7287-19-6	0.0059	na	na	—
Pronamide	Herbicide	82676	23950-58-5	0.004	RSD5	200	—
Propargite[2]	Insecticide	82685	2312-35-8	0.023	na	na	—
Propanil	Herbicide	82679	709-98-8	0.011	na	na	D
cis-Propiconazole	Fungicide	79846	60207-90-1	0.013	na	na	D
trans-Propiconazole	Fungicide	79847	60207-90-1	0.034	na	na	D
Simazine	Herbicide	04035	122-34-9	0.005	MCL-US	4	D
Tebuconazole[2]	Fungicide	62852	107534-96-3	0.0136	na	na	—
Tebuthiuron	Herbicide	82670	34014-18-1	0.016	HAL-US	500	D
Tefluthrin[2]	Insecticide	61606	79538-32-2	0.0033	na	na	—
Terbufos	Insecticide	82675	13071-79-9	0.017	HAL-US	0.4	—
Terbufos oxygen analog sulfone	Degradate	61674	56070-15-6	0.045	na	na	—
Terbuthylazine	Herbicide	04022	5915-41-3	0.0083	na	na	—
Thiobencarb	Herbicide	82681	28249-77-6	0.01	MCL-CA	70	—
Tribufos	Herbicide	61610	78-48-8	0.035	na	na	—
Trifluralin	Herbicide	82661	1582-09-8	0.009	HAL-US	10	—

[1] Constituents on both Schedules 2032 and 2033 unless noted otherwise.

[2] Constituent on Schedule 2033 only.

Table 3D. Pesticides and pesticide degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 2060.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Type of comparison threshold	Threshold (µg/L)	Detection
Acifluorfen	Herbicide	49315	50594-66-6	0.028	na	na	—
Aldicarb	Insecticide	49312	116-06-3	0.15	MCL-US	3	—
Aldicarb sulfone	Insecticide/degradate	49313	1646-88-4	0.018	MCL-US	2	—
Aldicarb sulfoxide	Degradate	49314	1646-87-3	0.1	MCL-US	4	—
Atrazine	Herbicide	39632	1912-24-9	0.008	MCL-CA	1	D
Bendiocarb	Insecticide	50299	22781-23-3	0.08	na	na	—
Benomyl	Fungicide	50300	17804-35-2	0.022	na	na	—
Bensulfuron-methyl	Herbicide	61693	83055-99-6	0.018	na	na	D
Bentazon	Herbicide	38711	25057-89-0	0.024	MCL-CA	18	D
Bromacil	Herbicide	04029	314-40-9	0.018	HAL-US	70	—
Bromoxynil	Herbicide	49311	1689-84-5	0.044	na	na	—
Caffeine	Beverages	50305	58-08-2	0.018	na	na	—
Carbaryl	Insecticide	49310	63-25-2	0.018	RSD5	400	D
Carbofuran	Herbicide	49309	1563-66-2	0.016	MCL-CA	18	—
Chloramben, methyl ester	Herbicide	61188	7286-84-2	0.024	na	na	—
Chlorimuron-ethyl	Herbicide	50306	90982-32-4	0.032	na	na	D
2-Chloro-6-ethylamino-4-amino-*s*-triazine (deisopropylatrazine)	Degradate	04038	1007-28-9	0.08	na	na	D
2-Chloro-4-isopropylamino-6-amino-*s*-triazine (deethylatrazine)	Degradate	04040	6190-65-4	0.028	na	na	D
3-(4-Chlorophenyl)-1-methyl urea	Degradate	61692	5352-88-5	0.036	na	na	—
Clopyralid	Herbicide	49305	1702-17-6	0.067	na	na	—
Cycloate	Herbicide	04031	1134-23-2	0.014	na	na	—
DCPA (Dactal) monoacid	Degradate	49304	887-54-7	0.028	na	na	—
Dicamba	Herbicide	38442	1918-00-9	0.036	HAL-US	400	—
2,4-D and 2,4-D methyl ester, summed on molar basis, reported as 2,4-D	Herbicide	66496	94-75-7	0.009	MCL-US	70	D
4-(2,4-Dichlorophenoxy)butyric acid (2,4-DB)	Herbicide	38746	94-82-6	0.020	na	na	—
Dichlorprop	Herbicide	49302	120-36-5	0.028	na	na	—
Dinoseb	Herbicide	49301	88-85-7	0.038	MCL-US	7	D
Diphenamid	Herbicide	04033	957-51-7	0.010	HAL-US	200	—
Diuron	Herbicide	49300	330-54-1	0.016	RSD5	200	D
Fenuron	Herbicide	49297	101-42-8	0.01	na	na	—
Flumetsulam	Herbicide	61694	98967-40-9	0.04	na	na	—
Fluometuron	Herbicide	38811	2164-17-2	0.016	HAL-US	90	—
3-Hydroxycarbofuran	Degradate	49308	16655-82-6	0.008	na	na	—
2-Hydroxy-4-isopropylamino-6-ethylamino-*s*-triazine (hydroxyatrazine)	Degradate	50355	2163-68-0	0.032	na	na	D
Imazaquin	Herbicide	50356	81335-37-7	0.036	na	na	—
Imazethapyr	Herbicide	50407	81335-77-5	0.038	na	na	—
Imidacloprid	Insecticide	61695	138261-41-3	0.02	na	na	—
Linuron	Herbicide	38478	330-55-2	0.014	na	na	—
Metalaxyl	Fungicide	50359	57837-19-1	0.03	na	na	—
Methiocarb	Insecticide	38501	2032-65-7	0.034	na	na	—
Methomyl	Insecticide	49296	16752-77-5	0.07	HAL-US	200	—
2-Methyl-4-chlorophenoxyacetic acid (MCPA)	Herbicide	38482	94-74-6	0.07	HAL-US	4	D

Table 3D. Pesticides and pesticide degradates, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 2060.—Continued

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, analyzed but not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	LRL (µg/L)	Type of comparison threshold	Threshold (µg/L)	Detection
4-(2-Methyl-4-chlorophenoxy) butyric acid (MCPB)	Herbicide	38487	94-81-5	0.1	na	na	—
Metsulfuron methyl[1]	Herbicide	61697	74223-64-6	0.067	na	na	—
Neburon	Herbicide	49294	555-37-3	0.012	na	na	—
Nicosulfuron	Herbicide	50364	111991-09-4	0.04	na	na	—
Norflurazon	Herbicide	49293	27314-13-2	0.02	na	na	—
Oryzalin	Herbicide	49292	19044-88-3	0.023	na	na	—
Oxamyl	Insecticide	38866	23135-22-0	0.05	MCL-CA	50	—
Picloram	Herbicide	49291	1918-02-01	0.032	MCL-US	500	—
Propham	Herbicide	49236	122-42-9	0.03	HAL-US	100	—
Propiconazole	Fungicide	50471	60207-90-1	0.01	na	na	D
Propoxur	Insecticide	38538	114-26-1	0.008	na	na	—
Siduron	Herbicide	38548	1982-49-6	0.02	na	na	—
Sulfometuron-methyl	Herbicide	50337	74222-97-2	0.09	na	na	—
Tebuthiuron	Herbicide	82670	34014-18-1	0.026	HAL-US	500	D
Terbacil	Herbicide	04032	5902-51-2	0.026	HAL-US	90	—
Triclopyr	Herbicide	49235	55335-06-3	0.026	na	na	D

[1] These constituents were reported using method reporting levels (MRLs) during the period of this study.

Table 3E. Pharmaceutical compounds, primary uses or sources, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 2080.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. Thresholds and threshold values as of February 10, 2007. CAS, Chemical Abstracts Service; MDL, method detection limit; na, not available; µg/L, micrograms per liter]

Constituent	Primary use or source	USGS parameter code	CAS number	MDL[1] (µg/L)	Threshold type	Threshold value (µg/L)
Acetaminophen	Analgesic	62000	103-90-2	0.60	na	na
Albuterol	Anti-inflammatory; bronchodilator	62020	18559-94-9	0.03	na	na
Caffeine	Stimulant	50305	58-08-2	0.40	na	na
Carbamazapine	Anticonvulsant; mood stabilizer	62793	298-46-4	0.02	na	na
Codeine	Opiod narcotic	62003	76-57-3	0.02	na	na
Cotinine	Nicotine metabolite	62005	486-56-6	0.03	na	na
Dehydronifedipine	Antianginal metabolite	62004	67035-22-7	0.03	na	na
Diltiazem	Antianginal; antihypertensive	62008	42399-41-7	0.02	na	na
Diphenhydramine	Antihistamine	62796	58-73-1	0.03	na	na
Paraxanthine	Caffeine metabolite	62030	611-59-6	0.10	na	na
Sulfamethoxazole	Antibacterial, antiprotozoal	62021	723-46-6	0.05	na	na
Thiabendazole	Anthelmintic	62801	148-79-8	0.02	na	na
Trimethoprim	Antibacterial	62023	738-70-5	0.01	na	na
Warfarin	Anticoagulant	62024	81-81-2	0.03	na	na

[1]The California Groundwater Ambient Monitoring and Assessment (GAMA) program uses more conservative reporting limits for the pharmaceutical compounds than recommended by the USGS's National Water Quality Laboratory. For albuterol, carbamazepine, codeine, dehydronifedipine, diltiazem, sulfamethoxazole, thiabendazole, trimethoprim, and warfarin, the MDL corresponds to the long-term method detection limit determined by the USGS's Branch of Quality Systems in October 2007 (BQS LT-MDL). For acetaminophen, caffeine, cotinine, diphenhydramine, and paraxanthine, the MDL corresponds to the effective method detection limit determined from assessment of quality-control data associated with GAMA samples collected from May 2004 to September 2007 (GAMA E-MDL). The GAMA E-MDL is higher than the BQS LT-MDL for those compounds. Detections reported by the USGS's National Water Quality Laboratory with concentrations lower than the BQS LT-MDL or GAMA E-MDL are reported as nondetections by the GAMA program.

Table 3F. Constituents of special interest, primary uses or sources, comparative thresholds, and reporting information for the Montgomery Watson Harza laboratory.

[The five-digit U.S. Geological Survey (USGS) parameter code is used to uniquely identify a specific constituent or property. Thresholds and threshold values as of October 18, 2007. The laboratory entity code for the Montgomery Watson Harza laboratory in the USGS's National Water Information System (NWIS) is CA-MWHL. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-CA, Lifetime Health Advisory Level (CDPH); MCL-CA, maximum contaminant level (CDPH); MRL, minimum reporting level; NL-CA, notification level (CDPH); µg/L, micrograms per liter; —, not detected]

Constituent	Primary use or source	USGS parameter code	CAS number	MRL (µg/L)	Threshold type	Threshold value (µg/L)	Detection
Perchlorate	Rocket fuel, fireworks, flares	61209	14797-73-0	0.5	MCL-CA	6	D
1,2,3-Trichloropropane (1,2,3-TCP)	Fumigant, solvent	77443	96-18-4	0.005	HAL-CA	40	—
N-Nitrosodimethylamine (NDMA)	Rocket fuel, plasticizer	64176	62-75-9	0.002	NL-CA	10	—

Table 3G. Nutrients and dissolved organic carbon, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 2755 and parameter code 2613.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. CAS, Chemical Abstracts Service; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-US, maximum contaminant level (USEPA); mg/L, milligrams per liter; na, not available; USEPA, U.S. Environmental Protection Agency]

Constituent	USGS parameter code	CAS number	LRL (mg/L)	Threshold type	Threshold value (mg/L)	Detection
Ammonia (as nitrogen)	00608	7664-41-7	0.01	HAL-US	30	D
Nitrate plus nitrite (as nitrogen)	00631	na	0.06	MCL-US	10	D
Nitrite (as nitrogen)	00613	14797-65-0	0.002	MCL-US	1	D
Total nitrogen (ammonia + nitrate + nitrite + organic nitrogen as nitrogen)	62854	17778-88-0	0.06	na	na	D
Orthophosphate (as phosphorus)	00671	14265-44-2	0.006	na	na	D
Dissolved organic carbon (DOC)	00681	na	0.33	na	na	D

Table 3H. Major and minor ions and trace elements, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedule 1948.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); mg/L, milligrams per liter; na, not available; NL-CA, notification level (CDPH); SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter; —, not detected]

Constituent	USGS parameter code	CAS number	LRL	Threshold type	Threshold value	Detection
Major and minor ions (mg/L)						
Bromide	71870	24959-67-9	0.02	na	na	D
Calcium	00915	7440-70-2	0.02	na	na	D
Chloride	00940	16887-00-6	0.2	SMCL-CA	250 (500)[1]	D
Fluoride	00950	16984-48-8	0.1	MCL-CA	2	D
Iodide	78165	7553-56-2	0.002	na	na	D
Magnesium	00925	7439-95-4	0.008	na	na	D
Potassium	00935	7440-09-7	0.16	na	na	D
Silica	00955	7631-86-9	0.04	na	na	D
Sodium	00930	7440-23-5	0.2	na	na	D
Sulfate	00945	14808-79-8	0.18	SMCL-CA	250 (500)[1]	D
Total dissolved solids (TDS)	70300	na	10	SMCL-US	500 (1,000)[1]	D
Trace elements (µg/L)						
Aluminum	01106	7429-90-5	1.6	MCL-CA	1,000	D
Antimony	01095	7440-36-0	0.2	MCL-US	6	D
Arsenic	01000	7440-38-2	0.12	MCL-US	10	D
Barium	01005	7440-39-3	0.2	MCL-CA	1,000	D
Beryllium	01010	7440-41-7	0.06	MCL-US	4	—
Boron	01020	7440-42-8	8	NL-CA	1,000	D
Cadmium	01025	7440-43-9	0.04	MCL-US	5	D
Chromium	01030	7440-47-3	0.4	MCL-CA	50	D
Cobalt	01035	7440-48-4	0.04	na	na	D
Copper	01040	7440-50-8	0.4	AL-US	1,300	D
Iron	01046	7439-89-6	6	SMCL-CA	300	D
Lead	01049	7439-92-1	0.08	AL-US	15	D
Lithium	01130	7439-93-2	0.6	na	na	D
Manganese	01056	7439-96-5	0.2	SMCL-CA	50	D
Mercury	71890	7439-97-6	0.01	MCL-US	2	—
Molybdenum	01060	7439-98-7	0.4	HAL-US	40	D
Nickel	01065	7440-02-0	0.06	MCL-CA	100	D
Selenium	01145	7782-49-2	0.8	MCL-US	50	D
Silver	01075	7440-22-4	0.2	SMCL-CA	100	—
Strontium	01080	7440-24-6	0.4	HAL-US	4,000	D
Thallium	01057	7440-28-0	0.04	MCL-US	2	D
Tungsten	01155	7440-33-7	0.06	na	na	D
Uranium	22703	7440-61-1	0.04	MCL-US	30	D
Vanadium	01085	7440-62-2	0.1	NL-CA	50	D
Zinc	01090	7440-66-6	0.6	SMCL-US	5,000	D

[1] The recommended SMCL-CA thresholds for chloride, sulfate, and TDS are listed with the upper SMCL-CA thresholds in parentheses.

Table 3I. Arsenic, chromium, and iron species, comparative thresholds, and reporting information for the U.S. Geological Survey's (USGS) Trace Metal Laboratory, Boulder, Colorado.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. The laboratory entity code for the USGS Trace Metal Laboratory in the USGS's National Water Information System (NWIS) is USGSTMCO. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); MDL, method detection limit; na, not available; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; µg/L, micrograms per liter]

Constituent (valence state)	USGS parameter code	CAS number	MDL (µg/L)	Threshold type	Threshold level (µg/L)	Detection
Inorganic Arsenic(III)	99034	22569-72-8	1	na	na	D
Inorganic Arsenic(Total)	99033	7440-38-2	0.5	MCL-US	10	D
Chromium(VI)	01032	18540-29-9	1	na	na	D
Chromium(Total)	01030	7440-47-3	1	MCL-CA	50	D
Iron(II)	01047	7439-89-6	2	na	na	D
Iron(Total)	01046	7439-89-6	2	SMCL-CA	300	D

Table 3J. Isotopic and radioactive constituents, comparative thresholds, and reporting information for laboratories.

[The five-digit U.S. Geological Survey (USGS) parameter code is used to uniquely identify a specific constituent or property. The laboratory entity codes for the laboratories in the USGS's National Water Information System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; D, detected; hr, hour; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); MRL, minimum reporting level; MU, method uncertainty; na, not available; pCi/L, picocuries per liter; SSMDC, sample-specific minimum detectable concentration; USEPA, U.S. Environmental Protection Agency; —, not detected]

Constituent	USGS parameter code	CAS number	Reporting level type	Reporting level or uncertainty	Threshold type[1]	Threshold value	Detection
Stable isotope ratios (per mil)							
$\delta^{2}H$ of water[2]	82082	na	MU	2	na	na	D
$\delta^{18}O$ of water[2]	82085	na	MU	0.20	na	na	D
$\delta^{15}N$ of nitrate[2]	82690	na	MU	0.50	na	na	D
$\delta^{18}O$ of nitrate[2]	63041	na	MU	1.00	na	na	D
$\delta^{13}O$ of dissolved carbonates[3]	82081	na	1 sigma	0.05	na	na	D
Radioactive constituents (percent modern)							
Carbon-14[4]	49933	14762-75-5	1 sigma	0.0015	na	na	D
Radioactive constituents (pCi/L)							
Radon-222[5]	82303	14859-67-7	SSMDC	see table 14	Proposed MCL-US[2]	[6]300 (4,000)	D
Tritium[7]	07000	10028-17-8	MRL	1	MCL-CA	20,000	D
Gross-alpha radioactivity, 72-hr count and 30-day counts[8]	62636, 62639	12587-46-1	SSMDC	see table 14	MCL-US	15	D
Gross-beta radioactivity, 72-hr count and 30-day counts[8]	62642, 62645	12587-47-2	SSMDC	see table 14	MCL-CA	50	D
Radium-226[8]	09511	13982-63-3	SSMDC	see table 14	MCL-US[9]	5	D
Radium-228[8]	81366	15262-20-1	SSMDC	see table 14	MCL-US[9]	5	D

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA).

[3] University of Waterloo (contract laboratory) (CAN-UWIL).

[4] University of Arizona, Accelerator Mass Spectrometry Laboratory (contract laboratory) (AZ-UAMSL).

[5] USGS National Water Quality Laboratory (USGSNWQL).

[6] Two MCLs have been proposed for radon-222. The proposed alternaltive MCL is given in parentheses.

[7] USGS Stable Isotope and Tritium Laboratory, Menlo Park, California (USGSH3CA).

[8] Eberline Analytical Services (contract laboratory) (CA-EBERL).

[9] The MCL-US threshold for radium is the sum of radium-226 and radium-228.

Table 3K. Noble gases and tritium, comparison thresholds and reporting information for the Lawrence Livermore National Laboratory.

[The five-digit U.S. Geological Survey (USGS) parameter code is used to uniquely identify a specific constituent or property. The laboratory entity code for the Lawrence Livermore National Laboratory in the USGS's National Water Information System (NWIS) is CA-LLNL. CAS, Chemical Abstracts Service; CDPH, California Department of Public Health; cm^3 STP/g H_2O, cubic centimeters of gas at standard temperature and pressure per gram of water; MCL-CA, maximum contaminant level (CDPH); na, not available; pCi/L, picocuries per liter]

Constituent	USGS parameter code	CAS number	MU (percent)	Reporting units	Threshold type	Threshold value (pCi/L)	Detection
Helium-3/Helium-4	61040	na/7440-59-7	0.75	atom ratio	na	na	na
Argon	85563	7440-37-1	2	cm^3STP/g H_2O	na	na	na
Helium-4	85561	7440-59-7	2	cm^3STP/g H_2O	na	na	na
Krypton	85565	7439-90-9	2	cm^3STP/g H_2O	na	na	na
Neon	61046	7440-01-09	2	cm^3STP/g H_2O	na	na	na
Xenon	85567	7440-63-3	2	cm^3STP/g H_2O	na	na	na
Tritium	07000	10028-17-8	1	pCi/L	MCL-CA	20,000	na

Table 3L. Microbial constituents, comparison thresholds, and reporting information for the U.S. Geological Survey's (USGS) Ohio Microbiology Laboratory parameter codes 90901, 90900, 99335, and 99332.

[The five-digit USGS parameter code is used to uniquely identify a specific constituent or property. The laboratory entity code for the USGS's Ohio Microbiology Laboratory in the USGS's National Water Information System (NWIS) is given in footnote 3. MCL-US, maximum contaminant level (USEPA); MDL, method detection limit; mL, milliliters; na, not available; TT-US, U.S. Environmental Protection Agency treatment technique—a required process intended to reduce the level of contamination in drinking water; USEPA, U.S. Environmental Protection Agency; —, analyzed but not detected]

Constituent	USGS parameter code	Primary source	MDL	Threshold type[1]	Threshold value	Detection
Escherichia coliform[2]	90901	Sewage and animal waste indicator/intestinal tracts of humans and animals	1 colony/100 mL	TT-US	No fecal coliforms are allowed.	—
Total coliform (including fecal coliform and *E. coli*)[2]	90900	Water-quality indicator/ soil, water and intestinal tracts of animals	1 colony/100 mL	MCL-US	No more then 5 percent samples total coliform-positives in a month. Every sample that has total coloforms must be analyzed for fecal coliforms; no fecal coliforms are allowed.	—
F-specific coliphage[3]	99335	Viral indicator/intestinal tracts of warm-blooded animals	na	TT-US	99.99 percent killed/ inactivated	—
Somatic coliphage[3]	99332	Viral indicator/fecal contaminated waters	na	TT-US	99.99 percent killed/ inactivated	—

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] Analyzed in the field.

[3] Analyzed by the USGS's Ohio Microbiology Laboratory (laboratory entity code USGSOHML).

Table 4. Water-quality indicators in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[The five-digit number below the constituent name in the headings is the U.S. Geological Survey (USGS) parameter code used to uniquely identify a specific constituent or property. °C, degrees Celsius; CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; mg/L, milligrams per liter; mm, millimeter; na, not available; nc, sample not collected; no., number; NTU, nephelometric turbidity unit; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); SMCL-U.S., secondary maximum contaminant level (USEPA); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µS/cm, microsiemens per centimeter; *, value above recommended threshold level; **, value above upper threshold level; <, less than]

GAMA identification no.	Turbidity (NTU) (63676)	Dissolved oxygen (mg/L) (00300)	Water temperature (°C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab (µS/cm at 25°C) (90095)	Specific conductance, field (µS/cm at 25°C) (00095)	Alkalinity, lab (mg/L as $CaCO_3$) (29801)	Alkalinity, field (mg/L as $CaCO_3$) (29802)
Reporting limit or range	**0.1**	**0.2**	**0.0-38.5**	**0-14**	**0-14**	**5**	**5**	**1**	**1**
Threshold type	**na**[1]	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA**[2]	**SMCL-CA**[2]	**na**	**na**
Threshold level	**na**[1]	**na**	**na**	**6.5–8.5**	**6.5–8.5**	**900 (1,600)**	**900 (1,600)**	**na**	**na**
				Grid wells					
ESAC-01	nc	2.4	19.0	nc	nc	nc	372	nc	nc
ESAC-02	nc	<0.2	19.0	nc	nc	nc	** 2,040	nc	nc
ESAC-03	nc	3.2	23.0	7.8	7.8	432	417	146	nc
ESAC-04	nc	6.8	19.5	nc	7.5	nc	422	nc	nc
ESAC-05	nc	1.6	19.0	7.7	7.1	511	507	195	nc
ESAC-06	nc	6.9	21.0	7.5	7.1	209	208	106	nc
ESAC-07	nc	4.7	21.5	nc	7.7	nc	255	nc	nc
ESAC-08	nc	1.9	16.5	nc	7.7	nc	459	nc	nc
ESAC-09	nc	2.6	19.0	nc	* 6.3	nc	418	nc	nc
ESAC-10	nc	0.4	19.5	7.6	7.3	511	513	210	nc
ESAC-11	nc	0.4	21.0	7.7	7.4	212	220	111	nc
ESAC-12	nc	nc	18.5	7.9	nc	338	341	179	nc
ESAC-13	nc	3.9	16.5	nc	nc	nc	322	nc	nc
ESAC-14	nc	2.5	19.5	nc	7.0	nc	373	nc	nc
ESAC-15	nc	10.1	18.0	7.8	7.6	281	280	118	nc
ESAC-16	nc	9.9	20.0	7.7	7.5	385	380	134	nc
ESAC-17	nc	<0.2	19.0	7.7	7.3	* 959	898	304	nc
ESAC-18	nc	8.7	19.0	7.9	7.7	227	227	111	nc
ESAC-19	nc	2.3	21.0	7.6	7.0	429	421	191	nc
ESAC-20	nc	<0.2	20.6	nc	7.5	nc	321	nc	nc
ESAC-21	nc	<0.2	17.5	7.9	7.6	** 2,380	** 2,370	218	nc
ESAC-22	nc	8.9	18.5	7.0	* 6.5	312	314	81	nc
ESAC-23	nc	3.4	17.0	nc	* 6.3	nc	254	nc	nc
ESAC-24	nc	nc	19.5	nc	7.5	nc	281	nc	nc
ESAC-25	0.2	6.9	21.5	7.8	7.2	205	207	106	98
ESAC-26	0.1	<0.2	16.0	7.9	7.9	306	292	162	148
ESAC-27	0.1	0.8	19.0	7.3	7.1	497	486	221	212

Table 4. Water-quality indicators in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[The five-digit number below the constituent name in the headings is the U.S. Geological Survey (USGS) parameter code used to uniquely identify a specific constituent or property. °C, degrees Celsius; CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; mg/L, milligrams per liter; mm, millimeter; na, not available; nc, sample not collected; no., number; NTU, nephelometric turbidity unit; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); SMCL-U.S., secondary maximum contaminant level (USEPA); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µS/cm, microsiemens per centimeter; *, value above recommended threshold level; **, value above upper threshold level; <, less than]

GAMA identification no.	Turbidity (NTU) (63676)	Dissolved oxygen (mg/L) (00300)	Water temperature (°C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab (µS/cm at 25°C) (90095)	Specific conductance, field (µS/cm at 25°C) (00095)	Alkalinity, lab (mg/L as $CaCO_3$) (29801)	Alkalinity, field (mg/L as $CaCO_3$) (29802)
Reporting limit or range	**0.1**	**0.2**	**0.0-38.5**	**0-14**	**0-14**	**5**	**5**	**1**	**1**
Threshold type	**na[1]**	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA[2]**	**SMCL-CA[2]**	**na**	**na**
Threshold level	**na[1]**	**na**	**na**	**6.5–8.5**	**6.5–8.5**	**900 (1,600)**	**900 (1,600)**	**na**	**na**
ESAC-28	0.1	2.1	20.0	7.4	7.4	371	368	186	180
ESAC-29	nc	<0.2	17.0	8.0	nc	473	465	225	nc
ESAC-30	nc	0.2	15.5	7.9	7.8	432	408	121	nc
ESAC-31	nc	<0.2	18.5	7.8	7.6	642	613	297	nc
ESAC-32	nc	1.0	18.0	7.4	7.2	356	362	174	nc
ESAC-33	nc	4.1	20.0	nc	7.0	nc	367	nc	nc
ESAC-34	nc	2.5	17.5	7.6	7.2	593	591	273	nc
ESAC-35	nc	nc	17.5	7.7	7.4	331	324	168	nc
WSAC-01	nc	2.0	22.5	nc	8.1	nc	367	nc	nc
WSAC-02	nc	6.3	19.0	nc	7.3	nc	476	nc	nc
WSAC-03	0.1	7.7	20.0	7.5	7.3	338	337	133	122
WSAC-04	nc	<0.2	24.5	8.2	7.9	318	321	173	nc
WSAC-05	nc	<0.2	19.0	nc	7.9	nc	354	nc	nc
WSAC-06	nc	2.7	19.5	7.3	7.0	572	574	275	nc
WSAC-07	nc	7.0	18.0	nc	nc	nc	500	nc	nc
WSAC-07	nc	5.4	18.0	nc	7.1	nc	481	nc	nc
WSAC-08	0.2	4.1	20.5	7.4	7.0	535	536	221	202
WSAC-09	nc	6.3	19.0	nc	nc	nc	392	nc	nc
WSAC-09	nc	5.9	18.5	nc	6.9	nc	387	nc	nc
WSAC-10	nc	6.9	19.5	7.5	7.4	597	602	231	nc
WSAC-10	nc	6.2	19.5	nc	7.2	nc	562	nc	nc
WSAC-11	nc	7.1	23.5	7.8	7.8	652	649	189	nc
WSAC-11	nc	5.6	20.5	nc	7.7	nc	625	nc	nc
WSAC-12	0.3	<0.2	20.5	8.1	7.6	719	729	213	nc
WSAC-13	nc	2.1	20.0	nc	7.1	nc	782	nc	nc
WSAC-14	nc	<0.2	17.5	7.8	7.2	** 2,040	** 2,100	324	nc
WSAC-15	nc	6.9	18.0	7.6	7.1	* 938	* 931	388	nc

Table 4. Water-quality indicators in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[The five-digit number below the constituent name in the headings is the U.S. Geological Survey (USGS) parameter code used to uniquely identify a specific constituent or property. °C, degrees Celsius; CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; mg/L, milligrams per liter; mm, millimeter; na, not available; nc, sample not collected; no., number; NTU, nephelometric turbidity unit; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); SMCL-U.S., secondary maximum contaminant level (USEPA); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µS/cm, microsiemens per centimeter; *, value above recommended threshold level; **, value above upper threshold level; <, less than]

GAMA identification no.	Turbidity (NTU) (63676)	Dissolved oxygen (mg/L) (00300)	Water temperature (°C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab (µS/cm at 25°C) (90095)	Specific conductance, field (µS/cm at 25°C) (00095)	Alkalinity, lab (mg/L as $CaCO_3$) (29801)	Alkalinity, field (mg/L as $CaCO_3$) (29802)
Reporting limit or range	**0.1**	**0.2**	**0.0-38.5**	**0-14**	**0-14**	**5**	**5**	**1**	**1**
Threshold type	**na[1]**	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA[2]**	**SMCL-CA[2]**	**na**	**na**
Threshold level	**na[1]**	**na**	**na**	**6.5–8.5**	**6.5–8.5**	**900 (1,600)**	**900 (1,600)**	**na**	**na**
WSAC-16	nc	<0.2	19.0	nc	7.5	nc	* 1,240	nc	nc
WSAC-17	nc	1.3	18.0	7.5	7.2	428	429	204	nc
WSAC-18	0.1	<0.2	20.5	7.8	7.8	* 1,080	* 1,050	320	295
WSAC-19	nc	0.7	20.5	nc	7.6	nc	567	nc	nc
WSAC-20	nc	5.9	17.0	nc	7.0	nc	* 958	nc	nc
WSAC-21	nc	7.8	20.0	7.6	7.0	416	415	172	nc
WSAC-22	nc	5.1	21.0	7.8	7.7	516	523	211	nc
WSAC-23	nc	5.4	19.0	nc	7.2	nc	* 1,210	nc	nc
WSAC-24	nc	6.8	20.0	nc	7.2	nc	* 1,470	nc	nc
WSAC-25	nc	<0.2	19.5	8.0	7.8	465	449	222	nc
WSAC-26	nc	10.8	20.0	7.7	7.6	325	325	158	nc
WSAC-27	nc	0.5	18.5	nc	7.8	nc	* 914	nc	nc
WSAC-28	nc	4.8	19.5	7.4	7.2	433	425	168	nc
WSAC-29	nc	3.2	20.0	8.1	8.0	423	422	201	nc
WSAC-30	nc	2.2	19.0	7.7	7.4	** 1680	** 1,670	204	nc
WSAC-31	nc	1.8	19.0	8.2	8.0	279	280	129	nc
WSAC-32	nc	1.8	18.0	nc	7.8	nc	409	nc	nc
WSAC-33	nc	5.4	19.5	nc	7.6	nc	733	nc	nc
WSAC-34	nc	20.4	18.5	7.4	7.1	835	816	259	nc
WSAC-35	nc	13.3	18.5	7.6	7.3	475	478	206	nc
WSAC-36	nc	nc	18.5	7.9	7.6	424	461	216	nc
				Flow-path wells					
ESAC-FP-01	nc	<0.2	23.5	7.7	7.6	547	553	75	nc
ESAC-FP-02	6.6	4.0	23.5	7.5	7.2	441	449	202	nc
ESAC-FP-03	0.3	0.3	20.5	7.5	7.5	379	379	197	nc
ESAC-FP-04	1.0	0.5	20.5	8.2	8.3	206	206	108	nc
ESAC-FP-05	0.2	1.5	22.0	7.7	7.5	742	742	355	nc
ESAC-FP-06	3.1	0.2	22.0	* 8.9	* 8.8	315	316	134	nc

Table 4. Water-quality indicators in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[The five-digit number below the constituent name in the headings is the U.S. Geological Survey (USGS) parameter code used to uniquely identify a specific constituent or property. °C, degrees Celsius; CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; mg/L, milligrams per liter; mm, millimeter; na, not available; nc, sample not collected; no., number; NTU, nephelometric turbidity unit; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); SMCL-U.S., secondary maximum contaminant level (USEPA); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µS/cm, microsiemens per centimeter; *, value above recommended threshold level; **, value above upper threshold level; <, less than]

GAMA identification no.	Turbidity (NTU) (63676)	Dissolved oxygen (mg/L) (00300)	Water temperature (°C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab (µS/cm at 25°C) (90095)	Specific conductance, field (µS/cm at 25°C) (00095)	Alkalinity, lab (mg/L as $CaCO_3$) (29801)	Alkalinity, field (mg/L as $CaCO_3$) (29802)
Reporting limit or range	**0.1**	**0.2**	**0.0-38.5**	**0-14**	**0-14**	**5**	**5**	**1**	**1**
Threshold type	**na**[1]	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA**[2]	**SMCL-CA**[2]	**na**	**na**
Threshold level	**na**[1]	**na**	**na**	**6.5–8.5**	**6.5–8.5**	**900 (1,600)**	**900 (1,600)**	**na**	**na**
ESAC-FP-07	2.9	0.2	21.5	8.5	8.3	405	407	158	nc
WSAC-FP-01	0.7	5.7	24.0	7.9	7.6	342	338	182	nc
WSAC-FP-02	2.6	2.7	22.5	8.2	8.2	315	323	143	nc
WSAC-FP-03	3.6	5.8	23.0	8.0	7.8	416	421	176	nc
WSAC-FP-04	1.1	<0.2	20.0	* 8.6	* 8.6	315	312	148	nc
WSAC-FP-05	nc	0.2	21.5	8.0	8.0	* 928	* 934	250	nc
WSAC-FP-06	2.1	<0.2	21.0	8.5	8.4	349	344	142	nc
WSAC-FP-07	0.6	0.2	20.5	8.4	8.2	326	330	145	nc
WSAC-FP-08	1.4	1.4	20.5	7.9	7.6	403	409	185	nc
				RICE wells					
RICE-01	4.0	<0.2	19.0	7.0	6.8	** 13,600	** 13,800	nc	nc
RICE-02	0.3	<0.2	18.5	7.8	7.3	591	593	nc	335
RICE-03	0.2	<0.2	19.5	7.5	7.0	853	875	nc	432
RICE-04	0.7	0.4	17.5	7.4	6.8	630	644	nc	328
RICE-05	0.3	0.2	18.0	7.0	* 6.4	890	* 930	nc	426
RICE-06	0.2	<0.2	18.0	7.1	6.6	720	756	nc	384
RICE-07	1.1	0.2	20.0	7.8	7.3	784	803	nc	421
RICE-08	0.1	0.4	18.0	7.7	7.3	780	796	nc	378
RICE-09	1.8	<0.2	19.5	7.9	7.2	239	267	nc	128
RICE-10	0.4	<0.2	21.0	8.0	7.4	330	363	nc	169
RICE-11	0.9	0.2	20.0	7.3	7.0	*937	* 968	nc	414
RICE-12	0.9	<0.2	21.5	7.7	7.3	798	818	nc	397
RICE-13	1.0	<0.2	19.0	7.5	7.1	*915	* 944	nc	416
RICE-14	0.5	<0.2	18.5	7.3	7.0	823	844	nc	401
RICE-15	0.5	<0.2	17.0	7.8	7.3	* 947	* 944	nc	436
RICE-16	0.6	1.5	20.0	7.8	7.3	** 1,870	** 1840	nc	596

Table 4. Water-quality indicators in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[The five-digit number below the constituent name in the headings is the U.S. Geological Survey (USGS) parameter code used to uniquely identify a specific constituent or property. °C, degrees Celsius; CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; mg/L, milligrams per liter; mm, millimeter; na, not available; nc, sample not collected; no., number; NTU, nephelometric turbidity unit; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); SMCL-U.S., secondary maximum contaminant level (USEPA); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µS/cm, microsiemens per centimeter; *, value above recommended threshold level; **, value above upper threshold level; <, less than]

GAMA identification no.	Turbidity (NTU) (63676)	Dissolved oxygen (mg/L) (00300)	Water temperature (°C) (00010)	pH, lab (standard units) (00403)	pH, field (standard units) (00400)	Specific conductance, lab (µS/cm at 25°C) (90095)	Specific conductance, field (µS/cm at 25°C) (00095)	Alkalinity, lab (mg/L as $CaCO_3$) (29801)	Alkalinity, field (mg/L as $CaCO_3$) (29802)
Reporting limit or range	**0.1**	**0.2**	**0.0-38.5**	**0-14**	**0-14**	**5**	**5**	**1**	**1**
Threshold type	**na**[1]	**na**	**na**	**SMCL-US**	**SMCL-US**	**SMCL-CA**[2]	**SMCL-CA**[2]	**na**	**na**
Threshold level	**na**[1]	**na**	**na**	**6.5–8.5**	**6.5–8.5**	**900 (1,600)**	**900 (1,600)**	**na**	**na**
RICE-17	0.5	<0.2	18.5	7.7	7.4	** 4,770	** 4750	nc	350
RICE-18	0.4	<0.2	19.0	7.7	7.3	855	863	nc	343
RICE-19	0.2	<0.2	18.5	7.8	7.4	481	489	nc	245
RICE-20	0.2	<0.2	18.0	7.7	7.3	* 1,000	* 1,010	nc	407
RICE-21	0.1	0.2	18.5	7.6	7.3	** 1,650	** 1,680	nc	347
RICE-22	0.6	0.2	18.0	7.5	7.3	** 3,290	** 3,310	nc	415

[1]A TT-US threshold of 5 NTU does exist, but it applies to surface water and, therefore, is not included with this table.

[2] Specific conductance has a recommended and an upper threshold value. The upper value is shown in parentheses.

Table 5. Volatile organic compounds (VOCs), and gasoline oxygenates and degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use or source, and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Trihalomethanes			Gasoline Hydrocarbons and Oxygenates										
	Chloroform (Trichloromethane) (µg/L) (32106)	Bromodichloromethane (µg/L) (32101)	Bromoform (µg/L) (32104)	Methyl *tert*-butyl ether (MTBE) (µg/L) (78032)	1,2,4-Trimethylbenzene (µg/L) (77222)	1,3,5-Trimethylbenzene (µg/L) (77226)	1,2,3-Trimethylbenzene (µg/L) (77221)	1,2,3,4-Tetramethylbenzene (µg/L) (49999)	1,2,3,5-Tetramethylbenzene (µg/L) (50000)	2-Ethyltoluene (µg/L) (77220)	4-Isopropyltoluene (µg/L) (77356)	Benzene (µg/L) (34030)	*m*- and *p*-Xylene (µg/L) (85795)	Toluene (µg/L) (34010)
[LRL]	[0.024]	[0.028]	[0.1]	[0.1]	[0.056]	[0.044]	[0.09]	[0.14]	[0.18]	[0.06]	[0.08]	[0.021]	[0.06]	[0.02]
Threshold type[1]	MCL-US	MCL-US	MCL-US	MCL-CA	NL-CA	NL-CA	na	na	na	na	na	MCL-CA	MCL-CA	MCL-CA
Threshold (µg/L)	[2]80	[2]80	[2]80	13	330	330	na	na	na	na	na	1	1750	150
Grid wells														
ESAC-01	V0.01	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-02	V0.01	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-03	0.14	—	—	E0.1	—	—	—	—	—	—	—	—	—	—
ESAC-07	E0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-15	E0.06	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-17	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-21	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-22	—	—	—	—	E0.07	E0.02	—	—	—	—	—	—	—	—
ESAC-25	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—
ESAC-27	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—
ESAC-28	E0.09	—	—	—	V0.05	—	—	—	—	—	—	—	—	—
ESAC-32	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-33	0.86	E0.04	—	0.1	—	—	—	—	—	—	—	—	—	—
WSAC-03	0.2	E0.03	0.11	—	—	—	—	—	—	—	—	—	—	—
WSAC-05	—	—	—	E0.1	—	—	—	—	—	—	—	—	—	—
WSAC-11	E0.08	—	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-12	—	—	—	—	V0.02	—	—	—	—	—	—	—	—	—
WSAC-16	0.16	E0.02	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-17	E0.05	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 5. Volatile organic compounds (VOCs), and gasoline oxygenates and degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use or source, and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Trihalomethanes			Gasoline Hydrocarbons and Oxygenates											
	Chloroform (Trichloromethane) (µg/L) (32106)	Bromodichloromethane (µg/L) (32101)	Bromoform (µg/L) (32104)	Methyl *tert*-butyl ether (MTBE) (µg/L) (78032)	1,2,4-Trimethylbenzene (µg/L) (77222)	1,3,5-Trimethylbenzene (µg/L) (77226)	1,2,3-Trimethylbenzene (µg/L) (77221)	1,2,3,4-Tetramethylbenzene (µg/L) (49999)	1,2,3,5-Tetramethylbenzene (µg/L) (50000)	2-Ethyltoluene (µg/L) (77220)	4-Isopropyltoluene (µg/L) (77356)	Benzene (µg/L) (34030)	*m*- and *p*-Xylene (µg/L) (85795)	Toluene (µg/L) (34010)
[LRL]	[0.024]	[0.028]	[0.1]	[0.1]	[0.056]	[0.044]	[0.09]	[0.14]	[0.18]	[0.06]	[0.08]	[0.021]	[0.06]	[0.02]
Threshold type[1]	MCL-US	MCL-US	MCL-US	MCL-CA	NL-CA	NL-CA	na	na	na	na	na	MCL-CA	MCL-CA	MCL-CA
Threshold (µg/L)	[2]80	[2]80	[2]80	13	330	330	na	na	na	na	na	1	1750	150
WSAC-18	—	—	—	—	0.15	—	—	—	—	—	—	—	—	—
WSAC-24	V0.02	—	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-27	—	—	—	—	V0.06	E0.04	E0.1	E0.1	E0.1	E0.02	E0.01	—	—	—
WSAC-28	—	—	—	—	V0.04	—	—	—	—	—	—	—	—	—
WSAC-33	E0.08	—	—	—	—	—	—	—	—	—	—	—	—	—
Number of wells with detections	10	3	1	4	3	2	1	1	1	1	1	0	0	0
Detection frequency (percent)	14	4	1	6	4	3	1	1	1	1	1			
Flow-path wells														
ESAC-FP-02	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-FP-03	—	—	—	—	—	—	—	—	—	—	—	—	—	V0.02
ESAC-FP-06	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-FP-07	—	—	—	—	V0.02	—	—	—	—	—	—	—	—	—
WSAC-FP-04	—	—	—	—	—	—	—	—	E0.1	—	—	—	—	—
WSAC-FP-05	—	—	—	—	V0.03	—	—	—	—	—	—	—	—	—
WSAC-FP-06	—	—	—	—	—	—	—	—	E0.2	—	—	—	—	—
RICE wells														
RICE-01	—	—	—	—	—	—	—	—	—	—	—	E0.02	—	—
RICE-05	—	—	—	—	—	—	—	—	—	—	—	—	V0.01	—

Table 5. Volatile organic compounds (VOCs), and gasoline oxygenates and degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Contined

[Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use or source, and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Solvents								Organic synthesis	Refrigerant	VOC detections per well
	Perchloroethene (PCE) (µg/L) (34475)	1,1-Dichloroethane (µg/L) (34496)	*cis*-1,2-Dichloroethene (µg/L) (77093)	Carbon tetrachloride (µg/L) (32102)	*trans*-1,2-Dichloroethene (µg/L) (34546)	Trichloroethene (TCE) (µg/L) (39180)	Acetone (µg/L) (81552)	2-Butanone (MEK, Methyl ethyl ketone) (µg/L) (81595)	Carbon disulfide (µg/L) (77041)	Trichlorofluoromethane (CFC-11) (µg/L) (34488)	
[LRL]	[0.03]	[0.035]	[0.024]	[0.06]	[0.032]	[0.038]	[6]	[2]	[0.038]	[0.08]	
Threshold type[1]	MCL-US	MCL-CA	MCL-CA	MCL-CA	MCL-CA	MCL-US	na	HAL-US	NL-CA	MCL-CA	
Threshold (µg/L)	5	5	6	0.5	10	5	na	4000	160	150	
Grid wells											
ESAC-01	—	—	—	—	—	—	—	—	—	—	0
ESAC-02	—	—	—	—	—	—	—	—	—	—	0
ESAC-03	E0.02	E0.03	—	—	—	—	—	—	—	—	4
ESAC-07	—	—	—	—	—	—	—	—	—	—	1
ESAC-15	0.51	0.11	2.06	—	E0.01	0.11	—	—	—	—	6
ESAC-17	—	—	—	—	—	—	—	—	0.15	—	1
ESAC-21	—	—	—	—	—	—	—	—	E0.05	—	1
ESAC-22	—	—	—	—	—	—	—	—	—	—	2
ESAC-25	—	—	—	—	—	—	—	—	—	—	1
ESAC-27	—	—	—	—	—	—	—	—	—	—	1
ESAC-28	—	—	—	—	—	—	—	—	—	—	1
ESAC-32	E0.05	—	—	—	—	—	—	—	—	—	1
ESAC-33	0.96	—	—	—	—	—	—	—	—	0.11	5
WSAC-03	—	—	—	—	—	—	—	—	—	—	3
WSAC-05	—	—	—	—	—	—	—	—	—	—	1
WSAC-11	—	—	—	—	—	—	—	—	—	—	1
WSAC-12	—	—	—	—	—	—	—	—	—	—	0
WSAC-16	—	—	—	—	—	—	—	—	—	—	2
WSAC-17	—	—	—	—	—	—	—	—	—	—	1

Table 5. Volatile organic compounds (VOCs), and gasoline oxygenates and degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Contined

[Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use or source, and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; NL-CA, notification level (CDPH); no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Solvents								Organic synthesis	Refrigerant	VOC detections per well
	Perchloroethene (PCE) (µg/L) (34475)	1,1-Dichloroethane (µg/L) (34496)	*cis*-1,2-Dichloroethene (µg/L) (77093)	Carbon tetrachloride (µg/L) (32102)	*trans*-1,2-Dichloroethene (µg/L) (34546)	Trichloroethene (TCE) (µg/L) (39180)	Acetone (µg/L) (81552)	2-Butanone (MEK, Methyl ethyl ketone)	Carbon disulfide (µg/L) (77041)	Trichlorofluoromethane (CFC-11) (µg/L) (34488)	
[LRL]	[0.03]	[0.035]	[0.024]	[0.06]	[0.032]	[0.038]	[6]	[2]	[0.038]	[0.08]	
Threshold type[1]	MCL-US	MCL-CA	MCL-CA	MCL-CA	MCL-CA	MCL-US	na	HAL-US	NL-CA	MCL-CA	
Threshold (µg/L)	5	5	6	0.5	10	5	na	4000	160	150	
WSAC-18	—	—	—	—	—	—	—	—	—	—	1
WSAC-24	—	—	—	E0.04	—	—	—	—	—	—	1
WSAC-27	—	—	—	—	—	—	—	—	—	—	6
WSAC-28	—	—	—	—	—	—	—	—	—	—	0
WSAC-33	—	—	—	—	—	—	—	—	—	—	1
Number of wells with detections	4	2	1	1	1	1	0	0	2	1	
Detection frequency (percent)	6	3	1	1	1	1			3	1	[3]28
Flow-path wells											
ESAC-FP-02	E0.03	—	—	0.18	—	—	—	—	—	—	2
ESAC-FP-03	—	—	—	—	—	—	—	—	—	—	0
ESAC-FP-06	—	—	—	—	—	—	—	—	E0.03	—	1
ESAC-FP-07	—	—	—	—	—	—	E2	6.4	E0.03	—	3
WSAC-FP-04	—	—	—	—	—	—	—	—	—	—	1
WSAC-FP-05	—	—	—	—	—	—	—	—	—	—	0
WSAC-FP-06	—	—	—	—	—	—	—	—	—	—	1
RICE wells											
RICE-01	—	—	—	—	—	—	—	—	—	—	1
RICE-05	—	—	—	—	—	—	—	—	—	—	0

[1]Maximum contaminant level thresholds are listed as MCL-US when MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The MCL-US threshold for trihalomethanes is the sum of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

[3] Frequency of detection of at least one VOC in the grid wells. Detections with V remark codes are not included.

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

	Herbicides											
GAMA identification no.	**Bentazon (µg/L) (38711)**	**Atrazine (µg/L) (39632)**	**Simazine (µg/L) (04035)**	**Metolachlor (µg/L) (39415)**	**Hexazinone (µg/L) (04025)**	**Dinoseb (µg/L) (49301)**	**Molinate (µg/L) (82671)**	**Prometon (µg/L) (04037)**	**Acetochlor (µg/L) (49260)**	**Metribuzin (µg/L) (82630)**	**Tebuthiuron (µg/L) (82670)**	**Propanil (µg/L) (82679)**
[LRL]	**[0.024]**	**[0.008]**	**[0.005]**	**[0.006]**	**[0.026]**	**[0.038]**	**[0.003]**	**[0.01]**	**[0.006]**	**[0.028]**	**[0.026]**	**[0.011]**
Threshold type[1]	**MCL-CA**	**MCL-CA**	**MCL-US**	**HAL-US**	**HAL-US**	**MCL-US**	**MCL-CA**	**HAL-US**	**na**	**HAL-US**	**HAL-US**	**na**
Threshold value	**18**	**1**	**4**	**700**	**400**	**7**	**20**	**100**	**na**	**70**	**500**	**na**
Grid wells												
ESAC-01	—	E0.004	E0.003	—	—	—	—	—	—	—	—	—
ESAC-05	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-09	0.09	—	E0.004	—	—	—	E0.02	—	—	—	—	0.097
ESAC-10	0.47	0.008	—	—	—	—	—	—	—	—	—	—
ESAC-20	0.02	—	—	—	—	—	0.013	—	—	—	—	—
ESAC-22	—	E0.004	E0.004	—	—	—	—	—	—	—	—	—
ESAC-23	—	0.077	—	0.028	—	—	—	0.02	0.059	—	—	—
ESAC-24	—	E0.007	E0.005	—	—	—	—	—	—	—	—	—
ESAC-26	—	—	0.011	—	—	—	—	—	—	—	—	—
ESAC-27	0.03	0.011	0.024	—	—	—	—	—	—	—	—	—
ESAC-28	0.05	E0.005	—	—	—	—	—	—	—	—	—	—
ESAC-31	0.43	—	—	—	—	—	—	—	—	—	—	—
ESAC-32	0.04	—	—	—	—	—	—	—	—	—	—	—
ESAC-33	0.04	E0.004	—	—	—	E0.004	—	—	—	—	—	—
ESAC-34	0.1	—	—	—	—	E0.01	—	—	—	—	—	—
ESAC-35	0.08	—	—	—	—	—	—	—	—	—	—	—
WSAC-02	—	0.04	E0.005	—	—	—	—	—	—	—	—	—
WSAC-06	—	E0.004	E0.004	—	—	—	—	—	—	—	—	—
WSAC-07	—	E0.005	E0.005	—	—	—	—	—	—	—	—	—
WSAC-08	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-09	—	E0.007	E0.004	—	—	—	—	—	—	—	—	—
WSAC-11	—	—	E0.005	—	—	—	—	—	—	—	—	—
WSAC-12	0.09	—	—	—	—	—	—	—	—	—	—	—
WSAC-13	0.08	—	—	—	—	—	—	—	—	—	—	—
WSAC-14	E0.01	—	—	—	—	—	—	—	—	—	—	—
WSAC-15	—	—	0.009	E0.005	E0.009	—	—	—	—	—	0.03	—
WSAC-16	E0.005	—	—	—	—	—	—	—	—	—	—	—

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Herbicides											
	Bentazon (µg/L) (38711)	Atrazine (µg/L) (39632)	Simazine (µg/L) (04035)	Metolachlor (µg/L) (39415)	Hexazinone (µg/L) (04025)	Dinoseb (µg/L) (49301)	Molinate (µg/L) (82671)	Prometon (µg/L) (04037)	Acetochlor (µg/L) (49260)	Metribuzin (µg/L) (82630)	Tebuthiuron (µg/L) (82670)	Propanil (µg/L) (82679)
[LRL]	**[0.024]**	**[0.008]**	**[0.005]**	**[0.006]**	**[0.026]**	**[0.038]**	**[0.003]**	**[0.01]**	**[0.006]**	**[0.028]**	**[0.026]**	**[0.011]**
Threshold type[1]	**MCL-CA**	**MCL-CA**	**MCL-US**	**HAL-US**	**HAL-US**	**MCL-US**	**MCL-CA**	**HAL-US**	**na**	**HAL-US**	**HAL-US**	**na**
Threshold value	**18**	**1**	**4**	**700**	**400**	**7**	**20**	**100**	**na**	**70**	**500**	**na**
WSAC-17	—	—	E0.006	—	E0.008	—	—	—	—	—	—	—
WSAC-18	E0.02	—	—	—	—	—	—	—	—	—	—	—
WSAC-20	—	E0.004	0.01	E0.005	—	—	—	—	—	0.113	—	—
WSAC-23	—	—	0.008	—	—	—	—	—	—	—	—	—
WSAC-27	0.29	—	—	—	—	—	—	—	—	—	—	—
WSAC-28	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-29	E0.004	E0.006	—	—	—	—	—	—	—	—	—	—
WSAC-31	0.09	—	—	—	—	—	—	—	—	—	—	—
WSAC-32	E0.01	E0.005	E0.004	—	—	—	—	—	—	—	—	—
WSAC-34	—	E0.008	—	—	—	—	—	—	—	—	—	—
WSAC-35	E0.005	E0.005	E0.004	—	E0.016	—	—	—	—	—	—	—
WSAC-36	0.11	—	—	—	—	—	—	—	—	—	—	—
Number of wells with detections	21	17	17	3	3	2	2	1	1	1	1	1
Detection frequency (percent)	30	24	24	4	4	3	3	1	1	1	1	1
Flow-path wells												
ESAC-FP-03	0.15	—	—	—	—	—	—	—	—	—	—	—
ESAC-FP-05	E0.01	—	—	—	—	—	—	—	—	—	—	—
ESAC-FP-06	—	—	—	—	—	—	—	—	—	—	—	—
ESAC-FP-07	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-FP-06	—	—	—	—	—	—	—	—	—	—	—	—
WSAC-FP-08	0.13	—	—	—	—	—	—	—	—	—	—	—

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Herbicides											
	Bentazon (µg/L) (38711)	Atrazine (µg/L) (39632)	Simazine (µg/L) (04035)	Metolachlor (µg/L) (39415)	Hexazinone (µg/L) (04025)	Dinoseb (µg/L) (49301)	Molinate (µg/L) (82671)	Prometon (µg/L) (04037)	Acetochlor (µg/L) (49260)	Metribuzin (µg/L) (82630)	Tebuthiuron (µg/L) (82670)	Propanil (µg/L) (82679)
[LRL]	**[0.024]**	**[0.008]**	**[0.005]**	**[0.006]**	**[0.026]**	**[0.038]**	**[0.003]**	**[0.01]**	**[0.006]**	**[0.028]**	**[0.026]**	**[0.011]**
Threshold type[1]	**MCL-CA**	**MCL-CA**	**MCL-US**	**HAL-US**	**HAL-US**	**MCL-US**	**MCL-CA**	**HAL-US**	**na**	**HAL-US**	**HAL-US**	**na**
Threshold value	**18**	**1**	**4**	**700**	**400**	**7**	**20**	**100**	**na**	**70**	**500**	**na**
RICE wells												
RICE-01	—	—	—	—	—	—	0.008	—	—	—	—	—
RICE-03	—	E0.007	E0.005	—	—	—	—	—	—	—	—	E0.006
RICE-04	0.11	—	—	—	—	—	—	—	—	—	—	—
RICE-06	0.04	—	E0.003	—	—	—	—	—	—	—	—	—
RICE-07	1.46	—	—	—	—	—	—	—	—	—	—	—
RICE-08	E0.02	—	—	—	—	—	—	—	—	—	—	—
RICE-09	—	—	E0.004	—	E0.013	—	—	—	—	—	—	—
RICE-10	—	—	0.082	—	—	—	—	—	—	—	—	—
RICE-11	0.03	E0.007	E0.005	—	—	—	—	—	—	—	—	—
RICE-12	0.42	E0.005	E0.008	—	—	—	—	—	—	—	—	—
RICE-13	0.32	—	—	—	—	—	—	—	—	—	—	—
RICE-14	0.14	—	—	—	—	—	—	—	—	—	0.02	—
RICE-15	0.32	E0.007	—	—	—	—	—	—	—	—	—	—
RICE-16	0.29	—	—	—	—	—	—	—	—	—	—	—
RICE-17	1.7	—	—	—	—	—	—	—	—	—	—	—
RICE-18	1.82	—	—	—	—	—	—	—	—	—	—	—
RICE-19	0.08	0.008	—	—	—	—	—	—	—	—	—	—
RICE-20	0.21	—	E0.004	—	—	—	—	—	—	—	—	—
RICE-21	0.45	—	—	—	—	—	—	—	—	—	—	—
RICE-22	0.23	—	—	—	E0.014	—	—	—	—	—	—	—

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Herbicides—continued						Insecticides		
	Bensulfuron-methyl (µg/L) (61693)	MCPA (µg/L) (38482)	Triclopyr (µg/L) (49235)	2,4-D, (µg/L) (39732)	Chlorimuron (µg/L) (50306)	Bromacil (µg/L) (04029)	Chlorpyrifos (µg/L) (38933)	Carbaryl (µg/L) (82680)	Fipronil (µg/L) (62166)
[LRL]	**[0.018]**	**[0.07]**	**[0.026]**	**[0.038]**	**[0.032]**	**0.018**	**[0.005]**	**[0.041]**	**[0.016]**
Threshold type[1]	**na**	**HAL-US**	**na**	**MCL-US**	**na**	**HAL-US**	**HAL-US**	**RSD5-US**	**na**
Threshold value	**na**	**30**	**na**	**70**	**na**	**70**	**2**	**400**	**na**
				Grid wells					
ESAC-01	—	—	—	—	—		—	—	—
ESAC-05	—	—	—	—	—	V0.01	—	—	—
ESAC-09	E0.01	E0.02	0.12	—	—	—	—	E0.007	—
ESAC-10	—	—	na	—	—	—	—	—	—
ESAC-20	—	—	na	—	—	—	—	—	—
ESAC-22	—	—	—	—	—	V0.03	—	—	—
ESAC-23	—	—	na	—	—	—	0.008	—	E0.017
ESAC-24	—	—	na	—	—	—	—	—	—
ESAC-26	—	—	na	—	—	—	—	—	—
ESAC-27	—	—	na	—	—	—	—	—	—
ESAC-28	—	—	—	—	—	—	—	—	—
ESAC-31	—	—	—	—	—	—	—	—	—
ESAC-32	—	—	—	—	—	—	—	—	—
ESAC-33	—	—	—	—	—	—	—	—	—
ESAC-34	—	—	—	—	—	—	—	—	—
ESAC-35	—	—	—	—	—	—	—	—	—
WSAC-02	—	—	—	—	—	—	—	—	—
WSAC-06	—	—	—	—	—	—	—	—	—
WSAC-07	—	—	—	—	—	V0.004	—	—	—
WSAC-08	—	—	na	—	—	—	—	—	—
WSAC-09	—	—	—	—	—	—	—	—	—
WSAC-11	—	—	—	—	—	—	—	—	—
WSAC-12	—	—	—	—	—	—	—	—	—
WSAC-13	—	—	na	—	—	—	—	—	—
WSAC-14	—	—	na	—	—	—	—	—	—
WSAC-15	—	—	—	—	—	—	—	—	—
WSAC-16	—	—	na	—	—	—	—	—	—
WSAC-17	—	—	na	—	—	—	—	—	—

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Herbicides—continued						Insecticides		
	Bensulfuron-methyl (µg/L) (61693)	MCPA (µg/L) (38482)	Triclopyr (µg/L) (49235)	2,4-D, (µg/L) (39732)	Chlorimuron (µg/L) (50306)	Bromacil (µg/L) (04029)	Chlorpyrifos (µg/L) (38933)	Carbaryl (µg/L) (82680)	Fipronil (µg/L) (62166)
[LRL]	**[0.018]**	**[0.07]**	**[0.026]**	**[0.038]**	**[0.032]**	**0.018**	**[0.005]**	**[0.041]**	**[0.016]**
Threshold type[1]	**na**	**HAL-US**	**na**	**MCL-US**	**na**	**HAL-US**	**HAL-US**	**RSD5-US**	**na**
Threshold value	**na**	**30**	**na**	**70**	**na**	**70**	**2**	**400**	**na**
WSAC-18	—	—	—	—	—	—	—	—	—
WSAC-20	—	—	—	—	—	—	—	—	—
WSAC-23	—	—	—	—	—	—	—	—	—
WSAC-27	—	—	—	—	—	—	—	—	—
WSAC-28	—	—	—	—	—	—	—	—	—
WSAC-29	—	—	—	—	—	—	—	—	—
WSAC-31	—	—	—	—	—	—	—	—	—
WSAC-32	—	—	—	—	—	—	—	—	—
WSAC-34	—	—	—	—	—	—	—	—	—
WSAC-35	—	—	—	—	—	—	—	—	—
WSAC-36	—	—	—	—	—	—	—	—	—
Number of wells with detections	1	1	1	0	0	0	1	1	1
Detection frequency (percent)	1	1	1				1	1	1
Flow-path wells									
ESAC-FP-03	—	—	—	—	—	—	—	—	—
ESAC-FP-05	—	—	—	E0.004	—	—	—	—	—
ESAC-FP-06	—	—	E0.02	—	—	—	—	—	—
ESAC-FP-07	—	—	E0.01	—	—	—	—	—	—
WSAC-FP-06	—	—	—	—	—	—	—	—	—
WSAC-FP-08	—	—	—	—	—	—	—	—	—

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Herbicides—continued						Insecticides		
	Bensulfuron-methyl (µg/L) (61693)	MCPA (µg/L) (38482)	Triclopyr (µg/L) (49235)	2,4-D, (µg/L) (39732)	Chlorimuron (µg/L) (50306)	Bromacil (µg/L) (04029)	Chlorpyrifos (µg/L) (38933)	Carbaryl (µg/L) (82680)	Fipronil (µg/L) (62166)
[LRL]	**[0.018]**	**[0.07]**	**[0.026]**	**[0.038]**	**[0.032]**	**0.018**	**[0.005]**	**[0.041]**	**[0.016]**
Threshold type[1]	**na**	**HAL-US**	**na**	**MCL-US**	**na**	**HAL-US**	**HAL-US**	**RSD5-US**	**na**
Threshold value	**na**	**30**	**na**	**70**	**na**	**70**	**2**	**400**	**na**
RICE wells									
RICE-01	—	—	—	—	—	—	—	—	—
RICE-03	—	—	—	—	—	—	—	—	—
RICE-04	—	—	—	—	—	—	—	—	—
RICE-06	—	—	—	—	—	—	—	—	—
RICE-07	—	—	—	—	—	—	—	—	—
RICE-08	—	—	—	—	—	—	—	—	—
RICE-09	—	—	—	—	—	—	—	—	—
RICE-10	—	—	—	—	1.57	—	—	—	—
RICE-11	—	—	—	—	—	—	—	—	—
RICE-12	—	—	—	—	—	—	—	—	—
RICE-13	—	—	—	—	—	—	—	—	—
RICE-14	—	—	—	—	—	—	—	—	—
RICE-15	—	—	—	—	—	—	—	—	—
RICE-16	—	—	—	—	—	—	—	—	—
RICE-17	—	—	—	—	—	—	—	—	—
RICE-18	—	—	—	—	—	—	—	—	—
RICE-19	—	—	—	—	—	—	—	—	—
RICE-20	—	—	—	—	—	—	—	—	—
RICE-21	—	—	—	—	—	—	—	—	—
RICE-22	—	—	—	—	—	—	—	—	—

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Fungicides		Degradates							Pesticide detections per well
	cis-Propiconazole (µg/L) (79846)	*trans*-Propiconazole (µg/L) (79847)	Deethylatrazine (µg/L) (04040)	3,4-Dichloroaniline (µg/L) (61625)	Hydroxyatrazine (µg/L) (50355)	Desulfinylfipronil (µg/L) (62170)	Fipronil sulfide (µg/L) (62167)	Fipronil sulfone (µg/L) (62168)	Deisopropylatrazine (µg/L) (04038)	
[LRL]	[0.013]	[0.034]	[0.028]	[0.0045]	[0.032]	[0.012]	[0.013]	[0.024]	[0.08]	
Threshold type[1]	na	na	na	na	na	na	na	na	na	
Threshold value	na	na	na	na	na	na	na	na	na	
Grid wells										
ESAC-01	—	—	E0.006	—	—	—	—	—	—	3
ESAC-05	—	—	—	—	—	—	—	—	—	0
ESAC-09	—	—	—	E0.541	—	—	—	—	—	9
ESAC-10	—	—	E0.008	—	—	—	—	—	—	3
ESAC-20	—	—	—	—	—	—	—	—	—	2
ESAC-22	—	—	—	—	—	—	—	—	—	2
ESAC-23	—	—	E0.022	—	—	E0.008	E0.006	E0.008	—	10
ESAC-24	—	—	E0.007	—	—	—	—	—	—	3
ESAC-26	—	—	—	—	—	—	—	—	—	1
ESAC-27	—	—	E0.011	—	—	—	—	—	—	4
ESAC-28	—	—	E0.009	—	—	—	—	—	—	3
ESAC-31	—	—	—	—	—	—	—	—	—	1
ESAC-32	—	—	—	—	—	—	—	—	—	1
ESAC-33	—	—	E0.01	—	—	—	—	—	—	4
ESAC-34	—	—	—	—	—	—	—	—	—	2
ESAC-35	—	—	—	—	—	—	—	—	—	1
WSAC-02	—	—	E0.057	E0.006	E0.003	—	—	—	—	5
WSAC-06	—	—	E0.007	—	na	—	—	—	—	3
WSAC-07	—	—	E0.006	—	—	—	—	—	—	3
WSAC-08	—	—	E0.007	—	—	—	—	—	—	1
WSAC-09	—	—	E0.009	—	—	—	—	—	—	3
WSAC-11	—	—	—	—	—	—	—	—	—	1
WSAC-12	—	—	—	—	—	—	—	—	—	1
WSAC-13	—	—	—	—	—	—	—	—	—	1
WSAC-14	—	—	—	—	—	—	—	—	—	1
WSAC-15	—	—	E0.005	—	—	—	—	—	—	5
WSAC-16	—	—	—	—	—	—	—	—	—	1

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Fungicides		Degradates							Pesticide detections per well
	cis-Propiconazole (µg/L) (79846)	*trans*-Propiconazole (µg/L) (79847)	Deethylatrazine (µg/L) (04040)	3,4-Dichloroaniline (µg/L) (61625)	Hydroxyatrazine (µg/L) (50355)	Desulfinylfipronil (µg/L) (62170)	Fipronil sulfide (µg/L) (62167)	Fipronil sulfone (µg/L) (62168)	Deisopropylatrazine (µg/L) (04038)	
[LRL]	**[0.013]**	**[0.034]**	**[0.028]**	**[0.0045]**	**[0.032]**	**[0.012]**	**[0.013]**	**[0.024]**	**[0.08]**	
Threshold type[1]	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	
Threshold value	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	**na**	
WSAC-17	—	—	—	E0.005	E0.024	—	—	—	—	4
WSAC-18	—	—	—	—	—	—	—	—	—	1
WSAC-20	—	—	E0.006	—	—	—	—	—	—	5
WSAC-23	—	—	—	—	—	—	—	—	—	1
WSAC-27	—	—	—	—	—	—	—	—	—	1
WSAC-28	—	—	E0.005	—	—	—	—	—	—	1
WSAC-29	—	—	E0.005	—	—	—	—	—	—	3
WSAC-31	—	—	—	—	—	—	—	—	—	1
WSAC-32	—	—	E0.006	—	—	—	—	—	—	4
WSAC-34	—	—	E0.007	—	—	—	—	—	—	2
WSAC-35	—	—	E0.006	E0.006	—	—	—	—	—	6
WSAC-36	—	—	—	—	—	—	—	—	—	1
Number of wells with detections	0	0	19	4	3	1	1	1	0	
Detection frequency (percent)			27	6	4	1	1	1		[2]54
Flow-path wells										
ESAC-FP-03	—	—	—	—	—	—	—	—	—	1
ESAC-FP-05	—	—	—	—	—	—	—	—	—	2
ESAC-FP-06	E0.001	E0.01	—	—	—	—	—	—	—	3
ESAC-FP-07	—	—	—	—	—	—	—	—	—	1
WSAC-FP-06	—	—	—	—	—	—	—	—	E0.04	1
WSAC-FP-08	—	—	—	—	—	—	—	—	—	1

Table 6. Pesticides and pesticide degradates detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Results are from the U.S. Geological Survey's (USGS) National Water Quality Laboratory Schedules 2032, 2033, and 2060. Samples from all 108 wells were analyzed, but only wells with detections are listed. Constituents are grouped by primary use of source and within each group are listed in order of decreasing detection frequency in the 71 grid wells. The five-digit number in parentheses below the constituent name is used by the USGS to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA; maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; no., number; RICE, RICE well; RSD5-US, U.S. Environmental Protection Agency risk specific dose at a risk factor of 10^{-5} µg/L (RSD5s are calculated by dividing the 10^{-4} cancer risk concentration established by the USEPA by 10); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected]

GAMA identification no.	Fungicides		Degradates							Pesticide detections per well
	cis-Propicon-azole (µg/L) (79846)	*trans*-Propicon-azole (µg/L) (79847)	Deethyl-atrazine (µg/L) (04040)	3,4-Dichloro-aniline (µg/L) (61625)	Hydroxy-atrazine (µg/L) (50355)	Desulfinyl-fipronil (µg/L) (62170)	Fipronil sulfide (µg/L) (62167)	Fipronil sulfone (µg/L) (62168)	Deisopropyl-atrazine (µg/L) (04038)	
[LRL]	[0.013]	[0.034]	[0.028]	[0.0045]	[0.032]	[0.012]	[0.013]	[0.024]	[0.08]	
Threshold type[1]	na	na	na	na	na	na	na	na	na	
Threshold value	na	na	na	na	na	na	na	na	na	
RICE wells										
RICE-01	—	—	—	—	—	—	—	—	—	1
RICE-03	—	—	E0.006	—	—	—	—	—	—	4
RICE-04	—	—	—	—	—	—	—	—	—	1
RICE-06	—	—	—	E0.004	—	—	—	—	—	3
RICE-07	—	—	—	—	—	—	—	—	—	1
RICE-08	—	—	—	—	—	—	—	—	—	1
RICE-09	—	—	—	—	—	—	—	—	—	2
RICE-10	—	—	—	E0.091	—	—	—	—	0.15	4
RICE-11	—	—	E0.006	—	—	—	—	—	—	4
RICE-12	—	—	E0.006	E0.006	—	—	—	—	—	5
RICE-13	—	—	—	—	—	—	—	—	—	1
RICE-14	—	—	—	—	—	—	—	—	—	2
RICE-15	—	—	—	—	—	—	—	—	—	2
RICE-16	—	—	—	—	—	—	—	—	—	1
RICE-17	—	—	—	E0.005	—	—	—	—	—	2
RICE-18	—	—	—	—	—	—	—	—	—	1
RICE-19	—	—	E0.006	—	—	—	—	—	—	3
RICE-20	—	—	—	—	—	—	—	—	—	2
RICE-21	—	—	—	—	—	—	—	—	—	1
RICE-22	—	—	—	—	—	—	—	—	—	2

[1] Maximum contaminant level thresholds are listed as MCL-US when MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] Frequency of detection of at least one pesticide in the grid wells. Detections with V remark codes are not included.

Table 7. Constituents of special interest (perchlorate, *N*-nitrosodimethylamine [NDMA], and 1,2,3-trichloropropane [1,2,3-TCP]) detected in samples collected in the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from all 108 wells were analyzed for perchlorate; samples from 45 grid wells and 15 flow-path wells were sampled for NDMA and 1,2,3-TCP; only wells with at least one detection are listed. Analyses done by the Mongomery Watson Harza laboratory. The laboratory entity code for the Montgomery Watson Harza laboratory in the U. S. Geological Survey's National Water Information System (NWIS) is CA-MWHL. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; MCL-CA, maximum contaminant level (CDPH); MRL, minimum reporting level; no., number; RICE, RICE well; WSAC, West study area of the middle Sacramento Valley study unit; µg/L, micrograms per liter]

GAMA identification no.	**Perchlorate (µg/L)**
Threshold Type	**MCL-CA**
Threshold (µg/L)	**6**
[MRL]	**[0.5]**
Grid wells	
ESAC-03	0.6
ESAC-04	1.4
WSAC-20	0.6
WSAC-24	1.4
Number of wells with detections	4
Detection frequency (percent)	6
RICE wells	
RICE-10	1.3

Table 8. Nutrients and dissolved organic carbon detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed for nutrients; samples from all slow grid wells and all RICE wells were analyzed for dissolved organic carbon. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-US, maximum contaminant level (USEPA); mg/L, milligrams per liter; na, not available; nc, not collected; no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Ammonia (mg/L) as nitrogen (00608)	Nitrite plus nitrate (mg/L) as nitrogen (00631)	Nitrite (mg/L) as nitrogen (00613)	Total nitrogen (nitrate + nitrite + ammonia + organic-N) (mg/L) (62854)	Orthophosphate (mg/L) as phosphorus (00671)	Dissolved organic carbon (DOC) (mg/L) (00681)
[LRL]	**[0.01]**	**[0.06]**	**[0.002]**	**[0.06]**	**[0.006]**	**[0.33]**
Threshold type[1]	**HAL-US**	**MCL-US**	**MCL-US**	**na**	**na**	**na**
Threshold value	**[2]24.7**	**10**	**1**	**na**	**na**	**na**
			Grid wells			
ESAC-03	—	2.46	—	2.50	0.075	nc
ESAC-05	—	6.25	—	6.25	0.168	nc
ESAC-06	—	0.79	—	0.82	0.118	nc
ESAC-10	0.016	0.30	0.005	0.34	0.095	nc
ESAC-11	—	—	—	—	0.100	nc
ESAC-12	—	0.82	—	[3]0.81	0.058	nc
ESAC-15	E0.008	—	—	[4]—	V0.003	nc
ESAC-16	E0.008	0.78	—	[5]0.71	0.092	nc
ESAC-17	0.075	—	—	V0.07	0.167	nc
ESAC-18	E0.006	0.74	—	[5]0.67	0.086	nc
ESAC-19	—	0.50	—	[5]0.45	0.090	nc
ESAC-21	0.117	—	—	V0.16	0.120	nc
ESAC-22	—	*10.4	—	8.81	0.053	nc
ESAC-25	—	0.54	—	0.54	0.112	E0.2
ESAC-26	0.056	—	—	V0.04	0.499	0.5
ESAC-27	E0.008	0.86	—	0.92	0.100	0.8
ESAC-28	—	1.62	—	[3]1.58	0.194	E0.3
ESAC-29	0.095	—	—	V0.12	0.240	nc
ESAC-30	—	0.13	0.011	V0.16	0.256	nc
ESAC-31	E0.006	0.13	E0.001	V0.14	0.101	nc
ESAC-32	—	0.92	—	0.95	0.090	nc
ESAC-34	—	0.89	—	0.91	0.108	nc
ESAC-35	—	0.76	—	0.78	0.066	nc
WSAC-03	—	3.38	—	[3]3.3	0.036	E0.2
WSAC-04	E0.005	—	—	[4]—	0.040	nc
WSAC-06	—	1.03	—	1.10	0.028	nc
WSAC-08	E0.006	3.43	—	[3]3.23	0.031	E0.3
WSAC-10	—	6.49	—	[3]6.35	0.027	nc
WSAC-11	—	2.27	—	[3]2.13	0.065	nc
WSAC-12	0.124	—	—	V0.17	0.200	0.5
WSAC-14	0.011	1.29	0.003	[3]1.26	0.077	nc
WSAC-15	—	*13	—	13.50	0.047	nc

Table 8. Nutrients and dissolved organic carbon detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed for nutrients; samples from all slow grid wells and all RICE wells were analyzed for dissolved organic carbon. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-US, maximum contaminant level (USEPA); mg/L, milligrams per liter; na, not available; nc, not collected; no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Ammonia (mg/L) as nitrogen (00608)	Nitrite plus nitrate (mg/L) as nitrogen (00631)	Nitrite (mg/L) as nitrogen (00613)	Total nitrogen (nitrate + nitrite + ammonia + organic-N) (mg/L) (62854)	Orthophosphate (mg/L) as phosphorus (00671)	Dissolved organic carbon (DOC) (mg/L) (00681)
[LRL]	**[0.01]**	**[0.06]**	**[0.002]**	**[0.06]**	**[0.006]**	**[0.33]**
Threshold type[1]	**HAL-US**	**MCL-US**	**MCL-US**	**na**	**na**	**na**
Threshold value	**[2]24.7**	**10**	**1**	**na**	**na**	**na**
WSAC-17	—	0.73	—	[3]0.72	0.257	nc
WSAC-18	—	0.57	0.003	0.59	0.070	E0.2
WSAC-21	—	6.04	—	[3]5.73	0.081	nc
WSAC-22	E0.008	1.24	—	[3]1.22	0.047	nc
WSAC-25	E0.006	E0.05	—	V0.06	0.101	nc
WSAC-26	E0.005	3.02	—	3.15	0.049	nc
WSAC-28	—	2.54	—	2.64	0.097	nc
WSAC-29	E0.005	1.84	—	1.89	0.043	nc
WSAC-30	E0.005	7.38	—	[3]7.36	0.037	nc
WSAC-31	—	0.77	—	[3]0.75	0.077	nc
WSAC-34	—	9.10	—	[3]8.99	0.032	nc
WSAC-35	—	0.97	—	1.04	0.036	nc
WSAC-36	—	0.45	—	0.51	0.103	nc
			Flow-path wells			
ESAC-FP-01	0.320	—	—	V0.33	0.031	nc
ESAC-FP-02	—	2.37	0.010	[3]2.20	0.033	nc
ESAC-FP-03	—	0.33	0.018	V0.35	0.084	nc
ESAC-FP-04	—	0.16	0.002	V0.14	0.056	nc
ESAC-FP-05	—	6.01	E0.002	[3]5.61	0.100	nc
ESAC-FP-06	0.027	—	—	[4]—	0.062	nc
ESAC-FP-07	0.028	—	—	[4]—	0.077	nc
WSAC-FP-01	V0.007	1.32	—	1.42	0.050	nc
WSAC-FP-02	V0.007	0.76	—	0.76	0.038	nc
WSAC-FP-03	V0.009	2.82	E0.001	2.78	0.040	nc
WSAC-FP-04	0.014	—	—	[4]—	0.063	nc
WSAC-FP-05	E0.009	E0.03	E0.002	V0.07	0.064	nc
WSAC-FP-06	—	0.27	0.008	V0.27	0.034	nc
WSAC-FP-07	V0.009	—	—	[4]—	0.055	nc
WSAC-FP-08	—	1.89	—	1.97	0.052	nc

Table 8. Nutrients and dissolved organic carbon detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed for nutrients; samples from all slow grid wells and all RICE wells were analyzed for dissolved organic carbon. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-US, maximum contaminant level (USEPA); mg/L, milligrams per liter; na, not available; nc, not collected; no., number; RICE, RICE well; USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Ammonia (mg/L) as nitrogen (00608)	Nitrite plus nitrate (mg/L) as nitrogen (00631)	Nitrite (mg/L) as nitrogen (00613)	Total nitrogen (nitrate + nitrite + ammonia + organic-N) (mg/L) (62854)	Orthophosphate (mg/L) as phosphorus (00671)	Dissolved organic carbon (DOC) (mg/L) (00681)
[LRL]	**[0.01]**	**[0.06]**	**[0.002]**	**[0.06]**	**[0.006]**	**[0.33]**
Threshold type[1]	**HAL-US**	**MCL-US**	**MCL-US**	**na**	**na**	**na**
Threshold value	[2]**24.7**	**10**	**1**	**na**	**na**	**na**
			RICE wells			
RICE-01	0.517	—	—	0.51	0.109	—
RICE-02	—	0.88	—	0.86	0.149	V0.8
RICE-03	—	1.72	—	1.67	0.057	V0.9
RICE-04	V0.007	0.47	—	0.55	0.093	1.1
RICE-05	V0.013	—	—	V0.13	0.099	2.4
RICE-06	V0.005	0.27	—	V0.32	0.079	1.6
RICE-07	V0.006	0.11	—	V0.11	0.098	1.0
RICE-08	—	1.83	—	1.78	0.082	V0.5
RICE-09	—	E0.04	—	V0.07	0.101	V0.7
RICE-19	V0.008	—	—	V0.06	0.106	1.1
RICE-20	V0.005	3.77	0.005	3.80	0.326	1.4
RICE-10	—	0.36	—	V0.37	0.160	1.0
RICE-11	V0.008	4.93	0.006	4.98	0.058	2.6
RICE-12	V0.01	0.40	0.006	0.47	0.115	1.4
RICE-13	—	3.82	0.026	3.75	0.104	2.3
RICE-14	—	—	—	V0.1	0.051	2.3
RICE-15	—	0.30	—	V0.31	0.097	1.3
RICE-16	V0.007	0.08	0.003	V0.1	0.086	1.2
RICE-17	V0.005	0.88	—	0.99	0.100	2.1
RICE-18	V0.006	0.71	—	0.78	0.076	V0.7
RICE-21	V0.011	0.17	—	V0.21	0.041	V0.8
RICE-22	V0.011	—	—	V0.08	0.048	1.3

[1]Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The HAL-US is 30 mg/L "as ammonia." To facilitate comparison to the analytical results, we have converted and reported this HAL-US as 24.7 mg/L "as nitrogen."

[3]Total nitrogen in these samples is less than the sum of the filtered nitrogen analytes, but falls within the USGS's National Water Quality Laboratory acceptance criteria of a 10 percent relative percent difference.

[4]Total nitrogen in these samples is less than the sum of the filtered nitrogen analytes and exceeds the USGS's National Water Quality Laboratory acceptance criteria of 10 percent relative difference, but the sum of the filtered nitrogen analytes is less than the LRL for total nitrogen.

[5]Total nitrogen in these samples is less than the sum of the filtered nitrogen analytes and exceeds the USGS's National Water Quality Laboratory acceptance criteria of 10 percent relative difference. Values were verified by the laboratory.

Table 9. Major and minor ions and total dissolved solids detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); mg/L, milligrams per liter; na, not available; no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, analyzed but not detected; *, value above threshold level; **, value above upper threshold level]

GAMA identification no.	Bromide (mg/L) (71870)	Calcium (mg/L) (00915)	Chloride (mg/L) (00940)	Fluoride (mg/L) (00950)	Iodide (mg/L) (71865)	Magnesium (mg/L) (00925)	Potassium (mg/L) (00935)	Silica (mg/L) (00955)	Sodium (mg/L) (00930)	Sulfate (mg/L) (00945)	Total dissolved solids (TDS) (mg/L) (70301)	Bicarbonate[1] (mg/L as $CaCO_3$)	Carbonate[1] (mg/L as $CaCO_3$)
Threshold type[2]	**na**	**na**	**SMCL-CA[3]**	**MCL-CA**	**na**	**na**	**na**	**na**	**na**	**SMCL-CA[3]**	**SMCL-CA[3]**	**na**	**na**
Threshold (mg/L)	**na**	**na**	**250 (500)**	**2.00**	**na**	**na**	**na**	**na**	**na**	**250 (500)**	**500 (1,000)**	**na**	**na**
[LRL]	**[0.02]**	**[0.02]**	**[0.2]**	**[0.1]**	**[0.002]**	**[0.008]**	**[0.16]**	**[0.04]**	**[0.2]**	**[0.18]**	**[10]**	**[1]**	**[1]**
Grid wells													
ESAC-03	0.06	29.1	21.5	E0.09	0.002	16.4	1.39	34.2	38.1	33.5	274	177	1
ESAC-05	0.11	32.7	7.85	E0.07	0.002	36.8	3.51	63.6	19.1	44.1	353	237	1
ESAC-06	—	18.1	2.26	E0.08	—	12.1	1.75	71.7	7.33	1.5	183	129	—
ESAC-10	0.11	40.6	36.6	0.15	0.036	28.1	1.73	42.7	23.6	13.9	316	255	—
ESAC-11	0.03	13.6	4.62	E0.07	0.019	10.5	3.73	75.7	17.1	2.0	194	135	—
ESAC-12	0.05	23.9	12.9	0.12	E0.001	12.5	1.59	34.9	30	9.5	237	217	1
ESAC-15	0.03	22.4	8.13	E0.07	—	14.4	1.17	60.0	11.9	6.3	195	143	—
ESAC-16	0.08	18.9	36.3	E0.08	—	14.0	3.25	63.7	35.9	10.3	267	163	—
ESAC-17	0.23	55.4	124	0.11	0.079	48.9	5.10	50.3	61.7	22.0	* 552	369	1
ESAC-18	—	17.9	5.12	E0.09	—	11.3	2.38	59.1	10.7	2.6	179	134	—
ESAC-19	E0.01	38.1	9.65	0.24	—	17.8	3.46	69.5	24.7	25.0	306	232	—
ESAC-21	1.71	58.2	** 626	—	1.110	25.0	8.28	36.8	401	—	**1,290	264	1
ESAC-22	0.05	23.0	11.4	—	E0.001	17.4	0.31	60.6	12	21.0	240	99	—
ESAC-25	—	17.2	2.07	E0.09	—	11.3	1.35	67.4	8.43	2.5	177	129	—
ESAC-26	—	8.84	4.12	0.14	0.025	7.85	1.20	47.4	47.7	4.0	212	196	1
ESAC-27	0.14	39.6	19.6	E0.06	0.037	29.0	1.68	50.1	20.6	20.6	312	269	—
ESAC-28	0.02	24.1	5.55	0.14	E0.001	26.4	2.62	61.2	15.2	6.8	259	226	—
ESAC-29	0.07	24.5	15.0	E0.08	0.068	15.6	2.44	37.1	54.8	10.6	297	272	1
ESAC-30	0.16	18.7	58.5	0.11	0.040	21.7	1.67	48.6	36.6	7.3	268	146	1
ESAC-31	0.09	50.1	27.9	E0.08	0.105	32.2	2.49	50.3	49.5	17.4	410	360	1
ESAC-32	E0.02	32.5	4.62	—	—	21.7	1.45	52.1	9.17	12.6	243	212	—
ESAC-34	0.08	50.3	13.5	0.11	0.003	34.4	1.83	62.4	26.9	38.6	397	332	1
ESAC-35	—	28.8	2.60	—	—	19.2	1.55	57.0	10.2	8.4	232	204	—
WSAC-03	—	32.3	7.11	0.10	—	16.2	0.70	28.9	12.8	20.8	207	162	—
WSAC-04	0.03	16.5	5.11	0.18	0.021	15.9	0.56	24.9	34.2	1.2	203	208	2
WSAC-06	0.05	40.5	15.2	0.29	0.003	37.7	0.57	30.3	24.4	24.7	344	335	—
WSAC-08	0.05	67.5	21.4	E0.09	E0.001	19.7	0.84	19.5	17.9	25.8	310	269	—
WSAC-10	0.06	66.5	23.1	E0.08	E0.002	23.8	0.87	21.8	21.8	31.8	329	281	—
WSAC-11	0.28	29.4	87.4	0.21	0.006	29.9	1.05	30.0	51.9	10.5	365	229	1
WSAC-12	0.25	22.8	50.8	0.11	0.125	16.2	1.50	41.3	115	62.3	440	257	1
WSAC-14	0.81	84.5	236	0.42	0.524	70.4	2.12	42.0	259	* 429	** 1,330	393	1
WSAC-15	0.12	48.6	27.1	0.29	0.010	35.6	1.80	26.0	101	49.5	* 584	472	1

Table 9. Major and minor ions and total dissolved solids detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); mg/L, milligrams per liter; na, not available; no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, analyzed but not detected; *, value above threshold level; **, value above upper threshold level]

GAMA identification no.	Bromide (mg/L) (71870)	Calcium (mg/L) (00915)	Chloride (mg/L) (00940)	Fluoride (mg/L) (00950)	Iodide (mg/L) (71865)	Magnesium (mg/L) (00925)	Potassium (mg/L) (00935)	Silica (mg/L) (00955)	Sodium (mg/L) (00930)	Sulfate (mg/L) (00945)	Total dissolved solids (TDS) (mg/L) (70301)	Bicarbonate[1] (mg/L as $CaCO_3$)	Carbonate[1] (mg/L as $CaCO_3$)
Threshold type[2]	**na**	**na**	**SMCL-CA[3]**	**MCL-CA**	**na**	**na**	**na**	**na**	**na**	**SMCL-CA[3]**	**SMCL-CA[3]**	**na**	**na**
Threshold (mg/L)	**na**	**na**	**250 (500)**	**2.00**	**na**	**na**	**na**	**na**	**na**	**250 (500)**	**500 (1,000)**	**na**	**na**
[LRL]	**[0.02]**	**[0.02]**	**[0.2]**	**[0.1]**	**[0.002]**	**[0.008]**	**[0.16]**	**[0.04]**	**[0.2]**	**[0.18]**	**[10]**	**[1]**	**[1]**
WSAC-17	E0.01	27.3	7.38	0.12	0.008	23.4	1.62	37.6	29.7	20.6	275	248	—
WSAC-18	0.40	50.5	96.4	0.47	0.420	37.6	1.26	28.2	117	110	* 623	388	1
WSAC-21	0.04	27.6	14.0	0.30	0.003	19.8	0.50	29.9	26.9	7.0	257	209	—
WSAC-22	0.16	29.8	34.1	0.20	0.026	24.5	1.05	22.4	39.9	12.0	297	256	1
WSAC-25	0.08	23.0	17.5	0.18	0.013	22.4	2.35	41.5	44.1	8.3	294	268	1
WSAC-26	0.03	33.3	2.80	0.43	—	16.3	0.56	30.0	11.7	3.9	208	192	—
WSAC-28	0.04	43.8	20.1	E0.08	—	22.1	0.69	26.1	10.9	21.0	258	204	—
WSAC-29	0.05	20.9	8.49	0.29	0.008	21.5	0.80	23.3	36.2	11.9	253	242	1
WSAC-30	1.29	79.5	* 358	0.64	—	68.5	0.53	21.4	136	87.0	* 910	248	1
WSAC-31	0.03	18.9	4.23	0.19	E0.002	11.3	0.74	28.2	25	11.1	181	155	1
WSAC-34	0.08	88.9	74.0	E0.09	E0.002	38.5	1.10	23.4	23.4	39.4	486	315	—
WSAC-35	0.02	45.2	16.9	E0.07	0.003	18.9	0.86	22.9	23.6	19.9	277	250	—
WSAC-36	—	24.6	4.41	0.17	0.020	22.5	1.03	30.7	31.7	8.0	256	262	1
Flow-path wells													
ESAC-FP-01	0.31	45.3	124	E0.09	0.026	9.09	1.87	65.1	39	—	331	91	—
ESAC-FP-02	0.03	40.3	13.5	E0.06	E0.002	26.0	1.54	60.2	18.5	11.3	304	246	—
ESAC-FP-03	—	33.0	2.43	E0.05	0.008	23.5	1.34	56.4	10.3	9.2	257	240	—
ESAC-FP-04	—	14.3	1.79	—	E0.002	11.2	2.29	57.7	10.9	2.1	166	130	1
ESAC-FP-05	—	66.1	9.43	E0.08	0.006	41.5	2.75	51.0	22.4	26.5	460	431	1
ESAC-FP-06	0.07	13.5	19.4	E0.09	0.054	3.99	2.88	41.8	51.7	1.4	216	152	6
ESAC-FP-07	0.13	14.6	35.9	E0.09	0.101	4.69	2.73	46.9	68.8	0.3	270	187	3
WSAC-FP-01	E0.02	24.7	2.33	0.33	—	20.5	0.76	31.1	19.9	1.7	217	220	1
WSAC-FP-02	0.04	20.6	11.1	0.15	0.002	16.7	0.75	27.3	21.8	8.9	197	172	1
WSAC-FP-03	0.05	35.4	15.7	0.13	E0.001	24.8	0.75	30.2	16.4	16.7	259	213	1
WSAC-FP-04	0.05	19.9	13.9	0.13	0.032	7.34	1.89	21.3	34.5	0.6	189	174	3
WSAC-FP-05	0.41	28.7	100	0.29	0.227	25.3	2.38	40.4	128	88.4	* 565	302	1
WSAC-FP-06	0.10	16.0	22.4	0.18	0.055	15.8	0.87	21.1	30.4	7.6	202	168	2
WSAC-FP-07	0.07	15.9	15.1	0.12	0.041	7.21	1.56	37.1	41.1	7.2	213	173	2
WSAC-FP-08	0.04	36.9	10.5	0.12	E0.002	18.6	0.73	25.5	18.5	12.6	244	224	1

Table 9. Major and minor ions and total dissolved solids detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); mg/L, milligrams per liter; na, not available; no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, analyzed but not detected; *, value above threshold level; **, value above upper threshold level]

GAMA identification no.	Bromide (mg/L) (71870)	Calcium (mg/L) (00915)	Chloride (mg/L) (00940)	Fluoride (mg/L) (00950)	Iodide (mg/L) (71865)	Magnesium (mg/L) (00925)	Potassium (mg/L) (00935)	Silica (mg/L) (00955)	Sodium (mg/L) (00930)	Sulfate (mg/L) (00945)	Total dissolved solids (TDS) (mg/L) (70301)	Bicarbonate[1] (mg/L as $CaCO_3$)	Carbonate[1] (mg/L as $CaCO_3$)
Threshold type[2]	na	na	SMCL-CA[3]	MCL-CA	na	na	na	na	na	SMCL-CA[3]	SMCL-CA[3]	na	na
Threshold (mg/L)	na	na	250 (500)	2.00	na	na	na	na	na	250 (500)	500 (1,000)	na	na
[LRL]	[0.02]	[0.02]	[0.2]	[0.1]	[0.002]	[0.008]	[0.16]	[0.04]	[0.2]	[0.18]	[10]	[1]	[1]
RICE wells													
RICE-01	12.60	814	** 4730	—	nc	447	11.50	24.3	1250	[4]—	** 7,390	135	—
RICE-02	0.05	41.5	8.07	E0.08	nc	36.5	0.87	52.4	33.3	23.3	402	406	1
RICE-03	0.19	67.4	34.4	E0.08	nc	43.9	2.54	58.4	53.3	37.8	* 566	525	1
RICE-04	—	63.3	7.05	0.18	nc	40.2	2.05	57.3	16.9	17.7	404	399	—
RICE-05	0.07	85.1	16.9	0.13	nc	54.7	1.66	70.2	35.5	48.0	* 569	519	—
RICE-06	—	68.7	2.44	0.11	nc	51.9	1.36	67.9	16.1	15.2	456	468	—
RICE-07	0.04	73.0	3.88	0.15	nc	52.4	1.36	52.3	23.1	28.1	488	511	1
RICE-08	0.05	68.2	9.57	E0.1	nc	49.0	1.12	52.4	34.3	36.4	487	459	1
RICE-09	—	22.5	3.05	E0.09	nc	15.1	0.77	39.6	11	5.1	174	155	1
RICE-10	0.03	36.8	3.85	0.24	nc	18.8	0.69	28.5	11.2	7.8	212	204	1
RICE-11	0.10	91.3	26.8	0.18	nc	60.6	0.62	33.4	27.8	49.4	* 562	504	—
RICE-12	0.08	59.9	14.0	0.32	nc	45.6	0.50	30.5	55	20.4	468	482	1
RICE-13	0.10	66.5	26.7	0.12	nc	50.2	0.91	32.7	56.7	37.4	* 539	506	1
RICE-14	0.07	59.5	9.67	0.19	nc	50.9	0.49	28.8	47.7	38.4	478	488	—
RICE-15	0.04	39.2	7.10	0.89	nc	47.7	0.45	21.9	105	79.5	* 566	529	2
RICE-16	0.15	29.2	23.9	1.70	nc	31.9	0.56	17.6	356	* 375	** 1,200	723	2
RICE-17	0.60	92.8	147	1.70	nc	114	0.72	21.5	838	** 2,080	** 3,510	423	2
RICE-18	0.05	59.4	9.18	0.26	nc	38.3	0.81	27.4	72.8	104.0	* 522	416	1
RICE-19	0.04	38.0	3.56	E0.07	nc	25.4	1.23	42.3	27.4	8.5	294	297	1
RICE-20	0.21	47.9	46.9	0.41	nc	64.1	0.85	46.6	81	63.2	* 614	494	1
RICE-21	0.42	77.2	106	0.62	nc	44.3	0.54	19.9	232	* 359	** 1,050	422	1
RICE-22	0.65	73.1	156	0.90	nc	50.0	0.53	16.7	603	** 1,080	** 2,240	505	1

[1]Bicarbonate and carbonate concentrations were calculated from the laboratory alkalinity and pH values (table 4) using the advance speciation method (http://or.water.usgs.gov/alk/methods.html).

[2]Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[3]The SMCL-CA for chloride, sulfate, and total dissolved solids have recommended and upper threshold values. The upper value is shown in parentheses.

[4]Laboratory reporting level is 4.5 mg/L.

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in groundwater quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Aluminum (µg/L) (01106)	Antimony (µg/L) (01095)	Arsenic (µg/L) (01000)	Barium (µg/L) (01005)	Boron (µg/L) (01020)	Cadmium (µg/L) (01025)	Chromium (µg/L) (01030)	Cobalt (µg/L) (01035)	Copper (µg/L) (01040)	Iron (µg/L) (01046)	Lead (µg/L) (01049)
[LRL]	[1.6]	[0.2]	[0.12]	[0.2]	[8]	[0.04]	[0.04]	[0.04]	[0.4]	[6]	[0.08]
Threshold type[1]	MCL-CA	MCL-US	MCL-US	MCL-CA	NL-CA	MCL-US	MCL-CA	na	AL-US	SMCL-CA	AL-US
Threshold level	1000	6	10	1000	1000	5	50	na	1300	300	15
					Grid wells						
ESAC-03	—	—	0.83	56	808	—	1.1	0.078	7.6	—	1.37
ESAC-05	—	E0.1	*19.6	104	26	—	4.9	0.084	1.2	—	0.24
ESAC-06	E1.5	—	0.97	15	—	—	1.2	—	3.3	—	2.11
ESAC-10	—	—	5	99	20	—	0.16	—	—	30	0.19
ESAC-11	—	0.87	*70	130	53	—	V0.02	E0.03	—	7	0.19
ESAC-12	4.5	—	4.4	87	107	—	6.0	—	3.2	E4	1.03
ESAC-15	E0.8	—	0.47	16	83	—	6.7	—	E0.21	—	0.14
ESAC-16	E1.1	—	0.78	25	316	—	0.58	—	—	—	0.1
ESAC-17	—	—	*15.9	385	379	—	V0.02	—	—	*355	0.2
ESAC-18	E1.4	—	0.73	21	70	—	0.94	—	—	—	0.09
ESAC-19	E1.1	0.38	9.2	147	96	—	6.9	—	0.72	8	0.43
ESAC-21	E1.5	—	*80.6	461	*1,010	E0.03	V0.04	E0.02	—	221	0.51
ESAC-22	—	—	0.39	19	13	—	1.1	0.07	1.7	—	0.86
ESAC-25	E1.3	—	0.83	13	16	—	0.73	—	0.57	—	0.15
ESAC-26	1.7	E0.11	*23.1	39	237	—	V0.02	—	—	6	0.26
ESAC-27	—	—	6.5	78	37	—	1.1	0.27	1.8	—	1.12
ESAC-28	—	—	*10.1	52	24	—	6.9	—	0.62	—	0.31
ESAC-29	E1.2	—	9.2	141	712	—	V0.03	—	—	295	0.08
ESAC-30	E1	E0.15	*17	38	111	—	V0.03	E0.02	E0.25	E4	E0.15
ESAC-31	E0.8	—	*12	124	140	—	0.12	E0.03	—	19	E0.1
ESAC-32	E1	—	2.6	29	14	—	3.0	—	1.9	E5	0.74
ESAC-34	E1.2	—	5.6	90	E6	—	4.6	—	E0.25	—	0.21
ESAC-35	1.9	—	0.8	23	27	—	4.5	—	E0.25	—	0.1

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Aluminum (µg/L) (01106)	Antimony (µg/L) (01095)	Arsenic (µg/L) (01000)	Barium (µg/L) (01005)	Boron (µg/L) (01020)	Cadmium (µg/L) (01025)	Chromium (µg/L) (01030)	Cobalt (µg/L) (01035)	Copper (µg/L) (01040)	Iron (µg/L) (01046)	Lead (µg/L) (01049)
[LRL]	**[1.6]**	**[0.2]**	**[0.12]**	**[0.2]**	**[8]**	**[0.04]**	**[0.04]**	**[0.04]**	**[0.4]**	**[6]**	**[0.08]**
Threshold type[1]	**MCL-CA**	**MCL-US**	**MCL-US**	**MCL-CA**	**NL-CA**	**MCL-US**	**MCL-CA**	**na**	**AL-US**	**SMCL-CA**	**AL-US**
Threshold level	**1000**	**6**	**10**	**1000**	**1000**	**5**	**50**	**na**	**1300**	**300**	**15**
WSAC-03	—	—	0.48	66	16	—	1.2	0.081	0.8	—	0.2
WSAC-04	—	—	3.6	98	33	—	—	0.041	E0.2	43	—
WSAC-06	—	—	0.63	86	87	—	0.72	—	2.6	E3	1.67
WSAC-08	—	—	0.24	103	160	—	1.1	—	0.56	E3	3.43
WSAC-10	—	—	0.36	123	197	—	1.6	—	2	—	0.16
WSAC-11	E1	—	2.6	232	599	—	11.1	—	0.47	—	0.27
WSAC-12	1.8	—	2.2	126	212	—	V0.04	—	E0.28	53	—
WSAC-14	E1.3	—	2.6	29	364	0.04	V0.05	0.09	2	E4	0.62
WSAC-15	E1	—	1.3	295	*2330	—	7.3	0.04	0.47	—	0.08
WSAC-17	E1	E0.17	6.7	48	344	—	0.80	E0.02	1.4	—	0.69
WSAC-18	E1.2	—	1.3	74	447	—	0.07	0.04	E0.24	—	1.37
WSAC-21	E1	—	1.4	198	193	—	8.0	—	E0.26	—	0.1
WSAC-22	E0.8	—	7.9	268	105	—	2.5	—	0.93	14	0.68
WSAC-25	E1	—	4	106	762	—	0.48	—	—	—	0.32
WSAC-26	E1.4	—	1.1	106	11	—	4.3	0.06	0.46	—	0.35
WSAC-28	—	—	0.33	63	36	—	1.3	—	E0.24	—	—
WSAC-29	E1	—	3.1	145	64	—	11.5	—	E0.25	—	0.42
WSAC-30	E0.8	—	0.39	58	339	—	6.0	—	2.7	E5	0.43
WSAC-31	E1.3	—	4.7	61	71	3.54	10.8	—	E0.22	—	0.17
WSAC-34	E0.9	—	0.46	197	—	—	2.7	E0.03	0.47	—	—
WSAC-35	E1.1	—	1.2	117	128	—	2.2	—	0.66	—	0.17
WSAC-36	E1.2	—	4.5	142	117	—	4.3	—	0.47	E4	0.32

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in groundwater quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Aluminum (µg/L) (01106)	Antimony (µg/L) (01095)	Arsenic (µg/L) (01000)	Barium (µg/L) (01005)	Boron (µg/L) (01020)	Cadmium (µg/L) (01025)	Chromium (µg/L) (01030)	Cobalt (µg/L) (01035)	Copper (µg/L) (01040)	Iron (µg/L) (01046)	Lead (µg/L) (01049)
[LRL]	**[1.6]**	**[0.2]**	**[0.12]**	**[0.2]**	**[8]**	**[0.04]**	**[0.04]**	**[0.04]**	**[0.4]**	**[6]**	**[0.08]**
Threshold type[1]	**MCL-CA**	**MCL-US**	**MCL-US**	**MCL-CA**	**NL-CA**	**MCL-US**	**MCL-CA**	**na**	**AL-US**	**SMCL-CA**	**AL-US**
Threshold level	**1000**	**6**	**10**	**1000**	**1000**	**5**	**50**	**na**	**1300**	**300**	**15**
					Flow-path wells						
ESAC-FP-01	1.3	—	1.1	73	171	—	V0.02	—	—	106	0.08
ESAC-FP-02	2.1	—	0.71	35	108	—	1.3	0.28	V0.2	65	0.13
ESAC-FP-03	V0.8	—	2.4	47	19	—	1.2	E0.03	—	134	0.11
ESAC-FP-04	V1.7	—	3.2	16	67	—	1.3	—	—	67	—
ESAC-FP-05	2.7	0.23	6.5	116	55	—	5.3	E0.03	—	—	—
ESAC-FP-06	39.4	E0.18	*12.7	17	208	—	0.70	E0.02	—	14	E0.07
ESAC-FP-07	17.2	—	9	35	243	—	0.22	E0.03	—	10	E0.05
WSAC-FP-01	V1.4	—	2.4	128	28	—	16.1	E0.02	—	—	—
WSAC-FP-02	2.2	E0.11	3.3	132	101	—	18.4	—	—	V6	—
WSAC-FP-03	3.7	E0.13	1.6	173	81	—	4.8	E0.02	V0.55	—	—
WSAC-FP-04	11.1	—	5.5	91	80	—	0.16	0.04	—	V6	—
WSAC-FP-05	4.5	—	8.3	42	230	E0.02	—	—	0.35	9	0.8
WSAC-FP-06	3.0	E0.15	4	167	98	—	0.33	—	—	15	—
WSAC-FP-07	4.4	—	*10.6	8	99	—	V0.07	—	—	40	—
WSAC-FP-08	V1.4	—	1.1	99	114	—	4.8	—	—	10	—

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in groundwater quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Aluminum (µg/L) (01106)	Antimony (µg/L) (01095)	Arsenic (µg/L) (01000)	Barium (µg/L) (01005)	Boron (µg/L) (01020)	Cadmium (µg/L) (01025)	Chromium (µg/L) (01030)	Cobalt (µg/L) (01035)	Copper (µg/L) (01040)	Iron (µg/L) (01046)	Lead (µg/L) (01049)
[LRL]	**[1.6]**	**[0.2]**	**[0.12]**	**[0.2]**	**[8]**	**[0.04]**	**[0.04]**	**[0.04]**	**[0.4]**	**[6]**	**[0.08]**
Threshold type[1]	**MCL-CA**	**MCL-US**	**MCL-US**	**MCL-CA**	**NL-CA**	**MCL-US**	**MCL-CA**	**na**	**AL-US**	**SMCL-CA**	**AL-US**
Threshold level	**1000**	**6**	**10**	**1000**	**1000**	**5**	**50**	**na**	**1300**	**300**	**15**
					RICE wells						
RICE-01	—[2]	—[2]	4.9	*5,900	*1,260	—[2]	0.42	E0.18	—[2]	*4,610	—[2]
RICE-02	V1.3	E0.11	*10.4	39	55	—	2.4	0.09	—	V3	—
RICE-03	V0.8	E0.14	6.2	188	117	—	2.0	E0.02	V0.31	V5	—
RICE-04	—	—	4.7	154	16	—	1.7	E0.03	V0.54	57	—
RICE-05	—	—	1.4	160	9	E0.02	0.14	0.27	V0.97	28	—
RICE-06	—	—	1.8	85	16	—	0.41	0.04	V0.62	V4	—
RICE-07	V1.0	—	6.2	78	25	—	1.6	E0.02	V0.24	—	—
RICE-08	V1.0	—	6	96	35	—	4.1	—	—	—	—
RICE-09	1.8	E0.18	4.6	26	62	—	V0.07	0.15	V0.28	V6	—
RICE-10	V1.1	E0.16	3.1	87	57	—	0.37	E0.02	V0.32	—	—
RICE-11	V1.1	E0.1	1.6	552	92	E0.02	1.3	0.21	V1.1	V4	—
RICE-12	V1.0	E0.1	3.2	408	223	—	0.08	0.31	—	218	E0.04
RICE-13	V1.2	E0.11	2.3	286	199	—	3.1	0.44	V1.1	—	0.08
RICE-14	V1.2	—	1.1	357	174	—	V0.10	0.39	V0.27	110	—
RICE-15	—	—	1.1	65	551	—	0.77	0.04	V0.48	—	—
RICE-16	V1.3	—	0.57	20	945	—	V0.05	0.13	—	*304	—
RICE-17	E2.4	—	1.6	15	*1,640	0.05	13.1	0.13	V0.83	—	—
RICE-18	2.9	—	1	81	204	—	7.8	0.06	V0.53	—	—
RICE-19	V1.6	E0.11	4.1	61	68	—	V0.08	0.05	V0.69	—	—
RICE-20	V1.4	E0.14	7.5	46	195	0.04	V0.02	0.6	V0.80	—	—
RICE-21	2.2	—	0.38	46	97	—	0.13	0.13	V0.29	155	0.13
RICE-22	—	—	1.9	15	*4,630	—	0.85	1.6	—	166	—

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)	Uranium (µg/L) (22703)
[LRL]	**[0.6]**	**[0.2]**	**[0.4]**	**[0.06]**	**[0.08]**	**[0.4]**	**[0.04]**	**[0.06]**	**[0.1]**	**[0.6]**	**[0.04]**
Threshold type[1]	**na**	**SMCL-CA**	**HAL-US**	**MCL-CA**	**MCL-US**	**HAL-US**	**MCL-US**	**na**	**NL-CA**	**SMCL-CA**	**MCL-US**
Threshold level	**na**	**50**	**40**	**100**	**50**	**4000**	**2**	**na**	**50**	**5000**	**30**
					Grid wells						
ESAC-03	14.1	E0.1	0.5	1.19	0.09	254	—	0.35	9.7	3.6	0.37
ESAC-05	E0.4	—	1.8	1.38	0.61	214	—	0.06	28.8	2.8	2.76
ESAC-06	2.1	E0.2	E0.2	0.26	E0.05	112	—	—	28.8	10.7	0.12
ESAC-10	E0.4	*95.1	0.6	0.18	1.0	319	—	E0.05	6.5	1.7	6.07
ESAC-11	20.9	*112	2.0	V0.04	—	138	—	0.27	40.4	V0.42	0.69
ESAC-12	2.8	0.2	2.3	0.13	0.40	290	—	0.11	12.2	4.4	0.45
ESAC-15	—	—	—	V0.07	0.16	145	—	—	17.7	V0.73	0.08
ESAC-16	6.5	E0.1	E0.2	0.14	E0.06	123	—	—	21.1	V0.52	0.23
ESAC-17	0.7	*568	1.8	0.22	—	488	—	0.23	E0.05	3.2	—
ESAC-18	1.6	—	E0.2	0.09	E0.04	116	—	E0.03	19.8	V0.58	0.35
ESAC-19	4.8	—	1.1	0.14	0.6	342	—	0.07	22.7	3.2	1.50
ESAC-21	3.8	*257	16.5	V0.07	—	460	—	0.1	0.11	1.3	—
ESAC-22	0.7	E0.2	—	0.58	0.09	111	—	—	6.8	6.3	0.04
ESAC-25	4.1	—	E0.3	0.12	E0.06	115	—	—	30.6	V1.2	0.07
ESAC-26	1.0	*80.2	4.2	—	—	112	—	0.53	9.6	1.3	0.21
ESAC-27	0.7	*110	0.8	0.57	0.24	258	—	—	8.4	V0.93	2.24
ESAC-28	E0.6	1.3	1.1	0.11	0.12	179	—	0.07	26.2	1.3	1.41
ESAC-29	2.4	*219	E4	0.09	—	276	—	0.23	0.42	12.2	—
ESAC-30	1.7	*99.6	1.4	0.08	0.31	195	—	0.28	35	V0.97	0.39
ESAC-31	1.9	*72.2	2.6	0.13	0.10	388	—	0.08	13.9	V0.92	1.88
ESAC-32	0.7	E0.1	—	0.17	0.16	227	—	—	9.5	4.5	1.09

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)	Uranium (µg/L) (22703)
[LRL]	[0.6]	[0.2]	[0.4]	[0.06]	[0.08]	[0.4]	[0.04]	[0.06]	[0.1]	[0.6]	[0.04]
Threshold type[1]	na	SMCL-CA	HAL-US	MCL-CA	MCL-US	HAL-US	MCL-US	na	NL-CA	SMCL-CA	MCL-US
Threshold level	na	50	40	100	50	4000	2	na	50	5000	30
ESAC-34	0.8	—	0.5	0.10	0.36	360	—	E0.03	38.5	137	3.71
ESAC-35	1.3	—	—	—	E0.05	197	—	E0.05	22.4	V0.84	1.05
WSAC-03	3.7	—	1.0	1.32	0.10	368	—	—	3.9	6.6	0.14
WSAC-04	4.4	43.3	1.6	0.59	—	199	—	E0.03	—	V1.2	—
WSAC-06	11.5	—	0.5	0.21	0.08	506	—	—	5.0	62.9	0.40
WSAC-08	3.9	0.2	1.0	0.12	0.09	841	—	—	1.8	10.2	0.54
WSAC-10	6.4	—	E0.7	E0.14	0.09	849	—	—	2.8	13.3	0.78
WSAC-11	21.6	—	—	—	0.50	360	—	—	8.3	V0.51	0.28
WSAC-12	3.8	*106	7.8	V0.05	—	256	—	0.42	0.53	V0.67	0.07
WSAC-14	24.8	*89.8	4.5	0.36	10.8	1570	E0.02	0.08	10.7	8.6	2.57
WSAC-15	37	E0.1	0.5	0.66	1.4	641	—	0.18	5.7	V0.68	2.61
WSAC-17	1.3	0.2	4.0	0.17	0.57	234	—	0.07	18.5	36.4	1.16
WSAC-18	18.6	*84.6	3.7	V0.05	1.2	877	—	E0.05	8.4	V0.37	E0.14
WSAC-21	14.9	E0.1	E0.3	0.08	0.36	276	—	—	5.5	28.1	0.18
WSAC-22	15	36.6	0.6	0.11	0.16	435	—	E0.03	2.6	16.4	0.25
WSAC-25	26.9	1.8	3.5	V0.05	0.31	332	—	0.19	10.8	5.4	0.64
WSAC-26	14.9	—	0.9	V0.07	0.10	254	—	—	3.8	8.9	0.33
WSAC-28	4.1	—	E0.4	0.12	E0.04	428	—	—	2.8	V0.43	0.10
WSAC-29	9.8	3.1	1.0	0.18	0.77	395	—	—	10.8	3.4	0.43
WSAC-30	22	E0.1	1.0	0.30	0.75	1480	—	—	3.7	4.5	1.06
WSAC-31	2.7	—	2.0	V0.03	0.77	226	—	0.06	17.9	V0.53	0.19
WSAC-34	6.9	—	0.7	0.33	0.08	1130	—	—	3.0	2.0	0.79
WSAC-35	5.5	—	0.8	0.11	0.17	619	—	—	3.8	3.3	0.46
WSAC-36	4.6	0.5	3.1	V0.06	0.30	439	—	E0.05	9.4	1.5	0.72

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)	Uranium (µg/L) (22703)
[LRL]	**[0.6]**	**[0.2]**	**[0.4]**	**[0.06]**	**[0.08]**	**[0.4]**	**[0.04]**	**[0.06]**	**[0.1]**	**[0.6]**	**[0.04]**
Threshold type[1]	**na**	**SMCL-CA**	**HAL-US**	**MCL-CA**	**MCL-US**	**HAL-US**	**MCL-US**	**na**	**NL-CA**	**SMCL-CA**	**MCL-US**
Threshold level	**na**	**50**	**40**	**100**	**50**	**4000**	**2**	**na**	**50**	**5000**	**30**
					Flow-path wells						
ESAC-FP-01	0.6	*184	0.8	V0.05	—	455	—	0.22	E0.05	6.4	—
ESAC-FP-02	—	14.5	0.7	2.2	E0.07	261	—	V0.05	7.5	6.3	0.46
ESAC-FP-03	—	16.8	E0.2	0.31	—	225	—	0.09	23.4	—	0.70
ESAC-FP-04	—	3.5	0.4	0.30	0.12	100	—	0.21	10.0	V0.68	0.09
ESAC-FP-05	1.3	V0.3	0.6	0.57	0.38	534	—	0.31	26.3	—	5.44
ESAC-FP-06	0.7	8.4	4.9	0.47	—	127	—	1.1	2.9	—	0.07
ESAC-FP-07	E0.4	16.4	8.3	0.76	—	96.7	—	0.69	0.7	—	0.05
WSAC-FP-01	12.7	—	0.8	0.31	0.57	439	—	0.03	8.9	—	0.36
WSAC-FP-02	8.5	V0.5	0.8	0.33	0.39	379	—	0.07	10.3	V0.6	0.20
WSAC-FP-03	13.4	V0.8	0.6	0.72	0.11	410	—	0.09	6.4	V1.2	0.12
WSAC-FP-04	16.9	8.4	1.9	1.1	—	635	—	1.4	0.19	—	0.07
WSAC-FP-05	5.6	*60.6	3.9	0.09	E0.06	758	—	0.21	0.82	2.4	0.56
WSAC-FP-06	7.6	7.2	1.1	0.33	0.20	449	—	0.36	8	V1.2	0.07
WSAC-FP-07	4	22.6	2.1	V0.17	—	296	—	0.33	—	—	0.04
WSAC-FP-08	5.5	V0.4	1.3	0.27	0.08	475	—	V0.03	6	V1.4	0.22

Table 10. Trace elements detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey to uniquely identify a specific constituent or property. AL-US, action level (USEPA); CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; HAL-US, Lifetime Health Advisory Level (USEPA); LRL, laboratory reporting level; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); na, not available; nc, not collected; NL-CA, notification level (CDPH); no., number; RICE, RICE well; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Lithium (µg/L) (01130)	Manganese (µg/L) (01056)	Molybdenum (µg/L) (01060)	Nickel (µg/L) (01065)	Selenium (µg/L) (01145)	Strontium (µg/L) (01080)	Thallium (µg/L) (01057)	Tungsten (µg/L) (01155)	Vanadium (µg/L) (01085)	Zinc (µg/L) (01090)	Uranium (µg/L) (22703)
[LRL]	[0.6]	[0.2]	[0.4]	[0.06]	[0.08]	[0.4]	[0.04]	[0.06]	[0.1]	[0.6]	[0.04]
Threshold type[1]	na	SMCL-CA	HAL-US	MCL-CA	MCL-US	HAL-US	MCL-US	na	NL-CA	SMCL-CA	MCL-US
Threshold level	na	50	40	100	50	4000	2	na	50	5000	30
RICE wells											
RICE-01	E3.3	*3,420	E1.6	1.3	—[2]	*7,880	—[2]	nc	1.1	4.7	—[2]
RICE-02	E0.4	14.2	1.3	0.46	E0.06	354	—	nc	*51.3	V0.48	4.29
RICE-03	1.1	2.6	—	0.38	E0.04	800	—	nc	34.4	V0.56	4.44
RICE-04	0.8	19.9	0.6	0.96	0.09	449	—	nc	25.7	V0.75	3.36
RICE-05	0.7	*75.4	—	1.9	—	618	—	nc	27.1	V1.1	3.52
RICE-06	E0.3	34.1	—	0.86	E0.04	420	—	nc	40.9	V0.75	2.67
RICE-07	—	3.4	E0.4	0.28	—	660	—	nc	*57.4	V0.34	5.19
RICE-08	0.7	V0.2	E0.3	0.22	0.20	666	—	nc	38	V0.52	3.27
RICE-09	1.0	41.9	1.3	0.29	—	179	—	nc	18.4	—	0.34
RICE-10	2.5	7.9	2.5	0.22	E0.05	359	—	nc	10.9	—	0.64
RICE-11	18.3	9.1	0.5	1.6	—	1,340	—	nc	5.8	V1.0	1.13
RICE-12	14.3	*55.2	1.7	0.56	—	1,000	—	nc	2.2	V1.1	1.57
RICE-13	19.9	26.6	0.8	1.1	—	1,010	—	nc	8.4	V0.57	1.48
RICE-14	11.5	*379	1.2	1.3	—	919	—	nc	0.55	V0.99	1.65
RICE-15	23.3	1.3	5.4	0.40	0.43	812	—	nc	5.5	V0.47	4.44
RICE-16	26.1	*434	9.8	V0.20	11	795	—	nc	0.54	V0.53	7.76
RICE-17	31.2	27.5	*46.2	0.61	7.8	1,900	—	nc	8.5	V1.6	10.20
RICE-18	18.9	7.7	0.9	0.28	0.55	772	—	nc	5.2	V0.88	2.04
RICE-19	0.8	6.1	1.2	0.32	—	370	—	nc	24.8	V1.2	1.25
RICE-20	0.9	*216	10.9	1.3	0.32	461	—	nc	29.6	V0.44	4.90
RICE-21	19.7	*156	2.4	0.31	0.45	1200	—	nc	0.42	V0.8	2.38
RICE-22	102	*602	9.6	2.3	E0.77	*4,540	—	nc	E0.74	E4	4.81

[1] Maximum contaminant level thresholds are listed as MCL-US when MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] Laboratory reporting level is four times the LRL stated above.

Table 11. Species of inorganic arsenic, iron, and chromium detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed for iron, arsenic, and chromium; only wells with at least one detection are listed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Analyses made by the USGS's Trace Metals Laboratory. The laboratory entity code for the USGS's Trace Metals Laboratory in the USGS's National Water Information System (NWIS) is USGSTMCO. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); MDL, method detection limit; na, not available; no., number; NRP, National Research Program (USGS); NWQL, National Water Quality Laboratory (USGS); RICE, RICE well; RSD, relative standard deviation; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; * , value above threshold level]

GAMA identification no.	Iron(Total)[2] (µg/L) (01046)	Iron(II) (µg/L) (01047)	Inorganic Arsenic(Total)[2] (µg/L) (99033)	Inorganic Arsenic(III) (µg/L) (99034)	Chromium(Total) (µg/L) (01030)	Chromium(VI) (µg/L) (01032)
Threshold type[1]	**SMCL-CA**	**na**	**MCL-US**	**na**	**MCL-CA**	**na**
Threshold (µg/L)	**300**	**na**	**10**	**na**	**50**	**na**
[MDL]	**[2]**	**[2]**	**[0.5]**	**[1]**	**[1]**	**[1]**
			Grid wells			
ESAC-03	—	—	—	—	1	—
ESAC-05	—	—	* 17	—	4	4
ESAC-06	—	—	V3.6	—	—	—
ESAC-10	28	17	4.9	—	—	—
ESAC-11	6	4	[3]* 35	—	—	—
ESAC-12	3	—	3.6	—	6	5
ESAC-15	—	—	V0.7	—	2	—
ESAC-16	—	—	V1.2	—	—	—
ESAC-17	* 359	238	* 14	13	—	—
ESAC-18	—	—	V1.7	—	—	—
ESAC-19	6	—	8.0	—	5	5
ESAC-21	198	57	* 70	70	—	—
ESAC-22	—	—	—	—	1	1
ESAC-25	—	—	V4.3	—	—	—
ESAC-26	6	4	* 19	4	—	—
ESAC-27	—	—	6.2	—	—	—
ESAC-28	—	—	7.8	—	5	4
ESAC-29	* 304	26	8.7	7	—	—
ESAC-30	4	3	* 15	—	—	—
ESAC-31	21	18	* 11	4	—	—
ESAC-32	—	—	2.0	—	2	2
ESAC-34	—	—	5.1	—	4	3
ESAC-35	—	—	V1.7	—	3	2
WSAC-03	—	—	—	—	—	—
WSAC-04	36	23	V5.0	—	—	—
WSAC-06	—	—	V1.5	—	—	—
WSAC-08	2	—	V0.8	—	—	—
WSAC-10	4	—	—	—	1	1
WSAC-11	2	—	1.9	—	9	8
WSAC-12	54	36	1.9	1	—	—
WSAC-14	4	4	2.0	—	—	—

Table 11. Species of inorganic arsenic, iron, and chromium detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed for iron, arsenic, and chromium; only wells with at least one detection are listed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Analyses made by the USGS's Trace Metals Laboratory. The laboratory entity code for the USGS's Trace Metals Laboratory in the USGS's National Water Information System (NWIS) is USGSTMCO. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); MDL, method detection limit; na, not available; no., number; NRP, National Research Program (USGS); NWQL, National Water Quality Laboratory (USGS); RICE, RICE well; RSD, relative standard deviation; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Iron(Total)[2] (µg/L) (01046)	Iron(II) (µg/L) (01047)	Inorganic Arsenic(Total)[2] (µg/L) (99033)	Inorganic Arsenic(III) (µg/L) (99034)	Chromium(Total) (µg/L) (01030)	Chromium(VI) (µg/L) (01032)
Threshold type[1]	**SMCL-CA**	**na**	**MCL-US**	**na**	**MCL-CA**	**na**
Threshold (µg/L)	**300**	**na**	**10**	**na**	**50**	**na**
[MDL]	**[2]**	**[2]**	**[0.5]**	**[1]**	**[1]**	**[1]**
WSAC-15	—	—	1.6	—	6	5
WSAC-17	—	—	5.9	—	—	—
WSAC-18	—	—	1.3	—	—	—
WSAC-21	2	—	1.5	—	6	5
WSAC-22	11	—	6.5	—	2	1
WSAC-25	—	—	[3]2.6	—	—	—
WSAC-26	—	—	V1.8	—	3	2
WSAC-28	—	—	V0.9	—	—	—
WSAC-29	—	—	3.6	—	11	10
WSAC-30	4	—	—	—	7	5
WSAC-31	—	—	4.1	—	9	5
WSAC-34	—	—	V1.0	—	2	2
WSAC-35	—	—	V3.5	—	1	1
WSAC-36	4	3	5.7	—	3	2
			Flow-path wells			
ESAC-FP-01	103	82	V1.8	—	—	—
ESAC-FP-02	61	10	V1.4	—	4	2
ESAC-FP-03	130	69	1.8	—	2	—
ESAC-FP-04	62	—	3.5	—	2	1
ESAC-FP-05	—	—	6.0	—	5	4
ESAC-FP-06	12	6	* 12	—	—	—
ESAC-FP-07	8	2	8.0	—	—	—
WSAC-FP-01	—	—	1.5	—	17	17
WSAC-FP-02	5	—	2.7	—	21	19
WSAC-FP-03	3	—	1.1	—	4	3
WSAC-FP-04	6	—	5.4	4	—	—
WSAC-FP-05	10	—	6.9	—	—	—
WSAC-FP-06	13	3	4.3	—	—	—
WSAC-FP-07	39	11	9.3	9	—	—
WSAC-FP-08	6	—	0.7	—	4	4

Table 11. Species of inorganic arsenic, iron, and chromium detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from the 45 slow and intermediate grid wells, 15 flow-path wells, and 22 RICE wells were analyzed for iron, arsenic, and chromium; only wells with at least one detection are listed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Analyses made by the USGS's Trace Metals Laboratory. The laboratory entity code for the USGS's Trace Metals Laboratory in the USGS's National Water Information System (NWIS) is USGSTMCO. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); MDL, method detection limit; na, not available; no., number; NRP, National Research Program (USGS); NWQL, National Water Quality Laboratory (USGS); RICE, RICE well; RSD, relative standard deviation; SMCL-CA, secondary maximum contaminant level (CDPH); USEPA, U.S. Environmental Protection Agency; V, analyte detected in sample and an associated blank—thus data are not included in ground-water quality analysis results; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; µg/L, micrograms per liter; —, analyzed but not detected; *, value above threshold level]

GAMA identification no.	Iron(Total)[2] (µg/L) (01046)	Iron(II) (µg/L) (01047)	Inorganic Arsenic(Total)[2] (µg/L) (99033)	Inorganic Arsenic(III) (µg/L) (99034)	Chromium(Total) (µg/L) (01030)	Chromium(VI) (µg/L) (01032)
Threshold type[1]	**SMCL-CA**	**na**	**MCL-US**	**na**	**MCL-CA**	**na**
Threshold (µg/L)	**300**	**na**	**10**	**na**	**50**	**na**
[MDL]	**[2]**	**[2]**	**[0.5]**	**[1]**	**[1]**	**[1]**
			RICE wells			
RICE-01	* 4,790	4,720	3.7	4	1	—
RICE-02	3	—	8.8	—	—	—
RICE-03	4	2	[3]4	—	1	1
RICE-04	[3]4	4	4.0	—	1	—
RICE-05	28	28	0.9	—	—	—
RICE-06	4	3	1.5	—	—	—
RICE-07	2	2	5.5	—	1	—
RICE-08	3	3	5.3	—	4	4
RICE-09	3	2	3.8	—	—	—
RICE-10	2	2	2.8	—	—	—
RICE-11	—	—	V2.5	—	—	—
RICE-12	207	126	3.0	—	—	—
RICE-13	—	—	V3.5	—	2	2
RICE-14	112	96	0.7	—	—	—
RICE-15	—	—	V1.5	—	—	—
RICE-16	* 309	250	0.6	—	—	—
RICE-17	2	—	V3.0	—	12	9
RICE-18	—	—	1.1	—	6	5
RICE-19	—	—	3.5	—	—	—
RICE-20	—	—	6.8	—	—	—
RICE-21	140	130	—	—	—	—
RICE-22	[3]6	3	0.7	—	—	—

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] V codes were applied to ground-water samples for which the concentration measured by the NRP laboratory was greater than the concentration measured by the NWQL preferred method (table 10), and the difference between the results was greater than 20 percent RSD.

[3] Concentration measured by the NRP laboratory was less than the concentration measured by the NWQL preferred method (table 10), and the difference between the results was greater than 20 percent RSD.

Table 12. Stable isotope ratios of water and tritium detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from 70 of the grid wells (WSAC-14 not analyzed), the 15 flow-path wells, and 2 of the RICE wells were analyzed for stable isotopes of water; samples from 70 of the grid wells (WSAC-13 not analyzed), and the 15 flow-path wells were analyzed for tritium. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. The laboratory entity codes for the laboratories in the USGS's National Water Information System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; MCL-CA, maximum contaminant level (CDPH); nc, sample not collected; no., number; pCi/L, picocuries per liter; RICE, RICE well; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; <, less than]

GAMA identification no.	δ^{2}H of water[1] (per mil) (82082)	δ^{18}O of water[1] (per mil) (82085)	Tritium[2] (pCi/L) (07000)
Threshold type	**na**	**na**	**MCL-CA**
Threshold	**na**	**na**	**20,000**
	Grid wells		
ESAC-01	–63.1	–8.81	1.9
ESAC-02	–63.4	–8.68	11.5
ESAC-03	–63.4	–8.80	8
ESAC-04	–59.8	–8.19	2.8
ESAC-05	–63.8	–8.88	8
ESAC-06	–59.0	–8.25	1.3
ESAC-07	–56.6	–7.92	4.2
ESAC-08	–78.9	–11.02	9.9
ESAC-09	–56.6	–7.83	3.8
ESAC-10	–48.7	–6.65	2.9
ESAC-11	–60.0	–8.47	<1
ESAC-12	–71.1	–10.11	1
ESAC-13	–80.0	–11.35	3.5
ESAC-14	–57.0	–8.10	2.6
ESAC-15	–67.0	–9.73	1
ESAC-16	–60.0	–8.80	2.9
ESAC-17	–60.8	–8.28	3.5
ESAC-18	–66.1	–9.58	<1
ESAC-19	–56.3	–7.91	<1
ESAC-20	–54.3	–7.78	<1
ESAC-21	–75.2	–10.31	<1
ESAC-22	–53.0	–7.51	12.2
ESAC-23	–72.5	–10.43	10.2
ESAC-24	–57.9	–8.25	<1
ESAC-25	–61.2	–8.72	<1
ESAC-26	–82.2	–11.52	<1
ESAC-27	–55.2	–7.51	9.3
ESAC-28	–67.5	–9.48	7.4
ESAC-29	–59.2	–8.10	2.9
ESAC-30	–83.0	–11.74	<1
ESAC-31	–70.2	–9.41	8.6
ESAC-32	–67.6	–9.47	9.6
ESAC-33	–61.2	–8.70	12.5
ESAC-34	–55.9	–7.37	13.4
ESAC-35	–70.6	–9.88	4.2

Table 12. Stable isotope ratios of water and tritium detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from 70 of the grid wells (WSAC-14 not analyzed), the 15 flow-path wells, and 2 of the RICE wells were analyzed for stable isotopes of water; samples from 70 of the grid wells (WSAC-13 not analyzed), and the 15 flow-path wells were analyzed for tritium. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. The laboratory entity codes for the laboratories in the USGS's National Water Information System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; MCL-CA, maximum contaminant level (CDPH); nc, sample not collected; no., number; pCi/L, picocuries per liter; RICE, RICE well; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; <, less than]

GAMA identification no.	δ^{2}H of water[1] (per mil) (82082)	δ^{18}O of water[1] (per mil) (82085)	Tritium[2] (pCi/L) (07000)
Threshold type	**na**	**na**	**MCL-CA**
Threshold	**na**	**na**	**20,000**
WSAC-01	–72.1	–9.98	<1
WSAC-02	–63.0	–8.41	6.4
WSAC-03	–68.1	–9.64	7.4
WSAC-04	–67.4	–9.24	<1
WSAC-05	–65.0	–8.90	7.7
WSAC-06	–66.2	–9.46	8.6
WSAC-07	–66.9	–9.24	13.4
WSAC-08	–62.6	–8.61	11.8
WSAC-09	–63.3	–8.83	6.7
WSAC-10	–63.7	–8.82	7.4
WSAC-11	–59.5	–8.60	<1
WSAC-12	–76.3	–10.35	<1
WSAC-13	–63.9	–8.91	nc
WSAC-14	nc	nc	<1
WSAC-15	–44.7	–5.81	8.3
WSAC-16	–52.1	–6.93	2.6
WSAC-17	–75.9	–10.61	8.6
WSAC-18	–62.2	–8.45	1.6
WSAC-19	–58.7	–8.37	<1
WSAC-20	–44.4	–5.90	4.5
WSAC-21	–59.0	–8.38	1.9
WSAC-22	–59.5	–8.53	5.8
WSAC-23	–60.5	–8.15	7.7
WSAC-24	–59.1	–8.54	1.3
WSAC-25	–51.7	–7.14	<1
WSAC-26	–64.2	–9.08	3.8
WSAC-27	–65.4	–8.84	9.3
WSAC-28	–63.6	–8.75	11.8
WSAC-29	–64.4	–8.87	<1
WSAC-30	–66.9	–9.21	14.7
WSAC-31	–64.8	–9.21	<1
WSAC-32	–74.3	–10.51	8.3
WSAC-33	–62.0	–8.88	<1
WSAC-34	–64.8	–9.04	9.6
WSAC-35	–68.8	–9.37	7.4
WSAC-36	–66.6	–9.26	1.6

Table 12. Stable isotope ratios of water and tritium detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from 70 of the grid wells (WSAC-14 not analyzed), the 15 flow-path wells, and 2 of the RICE wells were analyzed for stable isotopes of water; samples from 70 of the grid wells (WSAC-13 not analyzed), and the 15 flow-path wells were analyzed for tritium. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Stable isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. The laboratory entity codes for the laboratories in the USGS's National Water Information System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. CDPH, California Department of Public Health; ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; MCL-CA, maximum contaminant level (CDPH); nc, sample not collected; no., number; pCi/L, picocuries per liter; RICE, RICE well; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; <, less than]

GAMA identification no.	δ^{2}H of water[1] (per mil) (82082)	δ^{18}O of water[1] (per mil) (82085)	Tritium[2] (pCi/L) (07000)
Threshold type	**na**	**na**	**MCL-CA**
Threshold	**na**	**na**	**20,000**
	Flow-path wells		
ESAC-FP-01	–53.6	–7.34	<1
ESAC-FP-02	–69.4	–10.06	3.5
ESAC-FP-03	–72.9	–10.11	6.4
ESAC-FP-04	–64.0	–9.14	<1
ESAC-FP-05	–61.7	–8.01	12.8
ESAC-FP-06	–75.5	–10.58	<1
ESAC-FP-07	–80.8	–11.08	<1
WSAC-FP-01	–65.3	–9.13	<1
WSAC-FP-02	–67.7	–9.55	<1
WSAC-FP-03	–63.5	–8.96	9.0
WSAC-FP-04	–66.6	–9.43	1.3
WSAC-FP-05	–71.6	–9.63	<1
WSAC-FP-06	–69.7	–9.66	<1
WSAC-FP-07	–72.9	–10.22	<1
WSAC-FP-08	–69.2	–9.70	12.8
	RICE wells		
RICE-07	–54.1	–6.63	nc
RICE-11	–63.0	–8.47	nc

[1] USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA).

[2] USGS Stable Isotope and Tritium Laboratory, Menlo Park, California (USGSH3CA).

Table 13. Nitrogen and oxygen isotopes in nitrate, nitrogen isotopes in nitrogen gas, and carbon-14 activities detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Samples from 42 of the slow and intermediate grid wells (ESAC-35, WSAC-10, and WSAC-11 not analyzed) and the 15 flow-path wells were analyzed for isotopes of nitrate; samples from 43 of the slow and intermediate grid wells (ESAC-35 and WSAC-11 not analyzed) and the 15 flow-path wells were analyzed for carbon-14 activities. Nitrogen and oxygen isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. The laboratoroy entity codes for the laboratories in the USGS's National Water Information System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; na, not available; nc, sample not collected; no., number; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, nitrate not detected, therefore sample was not analyzed for nitrate isotopes]

GAMA identification no.	δ^{18}O of nitrate[1] (per mil) (63041)	δ^{15}N of nitrate[1] (per mil) (82690)	δ^{13}O of dissolved carbonates[2] (per mil) (82081)	[3]Carbon-14 (percent modern) (49933)
Threshold type	**na**	**na**	**na**	**na**
Threshold	**na**	**na**	**na**	**na**
		Grid wells		
ESAC-03	2.76	8.43	–16.37	89
ESAC-05	4.00	6.41	–15.53	98
ESAC-06	2.58	3.92	–17.02	91
ESAC-10	5.28	11.76	–14.19	106
ESAC–11	—	—	–16.57	25
ESAC-12	0.46	4.59	–15.62	62
ESAC-15	—	—	–14.19	95
ESAC-16	1.00	4.38	–17.44	88
ESAC-17	—	—	–14.18	81
ESAC-18	1.39	4.59	–14.84	93
ESAC-19	–0.55	4.55	–15.46	82
ESAC-21	—	—	5.57	11
ESAC-22	3.99	3.52	–18.13	111
ESAC-25	0.01	2.71	–16.03	90
ESAC-26	—	—	–12.79	50
ESAC-27	3.54	9.35	–17.24	93
ESAC-28	2.86	6.38	–15.29	99
ESAC-29	—	—	–15.00	53
ESAC-30	11.21	26.65	–12.86	56
ESAC-31	16.33	24.47	–17.50	82
ESAC-32	6.60	7.46	–19.37	108
ESAC-34	5.64	9.88	–17.47	100
WSAC-03	2.28	4.23	–16.32	103
WSAC-04	—	—	–8.58	34
WSAC-06	3.57	11.54	–16.17	102
WSAC-08	1.02	5.82	–14.29	23
WSAC-10	nc	nc	–14.04	114
WSAC-11	nc	nc	–15.69	66
WSAC-12	—	—	nc	nc
WSAC-14	14.65	25.43	–12.09	40
WSAC-15	3.37	4.53	–15.09	104

Table 13. Nitrogen and oxygen isotopes in nitrate, nitrogen isotopes in nitrogen gas, and carbon-14 activities detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Samples from 42 of the slow and intermediate grid wells (ESAC-35, WSAC-10, and WSAC-11 not analyzed) and the 15 flow-path wells were analyzed for isotopes of nitrate; samples from 43 of the slow and intermediate grid wells (ESAC-35 and WSAC-11 not analyzed) and the 15 flow-path wells were analyzed for carbon-14 activities. Nitrogen and oxygen isotope ratios are reported in the standard delta notation (δ), the ratio of a heavier isotope to more common lighter isotope of that element, relative to a standard reference material. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. The laboratoroy entity codes for the laboratories in the USGS's National Water Information System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. ESAC, East study area of the middle Sacramento Valley study unit; ESAC-FP, East study area of the middle Sacramento Valley study unit–flow path; na, not available; nc, sample not collected; no., number; WSAC, West study area of the middle Sacramento Valley study unit; WSAC-FP, West study area of the middle Sacramento Valley study unit–flow path; —, nitrate not detected, therefore sample was not analyzed for nitrate isotopes]

GAMA identification no.	δ^{18}O of nitrate[1] (per mil) (63041)	δ^{15}N of nitrate[1] (per mil) (82690)	δ^{13}O of dissolved carbonates[2] (per mil) (82081)	[3]Carbon-14 (percent modern) (49933)
Threshold type	**na**	**na**	**na**	**na**
Threshold	**na**	**na**	**na**	**na**
WSAC-17	5.58	13.78	–15.50	81
WSAC-18	12.82	27.24	–13.10	34
WSAC-21	0.29	1.58	–17.09	88
WSAC-22	0.34	7.46	–15.13	78
WSAC-25	16.81	28.19	–14.14	39
WSAC-26	1.29	2.55	–14.62	74
WSAC-28	0.40	3.67	–13.78	114
WSAC-29	0.06	4.85	–15.03	44
WSAC-30	6.20	10.21	–13.42	84
WSAC-31	–0.20	5.00	–15.56	41
WSAC-34	1.96	5.07	–15.62	114
WSAC-35	2.63	7.86	–14.93	94
WSAC-36	7.25	13.64	–15.42	65
		Flow-path wells		
ESAC-FP-01	—	—	–15.25	27
ESAC-FP-02	0.38	8.30	–14.82	100
ESAC-FP-03	11.89	19.89	–17.50	93
ESAC-FP-04	2.17	4.07	–17.45	58
ESAC-FP-05	0.98	5.65	–22.23	100
ESAC-FP-06	—	—	–14.98	9
ESAC-FP-07	—	—	–11.63	5
WSAC-FP-01	0.47	4.18	–13.49	43
WSAC-FP-02	–3.09	2.52	–13.19	23
WSAC-FP-03	0.07	4.49	–17.89	85
WSAC-FP-04	—	—	–14.00	18
WSAC-FP-05	10.56	20.26	–16.50	14
WSAC-FP-06	6.69	9.76	–14.40	15
WSAC-FP-07	—	—	–14.82	15
WSAC-FP-08	3.42	7.43	–15.22	93

[1] USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA).

[2] University of Waterloo (contract laboratory) (CAN-UWIL).

[3] University of Arizona, Accelerator Mass Spectrometry Laboratory (contract laboratory) (AZ-UAMSL).

Table 14. Radioactive constituents detected in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) Program, California, June to September, 2006.

[Samples from the eight slow grid wells were analyzed. The five-digit number in parentheses below the constituent name in the headings is used by the U.S. Geological Survey (USGS) to uniquely identify a specific constituent or property. Analyses by Eberline Analytical Services. The laboratory entity code for Eberline Analytical Services in the USGS's National Water Information System (NWIS) is CA-EBERL. CDPH, California Department of Public Health; E, estimated value; ESAC, East study area of the middle Sacramento Valley study unit; MCL-CA, maximum contaminant level (CDPH); MCL-US, maximum contaminant level (USEPA); no., number; pCi/L, picocuries per liter; USEPA, U.S. Environmental Protection Agency; WSAC, West study area of the middle Sacramento Valley study unit; <, nondetection; L<, nondetection, however, result may be biased low on the basis of matrix-spike results with the potential for a false nondetection; *, value above lower threshold]

GAMA identification no.	Radium-226 (pCi/L) (09511)	Radium-228 (pCi/L) (81366)	Radon-222 (pCi/L) (82303)	Gross alpha radioactivity, 72-hour count (pCi/L) (62636)	Gross alpha radioactivity, 30-day count (pCi/L) (62639)	Gross beta radioactivity, 72-hour count (pCi/L) (62642)	Gross beta radioactivity, 30-day count (pCi/L) (62645)
Threshold type[1]	**MCL-US**[2]	**MCL-US**[2]	**proposed MCL-US**[3]	**MCL-US**	**MCL-US**	**MCL-CA**	**MCL-CA**
Threshold value	**5**	**5**	**300 (4,000)**	**15**	**15**	**50**	**50**
			Grid wells				
ESAC-25	E0.02	<0.46	78	<2.2	<2.1	E1.1	E1.6
ESAC-26	E0.03	<0.46	*307	<1.2	<2.5	E1.9	E2.0
ESAC-27	E0.05	<0.51	*972	E1.5	E1.2	E1.6	E1.4
ESAC-28	E0.03	<0.62	*343	E1.1	<2.2	2.7	E3.2
WSAC-03	E0.03	<0.44	*447	E0.6	<3.3	<1.9	<2.8
WSAC-08[4]	E0.03	<0.54	*463	L<2.2	L<2.1	E1.7	<1.7
WSAC-12	0.09	E0.45	*411	<1.7	<2.7	<2.0	E1.0
WSAC-18[4]	E0.05	<0.54	214	L<4.9	L<3.1	E1.2	E1.6

[1] Maximum contaminant level thresholds are listed as MCL-US when the MCL-US and MCL-CA are identical, and as MCL-CA when the MCL-CA is lower than the MCL-US or no MCL-US exists.

[2] The MCL-US threshold for radium is the sum of radium-226 and radium-228.

[3] Two MCL-US thresholds have been proposed: 300 pCi/L and 4,000 pCi/L.

[4] Potential to be biased low for gross alpha 72-hour and gross alpha 30-day radioactivity counts because of relatively high concentration of calcium.

Appendix

The appendix discusses methods used to collect and analyze ground-water samples and to report the data for the MSACV study unit. These methods were selected to obtain representative samples of the ground water used for drinking-water supplies in the study and to minimize potential bias of the data. Procedures to analyze and interpret QC data collected as part of the ground-water sampling are also discussed.

Sample Collection and Analysis

Ground-water samples were collected using standard and modified USGS protocols (Koterba and others, 1995), the National Field Manual for the collection of water quality data (U.S. Geological Survey, variously dated) and protocols described by Weiss (1968), Shelton and others (2001), Ball and McClesky (2003a,b), and Wright and others (2005).

Prior to sampling, each well was pumped continuously to purge at least three casing-volumes of water from the well (Wilde and others, 1999). Wells were sampled using Teflon tubing with brass and stainless-steel fittings attached to a sampling point on the well discharge pipe as close to the well as possible. The sampling point was always located upstream of any well-head treatment system or water storage tank. If a chlorinating system was attached to the well, the chlorinator was shut off at least 24 hours prior to purging and sampling the well to clear all chlorine out of the system.

For the *fast* and *intermediate* schedules, samples were collected at the well head using a foot-long length of Teflon tubing. For the *slow* schedule, the samples were collected inside an enclosed chamber located inside a mobile laboratory and connected to the well head by a 10- to 50-ft length of Teflon tubing (Lane and others, 2003).

For intermediate monitoring schedules (flow-path and RICE wells), samples were collected using a portable, 2-in. diameter submersible pump (Grundfos RediFlo2 pump) attached to reels of approximately 300 ft of Teflon tubing. The 10- to 50-ft Teflon tubing used to sample slow schedules was attached to the outflow section of the reels and samples were collected inside an enclosed chamber in a mobile laboratory. Two separate submersible pumps and reels were used to collect samples from monitoring wells in MSACV. All fittings and lengths of tubing were cleaned between samples (Wilde, 2004).

For the field measurements, ground water was pumped through a flow-through chamber fitted with a multiprobe meter that simultaneously measures the water-quality indicators dissolved oxygen, temperature, pH, turbidity, and specific conductance. Field measurements were made in accordance with protocols in the USGS's National Field Manuals (Lewis, 2006; Radtke and others, 2005; Wilde, 2006; Wilde and others, 2006; Wilde and Radtke, 2005). All sensors on the multiprobe meter were calibrated daily. Measurements of temperature, dissolved oxygen, pH, and specific conductance values were recorded at 5-minute intervals for at least 30 minutes, and when these values remained stable for 20 minutes, samples for laboratory analyses were then collected. Field measurements and instrument calibrations were recorded by hand on field record sheets and electronically in PCFF ("Personal Computer Field Forms")-GAMA, a software package designed by the USGS with support from the GAMA program. Analytical service requests were also managed by PCFF-GAMA. Chain of custody documentation forms were completed by hand or electronically. Information from PCFF-GAMA was uploaded directly into NWIS at the end of every week of sample collection.

For analyses requiring filtered water, ground water was diverted through a 0.45-µm pore size vented capsule filter, a disk filter, or a baked glass-fiber filter depending on the protocol for the analysis (Wilde, 2004; Wilde and others, 1999). Prior to sample collection, polyethylene sample bottles were prerinsed twice using dionized water and once with sample water before collection. Samples requiring acidification were acidified to a pH of 2 or less with the appropriate acids using ampoules of certified, traceable concentrated acids obtained from NWQL.

Temperature-sensitive samples were stored on ice prior to, and during, daily shipping to the various laboratories. The nontemperature-sensitive samples, tritium, noble gases, chromium speciation, and stable isotopes were shipped monthly, whereas VOCs, pesticides and pesticide degradates, constituents of special interest, dissolved organic carbon, radium isotopes, gross alpha and beta radioactivity, and radon-222 samples were shipped daily.

Detailed sampling protocols for individual analyses and groups of analytes are described in Koterba and others (1995) and the USGS's National Field Manuals (Wilde, 2004; Wilde and others, 1999) and in the references for analytical methods listed in table A1; only brief descriptions are given here. VOCs and gasoline oxygenates and degradates, and 1,2,3-TCP samples were collected in 40-mL baked amber glass sample vials that were purged with three vial volumes of sample water before bottom-filling to eliminate atmospheric contamination. Six normal (6 N) hydrochloric acid (HCl) was added as a preservative to the VOC samples, but not to the gasoline oxygenate and degradate samples, or the 1,2,3-TCP samples. Perchlorate samples were collected in 125-mL polyethylene bottles. Tritium samples were collected by bottom-filling two 1-L polyethylene bottles with unfiltered ground water, after first overfilling the bottle with three volumes of water. Stable isotopes of water were collected in 60-mL clear glass bottles filled with unfiltered water, sealed with a conical cap, and secured with electrical tape to prevent leakage and evaporation.

Pesticides and pesticide degradation products, pharmaceutical compounds, and NDMA samples were collected in 1-L baked amber glass bottles. Pesticide and pharmaceutical samples were filtered with a glass-fiber filter during collection, whereas the NDMA samples were filtered at the Montgomery Watson Harza laboratory prior to analysis.

Ground-water samples for major and minor ions, trace elements, alkalinity, and total dissolved solids analyses required filling one 250-mL polyethylene bottle with raw ground water, and one 500-mL and one 250-mL polyethylene bottles with filtered ground water (Wilde, 2004). A Whatman capsule filter was used for filtration. Each 250-mL filtered sample was then preserved with an ampoule of 7.5 N nitric acid. Mercury samples were collected by filtering ground water into a 250-mL glass bottle and preserving with an ampoule of 6 N HCl. Arsenic and iron speciation samples were filtered into 250-mL polyethylene bottles that were covered with tape to prevent light exposure and preserved with 6 N HCl. Nutrient samples were filtered into 125-mL brown polyethylene bottles. Nitrate isotope samples were filtered into 125-mL polyethylene bottles. Radium isotopes and gross alpha and beta radiation samples were filtered into 1-L polyethylene bottles and acidified with nitric acid. Carbon isotope samples were filtered and bottom-filled into two 500-mL glass bottles that were first overfilled with three bottle volumes of ground water. These samples had no headspace and were sealed with a conical cap to avoid atmospheric contamination. Samples for alkalinity titrations were collected by filtering ground water into 500-mL polyethylene bottles.

Dissolved organic carbon (DOC), chromium, radon-222, dissolved gases, and microbial constituents were collected from the hose bib at or near the well head, regardless of the sampling schedule (fast, intermediate, or slow). DOC was collected after rinsing the sampling equipment with universal blank water (Wilde, 2004). Using a 50-mL syringe and 0.45-µm disk filter, ground-water samples were filtered into 125-mL baked amber glass bottles and preserved with 4.5 N sulfuric acid. Chromium speciation samples were collected using a 10-mL syringe with an attached 0.45-µm disk filter. After the syringe was thoroughly rinsed and filled with ground water, 4 mL was forced through the disk filter; the next 2 mL of the ground water was then slowly filtered into a small centrifuge vial for analysis of total chromium. Hexavalent chromium, Cr(VI), was then collected by attaching a small cation-exchange column to the syringe filter, and after conditioning the column with 2 mL of sample water, 2 mL was collected in a second centrifuge vial. Both vials were preserved with 10 µL of 7.5 N nitric acid (Ball and McClesky, 2003a,b).

For the collection of radon-222, a stainless steel and Teflon valve assembly was attached to the sampling port at the well head (Wilde, 2004). The valve was partially closed to create back pressure, and a 10-mL sample was taken through a Teflon septum on the value assembly using a glass syringe affixed with a stainless-steel needle. The sample was then injected into a 25-mL vial partially filled with scintillation mixture (mineral oil) and shaken. The vial was then placed in a cardboard tube to shield it from light during shipping.

Noble gases were collected in 3/8-in. copper tubes using reinforced nylon tubing connected to the hose bib at the wellhead. Ground water was flushed through the tubing to dislodge bubbles before flow was restricted with a back pressure valve. Clamps on either side of the copper tube were then tightened, trapping a sample of ground water for analyses of noble gases (Weiss, 1968).

Samples for analysis of microbial constituents also were collected at the well head (Bushon, 2003; Myers, 2004). Prior to the collection of samples, the sampling port was sterilized using isopropyl alcohol, and ground water was run through the sampling port for at least three minutes to remove any traces of the sterilizing agent. One sterilized 3-L carboy was filled for coliphage analyses (F-specific and somatic coliphage determinations), and two sterilized 250-mL bottles were filled with ground water for coliform (total coliforms and *Escherichia* coliform) analyses. Total coliforms and *Escherichia* coliform (*E. coli*) plates were prepared using sterilized equipment and reagents (Myers, 2004). Plates were counted under an ultraviolet light, following a 22- to 24-hour incubation time.

Turbidity and alkalinity were measured in the mobile laboratory at the well site. Turbidity was measured in the field with a calibrated turbidity meter. Alkalinity concentrations were measured on filtered samples by Gran's titration method (Rounds, 2006). Titration data were entered directly into PCFF-GAMA, and the concentrations of bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) were automatically calculated from the titration data using the advanced speciation method. Concentrations of HCO_3^- and CO_3^{2-} were also calculated from the laboratory alkalinity and pH measurements. Calculations were made in a spreadsheet using the advanced speciation method (http://or.water.usgs.gov/alk/methods.html) with pK_1 = 6.35, pK_2 = 10.33, and pK_W = 14.

Ten laboratories performed chemical and microbial analyses for this study (see table A1), with most of the analyses being performed at NWQL or by laboratories contracted by NWQL. NWQL maintains a rigorous quality-assurance program (Maloney, 2005; Pirkey and Glodt, 1998). Laboratory QC samples, including method blanks, continuing calibration verification standards, standard reference samples, reagent spikes, external certified reference materials, and external blind proficiency samples, are analyzed regularly. Method detection limits are continuously tested and laboratory reporting levels updated accordingly. NWQL maintains National Environmental Laboratory Accreditation Program

(NELAP) and other certifications (http://nwql.usgs.gov/Public/lab_cert.shtml). In addition, the Branch of Quality Systems within the USGS's Office of Water Quality maintains independent oversight of quality assurance at NWQL and laboratories contracted by NWQL. The Branch of Quality Systems also runs a National Field Quality Assurance program that includes annual testing of all USGS field personal for proficiency in making field water-quality measurements (http://bqs.usgs.gov/nfqa/). Results for analyses made at NWQL or by laboratories contracted by NWQL are uploaded directly into NWIS by NWQL.

Data Reporting

Laboratory Reporting Conventions

NWQL uses the LRL as a threshold for reporting analytical results. The LRL is set to minimize the reporting of false negatives (not detecting a compound when it is actually present in a sample) to less than 1 percent (Childress and others, 1999). The LRL is set at two-times the long-term method detection level (LT-MDL). The LT-MDL is derived from the standard deviation of at least 24 MDL determinations made over an extended period of time. LT-MDLs are continually monitored and updated. The method detection limit (MDL) is the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the concentration is greater than zero (at the MDL, there is less than 1 percent chance of a false positive) (Childress and others, 1999; U.S. Environmental Protection Agency, 2002a). NWQL updates LRL values regularly, and the values listed in this report were in effect during the period analyses were made for ground-water samples from the MSACV study (June to September, 2006).

Detections between the LRL and the LT-MDL are reported as estimated concentrations (designated with an "E" before the value in the tables and text). For information-rich methods, detections below the LT-MDL have high certainty of detection, but the precise concentration is uncertain. Information-rich methods are those that utilize gas chromatography or high-performance liquid chromatography (HPLC) with mass spectrometry detection (VOCs, gasoline oxygenates and degradates, and pesticides and pesticide degradates). For these methods, compounds are identified by presence of characteristic fragmentation patterns in their mass spectra in addition to being quantified by measurement of peak areas at their associated chromatographic retention times. E-coded values also may result from detections outside the range of calibration standards for detections that did not meet all laboratory QC criteria and for samples that were diluted prior to analysis (Childress and others, 1999).

Some compound concentrations in this study are reported using minimum reporting levels (MRLs) or method uncertainties. The MRL is the smallest measurable concentration of a constituent that may be reliably reported using a given analytical method (Timme, 1995). The method uncertainty generally indicates the precision of a particular analytical measurement; it gives a range of values wherein the true value will be found.

The reporting levels for radiochemical constituents (gross-alpha radioactivity, gross-beta radioactivity, radium-226, and radium-228) are based on a sample-specific minimum detectable concentration (SSMDC), a sample-specific critical value, and the combined standard uncertainty (CSU) (Bennett and others, 2006; U.S. Environmental Protection Agency, 2004). A result above the critical value represents a greater-than-95-percent certainty that the result is greater than zero (significantly different from the instrument's background response to a blank sample), and a result above the SSMDC represents a greater-than-95-percent certainty that the result is greater than the critical value. Using these reporting level elements, three unique cases were possible when screening the raw analytical data, as described in Bennett and others (2006). If the analytical result was less than the critical value (case 1), the analyte was considered not detected, and the concentration was reported as less than the SSMDC. If the analytical result was greater than the critical value, the ratio of the CSU to the analytical result was calculated as a percent (percent relative CSU). For those samples with percent relative CSU greater than 20 percent (case 2), concentrations were reported as estimated values (designated by an "E" preceding the value). For those samples with percent relative CSU less than 20 percent, concentrations were reported unqualified (case 3). For table clarity, only the screened results were reported in table 14; the raw analytical results with their corresponding SSMDCs, critical values, and CSUs, are on file at the USGS California Water Science Center.

Stable isotopic compositions of oxygen, hydrogen, carbon, and nitrogen are reported as relative isotope ratios in units of per mil using the standard delta notation $\delta^{i}E$ (Coplen and others, 2002):

$$\delta^{i}E = \left[\frac{R_{sample}}{R_{reference}} - 1\right] \bullet 1{,}000 \text{ per mil}, \quad (1)$$

where

^{i}E is the heavier isotope (^{18}C, ^{13}C, or ^{2}H),

R_{sample} is the ratio of the abundance of the heavier isotope to the lighter isotope (^{16}O, ^{12}C, or ^{1}H) in the sample, and

$R_{reference}$ is the ratio of the abundance of the heavier isotope to the lighter isotope (^{16}O, ^{12}C, or ^{1}H) in the reference material.

The reference material for oxygen and hydrogen is Vienna Standard Mean Ocean Water (VSMOW), which is assigned $\delta^{18}O$ and $\delta^{2}H$ values of 0 per mil (note than $\delta^{2}H$ is also written as δD because the common name of the heavier isotope of hydrogen, hydrogen-2, is deuterium). The reference material for carbon is Vienna Peedee Belemnite (VPDB), which is assigned a $\delta^{13}C$ value of 0 per mil. Positive values indicate enrichment of the heavier isotope and negative values indicate depletion of the heavier isotope, compared with the ratios observed in the standard reference material.

Constituents on Multiple Analytical Schedules

Eighteen constituents targeted in this study are measured by more than one analytical schedule or more than one laboratory (table A2). The preferred methods for these constituents were selected on the basis of the procedure recommended by NWQL (http://wwwnwql.cr.usgs.gov/USGS/Preferred_method_selection_procedure.html). Methods with full approval are preferred over those with provisional approval and approved methods are favored over research methods. The method with greater accuracy and precision and lower LRLs for the overlapping constituents is generally preferred. However, the method with higher LRLs may be selected as the preferred method to provide consistency with historical data analyzed by the same method.

Five constituents appear on NWQL Schedules 2020 and 4024, and the preferred method is Schedule 2020 to provide consistency. All samples collected for the GAMA Priority Basin Assessment project are analyzed using Schedule 2020, whereas, only a subset are analyzed using Schedule 4024. Six constituents appear on NWQL Schedules 2032/2033 and 2060, and the preferred method is Schedule 2032/2033 because it has greater precision and accuracy for the six overlapping constituents. For constituents that appear on two NWQL schedules, only the values determined by the preferred method are reported.

The water-quality indicators pH, specific conductance, and alkalinity were measured in the field and at NWQL. The field measurements are the preferred method for all three constituents; however, both are reported because the laboratory alkalinity measurements were made on a greater number of samples.

The field and laboratory data were compared using the Wilcoxon signed-rank test, a nonparametric statistical test that is analogous to the parametric statistical test the paired t-test (Helsel and Hirsch, 2002). A nonparametric test was used because the data are not normally distributed. The Wilcoxon signed-rank test evaluates the null hypothesis that the median of the paired differences between the two datasets is zero. Results are reported as the probability, P, of obtaining the observed distribution of data, or one even less likely, when the null hypothesis is true. Therefore, a P value of 0.01 indicates 99 percent confidence that the two datasets are different.

Specific conductance was measured in both the field and the laboratory for 82 samples, and there was no statistical significance between the two datasets (P = 0.1035). Both laboratory and field pH measurements were made for 80 samples, and the two datasets were systematically different (P = <0.0001). Field pH values were lower by a median of 0.3 pH units. The increase in pH between field and laboratory measurement may be explained by equilibration of the sample with the atmosphere after collection. The partial pressure of CO_2 in ground water is often greater than the atmospheric partial pressure (Appelo and Postma, 2005); thus, CO_2 degasses from the ground water when it is brought in contact with the atmosphere. CO_2 loss results in increased pH. Field and laboratory alkalinities were measured for seven samples, and the two datasets were significantly different (P = 0.0156). Field alkalinity values were lower by a median of 11 mg/L as $CaCO_3$. The differences between the field and laboratory values were greater than 5 percent for all but two samples.

For arsenic, chromium, and iron concentrations, the standard methods used by NWQL are preferred over the research methods used by the USGS National Research Program (NRP) Trace Metal Laboratory (TML) in Boulder, Colorado. The concentrations measured by TML are used only to

calculated ratios of redox species for each element, $\frac{As(V)}{As(III)}$ for arsenic, $\frac{Cr(VI)}{Cr(III)}$ for chromium, and $\frac{Fe(III)}{Fe(II)}$ for iron. For example:

$$\frac{Fe(III)}{Fe(II)} = \frac{Fe(T) - Fe(II)}{Fe(II)}, \quad (2)$$

where

Fe(T) is the total iron concentration (measured),

Fe(II) is the concentration of ferrous iron (measured), and

Fe(III) is the concentration of ferric iron (calculated).

Quality Assurance

The purpose of quality-assurance is to identify which data best represent environmental conditions and which may have been affected by contamination or bias during sample collection, processing, storage, transportation, or laboratory analysis. Four types of QC tests were used in this study: blank samples were collected to assess contamination; replicate samples were collected to assess reproducibility; matrix spike tests were done to assess accuracy of laboratory analytical methods; and surrogate compounds were added to samples analyzed for organic constituents to assess bias of laboratory analytical methods. In the tables of this report, detections of organic constituents in ground-water samples that may have resulted from contamination were flagged with a “V” remark code, and were not considered detections for calculations

of detection frequencies in water-quality assessments. Detections of inorganic constituents in ground-water samples that may have resulted from contamination were flagged with a "V" remark code to indicate that the amount of potential contamination may have been sufficient to change a nondetection into a detection relative to the stated reporting level.

The quality-assurance used for this study followed the protocols used by the USGS's NAWQA program (Koterba and others, 1995) and described in the National Field Manual (U.S. Geological Survey, variously dated). The quality assurance plan followed by NWQL, the primary laboratory used to analyze samples for this study, is described in Maloney (2005) and Pirkey and Glodt (1998).

Blanks

Blank samples (blanks) were collected using two types of water certified by NWQL to contain less than the LRL or MRL of the analytes investigated in the study. First, inorganic blank water (IBW) was used to collect sample blanks of perchlorate, major ions and trace elements, nutrients, arsenic and iron speciation, and chromium speciation. All other blanks were collected using VOC-free (nitrogen-purged) blank water (VBW). Two types of blanks were collected: source-solution and field blanks. Source-solution blanks were collected to verify that the blank water used for the field blanks was free of analytes. Field and source solution blanks were collected at approximately 10 percent of the wells sampled to determine if equipment or procedures used in the field or laboratory introduced contamination. Field blanks were analyzed for VOCs, gasoline oxygenates and their degradates, pesticides and pesticide degradates, pharmaceuticals, perchlorate, NDMA, 1,2,3-TCP, nutrients, DOC, major and minor ions, trace elements, iron, arsenic, and chromium speciation, and radioactive constituents (table A3). NWQL-certified blank water is not available for tritium or noble gases; thus, source solution and field blanks were not collected for these constituents.

Field blanks were collected by pumping or pouring blank water through the sampling equipment (fittings and tubing) used to collect ground water, then processing and transporting the blank samples using the same protocols for the ground-water samples. The equipment used to collect samples from monitoring wells was significantly different than that used to collect samples from production wells; thus, the field blanks were separated into monitoring well and production well groups for comparison with ground-water data. Source-solution blanks were collected at the sampling site by pouring blank water directly into sample containers that were preserved, stored, shipped, and analyzed in the same manner as the ground-water samples. Source-solution blanks were not divided into two classes because they were not collected using the field sampling equipment.

If a constituent was detected in field or source-solution blanks, the data for that constituent in ground-water samples were examined for potential contamination. Detections in ground-water samples with concentrations less than the highest concentration measured in a blank plus the LT-MDL were marked with a "V" in the data tables (LRL equals twice the LT-MDL). The highest concentration measured in a blank was assumed to represent the highest potential amount of contamination. Thus, the V remark code flags results that could have changed from a nondetection to a detection relative to the LT-MDL because of contamination. For example, if the LT-MDL for a constituent is 0.10 µg/L, the measured concentration in a ground-water sample with a true concentration of 0.05 µg/L would be reported as a nondetection. But, if the ground-water sample was contaminated with 0.20 µg/L of the constituent, the measured concentration would be reported as 0.25 µg/L, a detection. If the maximum potential amount of contamination is 0.20 µg/L, then ground-water samples with measured concentrations less than 0.30 µg/L may actually have true concentrations less than the LT-MDL.

For organic constituents, results with V codes are not considered to be detections of the constituent when calculating detection frequencies for ground-water quality assessments. For inorganic constituents, results with V codes are considered to have concentrations less than the reported value (including the possibility of the concentration being less than the LT-MDL).

Replicates

Sequential replicate samples were collected to assess variability that may result from the processing and analyses of inorganic and organic constituents. RSD of the measured values was used to express the variability between replicate pairs for each compound (table A4). The RSD is defined as the standard deviation divided by the mean concentration for each replicate pair of samples, multiplied by 100 percent. If one value in a sample pair was reported as a nondetection and the other value was reported as an estimated value below the LRL or MRL, the RSD was set to zero because the values are analytically identical. If one value in a sample pair was reported as a nondetection and the other value was greater than the LRL or MRL, then the nondetection value was set equal to one-quarter of the LRL, and the RSD was calculated (Hamlin and others, 2002). Values of RSD less than 20 percent are considered acceptable in this study. An RSD value of 20 percent corresponds to a relative percent difference (RPD) value of 29 percent. High RSD values for a compound may indicate analytical uncertainty at low concentrations, particularly for concentrations within an order of magnitude of LT-MDL or MDL. Sequential replicate samples were collected at approximately 10 percent of the wells sampled.

Matrix Spikes

Addition of a known concentration of a constituent ("spike") to a replicate environmental sample enables the laboratory to determine the effect of the matrix, in this case ground water, on the analytical technique used to measure the constituent. The compounds added as matrix spikes are the same as those being analyzed in the method. This enables an analysis of matrix interferences on a compound by compound basis. Matrix spikes were added at the laboratory performing the analysis. Compounds with low recoveries are of particular concern if environmental concentrations are close to the MCLs; a concentration below an MCL could be above this threshold. Conversely, compounds with high recoveries are of potential concern if the environmental concentrations exceed MCLs; a high recovery could falsely indicate a concentration above the MCL.

Acceptable ranges for matrix-spike recoveries are based on the acceptable ranges established for laboratory "set" spike recoveries. Laboratory set spikes are aliquots of laboratory blank water to which the same spike solution used for the matrix spikes has been added. One set spike is analyzed with each set of samples. Acceptable ranges for set spike recoveries are 70 to 130 percent for NWQL Schedules 2020 and 4024 (VOCs and gasoline additives; Connor and others, 1998; Rose and Sandstrom, 2003; Zaugg and others, 2002), 60 to 120 percent for NWQL Schedules 2032, 2033, and 2060 (pesticides; Sandstrom and others, 2001), and 60 to 130 percent for Schedule 2080 (pharmaceuticals; Kolpin and others, 2002). On the basis of these ranges, we defined 70 to 130 percent as the acceptable range for matrix-spike recoveries for organic compounds in this study.

Laboratory matrix spikes were performed for VOCs, gasoline oxygenate and their degradates, pesticide compounds, pharmaceutical compounds, NDMA, and 1,2,3-TCP because the analytical methods for these constituents are chromatographic methods that may be susceptible to matrix interferences. Replicate samples for matrix-spike additions were collected at approximately 10 percent of the wells sampled, although not all analyte classes were tested for every well (tables A5A–D).

Surrogates

Surrogate compounds are added to environmental samples in the laboratory prior to analysis to evaluate the recovery of similar constituents. Surrogate compounds were added to all ground-water and QC samples that were analyzed for VOCs, gasoline oxygenates and their degradates, pesticide compounds, NDMA, and 1,2,3-TCP (table A6). Most of the surrogate compounds are deuterated analogs of compounds being analyzed. For example, the surrogate toluene-*d*8 used in the VOC analytical method has the same chemical structure as toluene, except that the eight hydrogen-1 atoms on the molecule have been replaced by deuterium (hydrogen-2). Toluene-*d*8 and toluene behave very similarly in the analytical procedure, but the small mass difference between the two results in slightly different chromatographic retention times; thus, the use of a toluene-*d*8 surrogate does not interfere with the analysis of toluene. Only 0.015 percent of hydrogen atoms are deuterium (Firestone and others, 1996); thus, deuterated compounds like toluene-*d*8 do not occur naturally and are not found in environmental samples. Surrogates are used to identify general problems that may arise during sample analysis that could affect the analysis results for all compounds in that sample. Potential problems include matrix interferences (such as high levels of dissolved organic carbon) that produce a positive bias, or incomplete laboratory recovery (possibly attributed to improper maintenance and calibration of analytical equipment) that produces a negative bias. A 70 to 130 percent recovery of surrogates is generally considered acceptable. Values outside this range indicate possible problems with the processing and analysis of samples (Connor and others, 1998; Sandstrom and others, 2001).

Quality-Control Sample Results

Detections in Field and Source-Solution Blanks

Field blanks were collected at approximately 10 percent of the sites sampled in MSACV. Table A3 presents a summary of compound detections in field blanks. Field blank results were grouped according to sampling methods (see "Sample Collection and Analysis" section) and analyzed to determine how field blank detections affected environmental data.

Seven source-solution blanks, seven field blanks at production wells, and five field blanks at monitoring wells were collected for analysis of VOCs. Eleven VOC constituents were detected in field blanks collected at production wells or in source-solution blanks (table A3). Only 2 of these 11 VOCs—chloroform and 1,2,4-trimethylbenzene—were detected in ground-water samples collected at production wells. Chloroform was detected in one field blank at a concentration of E0.04 µg/L. Three detections in ground-water samples with concentrations less than 0.05 µg/L (E0.04 µg/L plus one-half of the LRL of 0.02 µg/L) were flagged with a V code (table 5). 1,2,4-trimethlybenzene was detected in one source-solution blank at a concentration of E0.04 µg/L. Four detections in production well samples with concentrations less than 0.07 µg/L (E0.04 µg/L plus one-half the LRL of 0.056 µg/L) were flagged with a V code (table 5). The V-coded results were counted as nondetections for calculation of the detection frequency of chloroform and 1,2,4-trimethylbenzene in the grid wells.

Three VOC constituents were detected in field blanks collected at monitoring wells or in source-solution blanks (table A3), and all three were detected in ground-water samples collected at monitoring wells. 1,2,4-trimethlybenzene was detected in one source-solution blank and one field blank with a maximum concentration of E0.04 µg/L. A single detection in a ground-water sample with a concentration less than 0.07 µg/L (E0.04 µg/L plus one-half the LRL of 0.056 µg/L) was flagged with a V code (table 5). *m-* and *p-Xylene* was detected was detected in two fields with a maximum concentration of E0.07 µg/L. *m-* and *p-Xylene* was detected in one ground-water sample collected from a monitoring well. The concentration of *m- and p-Xylene* detected in the sample was less than 0.10 µg/L (0.07 µg/L plus one-half the LRL of 0.06 µg/L) and was, therefore, flagged with a V code. Toluene was detected in three source solution blanks and three field blanks with a maximum concentration of E0.07 µg/L. Low levels of toluene were detected in source-solution and field blanks in many of the earlier GAMA study units (Bennett and others, 2006; Dawson and others, 2008; Fram and Belitz, 2007; Kulongoski and Belitz, 2007; Kulongoski and others, 2006; Wright and others, 2005). Toluene was detected in one ground-water sample collected from a monitoring well. The concentration of toluene detected in the sample was less than 0.08 µg/L (0.07 µg/L plus one-half the LRL of 0.02 µg/L), and was, therefore, flagged with a V code. Seven field blanks were collected at production wells and four field blanks were collected at monitoring wells for analysis of pesticides and pesticide degradates. Three pesticide compounds were detected in one field blank collected at a production well (table A3), and one of these compounds, bromacil, was detected in ground-water samples collected from production wells. The concentration of bromacil detected in the field blank was E0.11 µg/L. All three detections of bromacil in ground-water samples were less than 0.012 µg/L (0.11 µg/L plus one-half the LRL of 0.018 µg/L), and were, therefore, flagged with a V code (table 6). The V-coded results were counted as nondetections for calculation of the detection frequency of bromacil in the grid wells.

Constituents of special interest (perchlorate, 1,2,3-TCP, and NDMA) and radioactive constituents (radium isotopes and gross alpha and beta radiation) were not detected in any source-solution or field blanks. One field blank was collected at a production well for analysis of radium isotopes and gross alpha and beta radiation. Eleven source-solution blanks, seven field blanks at production wells, and four field blanks at monitoring wells were collected for analysis of perchlorate. Six source solution-blanks, five field blanks at production wells, and one field blank at a monitoring well were collected for analysis of 1,2,3-TCP and NDMA.

DOC was analyzed in one field blank collected at a production well and three field blanks collected at monitoring wells. DOC was detected in all three field blanks collected at monitoring wells, with a maximum concentration of 0.7 mg/L. Six ground-water samples collected at monitoring wells had detections of DOC at concentrations less than 0.9 mg/L (0.7 mg/L plus one-half the LRL of 0.33 mg/L). These six samples were flagged with V codes (table 8), indicating that the concentration of DOC in the samples may be as high as the reported value, but may also be as low as a nondetection relative to the stated detection limit (one-half the LRL).

Nutrients were analyzed in five field blanks collected at production wells and four field blanks collected at monitoring wells. Nitrate and nitrite were not detected in any of the field blanks. Orthophosphate was detected at a concentration of E0.003 mg/L in one field blank collected at a production well, and in two field blanks collected at monitoring wells. One production well sample had an orthophosphate concentration less than 0.006 mg/L (0.003 plus one-half the LRL of 0.006 µg/L); this result was flagged with a V code. Ammonia was detected in two field blanks collected at monitoring wells, with a maximum concentration of E0.007 mg/L. Seventeen ground-water samples collected from monitoring wells had ammonia concentrations less than 0.012 mg/L (E0.007 mg/L plus one-half the LRL of 0.01 mg/L). These results were flagged with V codes, indicating that the ammonia concentration in the samples could be as high as the reported value if no contamination had occurred, but also be as low as a nondetection relative to the LT-MDL of 0.005 mg/L if the maximum potential amount of contamination (0.003 mg/L) had occurred. Total nitrogen was detected in three field blanks collected at production wells, with a maximum concentration of 0.26 mg/L, and in two field blanks collected at monitoring wells with a maximum concentration of 0.45 mg/L. The LRL for total nitrogen is 0.06 mg/L; thus, the threshold concentration for flagging results with V codes was 0.29 mg/L for ground-water samples collected at production wells and 0.48 mg/L for ground-water sampled collected at monitoring wells. Total nitrogen results for the 10 ground-water samples collected from production wells and the 14 collected from monitoring wells with concentrations less than these threshold concentrations were flagged with V codes.

Major ions were analyzed in five field blanks collected at production wells and four collected at monitoring wells. Calcium, chloride, magnesium, and silica were each detected in at least one field blank (table A3). However, for all four ions, the maximum concentration detected in the field blanks plus one-half the LRL was less than the minimum concentrations detected in ground-water samples. Therefore, no data were flagged with V codes.

Trace elements were analyzed in five field blanks collected at production wells and in five field blanks collected at monitoring wells. Maximum concentrations for the three trace elements detected in field blanks collected at production wells were: chromium, 0.04 µg/L; nickel, 0.05 µg/L; and zinc, 1.0 µg/L (table A3). The threshold concentration for flagging results with V codes in table 10 was the maximum concentration of the constituent detected in a field blank plus one-half the LRL for that constituent. Nine detections of chromium with concentrations less than 0.06 µg/L, 10 detections of nickel with concentrations less than 0.08 µg/L, and 16 detections of zinc with concentrations less than 1.3 µg/L in ground-water samples collected from production wells were flagged with V codes, indicating that the concentration in the ground-water sample may be as high as the reported concentration, but also may be as low as a nondetection. In all cases, the results flagged with V codes had concentrations far below health-based or other drinking-water quality thresholds (the MCL-CA for chromium is 50 µg/L; the MCL-CA for nickel is 100 µg/L; and the SMCL-CA for zinc is 5,000 µg/L).

Maximum concentrations for the 11 trace elements detected in at least one field blank collected at a monitoring well were: aluminum, E1 µg/L; barium, E0.9 µg/L; chromium, 0.10 µg/L; copper, 1.80 µg/L; iron, 8 µg/L; manganese, 0.7 µg/L; nickel, 0.20 µg/L; strontium, 0.55 µg/L; tungsten, E0.04 µg/L; vanadium, E0.08 µg/L; and zinc, 2.4 µg/L (table A3). The threshold concentration for flagging results with V codes in table 10 was the maximum concentration of the constituent detected in a field blank plus one-half the LRL for that constituent. Sixteen detections of aluminum, 6 detections of chromium, 18 detections of copper, 7 detections of iron, 5 detections of manganese, 2 detections of nickel, 2 detections of tungsten, and 23 detections of zinc in ground-water samples collected from monitoring wells were flagged with V codes, indicating that the concentration in the ground-water sample may be as high as the reported concentration, but also may be as low as a nondetection. In all cases, the results flagged with V codes had concentrations far below health-based or other drinking-water quality thresholds (table 10). No detections of barium, strontium, or vanadium were flagged with V codes because the maximum concentration detected in the field blanks plus one-half the LRL was less than the minimum concentration detected in ground-water samples.

Arsenic and iron were detected in field blank samples analyzed by the NRP (table A3). Arsenic was detected in two of five field blanks collected at production wells and in two of five field blanks collected at monitoring wells. The maximum concentration of arsenic detected in a field blank analyzed by the NRP laboratory was 4.5 µg/L. Arsenic was not detected in any field blank samples analyzed by NWQL; therefore, the arsenic detected in field blanks analyzed at the NRP laboratory were considered to have originated in the laboratory. Because the arsenic contamination was not related to sampling equipment, there was no basis for assessing NRP arsenic data differently for the two different types of sampling equipment. Because the arsenic concentration data from NWQL Schedule 1948 are preferred over the concentration data from the NRP laboratory, comparisons between the two sets of data were used in conjunction with the detections in the field blanks analyzed at the NRP laboratory to assess the NRP arsenic data. Arsenic concentrations from the NRP were greater than those from NWQL for 27 of the 82 ground-water samples analyzed, and for 19 of the 27, the difference was greater than 20 percent RSD, the criteria for acceptable replicate pairs. The NRP arsenic concentrations were up to 3.5 µg/L greater than the NWQL arsenic concentration in these 19 ground-water samples, a difference that is comparable to the maximum concentration of arsenic detected in the field blanks. Arsenic results from the NRP laboratory for these 19 ground-water samples were flagged with V codes (table 11) to indicate that disagreement between the NWQL and NRP arsenic concentrations may be due to contamination of ground-water samples analyzed at the NRP laboratory. The ratio of arsenic species, $\frac{\text{As(V)}}{\text{As(III)}}$, for these 19 samples may not be representative of the redox conditions in the ground water.

Iron was detected in 2 of 10 field blanks analyzed by the NRP laboratory, with a maximum concentration of 15 µg/L. For eight ground-water samples with iron concentrations greater than 6 µg/L (the NWQL LRL for iron), iron concentrations measured by the NRP laboratory were higher than those measured by NWQL. However, all eight pairs differed by less than 10 percent RSD; thus, none of the NRP iron results were flagged with V codes.

Variability in Replicate Samples

Most of the replicate sample pairs collected during the MSACV study had relative standard deviations (RSDs) of less than 20 percent (table A4). Replicate sample pairs for analytes not detected in any ground-water samples are not reported in table A4. Thirty replicate sample pairs, representing 20 chemical constituents, had RSDs greater than 20 percent; see table A4 for details. However, the replicate sample pairs with high RSDs had very low concentrations. At low concentrations, small deviations in measured values account for large RSDs. Because the variability in measurements occurred at low concentrations, well below regulatory thresholds, this variability was not of QC concern, and no detections were censored as a result of variability in replicate samples.

Matrix Spike Recoveries

Tables A5A–D present a summary of matrix-spike recoveries for the MSACV study. The addition of a spike or known concentration of a constituent to an environmental sample enables the laboratory to determine the effect of the matrix, in this case ground water, on the analytical technique used to measure the constituent. Thirteen environmental samples were spiked with VOCs to calculate matrix-spike recoveries (table A5A). Seventy-one of the 85 VOCs had matrix-spike recoveries in the acceptable range between 70 and 130 percent. Eleven VOCs had at least one-matrix spike recovery greater than 130 percent; however, of these compounds, 6 were not detected in ground-water samples. Seven VOCs had a recoveries below 70 percent; however, of these compounds, 4 were not detected in ground-water samples. The three VOCs that had recoveries less than 70 percent and were detected in ground water included carbon disulfide, 1,2,3,4-tetramethylbenzene, and 1,2,3,5-tetramethylbenzene, with recoveries of 67, 69, and 62 percent, respectively. The four VOCs that had recoveries less than 70 percent, but were not detected in ground water included dichloromethane, 2,2-dichloropropane, styrene, and 1,2,3-trichlorobenzene, with recoveries of 28, 62, 69, and 56 percent, respectively (NOTE: low recoveries may indicate that these compounds may not have been detected if they were present at very low levels).

Twelve environmental samples were spiked with pesticide and pesticide degradate compounds to calculate matrix-spike recoveries, although the number of spiked samples varied depending on laboratory procedures (table A5B). Forty-one of the 136 spike compounds had recoveries in the acceptable range between 70 and 130 percent. Eighteen of the compounds detected in ground-water samples had spike recoveries that exceeded the acceptable range. Twenty-three spike compounds had at least one recovery greater than 130 percent. Ninety-one spike compounds had at least one recovery below 70 percent, with recovery of phosmet being particularly poor. (NOTE: low recoveries may indicate that the compound might not have been detected in some samples if it was present at a very low concentration).

One, 7, and 5 ground-water samples were spiked with perchlorate, 1,2,3-TCP, and NDMA, respectively (table A5C). All spike recoveries were within the acceptable range of 70 to 130 percent.

Two ground-water samples were spiked with radium-226 and radium-228 (table A5D). All spike recoveries were within the acceptable range of 70 to 130 percent with the exception of gross alpha 72-hour and gross alpha 30-day counts for one of the samples. The spiked sample (WSAC-08) that had poor recovery of alpha radioactivity had relatively high concentration of calcium (table 9). Because calcium is known to interfere with alpha counts (Sinojmeri, 1999), this sample and WSAC-18, which had similar major-ion chemistry, were coded as having the potential to be biased low for gross alpha 72-hour and gross alpha 30-day counts.

Surrogate Compound Recoveries

Surrogate compounds were added to environmental samples in the laboratory and analyzed to evaluate the recovery of similar constituents. Table A6 lists each surrogate, the analytical schedule on which it was applied, the number of analyses for blank and nonblank samples, the number of surrogate recoveries below 70 percent, and the number of surrogate recoveries above 130 percent for the blanks and environmental samples. Blanks and environmental samples were considered separately to assess whether the matrices present in ground water affect surrogate recoveries. No systematic differences between surrogate recoveries in blanks and environmental samples were observed. Ninety-one percent of the surrogate recoveries in analyses of VOC and gasoline oxygenate and degradates were in the acceptable range of 70 to 130 percent recovery, as were 96 percent of the surrogate recoveries for pesticides and pesticide degradates, and 89 percent for NDMA and 1,2,3-TCP analyses.

Table A1. Analytical methods used for the determination of organic, inorganic, and microbial constituents by the U.S. Geological Survey's (USGS) National Water Quality Laboratory (NWQL) and additional contract laboratories.

[MI agar, supplemented nutrient agar in which coliforms (total and *Escherichia*) produce distinctly different fluorescence under ultraviolet lighting; RSIL, Reston Stable Isotope Laboratory (USGS); UV, ultraviolet; VOCs, volatile organic compounds]

Analyte	Analytical Method	Laboratory and analytical schedule or lab code	Citation(s)
Organic constituents			
VOCs	Purge and trap capillary gas chromatography/mass spectrometry	NWQL, Schedule 2020	Connor and others, 1998
Gasoline oxygenates	Heated purge and trap/gas chromatography/mass spectrometry	NWQL, Schedule 4024	Rose and Sandstrom, 2003
Pesticides	Solid-phase extraction and gas chromatography/mass spectrometry	NWQL, Schedules 2032, 2033, and 2060	Furlong and others, 2001; Lindley and others, 1996; Madsen and others, 2003; Sandstrom and others, 2001; Zaugg and others, 1995
Pharmaceuticals	Solid-phase extraction and HPLC/mass spectrometry	NWQL, Schedule 2080	Kolpin and others, 2002
Constituents of special interest			
Perchlorate	Chromatography and mass spectrometry	Montgomery Watson Harza laboratory[1]	Hautman and others, 1999
N-nitrosodimethylamine (NDMA)	Chromatography and mass spectrometry	Montgomery Watson Harza laboratory[1]	U.S. Environmental Protection Agency, 1996; U.S. Environmental Protection Agency, 1999b
1,2,3-Trichloropropane	Gas chromatography/electron capture detector	Montgomery Watson Harza laboratory[1]	U.S. Environmental Protection Agency, 1995
Inorganic constituents			
Nutrients	Alkaline persulfate digestion, Kjedahl digestion	NWQL, Schedule 2755	Fishman, 1993; Patton and Kryskalla, 2003
Dissolved organic carbon	UV-promoted persulfate oxidation and infrared spectrometry	NWQL, Lab Code 2613	Brenton and Arnett, 1993
Major and minor ions, trace elements and nutrients	Atomic absorption spectrometry, colorimetry, ion-exchange chromatography, inductively-coupled plasma atomic-emission spectrometry and mass spectrometry	NWQL, Schedule 1948	American Public Health Association, 1998; Faires, 1993; Fishman, 1993; Fishman and Friedman, 1989; Garbarino, 1999; Garbarino and Damrau, 2001; Garbarino and others, 2006; McLain, 1993
Chromium, arsenic and iron speciation	Various techniques of ultraviolet visible (UV-VIS) spectrophotometry and atomic-absorbance spectroscopy	USGS Trace Metal Laboratory, Boulder, Colorado[1]	Ball and McCleskey, 2003a,b; McCleskey and others, 2003; Stookey, 1970; To and others, 1998
Stable isotopes			
Stable isotopes of water	Gaseous hydrogen and carbon dioxide-water equilibration and stable-isotope mass spectrometry	USGS Stable Isotope Laboratory, Reston, Virginia, Schedule 1142	Coplen, 1994; Coplen and others, 1991; Epstein and Mayeda, 1953
Nitrogen and oxygen isotopes of nitrate	Denitrifier method and mass spectrometry	USGS Stable Isotope Laboratory, Reston, Virginia, RSIL Lab Code 2900	Révész, K., and Casciotti, K., 2007
Carbon isotopes	Accelerator mass spectrometry	University of Waterloo, Environmental Isotope Lab[1]; University of Arizona Accelerator Mass Spectrometry Lab[1]	Donahue and others, 1990; Jull and others, 2004

Table A1. Analytical methods used for the determination of organic, inorganic, and microbial constituents by the U.S. Geological Survey's (USGS) National Water Quality Laboratory (NWQL) and additional contract laboratories.—Continued

[MI agar, supplemented nutrient agar in which coliforms (total and *Escherichia*) produce distinctly different fluorescence under ultraviolet lighting; RSIL, Reston Stable Isotope Laboratory (USGS); UV, ultraviolet; VOCs, volatile organic compounds]

Analyte	Analytical Method	Laboratory and analytical schedule or lab code	Citation(s)
Radioactivity and gases			
Tritium	Electrolytic enrichment-liquid scintillation	USGS Stable Isotope and Tritium Laboratory, Menlo Park, California, Lab Code 1565	Thatcher and others, 1977
Tritium and noble gases	Helium-3 in-growth and mass spectrometry	Lawrence Livermore National Laboratory[1]	Eaton and others, 2004; Moran and others, 2002
Radon-222	Liquid scintillation counting	NWQL, Schedule 1369	American Society for Testing and Materials, 1998; U.S. Environmental Protection Agency, 1999a
Radium 226/228	Alpha activity counting	Eberline Analytical Services, NWQL method 1262	U.S. Environmental Protection Agency, 1980 (USEPA methods 903 and 904)
Gross alpha and beta radioactivity	Alpha and beta activity counting	Eberline Analytical Services, NWQL method 1792	U.S. Environmental Protection Agency, 1980 (USEPA method 900.0)
Microbial constituents			
F-specific and somatic coliphage	Single-agar layer (SAL) and two-step enrichment methods	USGS Ohio Water Microbiology Laboratory[1]	U.S. Environmental Protection Agency, 2001
Total and *Escherichia* coliform	Membrane filter technique with "MI agar"	USGS field measurement	U.S. Environmental Protection Agency, 2002b

[1] The analytes have no schedule or lab code assigned to them.

Table A2. Preferred analytical schedules/methods for constituents appearing on multiple schedules/methods for samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September 2006.

[Preferred analytical schedules are the methods of analysis with the greatest accuracy and precision out of the ones used for the compound in question. MWH, Montgomery Watson Harza laboratory; TML, U.S. Geological Survey's (USGS) Trace Metal Laboratory in Boulder, Colorado; VOC, volatile organic compound]

Constituent	Primary constituent classification	Analytical schedules/method	Preferred analytical schedule/method
Results from preferred method reported			
Acetone	VOC, gasoline degradate	2020, 4024	2020
Diisopropyl ether	VOC, gasoline degradate	2020, 4024	2020
Ethyl *tert*-Butyl ether (ETBE)	VOC, gasoline degradate	2020, 4024	2020
Methyl *tert*-butyl ether (MTBE)	VOC, gasoline degradate	2020, 4024	2020
Methyl *tert*-pentyl ether	VOC, gasoline degradate	2020, 4024	2020
Atrazine	Pesticide	2032/2033, 2060	2032/2033
Carbaryl	Insecticide	2032/2033, 2060	2032/2033
Carbofuran	Herbicide	2032/2033, 2060	2032/2033
Deethlyatrazine	Pesticide degradate	2032/2033, 2060	2032/2033
Metalaxyl	Fungicide	2032/2033, 2060	2032/2033
Tebuthiuron	Pesticide	2032/2033, 2060	2032/2033
Results from both methods reported			
Alkalinity	Water-quality indicator	1948, field	field
Arsenic(Total)	Trace element	1948, TML[1]	1948
Chromium(Total)	Trace element	1948, TML[1]	1948
Iron(Total)	Trace element	1948, TML[1]	1948
pH	Water-quality indicator	1948, field	field
Specific conductance	Water-quality indicator	1948, field	field
1,2,3-Trichloropropane (1,2,3-TCP)	VOC	2020, MWH[1]	MWH[1]

[1] In the USGS's National Water Information System (NWIS), the laboratory entity code for TML is USGSTMCO and for MWH is CA-MWHL.

Table A3. Constituents detected in field blanks collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[E, estimated value; mg/L, milligrams per liter; µg/L, micrograms per liter; —, not detected]

Constituent	Source-solution blanks		Field blanks at production wells		Field blanks at monitoring wells		Number of ground-water data affected
	Number of detections/ analyses	Detected concentrations	Number of detections/ analyses	Detected concentrations	Number of detections/ analyses	Detected concentrations	
Volatile organic compounds (µg/L)							
Acetone	0/7	—	3/7	E3, 6, 11	0/5	—	0
Benzene	0/7	—	1/7	E0.01	0/5	—	0
Dichloromethane	0/7	—	1/7	E0.1	0/5	—	0
2-Butanone (MEK, Methyl ethyl ketone)	0/7	—	2/7	E1.4, 5.9	0/5	—	0
Ethylbenzene	0/7	—	2/7	E0.01, E0.02	0/5	—	0
1,2,4-Trimethyl-benzene	1/7	E0.04	0/7	—	1/5	E0.02	6
m- and *p*-Xylene	0/7	—	3/7	E0.04, E0.06, E0.06	2/5	E0.03, E0.07	1
o-Xylene	0/7	—	1/7	E0.03	0/5	—	0
Styrene	0/7	—	3/7	E0.01, E0.02, E0.02	0/5	—	0
Toluene	3/7	E0.01, E0.01, E0.02	3/7	E0.08, 0.10, 0.16	3/5	E0.02, E0.02, E0.07	1
Chloroform	0/7	—	1/7	E0.04	0/5	—	3
Pesticide and pesticide degradates (µg/L)							
Bromacil			1/7	E0.11	0/4	—	3
2,4-D and 2,4-D methyl ester			1/7	0.28	0/4	—	0
Diuron			1/7	0.03	0/4	—	0
Nutrients and dissolved organic carbon (DOC) (mg/L)							
Ammonia (as nitrogen)			0/5	—	2/4	E0.006, E0.007	17
Dissolved organic carbon (DOC)			0/1	—	3/3	E0.2, E0.7, 0.7	6
Orthophosphate (as phosphorus)			1/5	E0.003	2/4	E0.003, E0.003	1
Total nitrogen			3/5	E0.04, E0.04, 0.26	2/4	E0.04, 0.45	24
Major and minor ions (mg/L)							
Calcium			0/5	—	2/4	E0.01, 0.08	0
Chloride			0/5	—	1/4	E0.13	0
Magnesium			1/5	E0.005	2/4	E0.004, 0.039	0
Silica			0/5	—	1/4	E0.03	0
Trace elements (µg/L)							
Aluminum			0/5	—	2/5	E0.9, E1	16
Barium			0/5	—	2/5	E0.8, E0.9	0
Chromium			4/5	E0.03, E0.03, 0.04, 0.04	4/5	0.04, 0.05, 0.08, 0.10	15
Copper			0/5	—	2/5	0.73, 1.80	18
Iron			0/5	—	1/4	8	7
Manganese			0/5	—	1/5	0.7	5
Nickel			1/5	E0.05	4/5	0.08, 0.16, 0.17, 0.20	12
Strontium			0/5	—	2/5	E0.23, 0.55	0
Tungsten			0/5	—	2/2	E0.03, E0.04	2
Vanadium			0/5	—	2/5	E0.08, E0.08	0
Zinc			2/5	E0.3, 1.0	3/5	1.2, 1.6, 2.4	39
Trace element species (µg/L)							
Inorganic arsenic(Total)			2/5	3.3, 4.5	2/5	0.6, 0.7	19
Iron(Total)			1/5	3	1/5	15	0

Table A4. Quality-control summary of replicate samples for constituents collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[The laboratory entity codes for the laboratories in the U.S. Geological Survey's (USGS) National Water Infomation System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. E, estimated value; mg/L, milligrams per liter; pCi/L, picocuries per liter; RSD, relative standard deviation; TU, tritium unit; µg/L, micrograms per liter; <, less than; —, no value]

Constitutent	Number of RSDs greater than 20 percent/number of replicates	Maximum RSD (percent)	Median RSD (percent)	Concentrations for replicates with RSDs greater than zero (environmental, replicate)
Volatile organic compounds, gasoline oxygenates and additives from Schedules 2020 and 4024				
1,2,4-Trimethylbenzene (µg/L)	2/15	40.4	23.6	(E0.07, E0.05), (0.10, 0.18)
Toluene (µg/L)	1/15	47.1	47.1	(E0.02, E0.01)
Chloroform (Trichloromethane) (µg/L)	2/15	28.3	16.5	(E0.08, E0.06), (E0.02, E0.03)
All other VOCs from Schedules 2020 and 4024	0/15	< 20	—	—
Pesticides and pesticide degradates from Schedules 2032, 2033, and 2060				
All pesticides and pesticide degradates from Schedule 2032	0/12	< 20	—	—
All pesticides and pesticide degradates from Schedule 2033	0/2	< 20	—	—
All pesticides and pesticide degradates from Schedule 2060	0/13	< 20	—	—
Pharmaceuticals				
All pharmaceuticals from Schedule 2080	0/9	< 20	—	—
Constituents of special interest[1]				
Perchlorate	0/15	< 20	—	—
1,2,3-Trichloropropane (1,2,3-TCP)	0/7	< 20	—	—
N-Nitrosodimethylamine (NDMA)	0/5	< 20	—	—
Major ions, minor ions, trace elements, and nutrients				
Ammonia (mg/L)	1/11	23.6	23.6	(E0.005, E0.007)
Dissolved organic carbon (DOC) (mg/L)	1/5	26.2	5.2	(1.6, 1.1)
Bromide (mg/L)	2/10	122.6	1.3	(0.03, E0.02), (0.07, 0.005)
Aluminum (µg/L)	1/6	47.1	47.1	(2, E1)
Cadmium (µg/L)	1/8	47.1	47.1	(0.04, E0.02)
Cobalt (µg/L)	4/8	101	18.0	(0.01, 0.06), (0.07, E0.03), (0.06, E0.02), (E0.03, 0.04)
Copper (µg/L)	1/8	32.9	3.4	(E0.28, 0.45)
Iron (µg/L)	2/10	47.1	3.3	(E3, 6), (6, E3)
Lead (µg/L)	1/8	97.9	2.9	(0.10, 0.08)
Nickel (µg/L)	1/8	60.6	1.8	(1.10, 0.44)
Selenium (µg/L)	1/8	20.2	20.2	(0.08, E0.06)
Tungsten (µg/L)	1/8	28.3	28.3	(0.09, 0.06)
Zinc (µg/L)	1/8	41.9	2.2	(E0.51, 0.94)
All other nutrients from Schedule 2755	0/11	< 20	—	—
All other major ions from Schedule 1948	0/10	< 20	—	—
All other trace elements from Schedule 1948	0/8	< 20	—	—

Table A4. Quality-control summary of replicate samples for constituents collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[The laboratory entity codes for the laboratories in the U.S. Geological Survey's (USGS) National Water Infomation System (NWIS) listed in the footnotes are shown in parentheses following the laboratory name. E, estimated value; mg/L, milligrams per liter; pCi/L, picocuries per liter; RSD, relative standard deviation; TU, tritium unit; µg/L, micrograms per liter; <, less than; —, no value]

Constitutent	Number of RSDs greater than 20 percent/number of replicates	Maximum RSD (percent)	Median RSD (percent)	Concentrations for replicates with RSDs greater than zero (environmental, replicate)
Isotopes and radioactivity				
$\delta^{18}O$ of nitrate[2] (per mil)	1/4	84.8	7.2	(0.01, 0.04)
Tritium[3] (TU)	4/12	141.4	10.9	(0.3, 0), (0.3, 0), (1.3, 1.9), (1.3, 0.7)
Gross-beta radioactivity, 72-hour count[4] (pCi/L)	1/2	39.0	39	(E1.12, E1.97)
Gross-beta radioactivity, 30-day count[4] (pCi/L)	1/2	33.8	21.7	(E1.62, 2.64)
All additional isotopes and radioactivity	0/2	< 20	—	—
Microbial indicators				
F-specific and somatic coliphage	0/1	< 20	0	—
E. coli, and total coliforms	0/30	< 20	0	—

[1] Analyses performed at Montgomery Watson Harza laboratory, Monrovia, California (CA-MWHL).

[2] USGS Stable Isotope Laboratory, Reston, Virginia (USGSSIVA).

[3] USGS Stable Isotope and Tritium Laboratory, Menlo Park, California (USGSH3CA).

[4] Analyses performed at Eberline Analytical Services, Richmond, California (CA-EBERL).

Table A5A. Quality-control summary for matrix-spike recoveries of volatile organic compounds (VOCs) and gasoline oxygenates and their degradates in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Acetone[1,2]	13	83	122	99
Acrylonitrile	13	93	104	102
tert-Amyl alcohol	2	97	107	102
Benzene[1]	13	91	109	104
Bromobenzene	13	98	115	102
Bromochloromethane[1]	13	83	115	105
Bromodichloromethane	13	91	130	104
Bromoform (Tribromomethane)[1]	13	85	123	98
2-Butanone (MEK, Methyl ethyl ketone)[1]	13	90	112	97
n-Butylbenzene	13	75	108	91
tert-Butyl alcohol (TBA)	2	94	104	99
sec-Butylbenzene	13	83	115	98
tert-Butylbenzene	13	89	126	107
Carbon disulfide[1]	13	67	125	82
Carbon tetrachloride (Tetrachloromethane)[1]	13	87	157	106
Chlorobenzene	13	92	115	102
Chloroethane	13	83	128	106
Chloroform (Trichloromethane)[1]	13	87	130	111
Chloromethane[1]	13	88	128	113
3-Chloro-1-propene	13	99	131	116
2-Chlorotoluene	13	91	109	102
4-Chlorotoluene	13	84	109	98
Dibromochloromethane[1]	13	85	122	101
1,2-Dibromo-3-chloropropane (DBCP)	13	84	113	96
1,2-Dibromoethane (EDB)	13	91	126	104
Dibromomethane	13	83	121	104
1,2-Dichlorobenzene	13	87	111	100
1,3-Dichlorobenzene	13	87	109	102
1,4-Dichlorobenzene	13	91	106	100
trans-1,4-Dichloro-2-butene	13	82	114	96
Dichlorodifluoromethane (CFC-12)	13	70	123	106
1,1-Dichloroethane[1]	13	97	142	112
1,2-Dichloroethane	13	90	132	111
1,1-Dichloroethene (DCE)	13	87	117	104
cis-1,2-Dichloroethene[1]	13	96	117	106
trans-1,2-Dichloroethene[1]	13	94	117	106
Dichloromethane (Methylene chloride)	13	28	128	106
1,2-Dichloropropane	13	94	119	106
1,3-Dichloropropane	13	92	126	106
2,2-Dichloropropane	13	62	124	96
1,1-Dichloropropene	13	93	145	104
cis-1,3-Dichloropropene	13	79	108	97
trans-1,3-Dichloropropene	13	80	116	92
Diethyl ether	13	91	118	102
Diisopropyl ether (DIPE)[2]	13	85	110	102
Ethylbenzene	13	89	115	100
Ethyl *tert*-butyl ether (ETBE)[2]	13	81	119	100
Ethyl methacrylate	13	82	107	96
1-Ethyl-2-methylbenzene (*o*-Ethyl toluene)[1]	13	82	106	94
Hexachlorobutadiene	13	70	108	85
Hexachloroethane	13	86	118	102

Table A5A. Quality-control summary for matrix-spike recoveries of volatile organic compounds (VOCs) and gasoline oxygenates and their degradates in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006. —Continued

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
2-Hexanone (*n*-Butyl methyl ketone)	13	92	112	99
Isopropylbenzene (Cumene)	13	91	119	104
4-Isopropyl-1-methylbenzene[1]	13	81	110	97
Methyl acetate	2	11	112	111
Methyl acrylate	13	95	111	99
Methyl acrylonitrile	13	86	110	104
Methyl bromide (Bromomethane)	13	81	179	111
Methyl *tert*-butyl ether (MTBE)[1,2]	13	86	123	102
Methyl iodide (Iodomethane)	13	75	145	108
Methyl isobutyl ketone (MIBK)	13	85	110	96
Methyl methacrylate	13	73	106	94
Methyl *tert*-pentyl ether (*tert*-Amyl methyl ether, TAME)[2]	13	89	124	100
Naphthalene	13	80	117	96
n-Propylbenzene	13	87	111	98
Styrene	13	69	104	94
1,1,1,2-Tetrachloroethane	13	83	121	102
1,1,2,2-Tetrachloroethane	13	89	116	104
Tetrachloroethene (PCE)[1]	13	91	119	106
Tetrahydrofuran	13	96	112	106
1,2,3,4-Tetramethylbenzene[1]	13	69	126	98
1,2,3,5-Tetramethylbenzene[1]	13	62	135	106
Toluene[1]	13	88	115	104
1,2,3-Trichlorobenzene	13	56	113	106
1,2,4-Trichlorobenzene	13	77	126	99
1,1,1-Trichloroethane (TCA)	13	96	133	106
1,1,2-Trichloroethane	13	84	113	104
Trichloroethene (TCE)[1]	13	91	121	104
Trichlorofluoromethane (CFC-11)[1]	13	96	143	118
1,2,3-Trichloropropane (1,2,3-TCP)	13	89	115	103
1,1,2-Trichloro-1,2,2-trifluoroethane (CFC-113)	13	79	113	98
1,2,3-Trimethylbenzene	13	84	116	105
1,2,4-Trimethylbenzene[1]	13	86	117	102
1,3,5-Trimethylbenzene[1]	13	85	108	100
Vinyl bromide (Bromoethene)	13	96	128	117
Vinyl chloride (Chloroethene)	13	90	128	117
m- and *p*-Xylene[1]	13	86	171	102
o-Xylene	13	82	113	98

[1] Constituents detected in ground-water samples.

[2] Constituents on schedules 2020 and 4024; only values from schedule 2020 are reported because it is the preferred analytical schedule.

Table A5B. Quality-control summary for matrix-spike recoveries of pesticides and pesticide degradates in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Acetochlor[1,2]	11	78	99	87
Acifluorfen	12	42	88	68
Alachlor[2]	11	83	97	91
Aldicarb	12	57	86	59
Aldicarb sulfone	12	28	103	65
Aldicarb sulfoxide	12	68	112	85
Atrazine[1,2,3]	11	87	98	92
Azinphos-methyl[2]	11	63	103	74
Azinphos-methyl oxon[2]	9	29	104	56
Bendiocarb	11	49	93	73
Benfluralin[2]	11	48	62	54
Benomyl	12	45	91	72
Bensulfuron-methyl[1]	12	91	146	108
Bentazon[1]	12	46	202	70
Bromacil[1]	12	51	109	86
Bromoxyni[1]	12	36	62	52
Caffeine	12	55	101	77
Carbaryl[1,2,3]	11	84	108	98
Carbofuran[2,3]	11	74	94	86
Chloramben, methyl ester	12	42	91	81
Chlorimuron-ethyl[1]	12	69	139	108
2-Chloro-2,6-diethylacetanilide[2]	11	80	98	93
2-Chloro-6-ethylamino-4-amino-*s*-triazine (deisopropylatrazine)[1]	12	24	95	76
2-Chloro-4-isopropylamino-6-amino-*s*-triazine (deethylatrazine)[1,2]	11	36	51	44
4-Chloro-2-methylphenol[2]	11	43	74	64
3-(4-Chlorophenyl)-1-methyl urea	12	42	115	76
Chlorpyrifos[1,2]	11	83	100	90
Chlorpyrifos, oxygen analog[2]	11	9	80	29
Clopyralid	12	55	81	69
Cyanazine	2	82	110	96
Cycloate	12	23	83	76
Cyfluthrin[2]	11	31	93	52
λ-Cyhalothrin[2]	11	16	53	37
Cypermethrin[2]	11	34	86	50
DCPA (Dacthal) monoacid	12	61	86	72
DCPA	11	88	104	97
Desulfinylfipronil[1,2]	11	73	97	87
Desulfinylfipronil amide[2]	11	50	108	76
Diazinon[2]	11	78	96	85
Dicamba	12	49	79	57
3,4-Dichloroaniline[1,2]	11	65	89	81
3,5-Dichloroaniline	2	81	95	88
2,4-D and 2,4-D methyl ester, summed on molar basis, reported as 2,4-D[1,4]	12	64	172	79
4-(2,4-Dichlorophenoxy)butyric acid (2,4-DB)	12	53	82	64
Dichlorprop	12	57	90	75
Dichlorvos[2]	11	9	60	30
Dicrotophos[2]	10	20	37	30
Dieldrin[2]	11	76	101	83
2,6-Diethylaniline[2]	11	87	105	96
Dimethoate[2]	11	27	34	29

Table A5B. Quality-control summary for matrix-spike recoveries of pesticides and pesticide degradates in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Dinoseb[1]	12	54	73	61
Diphenamid	12	42	101	90
Disulfoton	2	60	98	79
Disulfoton sulfone	2	100	118	109
Diuron[1]	12	71	97	88
α-Endosulfan	2	89	114	101
Endosulfan sulfate	2	89	125	107
EPTC	2	92	94	93
Ethion[2]	11	58	80	67
Ethion monoxon[2]	11	66	80	74
Ethoprophos	2	103	108	105
2-Ethyl-6-methylaniline[2]	11	81	108	92
Fenamiphos[2]	11	56	91	77
Fenamiphos sulfone[2]	11	40	172	70
Fenamiphos sulfoxide[2]	10	29	70	44
Fenuron	12	38	99	79
Fipronil[1,2]	11	60	105	81
Fipronil sulfide[1,2]	11	70	97	81
Fipronil sulfone[1,2]	11	52	127	71
Flumetsulam	12	75	158	86
Fluometuron	12	53	103	92
Fonofos[2]	11	77	93	83
Hexazinone[1,2]	11	61	112	77
3-Hydroxy carbofuran	11	52	95	74
2-Hydroxy-4-isopropylamino-6-ethylamino-*s*-triazine (hydroatrazine)[1]	12	13	106	97
Imazaquin	12	50	126	82
Imazethapyr	12	47	99	81
Imidacloprid	12	65	108	80
Isofenphos[2]	11	86	108	91
Linuron	12	65	97	90
Malaoxon[2]	11	67	93	80
Malathion[2]	11	82	103	92
Metalaxyl[2,3]	11	80	98	88
Methidathion[2]	11	71	108	93
Methiocarb	11	47	98	82
Methomyl	12	61	105	79
2-Methyl-4-chlorophenoxyacetic acid (MCPA)[1]	12	61	90	76
4-(2-Methyl-4-chlorophenoxy) butyric acid (MCPB)	12	53	82	65
Methyl paraoxon[2]	11	38	70	48
Methyl parathion[2]	11	57	83	65
Metolachlor[1,2]	11	96	110	102
Metribuzin[2]	11	57	239	70
Metsulfuron methyl[1]	12	55	150	80
Molinate[1,2]	11	87	110	93
Myclobutanil[2]	11	63	93	85
1-Naphthol[2]	11	20	70	30
Neburon	12	73	105	82
Nicosulfuron	12	61	154	96
Norflurazon	12	68	113	89
Oryzalin	12	19	85	76
Oxamyl	11	67	102	81

Table A5B. Quality-control summary for matrix-spike recoveries of pesticides and pesticide degradates in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.—Continued

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Oxyfluorfen	2	58	88	73
Pendimethalin[2]	11	72	91	80
cis-Permethrin[2]	11	41	71	57
Phorate[2]	11	58	84	76
Phorate oxygen analog[2]	11	60	100	80
Phosmet[2]	6	8	8	8
Phosmet oxon[2]	6	47	50	50
Picloram	12	44	111	66
Prometon[2]	11	80	93	85
Prometryn[2]	11	84	104	94
Pronamide[2]	11	76	96	82
Propanil[1,2]	11	73	118	95
Propargite	2	90	137	113
Propham	12	39	99	87
Propiconazole	12	46	122	84
cis-Propiconazole[1,2]	11	84	109	90
trans-Propiconazole[1,2]	11	67	94	86
Propoxur	11	51	97	86
Siduron	12	61	105	93
Simazine[1,2]	11	81	115	94
Sulfometuron-methyl	12	94	141	106
Tebuconazole	2	70	98	84
Tebuthiuron[1,2,3]	11	56	230	101
Tefluthrin	2	53	67	60
Terbacil	12	55	104	87
Terbufos[2]	11	77	131	101
Terbufos oxygen analog sulfone[2]	11	60	101	77
Terbuthylazine[2]	11	85	102	95
Thiobencarb[2]	11	89	116	111
Tribuphos[2]	11	44	68	57
Triclopyr[1]	9	68	86	75
Trifluralin[2]	11	52	72	60

[1] Constituents detected in ground-water samples.

[2] Constituents on Schedules 2032 and 2033; only values from Schedule 2032 are reported because it is the preferred analytical schedule.

[3] Constituents on Schedules 2032 and 2060; only values from Schedule 2032 are reported because it is the preferred analytical schedule.

[4] 2,4-D and 2,4-D methyl ester summed on a molar basis and reported as 2,4-D.

Table A5C. Quality-control summary for matrix-spike recoveries of constituents of special interest in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Acceptable recovery range is between 70 and 130 percent]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Perchlorate[1]	1	99	99	99
1,2,3-Trichloropropane (1,2,3-TCP)	7	88	106	100
N-Nitrosodimethylamine (NDMA)	5	85	106	93

[1] Constituent detected in ground-water samples.

Table A5D. Quality-control summary for matrix-spike recoveries of radioactive constituents in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[Acceptable recovery range is between 70 and 130 percent. hr, hour]

Constituent	Number of spike samples	Minimum recovery (percent)	Maximum recovery (percent)	Median recovery (percent)
Radium-226[1]	2	102	104	103
Radium-228[1]	2	105	117	111
Gross-alpha radioactivity, 72-hr count[1]	2	55	118	86
Gross-alpha radioactivity, 30-day count[1]	2	85	95	90
Gross-beta radioactivity, 72-hr count[1]	2	68	100	84
Gross-beta radioactivity, 30-day count[1]	2	96	98	97

[1] Constituents detected in ground-water samples.

Table A6. Quality-control summary of surrogate recoveries of volatile organic compounds, and gasoline oxygenates and their degradates, pesticides and pesticide degradates, and constituents of special interest in samples collected for the Middle Sacramento Valley Groundwater Ambient Monitoring and Assessment (GAMA) study, California, June to September, 2006.

[The laboratory entity code for the Montgomery Watson Harza laboratory in the U.S. Geological Survey's National Water Information System (NWIS) is CA-MWHL. 1,2,3-TCP, 1,2,3-Trichloropropane; MWH, Montgomery Watson Harza laboratory; NDMA, *N*-nitrosodimethylamine; VOC, volatile organic compound]

Surrogate	Analytical schedule	Constitutent or constituent class analyzed	Number of blank analyses	Median recovery in blanks (percent)	Number of surrogate recoveries below 70 percent in blanks	Number of surrogate recoveries above 130 percent in blanks	Number of environmental sample analyses	Median recovery in environmental samples (percent)	Number of surrogate recoveries below 70 percent in environmental samples	Number of surrogate recoveries above 130 percent in environmental samples
1-Bromo-4-fluorobenzene	2020, 4024	VOC	21	98	1	0	139	97	14	0
1,2-Dichloroethane-*d*4	2020, 4024	VOC	21	116	0	1	139	118	0	27
Isobutyl alcohol-*d*6	4024	VOC	1	132	0	1	10	103	0	1
Toluene-*d*8	2020, 4024	VOC	21	100	0	0	139	99	0	0
Diazinon-*d*10	2032, 2033	Pesticide	11	106	0	0	137	95	4	1
α-HCH-*d*6	2032, 2033	Pesticide	11	89	0	0	138	92	0	0
2,4,5-T	2060	Pesticide	11	78	1	0	136	81	2	0
Barban	2060	Pesticide	11	94	1	0	136	89	4	0
Caffeine-^{13}C	2060	Pesticide	11	101	2	0	135	92	15	0
Toluene-*d*8	MWH	Special interest (1,2,3-TCP)	12	98	0	0	63	96	0	0
NDMA-*d*6	MWH	Special interest (NDMA)	12	86	3	0	59	87	13	0

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ca.water.usgs.gov/projects/gama/water-quality-results/

Apps | Irrolis Web - Login | Solar | Backstop Solutions... | Conservis | Blu

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USGS CA GAMA-PBP Groundwater-Quality Results: Assessment and

DISPLAY DATA

Groundwater Sites by Study Type:

All Sites

Consitiuent Group:

Trace Elements

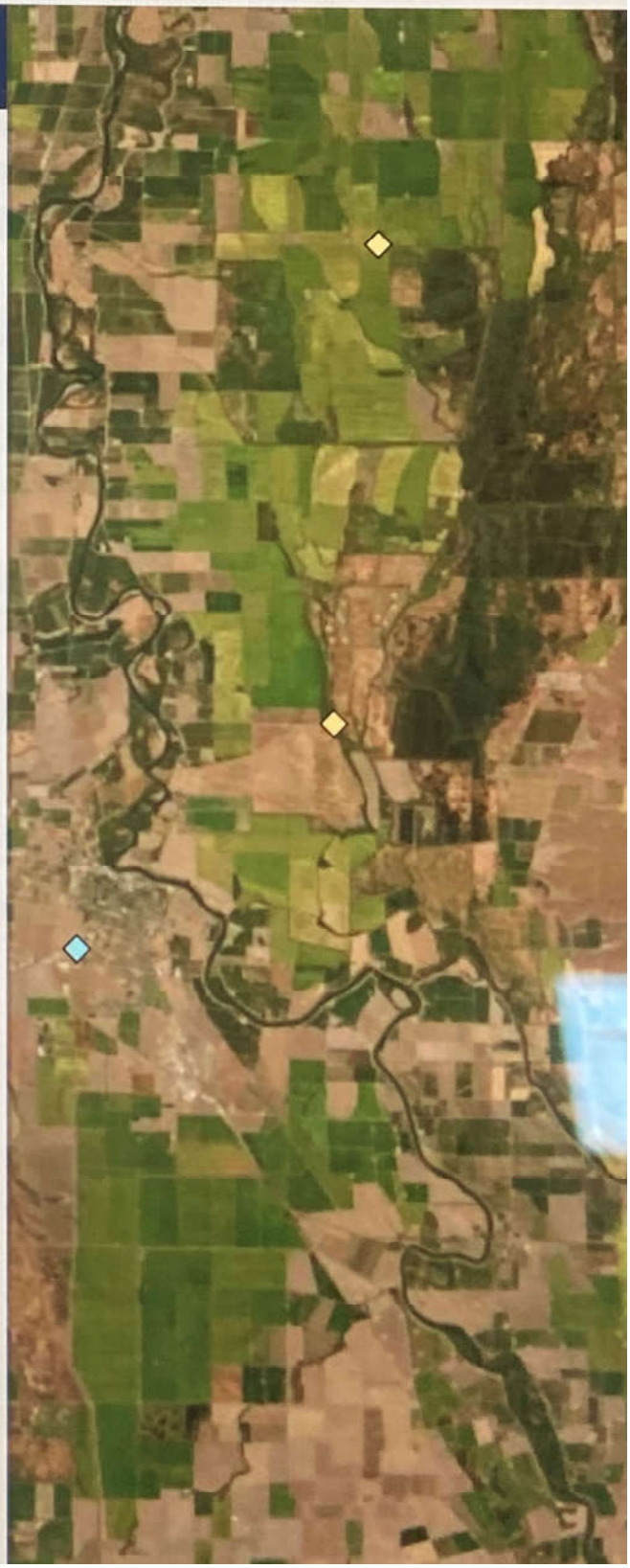
Constituent:

Arsenic

ADDITIONAL LAYERS

- [x] Domestic-supply Assessment Grid Cells
- [ ] Public-supply Assessment Grid Cells
- [ ] Domestic-supply Assessment Study Units
- [ ] Public-supply Assessment Study Units
- [ ] Hydrogeologic Provinces

The Groundwater Ambient Monitoring and Assessment - Priority Basin Project (GAMA - PBP) is



From:	Ken Loy
To:	Mary Fahey; Lisa Hunter
Cc:	Byron Clark
Subject:	FW: USGS Middle Sacramento Valley 2006 Water Quality Report
Date:	Wednesday, October 21, 2020 10:41:58 AM

CAUTION: This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

From: Ben King <bking@pacgoldag.com>
Sent: Saturday, October 17, 2020 9:59 AM
To: Ken Loy <kloy@westyost.com>
Cc: Ceppos, David M <dceppos@csus.edu>
Subject: Re: USGS Middle Sacramento Valley 2006 Water Quality Report

Thanks Ken

Perhaps we can work with the USGS to expand its network around the Sutter Buttes. Even if we get USGS testing every 10 years that may be enough to detect water quality trends. We just need a baseline because this may be 100 year issues. My concern is how the increased pumping to support permanent crops may effect the lateral and upward movement of natural contaminants. I think that recharge probably can mitigate this and may have contained the issue before the levees were built. With recharge we can tactically simulate some of the the natural benefits of the historical benefits of flooding in the Sacramento Valley while benefiting from the State's investment in flood control and reclamation.

Sent from my iPhone

> On Oct 16, 2020, at 4:07 PM, Ken Loy <KLoy@westyost.com> wrote:
>
> Ben:
>
> That's a good question worth a follow up.
>
> We'll compare the wells in the database to the report and let you know.
>
> Best,
>
> Ken
>
> > On Oct 16, 2020, at 3:37 PM, Ben King <bking@pacgoldag.com> wrote:

[This message has originated from outside of West Yost]

Thanks Ken

I was focusing on the Flow Path wells since I assumed they were deeper. Is that a good assumption – who owns the FP wells?

From: Ken Loy <kloy@westyost.com>
Sent: Friday, October 16, 2020 3:30 PM
To: Ceppos, David M <dceppos@csus.edu>; Ben King <bking@pacgoldag.com>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; Lisa Hunter <LHunter@countyofglenn.net>; Byron Clark <Byron@davidsengineering.com>; John Ayres <jwayres@woodardcurran.com>
Subject: RE: USGS Middle Sacramento Valley 2006 Water Quality Report

Ben:

We are familiar with this 2006 USGS GAMA report. Now that I know which report you were referring to, were you asking if the RICE or Flow Path wells could be used for water quality monitoring in the GSP?

Thank you,

Ken

Ken Loy
Principal Hydrogeologist
We're hiring! Visit our career site, here

WEST YOST
direct 530.792.3276
Currently working from home. Please use mobile: 530.574.1940

From: Ceppos, David M <dceppos@csus.edu>
Sent: Friday, October 16, 2020 3:21 PM
To: Ben King <bking@pacgoldag.com>; Ken Loy <kloy@westyost.com>
Subject: FW: USGS Middle Sacramento Valley 2006 Water Quality Report

[This message has originated from outside of West Yost]

Thanks Ben. Ken. See below and attached and please also note Ben's email and vice versa.

Have a great weekend!

Dave Ceppos I ***Managing Senior Mediator***
Consensus and Collaboration Program
College of Continuing Education – Sacramento State
304 S Street
Sacramento, CA 95811
916-539-0350 (c)
916-278-5015 (d)

He / Him / His
dceppos@csus.edu
csus.edu/cce
<image001.png>

From: Ben King <bking@pacgoldag.com>
Sent: Friday, October 16, 2020 3:17 PM
To: Ceppos, David M <dceppos@csus.edu>
Cc: Ben King <bking@pacgoldag.com>
Subject: USGS Middle Sacramento Valley 2006 Water Quality Report

Hi David,

See Figure 3 for well sites.

Also – I want to highlight the C 14 dating results and trace metal contamination levels for IASC 21 generally. See the Tables for IASC 21 at the end of the Report.

Best Regards,

Ben

ARSENIC IN CALIFORNIA DRINKING WATER

Three Years After EPA Notice of Noncompliance to State, Arsenic Levels Still Unsafe in Drinking Water for 55,000 Californians



ENVIRONMENTAL INTEGRITY PROJECT

SEPTEMBER, 2016

ACKNOWLEDGEMENTS

This report was researched and written by Tom Pelton, Courtney Bernhardt, and Eric Schaeffer of the Environmental Integrity Project. The map was created by Kira Burkhart and the graphics by Alana Natke.

THE ENVIRONMENTAL INTEGRITY PROJECT

The Environmental Integrity Project (http://www.environmentalintegrity.org) is a nonpartisan, nonprofit organization established in March of 2002 by former EPA enforcement attorneys to advocate for effective enforcement of environmental laws. EIP has three goals: 1) to provide objective analyses of how the failure to enforce or implement environmental laws increases pollution and affects public health; 2) to hold federal and state agencies, as well as individual corporations, accountable for failing to enforce or comply with environmental laws; and 3) to help local communities obtain the protection of environmental laws.

For questions about this report, please contact EIP Director of Communications
Tom Pelton at (202) 888-2703 or
tpelton@environmentalintegrity.org.

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Arsenic in California Drinking Water

More than three years after the U.S. Environmental Protection Agency found California in noncompliance with the federal Safe Drinking Water Act, 95 community water systems in the state, serving more than 55,000 people, are still providing water with illegal levels of arsenic, according to an examination of state data for the last two years.[1] Arsenic occurs naturally in the soil and groundwater in parts of California and is a known carcinogen that may also damage the developing brains of children and cause other health problems.[2] Many of the people drinking excessive levels of arsenic are poor and/or Latino or African-American, with a cluster in the San Joaquin Valley.[3] Nearly all have been exposed to excessive arsenic levels for at least five years and probably longer.[4]

California requires public water systems to notify their customers when arsenic fails to meet federal health standards. But strangely, the state's language for mailed advisories suggests the water is still safe to drink no matter how high the contimation levels or how long they persist, with the notices telling residents: "You do not need to use an alternative water supply (e.g., bottled water)." [5] That advice conflics with what California tells private well owners (who aren't covered by federal standards) on a state website: "If you suspect that your well may have arsenic, you should not use the water until it is tested, and you take appropriate measures to protect yourself and your family from potential chronic health effects if arsenic is present."[6] Whatever the intention, California's language for people on public water systems is likely to encourage them to drink contaminated water. (For the full text of the California's language, see Appendix A). As the state continues a multi-year effort to solve the contamination problem, it should immediately fix a communications problem so that it clearly warns people not to drink arsenic-tainted tap water.

The highest levels of arsenic in drinking water in California from 2011 through 2015 were in a group home for troubled teenage boys, the Valley Teen Ranch in Madera County. About 50 boys assigned by the courts to the facility have been living in a home with water that has arsenic at concentrations averaging more than 12 times the federal limit (10 parts per billion, or ppb) over these five years, according to state records.[7] "Nobody wants to drink the water because it's brown and nasty,"said Connie R. Clendenan, CEO of the nonprofit organization that runs the group home.[8] "It looks bad."



It is bad. Although California has made substantial progress in addressing

drinking water problems, the state still has 13 school districts, serving a total of 8,822 students, with arsenic in their drinking water that exceeded the federal limit from 2011 to 2015.[9] Twelve mobile home parks in California, serving 889 people, had arsenic in their tap water that averaged up to five times the legal limit. The average annual concentrations of arsenic in the drinking water of 58 residential communities (other than trailer parks) exceeded the legal limit during this time period, as did a military base, three wineries, two food preparation businesses and two campgrounds.

In many of the schools, the group home and military base, administrators say they verbally warn people not to drink tap water. They also provide bottled water as an alternative. But in the residential neighborhoods and trailer parks, it is not clear what warning – if any -- people are receiving. "There is no warning not to drink it. There is no 'non-drink' order out there," said Robert Johnson, President of the Shaver Lake Point 2 Mutual Water Company, which supplies 210 homes in Fresno County with tap water that has seven times the legal limit of arsenic. When asked if these residents should drink bottled water instead of his arsenic-tainted tap water, Johnson said: "It's one of those things, if you want to do it, that's your deal. It's not being recommended. We're not suggesting it. This is per the state of California. We are following their guidance."

The drinking water crisis in Flint, Michigan, was a reminder of how important it is for state governments to issue clear warnings to people with unhealthy tap water. California's mixed message is nearly identical to the one issued by Texas to homeowners with illegal levels of arsenic in their drinking water. Texas also tells consumers with excessive levels of arsenic: "You do not need an alternative water supply."[10] Many other states, however, are more direct in warning people not to drink water with excessive amounts of arsenic, at least for private well owners. Wisconsin, Michigan, Maine, and Washington, for example, simply tell residents not to consume water with more than 10 ppb arsenic (a health standard set by EPA in 2001). Wisconsin advises private well owners: "If your arsenic level is more than 10 ppb, the Wisconsin Department of Health Services recommends that you stop using your water for drinking or food preparation."[11] Florida advises its consumers to avoid water where arsenic contamination persists.[12] The U.S. Department of Health and Human Services makes similar recommendations.[13] If anything, the most recent science suggests that the current 10 ppb arsenic standard is not protective enough and that the IQ of children may be damaged at much lower exposures.[14]

In the wake of a 2013 EPA notice of noncompliance to California over its failure to invest enough money in its drinking water systems, the state has taken several important steps to fix its problems. Over the last three years, the state has more than doubled the amount of funding to build water treatment plants, pipelines, and new wells. The state and counties have filed compliance orders with local utilities to push them to upgrade their systems and are directing small, underfunded water systems to merge with larger utilities. Because of these measures, EPA announced in May 2016 that California was back in compliance with the federal Safe Drinking Water Act.

But in fact, the work is far from done – as witnessed by the 55,985 people in 95 communities across California who still have illegal levels of the carcinogen in their tap water, according to state records.[15] Why the delays? Local officials say that in some cases, bureaucratic

negotiations are holding up projects, which are sometimes stalled because of conflicts between county and state rules. In other cases, local water districts struggle with indecision or a lack of money.

Until these important water system improvements are complete, California and EPA must do a better job of warning consumers to stop drinking water that fails federal health standards. This report recommends:

- California and EPA should revise their regulations and guidance to require that local utilities warn people to stop drinking or cooking with water that fails to meet federal arsenic standards (10 ppb), especially when the contamination persists over several years. The advice should be sensitive to the additional risks posed when children and other sensitive populations drink contaminated water. If there is no reason for consumers to take precautions, there is no reason for Safe Drinking Water Act standards in the first place.

- Public notices mailed to consumers should inform them of options for treating contaminated water at home, e.g., through filtration systems that have proven to be effective. Conversely, the public should be told what doesn't work. For example, boiling water will not reduce arsenic concentrations.

- Federal and state authorities should provide enough money to these 95 California communities to allow them to install water filtration systems or take other steps to eliminate contamination problems. Although the state has already boosted its funding, it still faces a projected $30 billion plus in needed capital improvement projects to help its inadequate systems provide safe drinking water trough 2026.[16]

The big picture is that stepped-up investment in crumbling public infrastructure is sorely needed across the U.S., and it should be regarded as a top priority for both Congress and California lawmakers. But the state also needs to improve its efforts to better inform consumers so people can protect their own health. California does not have to wait for EPA action to strengthen its warnings because the state is already empowered to act independently of EPA.

Public health advisories that are contradictory and confusing – as they are in California -- are as bad as no warnings at all, because they undermine action and weaken public confidence in government.

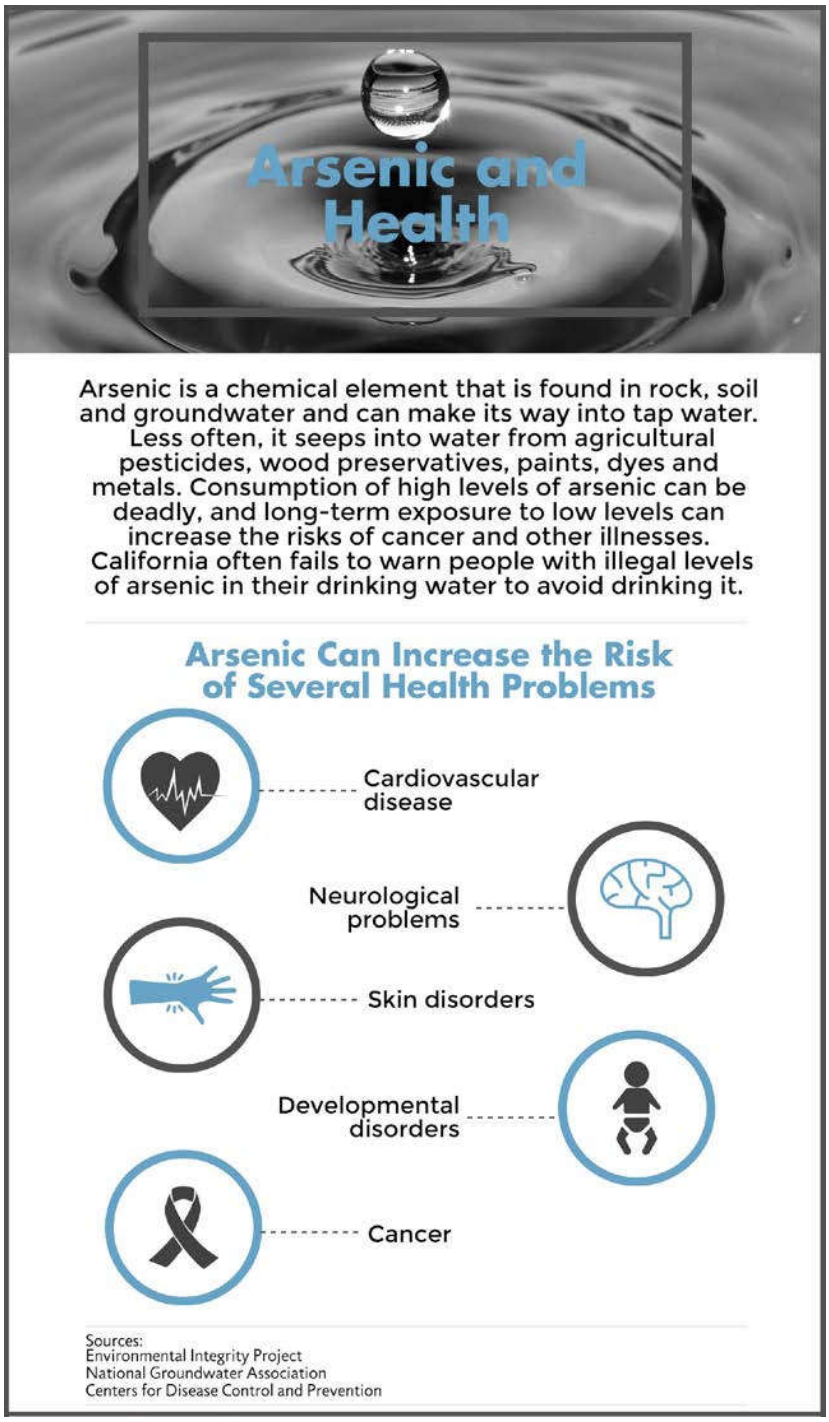
Table 1. Top 20 Arsenic Concentrations in California Public Water Systems

Water System (in Order of Arsenic Levels)	County	Pop. Served	2014-2015 avg (ppb)	2011-2015 avg (ppb)
Lakeview Improvement Association #1	Fresno	160	86.88	86.88*
Fountain Trailer Park Water	Kern	68	85.75	83.90
Hungry Gulch Water System	Kern	33	72.56	70.04
Corral De Tierra Estates WC	Monterey	45	72.50	78.40
Keeler Community Service District	Inyo	50	71.25	75.63
Quail Valley Water District- Eastside System	Kern	60	70.06	69.11
CSA 70 W-4 Pioneertown	San Bernardino	625	64.52	61.55
MD #06 Lake Shore Park	Madera	130	64.25	71.94
Valley Teen Ranch	Madera	50	62.00	120.80
Sierra East Mobile Home Community	Mono	50	54.63	47.03*
Shaver Lake Point #2	Fresno	210	52.31	42.88*
Winterhaven Mobile Estates	Los Angeles	40	52.13	53.35
Olam Spices And Vegetables Inc.	Kings	75	48.38	46.70
The Village Mobile Home Park	Los Angeles	70	45.05	47.04
Callier Water System	San Bernardino	1000	42.13	49.21*
Black Stallion Winery	Napa	25	41.75*	41.75*
Ironwood Camp	San Bernardino	1000	38.38	38.55
Boron CSD	Kern	2500	38.07	37.98
Edgewater Mobile Home Park	Sacramento	40	38.00	37.59
Prunedale MWC	Monterey	252	35.7	32.0

Note: The federal limit for arsenic is 10 ppb. * Average concentrations do not include concentrations from every year. For example, Lakeview Improvement Assn. #1 changed from a non-community water system to a community water system in 2013, and sampling data was only available from 2014 and 2015. Sampling results for Black Stallion Winery were only available for 2015. See Appendix B for annual concentrations in all systems that averaged above 10 ppb.

Health Risks Posed by Arsenic

Arsenic is a chemical element that occurs naturally in geological formations in California and elsewhere, and is also used in a variety of industrial products, including pesticides, paint, and wood preservatives.[17] It is a well-known poison at high doses. At lower doses, researchers have concluded it can cause cancers of the lung, kidney, bladder, skin, and other



organs with prolonged exposure. Any level of exposure, however, carries some risk.[18] According to EPA, the risk of developing cancer after drinking water containing 10 ppb arsenic over a lifetime is 1 in 2,000.[19] This level of risk is almost never 'acceptable' from a regulatory perspective. The agency usually tries to limit lifetime cancer risk to no more than 1 in 10,000, at most. EPA's risk estimate assumes that the cancer risk is linear, meaning if water contains 20 ppb arsenic, those who drink it over a long period of time have a 1 in 1,000 chance of developing cancer. People exposed over shorter periods of time have lower risks, but exposure during childhood may have a greater impact than exposure during adulthood.[20]

Morever, these risk calculations reflected the old thinking. New evidence suggests that the actual cancer risk may be much higher. EPA is currently revising its assessment of cancer risks from arsenic to incorporate more recent science. A 2010 draft of the assessment indicated that the risk of getting cancer from drinking water containing 10 ppb of arsenic is closer to 1 in 136, more than 17 times higher than current assumptions.[21] In addition to causing cancer, arsenic is also a neurotoxin that can harm developing brains at levels at or below the allowable limit.[22] One recent study in Maine, for example, found significant reductions in IQ and other problems in children exposed to arsenic concentrations of 5 to 10 ppb.[23] Specifically, children in homes with more than 5 ppb arsenic in the tap water tested roughly 6 points lower on a full-scale IQ test.[24] While EPA's

Scientific Advisory Board and the most recent studies suggest that the 'safe' level of arsenic is likely much lower than 10 ppb, any concentration higher than 10 is clearly unsafe.

Background on California's Problem

On April 19, 2013, EPA sent a letter to the California Department of Public Health notifying the state that it was out of compliance with the federal Safe Drinking Water Act.[25] The reason was that California's drinking water system was inadequate – providing contaminated water in many poor, rural communities – and the state was not investing enough money to fix the problem. A state investigation that year revealed that 680 community water systems serving 21 million people relied on groundwater that was compromised by one or more contaminants, with the most common being arsenic.[26]

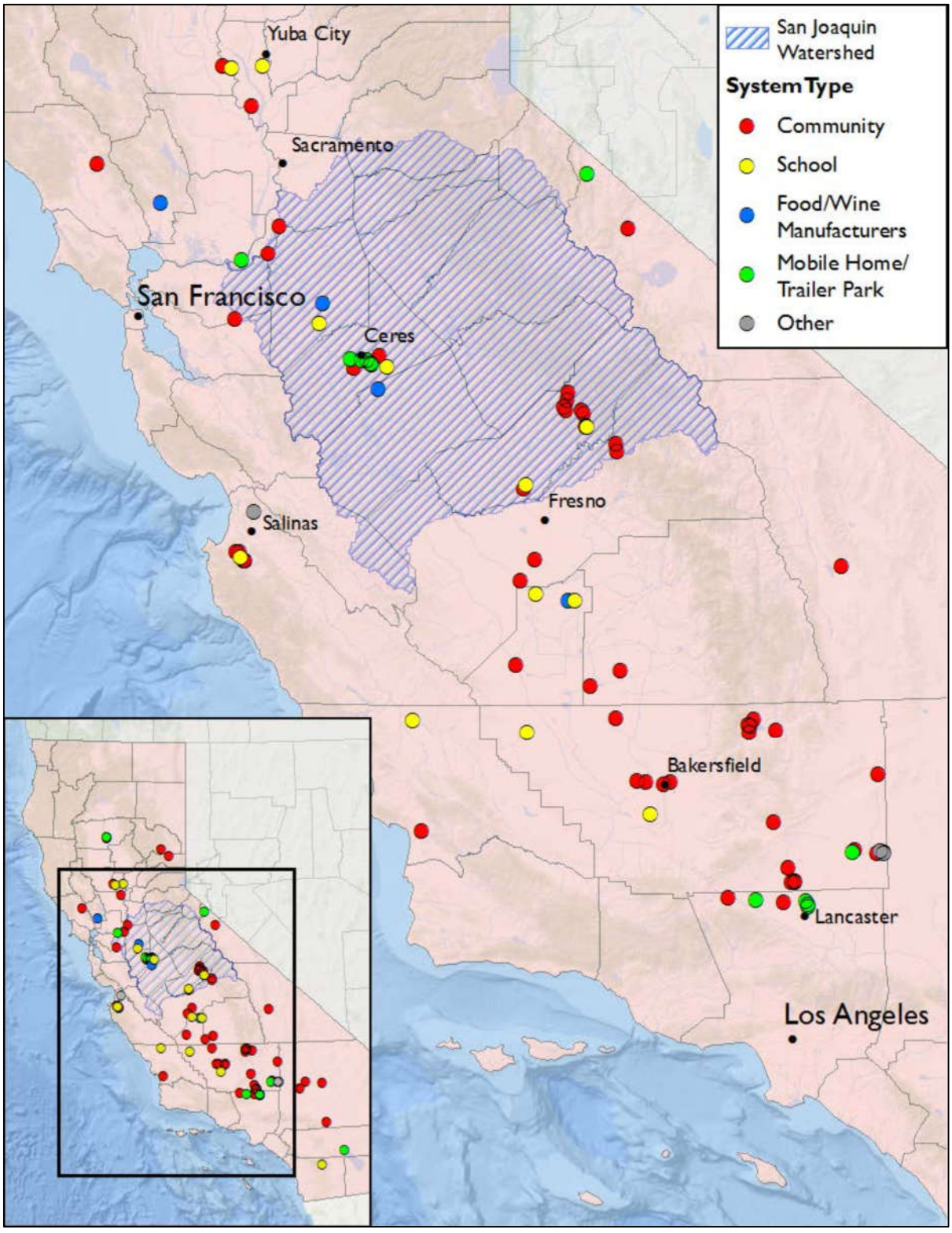
Not all of these 680 water systems provided tap water that had levels of contaminants in excess of federal health standards. In most wealthier and urban communities, the local water utilities treated the groundwater or diluted it with clean water from other wells so that it met the requirements of the federal Safe Drinking Water Act. But in 265 of these communities – often with small populations in rural, isolated areas – the tap water provided to customers had at least one violation of federal standards from 2002 to 2010 for a variety of contaminants, including nitrates from farm fertilizer, according to a 2013 report by the California Department of Health.[27]

In a separate study, researchers at the University of California, Berkeley, examined 464 community water systems serving 1.1 million people in California's San Joaquin Valley, one of the poorest regions in the state, and found that 15 percent of the systems and 14 percent of the people had tap water with arsenic above the federal limit.[28] Of the people exposed, 61 percent were either Latino or African-American. "Community water systems serving higher percentages of people of color had a 260 percent higher chance of having at least one (arsenic) violation," researcher Dr. Carolina L. Balazs and colleagues wrote.[29]

In response to the chronic drinking water problem, Congress had approved $1.5 billion to California over a decade to upgrade its water systems through a program called the Safe Drinking Water State Revolving Fund.[30] Yet because of bureaucratic obstacles and inefficiencies, the state by 2013 had not spent $455 million of those funds – the largest unspent balance of any state. According to EPA's 2013 letter of noncompliance to the California Department of Health, this violated a federal requirement that the state "make *timely* loan or grants using *all available* drinking water funds."[31]

EPA ordered the state to accelerate its efforts to fix public water systems. California Governor Jerry Brown's administration took action in several steps. These included switching control of the state's drinking water program from the Department of Health (where policy focus was dispersed among numerous problems, including drug abuse and AIDS), to the California State Water Resources Control Board (whose only focus is water) under the California Environmental Protection Agency. Since the EPA issued its

Map 1. Public Water Systems with Illegal Levels of Arsenic, 2014-2015



2013 letter of noncompliance, the state has more than doubled the amount of money it is distributing for water system upgrade projects, to an average of $738 million per year, compared to $366 million per year in the period of 2008 to 2012.[32] The unspent balance in the drinking water fund dropped to about $100 million.[33] As a result, EPA in May 2016 decided that California's system was back in compliance.[34]

Recent Analysis of California Records

The problem, however, is still far from fixed. An examination of California's online records by the Environmental Integrity Project (EIP) in May 2016 revealed that there were still 95 community water systems in the state, serving 55,985 people, providing drinking water with levels of arsenic that exceed the federal standard of 10 ppb in 2014 and 2015, according to two-year averages over those years. [35]

Over a longer period of time, 2011 through 2015, state records show 70 systems serving 46,772 residents, that each year have averaged higher than the limit in the Safe Drinking Water Act. These do not include homes on individual private wells, which are not covered by the federal Safe Drinking Water Act.

For a detailed discussion of the methods used to arrive at these numbers, please see Appendix C.

Examples of Drinking Water Contamination

Some of the worst water in community systems in California can be found in the Lakeview Community Association, which serves 160 residents in Shaver Lake (northeast of Fresno, in Fresno County). This community had an average arsenic concentration of nearly nine times the federal limit – 87 ppb – in 2014 and 2015, according to state data.[36]

Four water systems in the unincorporated community of Boron, in San Bernardino County, provided water to about 5,200 residents that had at least three times the safe limit of arsenic in 2014 and 2015.[37] In the city of Keyes in Stanislaus County, 4,891 people have tap water with arsenic concentrations that averaged above the federal limit each year for the last five years. The Pixley Public Utilities District, serving 3,310 residents, had arsenic levels in its drinking water that averaged 50 percent higher than health standards in 2011-2014.

Twelve school districts, serving a combined total of 5,462 students, had arsenic levels that averaged from 30 percent higher to three times the federal limit over the last five years. (See Table 4. Some of these school districts provided explanations, which will be discussed on pages 15 and 16 of this report).

Across California, there were 12 mobile home parks serving 889 people that had average arsenic levels ranging from 20 percent over legal limits to five times the federal standards from 2011 through 2015.[38]

Table 2: Top 10 Mobile Home Parks for Arsenic Contamination

Water System	County	People Served	2014-2015 Avg. (ppb)	2011-2015 Avg. (ppb)
Fountain Trailer Park Water	Kern	68	85.8	83.9
Sierra East Mobile Home Community	Mono	50	54.6	47.0*
Winterhaven Mobile Estates	Los Angeles	40	52.1	53.4
The Village Mobile Home Park	Los Angeles	70	45.1	47.0
Edgewater Mobile Home Park	Sacramento	40	38.0	37.6
Mitchell's Avenue E Mobile Home Park	Los Angeles	26	21.3	21.0
Millstream Mobile Home Park	Tehama	80	20.5	20.0
Country Western Mobile Home Park	Stanislaus	120	20.4	22.2
Saint Anthony Trailer Park	Riverside	300	19.7	21.5
New Orchard Mobile Home Park LLC	Tehama	125	19.6	19.0

Note: federal limit is 10 ppb arsenic. The 2011-2015 average for Sierra East Mobile Home Community reflects fewer than 5 years.

Response from California Officials

The Environmental Integrity Project asked the California State Water Resources Control Board why so many people are still exposed to contaminated drinking water after the state supposedly returned its system to compliance. Officials at the state agency replied in an interview and emails that they had issued orders to nearly all of the local utilities to fix the arsenic problem, but that some local government still need more time to upgrade their systems. In some cases, local utilities are building water filtration systems to remove arsenic, or digging new wells in an effort to extract cleaner water.

"The State Water Board Division of Drinking Water is working with each of these communities to return them to compliance," said Cindy Forbes, Deputy Director of the Division of Drinking Water at the Water Resources Board.[39] "District Office staff are working with these communities to evaluate alternative solutions, including new treatment options, new wells or modification of existing wells, and in some instances consolidation with larger water systems that can provide drinking water that meets all standards. The State Water Board is also helping communities that are struggling financially to reach compliance by offering financial assistance to solutions through low-interest loans and grants."

Public Notification of Drinking Water Violations

As the work continues to upgrade the drinking water systems, however, many citizens of California have not been given warnings to avoid drinking contaminated water.

The background is this: As part of the federal Safe Drinking Water Act, local water utilities are required to periodically test public drinking water systems that serve at least 25 people. When those results show more than 10 ppb arsenic (a standard imposed by EPA in 2001), the utilities must notify residents of the violation in writing by mail "as soon as practical, but within 30 days."[40] In California, however, the warning notices provide a mixed message, stating: "Our water system recently violated a drinking water standard," but also, "you do not need to use an alternative water supply (e.g., bottled water). This is not an emergency…. However, some people who drink water containing arsenic in excess of the (federal limit) over many years may experience skin damage or circulatory system problems, and may have an increased risk to getting cancer."[41] (For the full text of California's notice template for local utilities to use, see Appendix A)

This advisory says two contradictory things: Warning, you have a problem with your water. But don't worry – keep drinking it. If consumers are being told to ignore the federal health standards and keep drinking the contaminated water, there is no reason for the federal Safe Drinking Water standards for arsenic to exist. As stated previously in this report, California is much more clear about warning private well owners to "protect yourself and your family" from arsenic-tainted tap water. And other states – including Wisconsin, Michigan, Maine, and Washington – bluntly advise people not to drink private well water with more than 10 ppb arsenic.

In addition to receiving advisories about violations when they occur, customers also receive annual reports from their local water utilities called "Consumer Confidence Reports." These reports list the levels of more than a dozen different potential contaminants, including bacteria, lead, copper, nitrates and arsenic. When arsenic levels exceed the limit of 10 ppb, these reports provide the numbers and say: "Some people who drink water containing arsenic in excess of the MCL (maximum contaminant level) over many years may experience skin damage or circulatory system problems, and may have an increased risk of getting cancer."[42] But the reports do not tell consumers to stop drinking water with excessive levels of arsenic, and instead hint that it might not be a problem, saying: "Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants."

We asked the California State Water Resources Control Board why the agency doesn't tell people to avoid drinking water with illegal levels of arsenic. In response, Forbes, the deputy director for water, said that the state does provide this kind of blunt and immediate warning for other contaminants that can make consumers sick immediately, such as fecal bacteria. But for arsenic, she said, the threat is more long term. "Arsenic is categorized as a chronic contaminant that poses possible health risks after long-term exposure – 70-plus years of drinking two liters of arsenic-contaminated water a day above the maximum contaminant level," Forbes said. "There are no known acute/immediate health effects that would cause consumers to immediately stop drinking the water."

This answer, however, ignores the fact that many of these California residents have been drinking arsenic-contaminated water for decades. For example, Drs. Carolina Balazs and Isha Ray in 2014 published a study in the American Journal of Public Health in which they interviewed residents with contaminated tap water and found that the current notification requirements are poorly serving people with long-term exposure to pollutants.[43] "A resident from the community of Cutler explained that for years she had received Consumer Confidence Reports indicating that dibromochloropropane levels in the water exceeded the MCL (maximum contaminant level)," Balazs and Ray wrote. "These reports noted that residents should not worry because health impacts were not based on immediate exposure, but rather on lifetime exposure... She had lived in her community for nearly 30 years—so, she asked, should she worry or not? In these situations, water systems simply leave residents to cope with contaminated drinking water as best they can….In these instances, Safe Drinking Water Act regulations ultimately fail the (low-income) household."[44]

California's records identify more than 46,772 people whose tap water has had average levels of arsenic that have exceeded the federal standards for at least five years, from 2011 to 2015. But there is no reason to believe that these people received cleaner water before this. The longer a person drinks water contaminated with excessive levels of arsenic, the higher the increased risk of cancer. In much the same way, smoking a single cigarette is not an immediate health threat, in that it will instantly kill a person. But the longer a person smokes, the worse the health threat. For this reason, California would better protect public health if it told people to stop drinking arsenic-tainted water now, just as health warnings on tobacco required by the U.S. Food and Drug Administration advise, "WARNING: Quitting smoking now greatly reduces serious risks to your health." These advisories do not state, "WARNING: You do not need to change your smoking habits."

Evolution of the Science on Arsenic

One reason for stronger warning language is that scientific research continues to show that arsenic causes health problems – including brain damage in children -- at lower levels than previously thought.

The history of EPA's arsenic rule reflects the continuing evolution of scientific knowledge about the harms that even low levels of the element can cause. Back in 1996, Congress amended the Safe Drinking Water Act and directed EPA to establish new limits for arsenic to replace the old standard of 50 ppb. Based on the best available research, EPA proposed a limit of 5 ppb in 2000. Because arsenic is a carcinogen, some public health experts consider any level above zero to pose some risk. EPA then revised its proposal, based in part on cost considerations, and finalized a new arsenic standard of 10 ppb in 2001.

The EPA Administrator at the time, Christine Todd Whitman, explained that "the 10 ppb protects public health based on the best available science and ensures that the cost of the standard is achievable."[45] The new regulations required that public water systems across the U.S. meet the new standard by January 23, 2006.[46] The law allowed states to grant exemptions until January 23, 2015, for some small community water systems that had trouble complying.[47]

The 2014 Maine study discussed earlier in this report found found significant reductions in IQ in children exposed to arsenic concentrations of 5 to 10 ppb.[48] With this new information, EPA should change its own guidance for notification language so that people – especially parents of young children -- receive a clearer warning not to drink contaminated water. A template for warning language on the federal agency's website for drinking water systems with chemical contaminants such as arsenic advises utilities to tell their customers: "Some people who drink water containing arsenic in excess of the MCL (maxiumum contaminant level) over many years may have an increased risk of getting cancer." But the notices also say: "There is nothing you need to do….If you have specific health concerns, consult your doctor."[49] This is a problem, because many lower-income people do not have doctors with whom they can regularly consult about questions like water quality.

Responses from Local Drinking Water Systems

When asked about their drinking water violations by EIP, some of the utilities in California with illegal levels of arsenic replied that their attempts to fix the problem have been hindered by bureaucratic obstacles at the local level. Others indicated they are taking steps to solve the problem, but simply need more time or money. Not all public systems were contacted by EIP or provided answers.

Table 3. Top 10 Residential Water Systems for Arsenic Contamination (Excluding Mobile Home Parks)

System	County	Population Served	2014-2015 avg (ppb)	2011-2015 avg. (ppb)
Lakeview Improvement Association #1	Fresno	160	86.9	86.9*
Corral De Tierra Estates WC	Monterey	45	72.5	78.4
Keeler Community Service District	Inyo	50	71.3	75.6
Quail Valley Water District-Eastside System	Kern	60	70.1	69.1
MD #06 Lake Shore Park	Madera	130	64.3	71.9
Valley Teen Ranch	Madera	50	62.0	120.8
Shaver Lake Point #2	Fresno	210	52.3	42.9
Boron Community Service District	Kern	2500	38.1	38.0
Monterey Park Tract Comm. Service District	Stanislaus	186	31.9	34.3
North Edwards Water District	Kern	600	31.5	31.6

Note: The federal limit is 10 ppb arsenic. Lakeview had fewer than five years of data available.

At the **Lakeview Improvement Association** in Fresno County, 160 people have been receiving drinking water with more than eight times the legal limit of arsenic on average for

at least the last five years, according to state data. State records show that on May 16, 2016, the California Water Resources Control Board issued a citation to the association's water system, imposing a fine of $1,000 for its failure to follow the directives of two earlier compliance orders, in 2014 and 2015. "The water system continues to violate the arsenic maximum contaminant level (MCL) and does not appear to be making progress toward the compliance deadline," says the most recent letter from the state. "Additionally, the water system has failed to routinely conduct the public notification of the arsenic MCL violation, as required."

Philip Dutton, an engineer for surrounding Fresno County, said that the Lakeview Association's plan, as expressed verbally, is to test some in-home water filtration systems and see how well they perform.[50] "They've got a few of these (filtration systems) installed in homes, but they are sampling from different technologies to try and identify what is going to be the best long-term alternative," Dutton said. The California State Water Resources Control Board's website already lists which types of filtration technologies work well to remove arsenic.[51]

In **Kettleman City**, in Kings County, 1,450 residents have had tap water with excessive levels of arsenic for decades. The average from 2011 to 2015 was 20 percent above the legal limit, according to state data. "I have a daughter, a little one, who's still brushing her teeth with contaminated water, taking a bath in contaminated water," said Maricela Mares-Alatorre, a city resident, during a recent public hearing of the state water board.[52] The Kettleman City Community Services District has promised local residents that it will build a $9 million water treatment plant, but the project has been repeatedly delayed – with a target to open in the fall of 2016 recently pushed back to 2018.[53]

At the **Corral De Tierra Estates** subdivision in Monterey County, 45 people have been exposed to drinking water with arsenic levels almost eight times the legal limit from at least 2011 through 2016, state records indicate. This small water system has received 10 violations notices from the state for excessive levels of arsenic over the last decade, with the most recent in the first quarter of 2016, when it had 77 ppb of the contaminant (compared to the 10 ppb limit).

The manager of Monterey County's drinking water program, Cheryl Sandoval, said Corral De Tierra Estates is among at least five privately-owned water systems that have been issued corrective orders by the county because they are in violation of the arsenic standard. Solving the problem is taking longer than expected, Sandoval said, and some of the local water utilities are still debating the best path forward. "Dealing with the problem is very complicated," Sandoval said.[54] "They haven't made a lot of progress toward compliance, but they are going to have to." One challenge is that a water treatment plant for even a small system can cost hundreds of thousands of dollars and cause new waste disposal problems, because the plants produce concentrated arsenic sludge that must be handled carefully as a hazardous material. Corral De Tierra Estates and other subdivisions want to try in-home water treatment systems as a systemic solution, but county rules don't allow that, Sandoval said. However, debate over this in-home option continues, because new state regulations may open the door for in-home filtration as a systemic solution in the future.

Meanwhile, as the bureaucratic discussions continue, residents are receiving confusing advice about whether they should drink the water pouring from their taps with illegal levels of arsenic. One recent report from Corral de Tierra Estates to local water consumers, displayed on the state website and sent to homeowners in July 2014, advised people that arsenic levels were eight times above the legal limit.[55] But that fact was buried in the middle of a dense report with lots of numbers that also gave the impression that the exceedance was not a problem. The report told homeowners: "The presence of contaminants does not necessarily indicate that the water poses a health risk."[56]

At the **Quail Valley Water District-Eastside System** in Kern County, 60 residents have been receiving drinking water with seven times the legal limit of arsenic over the last five years, state records show. In April 2015, the state issued a compliance order to the local utility and mandated that it fix the problem by April 2018.

Randy Hardenbrook, Director of the Quail Valley Water District, said the problem should be solved within the next two years because a $5.8 million grant from the state is allowing the district to build a new pipeline. The pipe will be about 8.5 miles long and will connect a part of the system with arsenic-tainted water to a well that has good water.[57] In the interim, local residents receive quarterly letters with data on the arsenic exceedances but are not being provided with bottled water. More importantly, they are not being told to refrain from consuming the contaminated water. "We're not telling them not to drink it," Hardenbrook said, "but we are telling them there are long-term health effects."[58]

At the **Shaver Lake Point #2** subdivision in Fresno County, 210 people have been receiving tap water with more than four times legal levels of arsenic for at least the last five years, according to state data. In January 2015, the state wrote to the water system's administrators and ordered them to come into compliance with the federal and state arsenic limits by December 31, 2016.

With only four months left until the deadline, the arsenic levels remain illegally high and Robert Johnson, President of the Shaver Lake Point Mutual Water Company, said he is still thinking about what to do about the problem.[59] "Currently, it's being researched. We have engineers involved. We have water experts involved, and we are trying to figure it out," Johnson said. He added that building a water filtration system could cost as much as $250,000, so the subdivision is considering trying to blend water from its arsenic-tainted wells with cleaner water from different wells.

Meanwhile, nobody in the community is being warned to avoid the contaminated water. "There is no warning not to drink it. There is no 'non-drink' order out there," said Johnson.[60] When asked if his customers should drink bottled water as a precaution instead of the arsenic-tainted tap water, Johnson said: "It's one of those things, if you want to do it, that's your deal. It's not being recommended. We're not suggesting it. This is per the state of California."

Group Home for Troubled Children

The **Valley Teen Ranch**, a Christian residential treatment group home for 32 court-referred abused and neglected boys in Madera County, has arsenic in its tap water that averaged more than 12 times the federal limit from 2011 through 2015, according to state records.[61] "We've been out of compliance, but no children have gotten sick, no adults have gotten sick," said Connie R. Clendenan, CEO of the nonprofit organization that runs the group home. "Nobody wants to drink the water here because it's brown and nasty."[62]

About five years ago, the state approved a $5 million grant to help the group home solve the problem by linking its small water system to a larger one run by the county. But the work has not started yet. Because of ongoing negotiations at the county level, the fix could still be three years or more away, Clendanan said. Meanwhile, children are being given bottled water and are verbally warned not to drink tap water, although there are no warning signs posted above sinks.

"I want to get out of the water business. I'm in the kid business," Clendenan said. Of the continuing delays in fixing the problem with contaminated water, she said: "Nobody's mad. But it's government, and it takes a lot of time. It's just the stupid county."

Table 4. Schools with Excessive Arsenic in Drinking Water

System	County	Population Served	2014-2015 avg. (ppb)	2011-2015 avg. (ppb)
Kit Carson Elem. School	Kings	510	34.7	34.7*
Washington School WS	Monterey	250	26.1	27.7
MUSD-Nile Garden School	San Joaquin	804	20.9	22.8
Liberty High School	Madera	1340	17.9	20.5*
Island Union School	Kings	300	11.9	18.8
Winship Elementary School	Sutter	38	16.4	17.3*
Lakeside School	Kern	800	16.3	16.9
Barry Elementary School	Sutter	650	15.2	15.3
Pleasant Valley Elementary	San Luis Obispo	100	13.8	14.1
Gratton School	Stanislaus	110	13.5	13.5
North Fork Union School	Madera	350	12.9	12.4
Warner Unified School District	San Diego	250	10.9	11.4
Central Union Elementary	Kings	320	10.1	13.5

*Note: federal limit is10 ppb arsenic. *Indicates systems with monitoring gaps (less than five years available data)*

Arsenic in School Drinking Water

At the **Washington School in Salinas,** California, the tap water serving about 250 students has had almost three times the federal limit of arsenic for the last five years, 28 ppb on average over this time period, compared to the limit of 10 ppb.[63] School Principal Whitney Meyer said that the local school district has been discussing the problem for several years but does not yet have a solution. Meanwhile, students are given bottled water, she said.

"We remind them over and over that they cannot drink the water," Meyer said.[64] "Many of the students live out in this area and their homes are similarly impacted (with arsenic), so they also hear the message at home. We have drinking stations with clean water in every classroom, teaching space, and hallway. The fountains have all been shut down."

At the **Barry Elementary School in Yuba City**, California, the arsenic levels have averaged 50 percent above the federal limit for arsenic over the last five years. Because of the violations, the state issued a compliance order to the school in May 2015. Tom Butcher, Director of Maintenance and Facilities for the school system, said that the school has not yet solved the problem, but is giving bottled water to students as officials try to figure out a solution.[65] Adminstrators of the water system are discussing a consolidation with a larger neighboring system that has better water. "The (state) Water Board indicates a best case scenario of a consolidation in approximately 1.5 years," Butcher said. "Until the consolidation is completed (the school district) will continue to provide bottled drinking water."

At the **Kit Carson Elementary School**, in Hanford, Ca., arsenic levels in drinking water averaged more than three times the legal limit in 2011 through 2014, according to state records. In January 2015, the school solved the problem by connecting its pipes to the water system of the surrounding city,[66] whose arsenic levels are below the federal limits.

At the **Lakeside School in Bakersfield,** California, the arsenic levels in the drinking water averaged more than 70 percent above the federal limit for arsenic over the last five years, 17 ppb compared to the limit of 10 ppb. Ty Bryson, District Superintendent, said that the school notified all families by sending home notice letters with the students and by posting warnings in the office. "We provide bottled drinking water for students and staff," Bryson said. "We drilled an alternate well, but that also had unacceptable levels of contaminant. We are now pursuing an alternative source of drinking water by connecting to a local municipal water source via pipeline."

At the **Gratton School in Denair,** California, the drinking water system has had arsenic levels that averaged 40 percent above the federal limit for arsenic over the last five years, state records indicate. The school's superintendent, Shannon Sanford, said that students have been provided bottled water for the last two years. "Students were initially warned (not to drink the water) and signs were used until fountains were disabled," Sanford said. More recently, the school drilled a new well that will be used for the 2016-2017 school year that should solve the problem.

At the **Island Union School in Lemoore,** California, arsenic levels in the drinking water were nearly twice the federal limit from 2011 to 2015, averaging 18.8 ppb compared to

federal limit of 10 ppb, according to state records. Superintendent Charlotte Hines said the school dug a new well in 2015, and provided students and warnings and bottled water in the interim. "We know that bottled water is only a temporary solution," Hines said. "And in an effort to find a permanent solution, the school requested -- and was awarded -- state funding to drill a new well that would meet all primary drinking water standards."[67]

Military Base with Contaminated Water

At the **U.S. Army Base Fort Irwin** in San Bernardino County, 16,000 soldiers live in facilities that have had arsenic in some tap water at levels 50 percent higher than the federal limit from 2011 through 2015, state records indicate. For the last three years, the Army Corps of Engineers has been building a new $100 million water treatment plant at the base to solve the problem. The plant is now undergoing testing and is scheduled to go online in October 2016, base officials indicate.

"The new plant will treat all Fort Irwin water to comply with Safe Drinking Water act Standards for ALL pollutants of concern including …arsenic," said Muhammad A. Bari, Director Public Works at Fort Irwin.[68]

In the interim, soldiers have been provided with bottled water and warned which faucets to avoid, according to base managers.

Vineyards with High Arsenic Levels

In San Joaquin County, the **Delicato Family Vineyards** had arsenic levels in the tap water that averaged 18 ppb from 2011 through 2014, which was 80 percent higher than the federal limits, state records indicate. Kylie Barnett, a spokeswoman for the company, said that the vineyards worked with county officials in 2014 to build a new drinking water system, including by digging two new wells, which brought the arsenic levels down below the federal standard in 2015 and 2016.[69] "The drinking water is not used in production of our wine," Barnett noted. Before the repair, people working at the vineyards and visiting were provided bottled water, she said.

In Napa County, the **Larkmead Vineyards** had drinking water with six times more arsenic than allowed from 2011 through 2013, according to state records. No results were listed for 2014 or 2015, and it is unclear if the drinking water system, which serves 25 people, is used for workers or guests. (Wine making does not generally use tap water.) Emails sent to managers of the vineyard asking about the water were not returned. The researchers of this report also received no response from the **Black Stallion Winery** in Napa County, whose tap water had four times legal limits of arsenic from 2011 through 2015, according to state records.

Conclusion

California is making progress toward solving its drinking water contamination problem. The state has reorganized its drinking water agency, and increased its financial assistance to local utilities to build water treatment systems, dig new wells, and take other steps to resolve the issue. The work, however, is expected to take many more years. In the meantime, tens of thousands of people continue to be exposed to drinking water with illegal levels of arsenic, a carcinogen that could damage the developing brains of children and cause other health problems. And yet, the warnings that some of these residents receive from the government are contradictory and confusing.

Both California and the federal government need to do more to protect consumers, especially the young. This report recommends:

1) California and EPA should both revise the language for written notifications of violations of arsenic standards, so that people are clearly advised to stop drinking contaminated water. If the violations are in schools or group homes, warning signs should also be posted over all sinks and drinking fountains. The state should help provide bottled water as an interim solution.

2) Consumers should be provided more information through the mail about what works and what does not work to remove arsenic from tap water. Residents need to know, for example, that boiling water will not help, but that certain filtration systems can remove the carcinogen. In some cases, residents may need technical help from the state in understanding how to use filtration systems properly.

3) Both Congress and the state government should increase investments in upgrades to California's drinking water systems. This is not only an environmental justice issue, but also a sensible strategy to boost the local economy through the hiring of engineers, construction workers and others to improve local infrastructure.

Counter arguments made by California officials – that the state is already taking action, and that arsenic is not an immediate threat to public health – do not hold water. Although the state has issued enforcement orders to local utilities, some local officials clearly still need more prodding and money to upgrade their water systems. A growing amount of scientific research suggests that arsenic increases the risk of cancer and other diseases and may do so at a lower level than expressed in current federal regulations. Years more of exposure to arsenic-tainted water will only raise the risk of cancer or neurological damage for California residents.

The state and federal governments should advise people to stop drinking contaminated water immediately, just as public health experts urge smokers to change their habits sooner rather than later because it will increase their odds of survival.

With public health warnings, simple and direct is better than bureaucratic and complex, because safe is better than sorry when people's lives and minds are at risk.

APPENDIX A: California's Language for Public Notices about Arsenic Violations

IMPORTANT INFORMATION ABOUT YOUR DRINKING WATER

Este informe contiene información muy importante sobre su agua potable.
Tradúzcalo o hable con alguien que lo entienda bien.

[System] Has Levels of Arsenic Above the Drinking Water Standard

Our water system recently violated a drinking water standard. Although this is not an emergency, as our customers, you have a right to know what you should do, what happened, and what we are doing to correct this situation.

We routinely monitor for the presence of drinking water contaminants. Water sample results received on [date] showed arsenic levels of [level and units]. This is above the standard, or maximum contaminant level (MCL), of 0.010 milligrams per liter.

What should I do?

- **You do not need to use an alternative water supply (e.g., bottled water).**
- This is not an emergency. If it had been, you would have been notified immediately. However, *some people who drink water containing arsenic in excess of the MCL over many years may experience skin damage or circulatory system problems, and may have an increased risk to getting cancer.*
- If you have other health issues concerning the consumption of this water, you may wish to consult your doctor.

What happened? What is being done?

[Describe corrective action]. We anticipate resolving the problem within [estimated time frame].

For more information, please contact [name of contact] at [phone number] or [mailing address].

Please share this information with all the other people who drink this water, especially those who may not have received this notice directly (for example, people in apartments,

nursing homes, schools, and businesses). You can do this by posting this public notice in a public place or distributing copies by hand or mail.

Secondary Notification Requirements

Upon receipt of notification from a person operating a public water system, the following notification must be given within 10 days [Health and Safety Code Section 116450(g)]:

- SCHOOLS: Must notify school employees, students, and parents (if the students are minors).
- RESIDENTIAL RENTAL PROPERTY OWNERS OR MANAGERS (including nursing homes and care facilities): Must notify tenants.
- BUSINESS PROPERTY OWNERS, MANAGERS, OR OPERATORS: Must notify employees of businesses located on the property.

This notice is being sent to you by [system].

State Water System ID#: _____. Date distributed: _____.

APPENDIX B: Listing of All California Public Drinking Water Systems with Arsenic Levels that Averaged Over the Federal Limit over the Last Five Years

System Name	County	Pop. Served	2014-2015 Avg (ppb)	2011-2015 Avg (ppb)	
Lakeview Improvement Association #1	Fresno	160	86.9	86.9	^
Fountain Trailer Park Water	Kern	68	85.8	83.9	*
Hungry Gulch Water System	Kern	33	72.6	70.0	*
Corral De Tierra Estates WC	Monterey	45	72.5	78.4	*
Keeler Community Service District	Inyo	50	71.3	75.6	*
Quail Valley Water District-Eastside System	Kern	60	70.1	69.1	*
CSA 70 W-4 Pioneertown	San Bernardino	625	64.5	61.6	*
MD #06 Lake Shore Park	Madera	130	64.3	71.9	*
Valley Teen Ranch	Madera	50	62.0	120.8	*
Sierra East Mobile Home Community	Mono	50	54.6	47.0	^
Shaver Lake Point #2	Fresno	210	52.3	42.9	^
Winterhaven Mobile Estates	Los Angeles	40	52.1	53.4	*
Olam Spices And Vegetables Inc.	Kings	75	48.4	46.7	*

System Name	County	Pop. Served	2014-2015 Avg (ppb)	2011-2015 Avg (ppb)	
The Village Mobile Home Park	Los Angeles	70	45.1	47.0	*
Callier Water System	San Bernardino	1000	42.1	49.2	^
Black Stallion Winery	Napa	25	41.8	41.8	^
Ironwood Camp	San Bernardino	1000	38.4	38.6	*
Boron CSD	Kern	2500	38.1	38.0	*
Edgewater Mobile Home Park	Sacramento	40	38.0	37.6	*
Prunedale MWC	Monterey	252	35.7	32.0	
Kit Carson Elem. School	Kings	510	34.7	34.7	^
Darr Water Co.	San Bernardino	1000	34.3	36.0	*
Monterey Park Tract Community Service District	Stanislaus	186	31.9	34.3	*
North Edwards WD	Kern	600	31.5	31.6	*
Desert Lake Community Service District	Kern	700	31.0	32.5	*
Locke Water Works Co [SWS]	Sacramento	80	29.5	29.1	*
Lucky 18 On Rosamond, LLC.	Kern	73	28.0	24.3	*
Washington School WS	Monterey	250	26.1	27.7	*
Rancho Marina	Sacramento	250	24.0	30.1	*
Colusa Co. WWD #1 - Grimes	Colusa	500	23.9	24.7	*
Bridgeport PUD	Mono	850	23.3	24.0	*
Country Hills Estates	San Luis Obispo	60	23.0	26.8	^
Doubletree Ranch Water System	Contra Costa	49	21.6	22.4	*
Mitchell's Avenue E Mobile Home Park	Los Angeles	26	21.3	21.0	*
Vista Del Toro WS	Monterey	87	21.0	20.4	*
MUSD-Nile Garden School	San Joaquin	804	20.9	22.8	*
Country Villa Apts.	Stanislaus	30	20.8	21.1	*
Millstream Mobile Home Park	Tehama	80	20.5	20.0	*
Country Western Mobile Home Park	Stanislaus	120	20.4	22.2	*
Saint Anthony Trailer Park	Riverside	300	19.7	21.5	*
New Orchard Mobile Home Park LLC	Tehama	125	19.6	19.0	*
MD #24 Teaford Meadow Lakes	Madera	150	19.0	12.5	
William Fisher Memorial Water Company	Kern	53	19.0	18.4	*
Ceres West Mobile Home Park	Stanislaus	161	18.9	18.0	*
Boulder Canyon Water Association	Kern	28	18.4	17.9	*
Lakeview Ranchos Mutual Water Company	Kern	120	18.1	22.4	*
Liberty High School	Madera	1340	17.9	20.5	^
Sutter Co. WWD #1 (Robbins)	Sutter	350	17.9	18.1	*
MD #42 Still Meadow	Madera	100	17.7	17.7	^
Maher Mutual Water Company	Kern	150	17.7	20.8	*
Cedar Valley Mutual Water Co.	Madera	137	17.6	18.6	^
First Mutual Water System	Kern	35	17.5	15.1	*
Sierra Co. W.W.D #1 Calpine	Sierra	225	17.0	14.1	*
Bar-Len MWC	San Bernardino	124	16.6	16.2	*

System Name	County	Pop. Served	2014-2015 Avg (ppb)	2011-2015 Avg (ppb)	
Winship Elementary School	Sutter	38	16.4	17.3	^
Lakeside School	Kern	800	16.3	16.9	*
Lanare Community Services Dist	Fresno	660	16.2	17.3	*
Delicato Vineyards	San Joaquin	25	15.6	18.3	^
Fourth Street Water System	Kern	56	15.6	14.0	*
Barry Elementary School	Sutter	650	15.2	15.3	*
Rand Communities Water District	Kern	450	15.1	15.3	*
US Army Fort Irwin	San Bernardino	16000	14.9	15.4	*
Pond Mutual Water Company	Kern	48	14.7	14.4	^
Alpaugh Community Services District	Tulare	1026	14.5	17.8	
Lands Of Promise Mutual Water Associatio	Kern	190	14.4	15.0	*
Pixley Public Util Dist	Tulare	3310	14.4	15.0	*
Caruthers Comm Serv District	Fresno	2497	14.3	15.4	*
Nord Road Water Association	Kern	32	14.2	15.0	*
Lancaster Park Mobile Home Park	Los Angeles	53	14.2	15.0	*
Mesa Del Toro MWC	Monterey	90	14.2	13.1	*
Green Run Mobile Estates	Stanislaus	100	14.0	15.1	*
Pleasant Valley Elementary	San Luis Obispo	100	13.8	14.1	*
Loch Haven Mutual Water Company	Sonoma	50	13.8	13.1	*
Gratton School	Stanislaus	110	13.5	13.5	*
Hillview Water Co-Raymond	Madera	290	13.4	17.8	
Mettler Valley Mutual	Los Angeles	100	13.0	13.1	*
Mobile Plaza Park	Stanislaus	125	13.0	12.7	*
Hilmar Cheese Company	Merced	1000	13.0	13.3	
North Fork Union School	Madera	350	12.9	12.4	*
Yosemite Forks Est Mutual	Madera	110	12.8	11.6	
MD #08 North Fork Water System	Madera	264	12.8	13.9	^
Keyes Community Services Dist.	Stanislaus	4891	12.3	12.8	*
Countryside Mobile Home Park	Stanislaus	60	12.1	12.5	*
Land Project Mutual Water Co.	Los Angeles	1500	12.1	13.5	*
El Adobe POA, Inc.	Kern	200	12.1	12.1	*
Island Union School	Kings	300	11.9	18.8	
Plumas Eureka CSD	Plumas	325	11.6	11.4	*
Kettleman City CSD	Kings	1450	11.4	12.0	*
Laguna Seca WC	Monterey	162	11.1	11.7	*
Los Molinos Comm. Services Dist.	Tehama	1500	11.1	9.0	
R.S. Mutual Water Company	Kern	67	11.0	11.1	*
Oasis Property Owners Association	Kern	100	10.9	10.8	^
Warner Unified School District	San Diego	250	10.9	11.4	^
MD #07 Marina View Heights	Madera	200	10.5	9.3	
Central Union Elementary	Kings	320	10.1	13.5	^

Note: Click on the hyperlink in the name of the system to view the state records for each water system.

** Indicates a system that has had annual concentrations averaging over the federal limit (10 ppb) each year 2011-2015*

^ Indicates that the 2011-2015 average includes years for which data was not available.

APPENDIX C:

Methods

This report is based on public data available from the California Environmental Protection Agency's State Water Resources Control Board (SWRCB) as of May 2016. We downloaded the SWRCB's Water Quality Analyses Database Files for 2011-2016 and identified public water systems that had arsenic concentrations that exceeded the 10 ppb Maximum Contaminant Level, targeting the systems with frequent exceedances between 2011 and 2015. The SWRCB database contained results for each water source used by a drinking water system, such as wells, treated or blended water, and standby wells that are only allowed to be used for a few days during a year. SWRCB warns users of its database that results in the database may not reflect the quality of water that systems actually served their customers.

Calculating average arsenic concentrations

- We calculated the average arsenic concentration from each individual water source at each water system using the sampling results available in SWRCB's database as of May 2016. Some sampling results from the end of 2015 may not have been available in the database at the time we downloaded the data in May.

- We reviewed each water system's source descriptions to determine which sources represented water served to consumers and whether the source should be included in the system-wide average arsenic concentration. For example, if the database showed that a system had two groundwater wells and a 'treated' source, we assumed that consumers would be served the treated source if results for that treated source were available each year. If the database listed a treated source in 2011, for example, but contained no data from that source for the following years, we excluded that source from the average because it was not clear if the system continued treating water for arsenic. If a system listed a source as inactive or as a 'standby' option, we excluded that source from the analysis because we could not determine when or if the water was used. We compared the selected sources with available Consumer Confidence Reports available through California's Drinking Water Watch system and narrative information in public SWRCB enforcement action documents to verify, to the extent possible, that the sources we selected represented water that was provided to consumers. If no information was available for a particular system, we relied on the

assumptions described above (i.e. inactive and standby sources were not used, treated sources were used instead of untreated sources when concentrations were available for each year). We did not include purchased water sources.

- After identifying individual sources, we calculated the system's annual average arsenic concentration using the annual average concentrations from each source. The average concentrations during the two-year period between 2014 and 2015 and the five year period between 2011 and 2015 are time-weighted average concentrations (i.e. we averaged the annual average concentrations from each year). This method is similar to how the California EPA's Office of Environmental Health Hazard Assessment calculated average concentrations at drinking water systems for use in it's 2014 CalEnviroScreen 2.0 tool, except we focused on annual average concentrations from 2011-2015, rather than a single average concentration from 2005-2013.

- We excluded entire systems from the analysis if a) they were inactive, b) the available data and source descriptions did not allow us to confidently assume that customers received the sampled water at their taps, and c) the average concentration over the most recent two years (2014-2015) fell below the MCL.

Mapping Public Water Systems

To map water system locations, we found the centroids of public water system boundaries from the California Environmental Health Tracking Program's Water Systems Geographic Reporting Tool, or Water Boundary Tool (WBT). For systems without boundaries in the WBT, we determined coordinates from the addresses in the SWRCB Water Quality Analysis database files and the California Drinking Water Watch system.

Notes

[1] Based on averages for 2014-2015. Numbers in this report from the California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed May, 2016.
[2] U.S. EPA (1998), Integrated Risk Information System, Inorganic Arsenic, available at http://www.epa.gov/iris/subst/0278.htm.
[3] Carolina L. Balazs, Rachel Morello-Frosch, Alan E. Hubbard and Isha Ray, "Environmental justice implications of arsenic contamination in California's San Joaquin Valley: a cross-sectional, cluster-design examining exposure and compliance in community drinking water systems," Environmental Health, 2012. Link: https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-11-84
[4] California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed May. Records show 51,306 residents receiving drinking water from 2011-2015 with annual averages of more than 10 ppb.

[5] California Code of Regulations Title 22, Chapter 15, Section 64463.4(b)] reglations require notifications for arsenic exceedances. The California State Water Resources Board template for the language in notifications to be sent out by local water utilities is available on state agency's website at: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Notices.shtml.

[6] California State Water Resources Control Board website, link: http://www.waterboards.ca.gov/drinking_water/certlic/device/watertreatmentdevices.shtml
[7] Ibid.
[8] Telephone interview with Connie R. Clendenan, CEO of the Valley Teen Ranch nonprofit organization, on August 1, 2016.
[9] Ibid.
[10] Texas Commission on Environmental Quality Notice of Drinking Water Arsenic Violation. Available at https://www.tceq.texas.gov/assets/public/permitting/watersupply/pdw/notices/chemical/arsenic.pdf
[11] Wisconsin Department of Natural Resources, Arsenic, Available at: http://dnr.wi.gov/topic/groundwater/arsenic/, accessed 3/7/2016.
[12] Florida Department of health, Brueau of Environmental Health, "Chemicals in Private Drinking Water Wells Fact Sheet- Arsenic," Available at: http://www.floridahealth.gov/environmental-health/drinking-water/_documents/arsenic-fs.pdf. Accessed 3/7/2016.
[13] See e.g. U.S. Department of Health and Human Services, (2004), "Health Consultation: Arsenic in Private Drinking Water Wells, Cornville, Yavapai County, Arizona," available at: http://www.atsdr.cdc.gov/HAC/pha/ArsenicInPrivate061504-AZ/ArsenicInPrivateHC061504.pdf, accessed 3/8/2016.
[14] Wasserman et al. (2014), A Cross-Sectional Study of Well Water Arsenic and Child IQ in Maine Schoolchildren, Environ Health 13:23-32.
[15] Based on averages for 2014-2015. Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016.
[16] Letter from Jared Blumenfeld, Director of EPA's Region 9 office, to California Department of Public Health Director Dr. Ron Chapman, April 19, 2013. Link: https://www3.epa.gov/region9/water/grants/pdf/CDPHNoticeofNonCompliance.pdf
[17] U.S. Centers for Disease Control, fact sheet on arsenic. Available at http://www.cdc.gov/biomonitoring/pdf/Arsenic_FactSheet.pdf
[18] U.S. EPA (1998), Integrated Risk Information System, Inorganic Arsenic, available at http://www.epa.gov/iris/subst/0278.htm.

[19] The EPA describes arsenic's cancer-causing potency with a 'slope factor' (because it describes the slope of the dose-response curve). The current EPA slope factor for arsenic is 1.5 per mg/kg-d. This number represents the risk that can be expected from consuming one milligram of arsenic per kilogram of body weight per day. The EPA also translates the slope factor into a 'drinking water unit risk' of 5×10^{-5} per µg/L. For carcinogens, the formal MCL Goal is always zero. Zero is an unattainable goal, so in most cases the EPA will reduce exposure to carcinogens to a level of 'acceptable risk,' something between 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000).[19] One way of looking at this range is to assume that risks less than 1 in 1,000,000 are always 'acceptable,' while risks greater than 1 in 10,000 never are. The risks of drinking arsenic at the MCL of 10 µg /L are much higher than 1 in 10,000.

[20] See, e.g., National Research Council, Critical Aspects of EPA's IRIS Assessment of Inorganic Arsenic – Interim Report, 82 – 83 (2013). For health endpoints like childhood IQ, the critical window of exposure is obviously much less, encompassing in utero development and childhood.

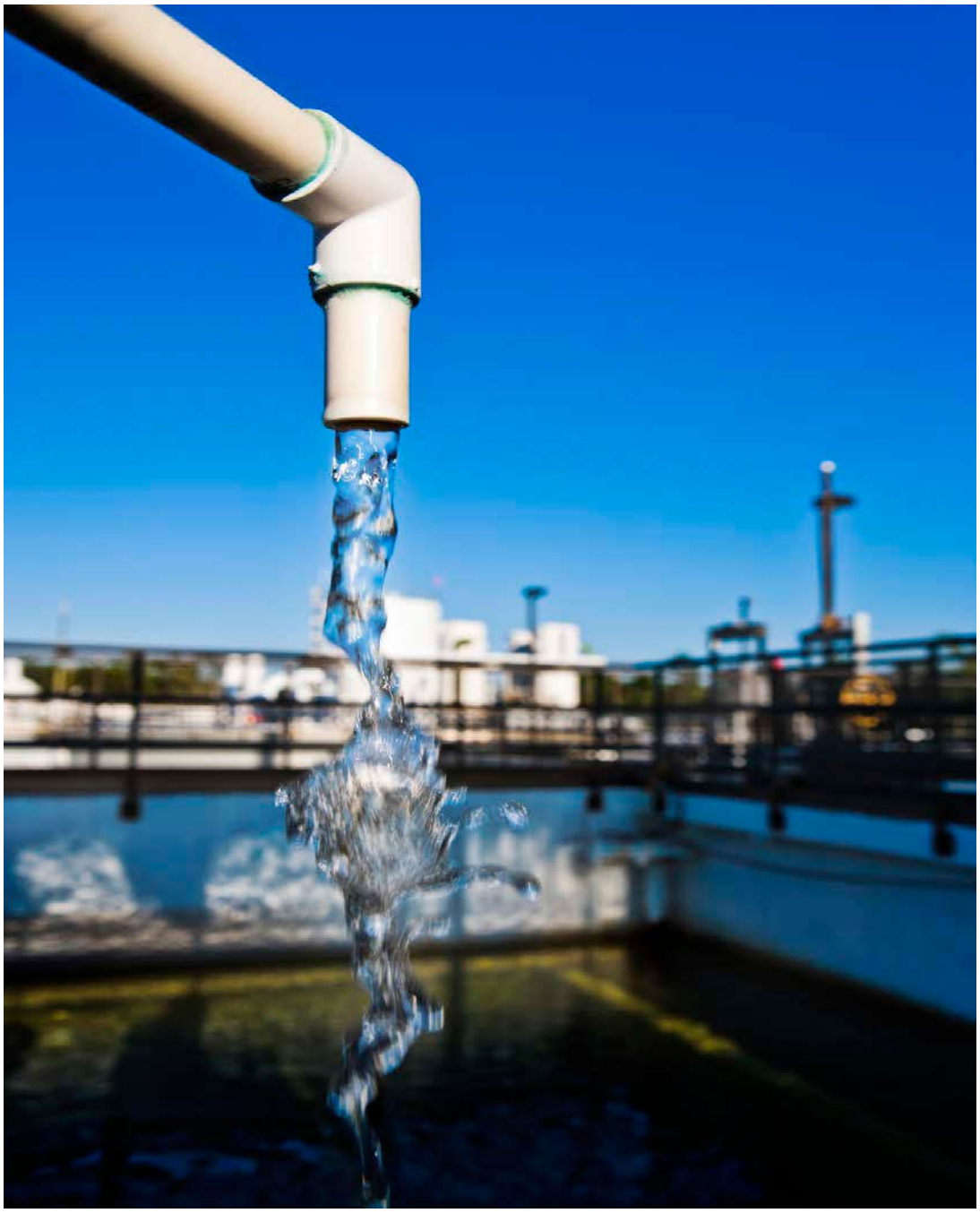
[21] EPA web page, "Drinking Water Arsenic Rule History," available at: https://www.epa.gov/dwreginfo/drinking-water-arsenic-rule-history.
[22] ATSDR (2007), Toxicological Profile for Arsenic; Grandjean and Landrigan (2014), Neurobehavioural Effects of Developmental Toxicity, *Lancet Neurol* 13:330-338.

[23] Wasserman et al. (2014), A Cross-Sectional Study of Well Water Arsenic and Child IQ in Maine Schoolchildren, *Environ Health* 13:23-32.

[24] Ibid.

[25] Ibid.
[26] California Water Resources Board report to the California legislature, "Communities that Rely on a Contaminated Groundwater Source for Drinking Water," January 2013. Link: http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/docs/ab2222.pdf
[27] California Water Resources Board report to the California legislature, "Communities that Rely on a Contaminated Groundwater Source for Drinking Water," January 2013. Link: http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/docs/ab2222.pdf
[28] Carolina L. Balazs and colleagues, "Environmental Justice Implications of Arsenic Contamination In California's San Joaquin Valley: a Cross-Sectional, Cluster-Design Examining Exposure and Compliance in Community Drinking Water Systems," Environmental Health, November 14, 2012. Link: https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-11-84
[29] Ibid.
[30] Letter from Jared Blumenfeld, Director of EPA's Region 9 office, to California Department of Public Health Director Dr. Ron Chapman, April 19, 2013. Link: https://www3.epa.gov/region9/water/grants/pdf/CDPHNoticeofNonCompliance.pdf
[31] Ibid.
[32] California Water Boards press release, "State Water Board, Drinking Water Revolving Fund Return to Safe Drinking Water Act Compliance," May 26, 2016. Link: http://www.waterboards.ca.gov/press_room/press_releases/2016/pr052616_cap_release.pdf
[33] Ibid.
[34] Ibid.
[35] Based on averages for 2014-2015. Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016.
[36] Ibid.
[37] Ibid.
[38] Ibid.
[39] Email from Andrew DiLuccia, Public Information Officer for the California State Water Resources Control Board, containing quote from Cindy Forbes, Deputy Director of the Division of Drinking Water, on August 8, 2016. Telephone interview with Forbes on August 4, 2016.
[40] California State Water Resources Board, template for public notification of Arsenic MCL Exceedance, Link: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Notices.shtml
[41] Ibid.
[42] Example of Consumer Confidence Report for a California system can be found on the state website: https://sdwis.waterboards.ca.gov/PDWW/JSP/WaterSystemDetail.jsp?tinwsys_is_number=370&tinwsys_st_code=CA&wsnumber=CA1000071#
[43] Carolina L. Balazs and Isha Ray, "The Drinking Water Disparities Framework: On the Origins and Persistence of Inequities in Exposure," American Journal of Public Health, April 2014, Vol 104, No. 4. Link: http://www.ncbi.nlm.nih.gov/pubmed/24524500.
[44] Ibid.
[45] Ibid.
[46] Ibid.
[47] 40 CFR 142.20(a)(2)
[48] Wasserman et al. (2014), A Cross-Sectional Study of Well Water Arsenic and Child IQ in Maine Schoolchildren, Environ Health 13:23-32.
[49] U.S. EPA public notification template on EPA website: https://www.epa.gov/dwreginfo/public-notification-templates-community-and-non-transient-non-community-water-systems
[50] Telephone interview on August 25, 2016 with Philip Dutton, engineer for Fresno County.
[51] California State Water Resources Control Board website, http://www.waterboards.ca.gov/drinking_water/certlic/device/watertreatmentdevices.shtml
[52] KFSN-TV, ABC-30 in Fresno, report "Kettleman City Residents Get Answers to Questions about Construction of Water Treatment Plant," August 31, 2016. Link: http://abc30.com/society/kettleman-city-residents-get-answers-to-questions-about-construction-of-water-treatment-plant/1493726/
[53] Ibid.

[54] Telephone interview on August 26, 2016, with Cheryl Sandoval, Supervising Environmental Health Specialist and Manager of Monterey County's drinking water program.
[55] Corral de Tierra Water Company 2013 Consumer Confidence Report, dated July 11, 2014.
[56] Ibid.
[57] Telephone interview on August 26, 2016, with Randy Hardenbrook, Director of the Quail Valley Water District.
[58] Ibid.
[59] Telephone interview on August 25, 2016, with Robert Johnson, President of the Shaver Lake Point 2 Mutual Water Company.
[60] Ibid.
[61] Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016.
[62] Telephone interview with Connie R. Clendenan, CEO of the Valley Teen Ranch nonprofit organization, on August 1, 2016.
[63] Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016
[64] Email from Whitney Meyer, Principal of the Washington School in Salinas, California, on August 1, 2016.
[65] Email from Robert Shemwell, Assistant Superintendent of Business Services of the Yuba City Unified School District, containing quote from Tom Butcher,Director of Maintenance and Facilities, on August 12, 2016.
[66] Email on August 24, 2016, from Liliana Stransky of the Kings County Department of Public Health.
[67] Email from Superintendent Charlotte Hines of the Island Union School in Lemoore, California, August 4, 2016.
[68] Email from Kenneth Drylie, Public Affairs Specialist at Fort Irwin, containing quotes from Muhammad A. Bari, Director Public Works at the forst, on August 11, 2016.
[69] Email from Kylie Barnett, Director Public Relations at Delicato Family Vineyards, August 10, 2016.



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From:	Ben King
To:	Mary Fahey
Cc:	Gosselin, Paul; Buck, Christina; Ben King
Subject:	FW: Hydrogeology of the Sutter Basin, California 1971
Date:	Monday, November 18, 2019 2:44:12 PM
Attachments:	George Curtin Sutter Basin.pdf USGS Sacramento Valley Tectonism.pdf

---

Hi Mary,

Here is the cite of the first paragraph of the Abstract for Hydrogeology of the Sutter Basin by George Curtin:

"***A mound of saline water exists in continental sediments between two fresh water rivers in the Sutter Basin of the Sacramento Valley, California. This saline water has moved from the marine sediments, at depth, upward along the Sutter Basin Fault and then through 2,000 feet of alluvium."***

I have also attached the USGS Sacramento Valley Tectonism Study published in 1987. This USGS report explains the faults surrounding the ancient Sutter Buttes volcano and the fact that the faults are still active.

As I mentioned, I am concerned about the potential for further later movement of the salt water northward towards the Butte Sink that may be cause by future groundwater substitution on east side of the Sacramento River near Colusa. As you know Colusa, Grimes, Sutter and Meridian use groundwater. The other issue that came to my mind was the potential for further deterioration due to future earthquake activity.

Perhaps – this area might be a good candidate for an Aerial mapping if the mapping could detect higher chloride levels in the groundwater?

Thanks again

Ben King

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Orchard Irrigation in Sutter-Yuba Area

STATE OF CALIFORNIA
EARL WARREN
GOVERNOR

PUBLICATION OF
STATE WATER RESOURCES BOARD

Bulletin No. 6

SUTTER-YUBA COUNTIES INVESTIGATION

September, 1952

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LETTER OF TRANSMITTAL

EARL WARREN
GOVERNOR



STATE OF CALIFORNIA
STATE WATER RESOURCES BOARD
PUBLIC WORKS BUILDING
SACRAMENTO 5, CALIFORNIA

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A. D. EDMONSTON, STATE ENGINEER
SECRETARY

August 27, 1952

ADDRESS ALL COMMUNICATIONS TO THE SECRETARY

HONORABLE EARL WARREN, *Governor, and*
Members of the Legislature of
the State of California

GENTLEMEN: I have the honor to transmit herewith Bulletin No. 6 of the State Water Resources Board, entitled "Sutter-Yuba Counties Investigation," as authorized by Chapter 1514, Statutes of 1945, as amended.

Under provisions of the cited statute, an agreement dated October 7, 1947, was entered into between the State Water Resources Board, the Counties of Sutter and Yuba, and the Department of Public Works acting through the agency of the State Engineer. The agreement provided for

> ". . . investigation and report on the underground water supply of the valley floor in the Counties of Sutter and Yuba, including quality, replenishment and utilization thereof, and, if possible, a method or methods of solving the problems involved . . .",

and authorized funds to meet the costs of the investigation for one year. A supplemental agreement executed by the same parties on December 3, 1948, authorized funds to complete the investigation and report.

The Sutter-Yuba Counties Investigation was conducted and Bulletin No. 6 was prepared by the Division of Water Resources of the Department of Public Works, under the direction of the State Water Resources Board. Funds to meet the cost of investigation and report were provided as follows: State of California (State Water Resources Board), $20,000; County of Sutter, $10,000; and County of Yuba, $10,000. Additional funds provided by the Legislature have been expended by the State Water Resources Board in connection with the current State-Wide Water Resources Investigation, certain results of which were used in connection with the Sutter-Yuba Counties Investigation.

Bulletin No. 6 contains an inventory of the underground and surface water resources of the valley floor in the Counties of Sutter and Yuba, estimates of present and probable ultimate water utilization, estimates of present and probable ultimate supplemental water requirements, and preliminary plans and cost estimates for water development works.

Very truly yours,

C. A. Griffith
Chairman

ACKNOWLEDGMENT

Valuable assistance and data used in the investigation were contributed by agencies of the Federal Government, cities, counties, public districts, and by private companies and individuals. This cooperation is gratefully acknowledged.

Special mention is also made of the helpful cooperation of the Boards of Supervisors of the Counties of Sutter and Yuba, the Sutter County Water Council, the Yuba County Water Development Association, the Yuba County Farm Advisor, the California Water Service Company, and the Pacific Gas and Electric Company.

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CHAPTER I

INTRODUCTION

In common with many other parts of California, the area under this investigation has recently experienced an increase in water utilization, and as a result is confronted with a need for more complete conservation of its water resources. An accelerated increase in ground water use in recent years, combined with progressive lowering of pumping levels and deterioration in quality of water at a number of wells, has brought about local concern regarding the adequacy of the ground water resources of Sutter and Yuba Counties.

AUTHORIZATION FOR INVESTIGATION

In consideration of the adverse ground water situation in Sutter and Yuba Counties, members of the Sutter County Water Council and the Yuba County Water Development Committee appeared before the State Water Resources Board at Sacramento on August 1, 1947, and proposed a state-county cooperative survey of ground water supplies of valley floor lands of the two counties. The Board referred the request to the State Engineer for preliminary examination and report on the need for such an investigation, and an estimate of its scope, duration, and cost.

The State Water Resources Board on September 5, 1947, approved a recommendation by the State Engineer, based on findings of the preliminary examination, for a two-year cooperative investigation, and authorized negotiation of an agreement with local agencies. The agreement, between the State Water Resources Board, the Counties of Sutter and Yuba, and the State Department of Public Works acting through the agency of the State Engineer, was executed on October 7, 1947. It provided that the work under the agreement "shall consist of investigation and report on the underground water supply of the valley floor lands in the Counties of Sutter and Yuba, including quality, replenishment and utilization thereof, and, if possible, a method or methods of solving the problems involved." This agreement authorized the provision of funds to meet the costs of investigation for one year. A supplemental agreement executed by the same parties on December 3, 1948, authorized funds to complete the investigation and report.

Funds to meet the costs of the investigation and report to the extent of $40,000 were provided as follows: State of California (State Water Resources Board), $20,000; County of Sutter, $10,000; and County of Yuba, $10,000. Additional funds have been expended in investigation of the Sutter-Yuba Area by the State Water Resources Board in connection with the current State-wide Water Resources Investigation, certain results of which have been used in connection with the Sutter-Yuba Counties Investigation.

Copies of the two agreements between the State Water Resources Board, the Counties of Sutter and Yuba, and the Department of Public Works, are included in Appendix A.

RELATED INVESTIGATIONS AND REPORTS

The following reports of prior investigations, containing information pertinent to evaluation of ground water problems in Sutter and Yuba Counties, were reviewed in connection with the current investigation:

"Soil Survey of the Marysville Area, California, 1909," by A. T. Strahorn, W. W. Mackie, L. C. Holmes, H. L. Westover, and Cornelius Van Duyne. Bureau of Soils, United States Department of Agriculture. October 25, 1911.

"Geology and Ground Water Resources of the Sacramento Valley, California," by Kirk Bryan. United States Geological Survey, Water-Supply Paper 495. 1923.

"Preliminary Report on the Proposed Sutter Irrigation District," by Milo B. Williams, Consulting Engineer. Typewritten. March 12, 1931.

"Report on Ground Water Conditions in the Proposed Sutter Irrigation District," by S. T. Harding, Consulting Engineer. Unpublished. November, 1931.

"Sacramento River Basin," Bulletin No. 26, Division of Water Resources, California State Department of Public Works. 1931.

"Memorandum on Ground Water Conditions in Area of Proposed Sutter Irrigation District During 1932," by S. T. Harding, Consulting Engineer. Unpublished. February, 1933.

"Sacramento Valley Water Investigations — Agricultural Aspects," Bureau of Agricultural Economics, United States Department of Agriculture. Mimeographed. March, 1944.

"Salt-Balance Conditions of Reclamation District No. 1500 in Sutter Basin for the Year Ending December 31, 1946," by L. V. Wilcox. Mimeographed. June, 1947.

"Salt-Balance Conditions of Reclamation District No. 1500 in Sutter Basin for the Year Ending December 31, 1947," by L. V. Wilcox. Mimeographed. April, 1948.

"Water Resources of California," Bulletin No. 1, California State Water Resources Board. 1951.

The Division of Water Resources is presently conducting surveys and studies for the State-wide Water Resources Investigation, authorized by Chapter 1541, Statutes of 1947. This investigation, under direction of the State Water Resources Board, has as its objective the formulation of The California Water Plan for full conservation, control, and utilization of the State's water resources to meet present and future water needs for all beneficial purposes and uses in all parts of the State insofar as practicable. Surveys and studies are also being conducted by the Division of Water Resources for the Survey of Mountainous Areas, authorized by Chapter 30, Statutes of 1947. This investigation, which is coordinated with the state-wide investi-

gation, has as its primary objective the determination of probable ultimate water requirements of certain counties of the Sierra Nevada, and the formulation of plans for projects which will meet those requirements. Results of both of the foregoing investigations will have direct bearing on solutions to the water problems of the Sutter-Yuba Area, particularly with regard to plans to meet supplemental water requirements of the area under ultimate conditions of cultural development.

SCOPE OF INVESTIGATION AND REPORT

It has been stated that under provisions of the authorizing agreements the general objectives of the Sutter-Yuba Counties Investigation included investigation and study of the underground water supply of valley floor lands in the investigational area, including quality, replenishment and utilization thereof, and, if possible, a method or methods of solving the water problems involved. In attaining these objectives it was necessary that the scope of the investigation include full consideration of surface as well as ground water supplies, and that it involve determination of present and ultimate water utilization and supplemental water requirements.

Field work in the investigational area, and office studies, as authorized by the initial and supplemental cooperative agreements, commenced in October, 1947, and continued into 1952.

In the course of the investigation, available precipitation and stream flow records were collected and compiled in order to evaluate water supplies available to the investigational area. Five new stream gaging stations were installed and maintained to supplement the available hydrographic data. These stations were on Pleasant Grove Creek at Lincoln Road, Auburn Ravine at Highway 99E, Coon Creek at Highway 99E, Dry Creek near Waldo, and South Honcut Creek at La Porte Road.

In order to determine ground water storage capacity and yield, geologic features of the ground water basin underlying the investigational area were investigated and reported on by the Ground Water Branch of the United States Geological Survey, under terms of a cooperative agreement with the Department of Public Works. This survey included the collection and study of about 700 well logs throughout the area. The report of the Geological Survey is included as Appendix B.

The effects of draft on and replenishment of the ground water basin were determined by measurements of static ground water levels made at about 850 wells during each spring and fall of the period of investigation. These wells were chosen to form a comprehensive measuring grid over the entire area. In addition, measurements to determine monthly fluctuations of water levels were made at approximately 90 control wells.

Present land use in the investigational area was determined by a complete survey of all culture on valley floor lands. This survey was conducted in 1948, and checked in 1949 to determine changes. The total area surveyed was about 327,000 acres. The cultural survey data were used in conjunction with available data on unit water use to determine total present water utilization in the investigational area.

In order to determine future water utilization, all valley floor lands were classified with regard to their suitability for irrigated agriculture. This involved collection, field checking, and re-evaluation of land classification data from the United States Bureau of Reclamation, supplemented by data from field surveys conducted by the Division of Water Resources.

Current irrigation practices in the investigational area were surveyed in order to determine unit application of water to important crops on lands of various soil types. During the 1948 irrigation season records of application of water were collected at 35 plots, and during the following season at 21 plots. The data collected included records of pump discharge, acreage served, crops irrigated, number and period of irrigations, and amount of water applied.

Studies were made of the mineral quality of surface and ground waters, in order to evaluate their suitability for irrigation use, and to determine the cause of degradation in their mineral quality during recent years. Data used in these studies included some 200 partial and 38 complete mineral analyses of ground water from wells. In addition, a large number of analyses of surface water supplies, covering the period since 1943, were collected and studied.

Field reconnaissance surveys, including geologic examinations, were made to locate and evaluate possible dam and reservoir sites for conservation of surface runoff. Reconnaissance surveys were also made of possible routes for conveyance of water to areas of use.

Results of the Sutter-Yuba Counties Investigation are presented in this report in the four ensuing chapters. Chapter II, "Water Supply," contains evaluations of precipitation, surface and subsurface inflow and outflow, and imports of water. It also includes results of investigation and study of the ground water basin, and contains data regarding mineral quality of surface and ground waters. Chapter III, "Water Utilization and Supplemental Requirements," includes data and estimates of present and probable ultimate land use and water utilization, and contains estimates of present and probable ultimate supplemental water requirements. It also includes available data on demands for water with respect to rates, times, and places of delivery. Chapter IV, "Plans for Water Development," describes preliminary plans for conservation and utilization of available water supplies to meet supplemental water requirements, including operation and yield studies, design considerations and criteria, and

cost estimates. Chapter V, "Conclusions and Recommendations," includes conclusions and recommendations resulting from the investigation and studies.

AREA UNDER INVESTIGATION

The area under investigation comprises those portions of the valley floor of Sutter and Yuba Counties which are in whole or in part served by ground water, and has been designated the "Sutter-Yuba Area." It includes the portions of Sutter County situated east of Feather River, Sutter By-pass, and a north-south line through the center of Sutter Buttes. It includes the portion of Yuba County lying on the Sacramento Valley floor from Feather River on the west to a line marking the approximate limit of the ground water service area near the base of the foothills on the east.

The Sutter-Yuba Area is situated on the east side of the central portion of the Sacramento Valley, and its southern boundary is about 10 miles north of the City of Sacramento. The area extends north and south for a distance of about 39 miles, varying in width from about 6 to about 19 miles. Its location is indicated on Plate 1, "Location of Sutter-Yuba Area," and the area is shown in greater detail on Plate 2, entitled "Hydrologic Zones and Organized Water Agencies, 1952."

In order to facilitate reference to its several parts, the Sutter-Yuba Area was divided into four principal zones, based on geographical considerations and on respective types of water service and sources of water supply. These were designated "West Side Zone," "Northeast Zone," "East Central Zone," and "South Side Zone," and are shown on Plate 2. The West Side Zone embraces the area between the Butte-Sutter county line and Nicolaus, and west of Feather River. The Northeast Zone consists of lands between Honcut Creek and Yuba River, and east of Feather River. Similarly, the East Central Zone consists of lands between the Yuba and Bear Rivers, and east of Feather River. The South Side Zone comprises those lands lying between Bear River and the Sutter-Sacramento county line, and east of the Feather and Sacramento Rivers. As shown on Plate 2, the West Side Zone was further subdivided into the area generally devoted to orchards and served by ground water, herein designated the "Peach Bowl," and the remainder of the zone which is largely served by surface water.

Drainage Basin

The eastern portion of the Sutter-Yuba Area comprises a gently rolling plain, which merges into nearly flat land over a large part of the central and western portions. The general ground surface slopes gently from east to west. Included valley floor lands lie below an elevation of about 100 feet. The Sutter Buttes, located in the northwest corner of the area, rise to 2,132 feet above sea level.

All watersheds on the west slope of the Sierra Nevada that head between Donner and Fredonyer Passes are tributary to the Sutter-Yuba Area. Their combined drainage areas total about 5,600 square miles. In order of importance, the principal tributary stream systems are those of the Feather, Yuba, and Bear Rivers. Minor tributary streams include Honcut, Dry, Coon, and Pleasant Grove Creeks, and Markham and Auburn Ravines. The extent of the various drainage basins is shown in the following tabulation:

Drainage basin	*Area, in square miles*
Feather River, above Oroville gaging station	3,611
Yuba River, above Smartville gaging station	1,194
Bear River, above gaging station near Wheatland	294
Minor streams, above valley floor, from Wyman Ravine to Pleasant Grove Creek	500
TOTAL	5,600

The tributary watersheds are in a zone of relatively heavy precipitation, and their aggregate mean seasonal natural runoff during the 53-year period from 1894-95 to 1946-47 is estimated to have approximated 1,360 acre-feet per square mile.

The Feather River traverses and roughly bisects the Sutter-Yuba Area from north to south, and joins the Sacramento River near Verona. The Yuba and Bear Rivers are tributary to the Feather within this reach, as are Honcut Creek and Nigger Jack Slough. Reeds, Hutchinson, and Dry Creeks, drain the East Central Zone and are tributary to Bear River within the area. Coon and Pleasant Grove Creeks and Markham and Auburn Ravines drain into Sacramento River near Verona by way of the Cross Canal. Gilsizer Slough, which flows more or less parallel to the Feather River through the West Side Zone and into Sutter By-pass, and Nigger Jack Slough are important as natural surface drains. Wadsworth Canal and its tributaries, together with other minor channels, drain the portion of the West Side Zone outside the Peach Bowl, discharging into Sutter By-pass.

Climate

The climate of the Sutter-Yuba Area is characterized by dry summers with high daytime temperatures and warm nights, and wet winters with moderate temperatures. More than 80 percent of the precipitation occurs during the five-month period from November to March, inclusive. The growing season is long, the 40-year recorded average for Marysville, centrally located in the area, being 273 days between killing frosts. Temperatures at Marysville have ranged from 16° F. to 118° F., and the monthly average for the period from 1871 to 1948 ranges from 46.9° F. in January to 79.3° F. in July.

Geology

The geologic formations of the Sutter-Yuba Area include pre-Cretaceous metamorphic and igneous rocks

of the Sierra Nevada block, which extends beneath the valley fill, overlain principally by Tertiary sedimentary formations derived from these and other rocks which are exposed in the Sierra Nevada to the east. The sedimentary rocks are of both marine and continental origin and are frequently interbedded with tuff-breccias. Volcanic rocks are also represented in the area in and about the Sutter Buttes, which are erosional remnants of an extinct Pliocene volcano. Only the sedimentary rocks can be considered as being water-bearing to any appreciable degree. The principal aquifers are composed of continental sediments of Pleistocene and Recent age. These consist of as much as 100 feet of Pleistocene sands and gravels overlain by up to 125 feet of Recent alluvial fan, flood plain, and stream channel deposits.

Soils

Soils of the Sutter-Yuba Area vary in their chemical and physical properties in accordance with differences in parent material, drainage, and age or degree of development since their deposition. The soils may be divided into two broad groups: (1) those derived from recent alluvial depositions, and (2) those derived from old alluvial fans or terraces. The first group may be further divided into stream bottom soils and basin soils.

Stream bottom soils occupy the flood plains immediately adjacent to stream channels generally throughout the area. They consist of unmodified to slightly modified alluvial deposits. These soils are highly productive and suited to a wide variety of crops, and have the highest agricultural value.

Basin soils of the Sutter-Yuba Area occupy large flat basin-like areas in the southwest portion of the West Side Zone and western portion of the South Side Zone. These basin soils are derived largely from fine-grained depositions by flood flows, and have developed under poor drainage conditions. Those areas of basin soils that have been drained and protected by levees from flooding are suitable for production of rice and other shallow-rooted crops.

Soils that have developed from old alluvial fans or terraces occupy most of the remainder of the Sutter-Yuba Area. These soils have undergone considerable physical and chemical change since their deposition and are entirely underlain by hardpan. They are restricted in their agricultural use by the depth of soil over the hardpan, and are only suited to the production of shallow-rooted crops.

Present Development

Development of the eastern portion of the Sacramento Valley has centered in the Sutter-Yuba Area since the first settlements early in the Nineteenth Century. Marysville became an important transportation center during the Gold Rush period, being the head of river traffic to the mining areas. The Counties of Sutter and Yuba embrace a rich agricultural region, and both irrigation and dry farming are of major importance.

The 1950 federal census showed that the population of Sutter County was 26,140, and that of Yuba County 24,240. The principal urban centers, Marysville and Yuba City, are situated only about two miles apart, near the confluence of the Yuba and Feather Rivers, and account for some 31 percent of the total population of the two counties. The 1950 census enumerated 7,856 persons in Yuba City, while 7,777 were counted in Marysville. Wheatland and Live Oak are the largest of a number of small communities, and the rural population is distributed generally throughout the area.

Agricultural development in the Sutter-Yuba Area is said to have begun with the growing of grain about 1845 near the site of Captain John A. Sutter's Hock Farm, south of Yuba City. Early agriculture on the valley floor was stimulated by the influx of settlers during and after the gold rush, but for many years was largely restricted to the growing of dry-farmed grain crops and stock raising. By 1865, a large portion of the area was given over to the production of wheat. Irrigation developed slowly, but it is probable that the first lands on the east side of the Sacramento Valley to receive irrigation water were near the confluence of Honcut Creek and Feather River. Diminishing profits from grain farming, together with the development of more satisfactory pumping plants, gave impetus to the increase in irrigated acreage after 1910. The transition from dry farming to irrigated cropping has continued to this time.

A survey conducted in 1949 as a part of the current investigation showed that irrigated lands in the Sutter-Yuba Area totaled about 149,000 acres, while approximately 140,000 acres were dry-farmed or fallow. Principal irrigated crops, in order of acreage devoted to each crop, were deciduous orchard consisting largely of peaches, and rice, permanent pasture, beans, and alfalfa. Principal dry-farmed crops were barley and wheat.

Industry in the Sutter-Yuba Area is supported largely by agricultural production. About 100 plants are operated during the harvest seasons to can and dehydrate fruits and vegetables, and to dry fruits, nuts, rice, and seed crops. Packing houses for packing fresh fruits and melons, and cold storage and refrigeration plants, have also been established. Several lumber reprocessing and molding plants near Marysville produce finished lumber and by-products. Sand and gravel works supply local demand for aggregates, while concrete pipe, generally used in irrigation distribution systems, is manufactured locally. A large gold dredging field is situated near the edge of the valley floor at Hammonton, south of Yuba River. Electric energy is available from nearby hydroelectric installations.

Water service agencies in the Sutter-Yuba Area are described in Chapter III. However, many public agencies have been organized in the area to deal with the problems of land reclamation and drainage. The provisions of California reclamation district laws have been used extensively to effect the unwatering of low lands and their protection from overflow. Active reclamation districts in the area and data concerning them are listed in the following tabulation:

Reclamation district	*Year organized*	*County*	*Gross area of district, in acres*
No. 10	1913	Yuba	11,300
No. 777	1907	Sutter	12,500
No. 784 (Plumas Lake)	1908	Yuba	19,600
No. 803 (Rideout)	1909	Sutter	2,000
No. 817	1910	Yuba	3,120
No. 823 (Marcuse)	1911	Sutter	2,800
No. 1000 (Natomas)	1911	Sutter, Sacramento	55,100
No. 1001 (Natomas)	1911	Sutter, Placer	31,200
No. 2054	1921	Sutter, Butte	12,900
No. 2056	1921	Sutter, Butte	9,100
No. 2066 (Abbott Lake)	1924	Sutter	600

Portions of Sutter and Yuba Counties are within the boundaries of the Sacramento and San Joaquin Drainage District, which comprises practically all swamp and overflow lands of both the Sacramento and San Joaquin Valleys. This large district was formed in 1911. Two levee districts in Sutter County, organized during the period of early agricultural development, built levees to protect eastern Sutter Basin lands from floods and overflow of Feather River. These districts, Sutter County Levee District No. 1, organized in 1873, and Sutter County Levee District No. 2, organized in 1879, contain 44,000 and 17,500 acres, respectively. The Sutter By-pass, and levees of the Feather and Yuba Rivers, are parts of the Sacramento River Flood Control Project. The function of Sutter By-pass is to receive and convey excess flood waters of Sacramento River and Butte Basin through Sutter Basin.

Areas included within the boundaries of the foregoing agencies, together with water service agencies in the Sutter-Yuba Area, are shown on Plate 2.

CHAPTER II

WATER SUPPLY

The sources of water supply of the Sutter-Yuba Area are direct precipitation on overlying lands, tributary surface and subsurface inflow, and imports by surface canals of water for irrigation. The water supply of the area is considered and evaluated in this chapter under the general headings "Precipitation," "Runoff," "Imported and Exported Water," "Underground Hydrology," and "Quality of Water."

The following terms are used as defined in connection with the discussion of water supply in this report:

Annual—This refers to the 12-month period from January 1st of a given year through December 31st of the same year, sometimes termed the "calendar year."

Seasonal—This refers to any 12-month period other than the calendar year.

Precipitation Season—This refers to the 12-month period from July 1st of a given year through June 30th of the following year.

Runoff Season—This refers to the 12-month period from October 1st of a given year through September 30th of the following year.

Investigational Seasons—This is used in reference to the two runoff seasons of 1947-48 and 1948-49, during which most of the field work on the Sutter-Yuba Counties Investigation was performed.

Mean Period—This is used in reference to periods chosen to represent conditions of water supply and climate over a long period of years.

Base Period—This is used in reference to periods chosen for detailed hydrologic analysis because prevailing conditions of water supply and climate were approximately equivalent to mean conditions, and because adequate data for such hydrologic analysis were available.

In studies for the current State-wide Water Resources Investigation it was determined that the 50 years from 1897-98 to 1946-47, inclusive, constituted the most satisfactory period for estimating mean seasonal precipitation generally throughout California. Similarly, the 53-year period from 1894-95 to 1946-47, inclusive, was selected for determining mean seasonal runoff. In studies for the Sutter-Yuba Area, conditions during these periods were considered representative of mean conditions of water supply and climate.

Studies were made to select a base period for hydrologic analysis of the Sutter-Yuba Area during which conditions of water supply and climate would approximate mean conditions, and for which adequate data on inflow, outflow, and ground water levels would be available. It was determined that the nine-year period from 1939-40 to 1947-48, inclusive, was the most satisfactory in this respect. Conditions during this chosen base period so closely approached conditions prevailing during the mean period that they were considered to be equivalent. For this reason, determined relationships between base period water supply and present and probable ultimate water utilization were assumed to be equivalent to corresponding relationships which might be expected under mean conditions of water supply and climate.

PRECIPITATION

The Sutter-Yuba Area lies within the southern fringe of storms which periodically sweep inland from the North Pacific during winter months. Although the rainfall resulting from these storms is moderate on the average, direct precipitation provides a substantial portion of the water supply of the area.

Precipitation Stations and Records

Fifteen precipitation stations in or adjacent to the Sutter-Yuba Area have unbroken records of 10 years duration or longer. These stations are fairly well distributed areally and their records were sufficient to provide an adequate pattern of precipitation. All of the records of precipitation have been published in bulletins of the United States Weather Bureau, with exception of the record obtained by the Sutter Basin Corporation for the station at Robbins. The Robbins record is included as Appendix C to this report. Locations of the precipitation stations are shown on Plate 3, "Lines of Equal Mean Seasonal Precipitation," with map reference numbers corresponding to those utilized in State Water Resources Board Bulletin No. 1, "Water Resources of California." The stations and map reference numbers are listed in Table 1, together with elevations of the stations, periods and sources of record, and mean, maximum, and minimum seasonal precipitation. In those instances where it was necessary, precipitation records were extended to cover the 50-year mean period by comparison with records of nearby stations having records covering this period.

Precipitation Characteristics

Because of the uniformity of the general precipitation pattern in the Sutter-Yuba Area, as indicated on Plate 3, and the central location of Marysville, precipitation at Marysville was considered to be fairly representative of rainfall over the area. A record of precipitation at Marysville was available from a United States Weather Bureau station maintained since

TABLE 1

MEAN, MAXIMUM, AND MINIMUM SEASONAL PRECIPITATION AT SELECTED STATIONS IN OR NEAR SUTTER-YUBA AREA

Map reference number	Station	Elevation, in feet	Period of record	Source of record	Mean seasonal precipitation, in inches	Maximum and minimum seasonal precipitation	
						Season	Inches
5-69	Biggs	98	1899-1916	USWB	*21.04	1913-1914 1911-1912	21.20 12.29
5-76	Camptonville	2,850	1907-1951	USWB	*64.17	1908-1909 1923-1924	108.30 30.13
5-75	Chute Camp.	1,250	1907-1940	USWB	*54.74	1937-1938 1923-1924	78.17 23.87
5-73	Colgate	700	1907-1951	USWB	*39.92	1940-1941 1923-1924	56.61 18.51
5-82	Colusa	60	1871-1951	USWB	15.89	1940-1941 1938-1939	31.65 6.78
5-74	Dobbins	1,650	1904-1946	USWB	*41.03	1906-1907 1923-1924	64.28 20.13
5-70	Gridley	97	1884-1951	USWB	24.00	1889-1890 1897-1898	47.00 12.34
5-97	Marysville	61	1871-1951	USWB	20.68	1889-1890 1884-1885	38.91 8.15
5-107	Nicolaus	46	1912-1951	USWB	*18.32	1940-1941 1912-1913	32.46 7.07
5-62	Oroville	250	1884-1951	USWB	27.27	1889-1890 1930-1931	49.64 14.71
5-71	Palermo	213	1891-1914	USWB	*23.29	1904-1905 1897-1898	32.77 10.94
5-106	Robbins	20	1926-1951	SBCo	*16.81	1940-1941 1930-1931	31.93 9.51
5-120	Rocklin	239	1870-1951	USWB	23.14	1906-1907 1923-1924	38.63 10.42
5-131	Sacramento	69	1849-1951	USWB	16.37	1852-1853 1850-1851	36.35 4.71
5-98	Wheatland	84	1887-1945	USWB	*20.84	1889-1890 1887-1888	33.69 11.07

* Estimated.
SBCo—Sutter Basin Corporation.
USWB—United States Weather Bureau.

1871-72. Recorded seasonal precipitation at this station is presented in Table 2 and shown on Plate 4, "Recorded Seasonal Precipitation at Marysville, 1871-72 Through 1950-51."

Precipitation in the Sutter-Yuba Area consists almost entirely of rainfall and snowfall is rare. It increases generally from west to east, as is shown on Plate 3, except on the Sutter Buttes where a sharp rise in elevation probably results in relatively heavy precipitation. Mean seasonal depth of precipitation ranges from about 18 inches along the western boundary of the area to about 23 inches at its extreme easterly limit. At Nicolaus in the southern portion of the area mean seasonal precipitation is about 18 inches, whereas at Biggs, about eight miles north of the area, it is approximately 21 inches.

Precipitation varies over wide limits from season to season, ranging from less than 40 percent of the seasonal mean to nearly 200 percent. Maximum seasonal precipitation at Marysville occurred in 1889-90 when 38.91 inches of rain were recorded. In 1884-85, the minimum season at this station, precipitation was only 8.15 inches. Long-term trends in precipitation in the Sutter-Yuba Area are indicated on Plate 5, "Accumulated Departure From Mean Seasonal Precipitation at Marysville."

More than 80 percent of the seasonal precipitation in the Sutter-Yuba Area occurs during the five months from November through March on the average, and the summers are dry. Mean monthly distribution of precipitation as recorded at Marysville is presented in Table 3.

TABLE 2

RECORDED SEASONAL PRECIPITATION AT MARYSVILLE 1871-72 THROUGH 1950-51

(In inches)

Season	Precipitation	Season	Precipitation	Season	Precipitation
1871-1872	21.57	1899-1900	28.07	1929-1930	20.81
73	13.10	01	24.02	31	12.40
74	27.74	02	20.54	32	17.35
		03	21.26	33	12.64
1874-1875	13.68	04	22.50	34	14.10
76	17.36				
77	12.16	1904-1905	26.50	1934-1935	23.33
78	23.74	06	27.76	36	22.79
79	15.76	07	32.25	37	21.88
		08	16.91	38	28.26
1879-1880	18.93	09	20.72	39	9.76
81	17.43				
82	14.38	1909-1910	19.48	1939-1940	27.32
83	15.25	11	26.42	41	33.28
84	15.28	12	11.76	42	29.13
		13	13.76	43	21.43
1884-1885	8.15	14	28.54	44	20.02
86	22.27				
87	12.86	1914-1915	27.57	1944-1945	19.72
88	14.28	16	21.69	46	17.33
89	23.28	17	16.17	47	15.21
		18	12.56	48	17.60
1889-1890	38.91	19	21.52	49	15.51
19	15.72				
92	18.99	1919-1920	12.90	1949-1950	16.96
93	22.93	21	25.08	51	23.21
94	10.27	22	21.02		
		23	22.20	Average for 9-year base period, 1939-40 through 1947-48: 22.31	
1894-1895	26.83	24	11.53		
96	19.61				
97	17.77	1924-1925	25.82	Mean for 50-year period, 1897-98 through 1946-47: 20.68	
98	12.74	26	21.26		
99	16.53	27	26.59		
		28	17.28	Average for 80-year period of record, 1871-72 through 1950-51: 19.82	
		29	14.04		

TABLE 3

MEAN MONTHLY DISTRIBUTION OF PRECIPITATION AT MARYSVILLE

Month	Precipitation		Month	Precipitation	
	In inches	In percent of seasonal total		In inches	In percent of seasonal total
July	0.00	0.0	January	4.16	20.1
August	0.00	0.0	February	3.97	19.2
September	0.27	1.3	March	2.67	12.9
October	0.93	4.5	April	1.34	6.5
November	2.23	10.8	May	0.74	3.6
December	4.14	20.0	June	0.23	1.1
			TOTALS	20.68	100.0

Quantity of Precipitation

The mean seasonal quantity of precipitation in the Sutter-Yuba Area was estimated by plotting recorded or estimated mean seasonal depth of precipitation at stations in or near the area on a map. Lines of equal mean seasonal precipitation, or isohyets, were then drawn, as are shown on Plate 3. By planimetering the areas between these isohyets, the weighted mean seasonal depth and total quantity of precipitation were estimated.

In order to determine seasonal depth and quantity of precipitation during the base period and investigational seasons, the foregoing estimates for the mean period were adjusted on the basis of recorded precipitation at Marysville. The results of the estimates are presented in Table 4, which also shows the precipitation index for the base period and each of the investigational seasons. The term "precipitation index" refers to the ratio of the amount of precipitation during a given season to the mean seasonal amount, and is expressed as a percentage.

TABLE 4

ESTIMATED WEIGHTED SEASONAL DEPTH AND TOTAL QUANTITY OF PRECIPITATION ON SUTTER-YUBA AREA

Season	Precipitation index	Precipitation	
		Depth, in inches	Quantity, in acre-feet
1947-48	89	18.2	529,000
1948-49	76	15.4	448,000
Average for 9-year base period, 1939-40 through 1947-48	107	21.8	635,000
Mean for 50-year period, 1897-98 through 1946-47	100	20.3	592,000

RUNOFF

Runoff from the highly productive watersheds of the Sierra Nevada constitutes the most important source of water supply available to the Sutter-Yuba Area. The Feather River, which traverses the area from north to south, is the principal tributary of the Sacramento River. The Feather River system, including the Yuba and Bear Rivers which join the Feather within the area, is largely unregulated and undeveloped and is a potential source of water to meet future requirements not only in the Sutter-Yuba Area but in water-deficient areas in other parts of California.

Stream Gaging Stations and Records

Available records of runoff of the principal streams of the Sutter-Yuba Area were sufficient in number, length, and reliability for purposes of required hydrographic studies. With respect to certain of the smaller streams, however, records of runoff were nonexistent or confined principally to measurements made during the investigational seasons. By comparison with records of nearby stations on major streams, adequate estimates were made of runoff of these smaller streams.

Table 5 lists those stream gaging stations pertinent to the hydrography of the Sutter-Yuba Area, together with their map reference numbers, drainage areas above stations where significant, and periods and sources of records. These stations are also shown on Plate 3. The map reference numbers for the first 11 stations listed correspond to those used in State Water Resources Board Bulletin No. 1, "Water Resources of California." New map reference numbers were assigned to the remaining stations listed. The last five stations listed in Table 5 were installed, operated, and maintained as a part of the Sutter-Yuba Counties Investigation. Most of the runoff records listed in Table 5 have been published by the United States Geological Survey in its Water-Supply Papers or by the Division of Water Resources in its Reports of Sacramento-San Joaquin Water Supervision. The following records have not been published elsewhere and are included in Appendix D to this report:

Coon Creek at Highway 99E—November, 1947–December, 1948
Auburn Ravine at Highway 99E—November, 1947–December, 1948
Dry Creek near Waldo—November, 1947–May, 1949
South Honcut Creek at La Porte Road—November, 1947–December, 1948

Runoff Characteristics

An excellent continuous record of flow of the Feather River at or near Oroville is available for the period since January, 1902, when a stream gaging station was established at Oroville by the United States Geological Survey. The station was moved five miles upstream in October, 1934, but without appreciable effect on characteristics of the record. Although this record does not provide an exact measure of flow of the Feather River into the Sutter-Yuba Area, it is the most important record of the Feather River system, and does reflect characteristics of tributary mountain runoff to the Sutter-Yuba Area.

Flow of the Feather River to the valley floor is impaired by operation of Lake Almanor and several smaller upstream reservoirs, and by operation of hydroelectric power plants. An estimate of the natural runoff of the Feather River at Oroville, as it would be if unaltered by upstream diversion, storage, importation, and exportation, is included in State Water Resources Board Bulletin No. 1, "Water Resources of California." This estimate, together with recorded seasonal runoff of the Feather River at or near Oroville, is presented in Table 6. The

TABLE 5

STREAM GAGING STATIONS IN OR NEAR SUTTER-YUBA AREA

Map reference number	Stream	Station	Drainage area, in square miles	Period of record	Source of record
5-192	Feather River	at Oroville	3,640	1902-1934	USGS
5-191	Feather River	near Oroville	3,611	1934-1951	USGS and DWR
5-193	Feather River	near Gridley		1944-1951	DWR
5-244	Feather River	at Nicolaus		1921-1942 1943-1951	USGS and DWR
5-234	Feather River	below Shanghai Bend		1944-1951	DWR
5-194	Feather River	at Yuba City		1944-1951	DWR
5-222	Yuba River	at Narrows Dam	1,110	1941-1951	USGS and DWR
5-233	Yuba River	at Marysville		1939-1951	USGS and DWR
5-228	Yuba River	at Smartville	1,201	1903-1941	USGS
5-227	Deer Creek	near Smartville	83.5	1935-1951	USGS and DWR
5-238	Bear River	near Wheatland	295	1928-1951	USGS and DWR
SY-1	Sutter Butte Canal	at Diversion		1923-1951	DWR
SY-2	Wadsworth Canal	near Sutter		1929-1951	DWR
SY-3	Pleasant Grove Creek	at Lincoln Road	12.5	1950-1951	DWR
SY-4	Auburn Ravine	at Highway 99E	34.6	1947-1951	DWR
SY-5	Coon Creek	at Highway 99E	82.5	1947-1951	DWR
SY-6	Dry Creek	near Waldo	69.4	1947-1949	DWR
SY-7	South Honcut Creek	at La Porte Road	68.6	1947-1949	DWR

USGS—United States Geological Survey.
DWR—Division of Water Resources.

estimate of natural flow is also shown graphically on Plate 6, "Estimated Seasonal Natural Runoff of Feather River at Oroville."

Estimates of natural flow of streams of the Feather River system indicate that average seasonal runoff during the nine-year base period approximated the seasonal mean during the 53-year period. For the Feather, Yuba, and Bear Rivers these estimates were obtained from State Water Resources Board Bulletin No. 1. Natural flow of minor streams, including those tributary to the Sutter-Yuba Area but not in the Feather River system, were estimated during the current investigation. The estimates of natural flow are presented in Table 7, together with runoff indices for the combined natural flow of the Feather River system. The term "runoff index" refers to the ratio of the amount of runoff during a given season to the mean seasonal amount, and is expressed as a percentage.

Discharge of streams of the Sierra Nevada which are tributary to the Sutter-Yuba Area varies between wide limits from season to season, and within the season. This is indicated by flow of the Feather River at

TABLE 6

RECORDED SEASONAL AND ESTIMATED NATURAL SEASONAL RUNOFF OF FEATHER RIVER AT OROVILLE

(In acre-feet)

Season	Recorded runoff at or near Oroville	Estimated natural runoff at Oroville	Season	Recorded runoff at or near Oroville	Estimated natural runoff at Oroville
1894-1895		7,093,000	1924-1925	2,780,000	3,114,000
1895-1896		7,786,000	1925-1926	2,870,000	3,126,000
1896-1897		5,440,000	1926-1927	5,000,000	5,679,000
1897-1898		2,304,000	1927-1928	3,650,000	4,142,000
1898-1899		2,872,000	1928-1929	2,010,000	1,910,000
1899-1900		6,788,000	1929-1930	3,590,000	3,984,000
1900-1901		6,281,000	1930-1931	1,490,000	1,485,000
1901-1902		4,048,000	1931-1932	2,810,000	3,351,000
1902-1903	4,430,000	4,555,000	1932-1933	1,640,000	1,986,000
1903-1904	9,330,000	9,451,000	1933-1934	1,840,000	2,071,000
1904-1905	4,490,000	4,606,000	1934-1935	3,864,000	4,253,000
1905-1906	6,710,000	6,833,000	1935-1936	4,079,000	4,328,000
1906-1907	9,340,000	9,504,000	1936-1937	2,821,000	3,175,000
1907-1908	3,490,000	3,651,000	1937-1938	8,175,000	8,547,000
1908-1909	7,380,000	7,527,000	1938-1939	1,773,000	1,912,000
1909-1910	4,500,000	4,651,000	1939-1940	5,275,000	5,672,000
1910-1911	6,980,000	7,136,000	1940-1941	6,116,000	6,516,000
1911-1912	2,090,000	2,276,000	1941-1942	6,258,000	6,662,000
1912-1913	2,600,000	2,785,000	1942-1943	5,296,000	5,638,000
1913-1914	6,540,000	6,928,000	1943-1944	2,622,000	2,830,000
1914-1915	5,200,000	5,422,000	1944-1945	3,412,000	3,767,000
1915-1916	5,910,000	6,156,000	1945-1946	3,996,000	4,185,000
1916-1917	4,380,000	4,637,000	1946-1947	2,273,000	2,579,000
1917-1918	2,450,000	2,684,000	1947-1948	3,368,000	3,401,000
1918-1919	3,390,000	3,621,000	1948-1949	2,495,000	2,590,000
1919-1920	2,050,000	2,231,000	1949-1950	3,465,000	3,837,000
1920-1921	5,600,000	5,940,000	1950-1951	5,403,000	5,676,000
1921-1922	4,730,000	5,040,000			
1922-1923	2,890,000	3,112,000	Mean seasonal natural runoff for 53-year mean period, 1894-95 through 1946-47: 4,596,000		
1923-1924	1,180,000	1,317,000			

TABLE 7

ESTIMATED SEASONAL NATURAL FLOW OF STREAMS OF THE FEATHER RIVER SYSTEM, 1939-40 THROUGH 1947-48

(In acre-feet)

Season	Runoff index	Feather River at Oroville	Yuba River at Smartville	Bear River at Wheatland	Minor streams	Combined flow
1939-1940	124	5,672,000	2,860,000	406,000	293,000	9,231,000
1940-1941	142	6,516,000	3,209,000	483,000	339,000	10,547,000
1941-1942	145	6,662,000	3,407,000	502,000	355,000	10,926,000
1942-1943	123	5,638,000	3,133,000	464,000	328,000	9,563,000
1943-1944	62	2,830,000	1,395,000	191,000	141,000	4,557,000
1944-1945	82	3,767,000	2,112,000	289,000	211,000	6,379,000
1945-1946	91	4,185,000	2,401,000	323,000	239,000	7,148,000
1946-1947	56	2,579,000	1,365,000	170,000	131,000	4,245,000
1947-1948	74	3,401,000	1,510,000	216,000	156,000	5,283,000
Average for 9-year base period, 1939-40 through 1947-48	100	4,583,000	2,377,000	339,000	244,000	7,542,000
Mean for 53-year period, 1894-95 through 1946-47	100	4,596,000	2,415,000	356,000	248,000	7,615,000

or near Oroville, where the maximum recorded seasonal runoff occurred in 1906-07 and amounted to more than 9,300,000 acre-feet. The minimum seasonal runoff recorded at this station occurred in 1923-24 and was less than 1,200,000 acre-feet. Maximum recorded instantaneous discharge was 230,000 second-feet on March 19, 1907, and the estimated minimum discharge was about 300 second-feet on November 9, 1931. Estimated mean monthly distribution of natural flow of the Feather River at Oroville is presented in Table 8.

TABLE 8

ESTIMATED MEAN MONTHLY DISTRIBUTION OF NATURAL FLOW OF FEATHER RIVER AT OROVILLE

Month	Runoff, in acre-feet	Percent of seasonal total
October	101,000	2.2
November	188,000	4.1
December	290,000	6.3
January	423,000	9.2
February	556,000	12.1
March	722,000	15.7
April	873,000	19.0
May	744,000	16.2
June	368,000	8.0
July	152,000	3.3
August	101,000	2.2
September	78,000	1.7
TOTALS	4,596,000	100.0

Quantity of Runoff

Available records of stream flow, including those obtained from measurements made in connection with the investigation, were sufficient to permit fairly reliable determination of surface inflow to and surface outflow from the Sutter-Yuba Area during the nine-year base period and during the two seasons of the investigation.

Surface inflow to the Sutter-Yuba Area from the Feather and Bear Rivers was directly measured at the stations near Gridley and near Wheatland, respectively. Inflow from Yuba River was determined by recorded flow at Smartville until the season of 1940-41, after which season that station was discontinued and inflow was determined as the combined flow of Yuba River at Narrows Dam and Deer Creek near Smartville. For seasons when records of inflow from South Honcut Creek at La Porte Road and French Dry Creek near Browns Valley were not available, inflow was estimated by correlation with the combined flow of Yuba River at Narrows Dam and Deer Creek near Smartville. Inflow to the area from Dry Creek near Waldo, Coon Creek at Highway 99E, Auburn Ravine at Highway 99E, and Pleasant Grove Creek at Lincoln Road, was estimated for seasons when records were not available by correlation with the flow of Bear River near Wheatland. Inflow to the area through the Sutter

TABLE 9

MEASURED AND ESTIMATED SEASONAL SURFACE INFLOW TO AND OUTFLOW FROM SUTTER-YUBA AREA, 1939-40 THROUGH 1948-49

(In acre-feet)

Source	Season										Average for 9-year base period, 1939-40 through 1947-48
	1939-40	1940-41	1941-42	1942-43	1943-44	1944-45	1945-46	1946-47	1947-48	1948-49	
Inflow											
Feather River	4,634,000	5,103,000	5,581,000	4,326,000	1,536,000	2,208,000	3,106,000	1,724,000	2,751,000	1,742,000	3,441,000
Yuba River	2,364,000	2,550,000	2,778,000	2,562,000	948,000	1,583,000	1,877,000	924,000	1,503,000	1,063,000	1,899,000
Bear River	411,000	505,000	516,000	494,000	149,000	314,000	368,000	151,000	208,000	197,000	346,000
Deer Creek	125,000	137,000	162,000	155,000	72,000	111,000	105,000	54,000	52,000	50,000	108,000
South Honcut Creek*	48,000	53,000	57,000	52,000	23,000	35,000	40,000	23,000	25,000	29,000	40,000
French Dry Creek†	91,000	102,000	108,000	100,000	45,000	67,000	76,000	44,000	48,000	35,000	76,000
Dry Creek*	39,000	46,000	48,000	44,000	18,000	28,000	31,000	16,000	21,000	18,000	32,000
Coon Creek*	35,000	42,000	43,000	40,000	17,000	25,000	28,000	15,000	19,000	36,000	29,000
Auburn Ravine*	71,000	85,000	88,000	81,000	34,000	51,000	57,000	30,000	38,000	47,000	59,000
Pleasant Grove Creek†	9,000	11,000	12,000	11,000	4,000	7,000	8,000	4,000	5,000	4,000	8,000
Snake Slough†	49,000	49,000	55,000	40,000	44,000	49,000	47,000	39,000	38,000	39,000	46,000
Sutter Butte Canal†	111,000	112,000	130,000	153,000	161,000	167,000	186,000	163,000	136,000	160,000	147,000
Minor Drainage†	10,000	11,000	12,000	11,000	4,000	7,000	8,000	4,000	5,000	5,000	8,000
TOTALS	7,997,000	8,806,000	9,590,000	8,069,000	3,055,000	4,652,000	5,937,000	3,191,000	4,849,000	3,425,000	6,239,000
Outflow											
Feather River	7,104,000	9,827,000	9,703,000	7,268,000	3,326,000	5,026,000	5,999,000	2,784,000	4,737,000	3,234,000	6,197,000
Wadsworth Canal	95,000	119,000	105,000	72,000	93,000	106,000	102,000	67,000	53,000	62,000	90,000
Drainage into Sutter By-Pass†	13,000	18,000	19,000	17,000	0	7,000	10,000	0	0	0	9,000
Cross Canal†	32,000	35,000	37,000	34,000	0	18,000	25,000	0	0	0	20,000
TOTALS	7,244,000	9,999,000	9,864,000	7,391,000	3,419,000	5,157,000	6,136,000	2,851,000	4,790,000	3,296,000	6,316,000

* Partially estimated.
† Estimated.

Butte Canal was estimated by adjusting measured diversions from Feather River on the basis of acreages of crops served each season within and outside the area. Inflow to the area from Snake Slough at Sanders Road during seasons of no record was estimated by correlation with flow in the Sutter Butte Canal. Inflow from minor unmeasured drainage areas was estimated by correlation with the flow of Bear River near Wheatland.

Surface outflow from the Sutter-Yuba Area in Feather River and the Wadsworth Canal was directly measured during the nine-year base period and during the investigational seasons at the stations at Nicolaus and near Sutter, respectively. Estimates of the net amount of outflow as drainage to the Sutter By-pass were based on partial records of pumping to and from the by-pass at pumping plants operated by the Division of Water Resources. Outflow from the Cross Canal was estimated by correlation with measured runoff of streams tributary to the canal, corrected for measured pumping diversions from the canal.

Measured and estimated seasonal surface inflow to and outflow from the Sutter-Yuba Area during the base period and during 1948-49 are presented in Table 9.

IMPORTED AND EXPORTED WATER

Water is imported to the Sutter-Yuba Area through the Sutter Butte Canal system for irrigation of lands in that portion of the West Side Zone outside of the Peach Bowl. This water is diverted from the Feather River at a point about 14 miles upstream from the north boundary of the area, and is conveyed in unlined canals through a service area situated along the right bank of the Feather River both inside and outside the Sutter-Yuba Area. The estimated amount of the import was 160,000 acre-feet during the 1948-49 season, and the estimated seasonal average during the base period was 147,000 acre-feet. These estimates are shown in Table 9. For purposes of current studies the Sutter Butte Canal import was considered to be a part of surface inflow to the Sutter-Yuba Area.

So far as was determined during the investigation, there is no record of export of water from the Sutter-Yuba Area.

UNDERGROUND HYDROLOGY

The Sutter-Yuba Area overlies a portion of the ground water basin of the Sacramento Valley, and water pumped from storage in the basin presently serves nearly two-thirds of the lands irrigated in the area. Percolation of rainfall, stream flow, and drainage from adjacent hills, and of the unconsumed portion of applied irrigation water, is the most important source of ground water replenishment.

The term "free ground water," as used in this report, generally refers to a body of ground water not overlain by impervious materials and moving under control of the water table slope. "Confined ground water" refers to a body of ground water overlain by material sufficiently impervious to sever free hydraulic connection with overlying water, and moving under pressure caused by the difference in head between intake and discharge areas of the confined water body. In areas of free ground water, the ground water basin provides regulatory storage to smooth out fluctuations in available water supplies, and changes in ground water storage are indicated by changes in ground water levels.

Data and information collected during the Sutter-Yuba Counties Investigation indicated that free ground water exists in present zones of pumping, although there may be some temporary or partial confinement in certain depth zones. Study of historic fluctuation of the water table in the Sutter-Yuba Area, under varying conditions of draft and replenishment, permitted a determination of changes in ground water storage in the basin, and its safe yield of water under stated conditions. Underground hydrology is discussed in this section under the following headings: "Ground Water Geology," "Specific Yield and Ground Water Storage Capacity," "Ground Water Levels," "Change in Ground Water Storage," "Subsurface Inflow and Outflow," "Yield of Wells," "High Water Table Areas," and "Safe Ground Water Yield."

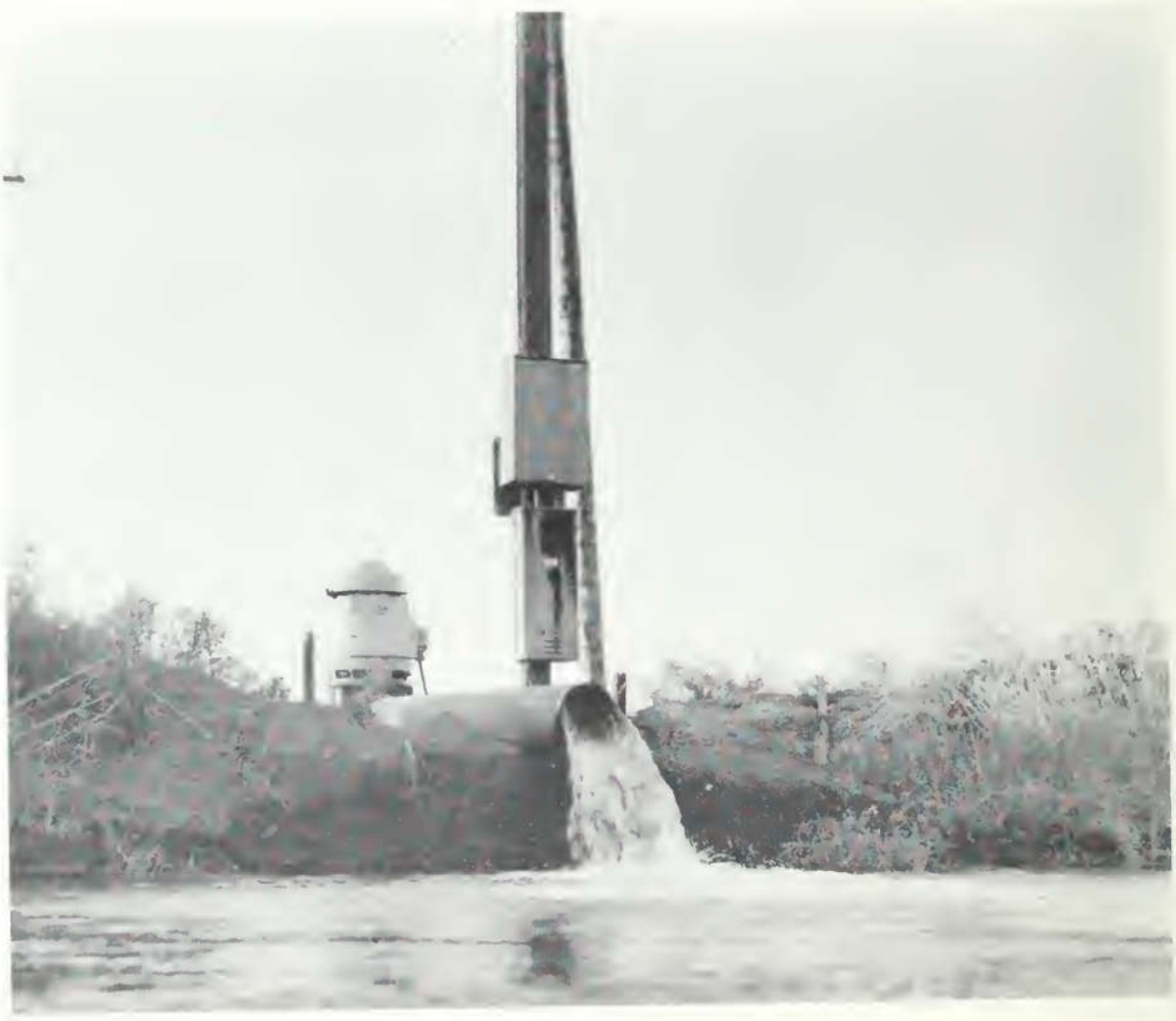
Ground Water Geology

Geologic features of the ground water basin underlying the Sutter-Yuba Area were investigated by the Ground Water Branch of the United States Geological Survey, under terms of an agreement between that agency and the State Department of Public Works. Appendix B comprises a detailed report by the Geological Survey on ground water storage capacity, within given pumping lifts, and on geologic features of the Sutter-Yuba Area, with a general geologic map, four geologic cross-sections, and a map showing ground water storage units, prepared under the direction of Joseph F. Poland, District Geologist, by G. H. Davis and F. H. Olmsted. Portions of an abstract of the geologic report follow:

"The Sutter-Yuba area occupies the east-central Sacramento Valley and part of the western foothills of the Sierra Nevada. The Sacramento Valley is a trough that has been receiving sediments from both sides since the middle part of Cretaceous time. Most of the sediments in the Sutter-Yuba area have been derived from the Sierra Nevada on the east, which is a block mountain range tilted about 1½° westward. Evidence indicates that the block continues westward beneath the sediments of the valley trough.

"The Sutter Buttes, erosional remnants of a Pliocene volcano, occupy a circular area about 10 miles in diameter near the center of the Sacramento Valley.

"Rocks exposed in the Sutter-Yuba area range in age from pre-Cretaceous metamorphic and igneous rocks of the Sierra Nevada block to Recent alluvium still undergoing deposition. The rocks may be divided into two general categories: (1) the basement complex of the Sierra Nevada, which extends beneath the Sacramento Valley at depth, and (2) the superjacent rocks; a sedimentary blanket of marine and continental deposits transported from the Sierra Nevada and deposited in the Great Valley trough.



Deep Well and Turbine Pump Installation in Sutter-Yuba Area

"The water-bearing deposits considered in this report are included in the superjacent rocks, although weathered and fractured zones in the basement complex contain small quantities of ground water. The marine sediments of Cretaceous and Tertiary age are penetrated by water wells in only a few places in the Sutter-Yuba area. Where marine sediments are encountered they are generally impervious and contain water of poor chemical quality.

"Volcanic activity in the Sierra Nevada during the Tertiary period produced tuff-breccia of mud-flow origin which are impermeable and yield little water, but interbedded volcanic sands and gravels are moderately permeable and yield water to deep wells in the Marysville, Wheatland, Roseville, and Camp Beale districts.

"Local volcanic activity at Sutter Buttes during the Pliocene epoch produced two principal groups of rocks: (1) intrusive rhyolite and andesite and vent tuffs of the central core; and (2) andesitic tuff-breccias that encircle the core. The core is hard and impervious, but sands and gravels interbedded with the tuff-breccias yield some water to wells in the Pennington and Sutter City district.

"Following the close of volcanic activity in the Sierra Nevada the streams deposited predominantly fine-grained sediments during the remainder of the Pliocene epoch. These old alluvial deposits underlie the dissected uplands or 'red lands' along the valley margin and extend westward beneath younger alluvial deposits. Poorly sorted alluvium composed of silt, clay, and cemented sand and gravel as much as 350 feet thick represent this time interval. Many wells penetrate thick sections of these materials, but well yields are low to moderate.

"Uplift of the Sierra block at the beginning of the Pleistocene epoch caused the deposition of coarser materials. Alluvium of Pleistocene age as much as 100 feet thick underlies the low plains of the Sutter-Yuba area. These deposits are moderately permeable throughout and tongues of sand and gravel provide large supplies of water to irrigation wells.

"Recent alluvium, defined as those materials undergoing deposition, falls into three general categories: (1) alluvial fans of the Sutter Buttes, (2) basin deposits, and (3) stream-channel deposits. Most of the alluvial-fan deposits of Sutter Buttes are poorly sorted and groundwater yields from them are low. Basin deposits consist of an accumulation of relatively impermeable clays and silts which have been laid down by overflow waters of the Sacramento and Feather Rivers. Generally these deposits produce little water. Stream-channel deposits of the major streams contain well sorted sands and gravels to depths of 125 feet. Well defined channels are found beneath the flood plains of the Feather, Yuba, and Bear Rivers. Wells penetrating these coarse deposits are highly productive."

Specific Yield and Ground Water Storage Capacity

The term "specific yield," when used in connection with ground water, refers to the ratio of the volume of water a saturated soil will yield by gravity to its own volume, and is commonly expressed as a percentage. Ground water storage capacity is estimated as the product of the specific yield and the volume of material in the depth intervals considered.

In its investigation of the Sutter-Yuba ground water basin, the United States Geological Survey estimated specific yield of different depth zones after study of some 700 well logs. The estimates were based on previously determined characteristics of the various types of material classified in the well logs. Ground water storage capacity of the Sutter-Yuba Area was determined by the Geological Survey for depth intervals from 20 to 50 feet, 50 to 100 feet, 100 to 200 feet, and for the entire interval from 20 to 200 feet below ground surface. However, in an area of saline ground water centered near the southern end of the West Side Zone, where storage capacity in the 100- to 200-foot depth interval was considered not usable under present conditions, the determination was limited to the 20- to 50-foot, and 50- to 100-foot depth intervals.

Storage capacity of the ground water basin underlying the Sutter-Yuba Area and the weighted average specific yield, as estimated by the United States Geological Survey, are shown in Table 10.

TABLE 10

ESTIMATED SPECIFIC YIELD AND GROUND WATER STORAGE CAPACITY, SUTTER-YUBA AREA

Depth interval, in feet from ground surface	Weighted average specific yield, in percent	Ground water storage capacity, in acre-feet
20 to 50	7.4	840,000
50 to 100	6.9	1,290,000
100 to 200	6.0	1,760,000
20 to 200	6.6	3,890,000

Ground Water Levels

The first indication of a cone of depression in the water table in the Sutter-Yuba Area was found by Kirk Bryan and reported in 1913 in United States Geological Survey Water-Supply Paper 495. At that time a small cone had developed along Gilsizer Slough southwest of Shanghai Bend.

In 1931, in a "Report on Proposed Sutter Irrigation District," S. T. Harding described a study of ground water conditions in the eastern portion of Sutter County. A fully developed depression cone was found in the water table existing at that time. In discussing the growth of pumping draft in the Peach Bowl up to 1931, the author wrote:

"Draft in 1920 was probably double that in 1913, much of the orchards being young in 1920 less water would be used. From 1920 there has been a continual increase in area and draft. Since 1924 the annual draft has probably varied more largely with variations in rainfall than of area. For the past five years there has been little new orchard planting and the existing orchards have been sufficiently mature to represent full draft.

"These conclusions correspond generally with the ground water record. Some lowering occurred prior to 1920 but this was not sufficient to cause concern. Lowering appears to have attracted attention in 1924 and to have increased in below normal years since 1924 being particularly marked in the last 3 years."

The Division of Water Resources has measured fall water levels at a series of control wells throughout the Sacramento Valley during most years from 1929 through 1940, and each year from 1947 to date. Forty of these control wells are in or adjacent to the Sutter-Yuba Area. The Sutter County Farm Adviser furnished data on water levels at 25 additional wells in the area which were measured several times annually from 1931 through 1941. The Pacific Gas and Electric Company has made frequent measurements since 1946 at approximately 25 wells in or adjacent to the Sutter-Yuba Area. This company also furnished records of

TABLE 11

MEASURED FALL DEPTHS TO GROUND WATER AT REPRESENTATIVE WELLS IN ZONES OF SUTTER-YUBA AREA

(In feet)

Year	West Side Zone			Northeast Zone		East Central Zone		South Side Zone	
	Well number								
	17N/3E-30F1	14N/3E-3P1	13N/3E-14C2	16N/4E-8A1	16N/4E-27N1	14N/4E-15C3	14N/4E-28N1	13N/4E-33R1	12N/4E-33L3
1929	4.7	28.3	15.4	18.4	10.4	15.4	10.5	20.7	15.4
1930	3.3	32.4	15.6	17.6	7.8	14.9	10.4	20.1	16.0
1931	6.2	33.8	15.4	19.5	10.8	15.4	11.0	20.8	16.4
1932	5.4	32.4	15.2	19.2	.....	14.7	11.1	20.1	12.7
1933	5.6	33.4	16.3	19.6	.....	10.0	11.2	20.5	15.6
1934	5.4	34.1	16.7	19.8	.....	.....	11.5	20.5	16.3
1936	.....	28.4	13.4	18.1	.....	9.7	11.9	22.7	12.5
1937	3.7	26.2	11.8	17.8	.....	14.8	12.0	24.8	9.4
1938	6.4	20.4	10.8	15.7	.....	11.1	9.2	19.0	8.9
1940	3.1	24.0	8.2	16.8	4.8	14.3	10.9	.....	3.4
1947	7.8	33.8	14.8	18.1	7.5	23.2	13.1	23.4	11.5
1948	9.3	34.2	14.2	21.0	12.0	24.3	13.4	25.3	11.0
1949	7.6	36.0	15.5	22.1	11.7	28.2	15.5	19.6	13.4
1950	8.6	39.1	15.5	23.6	8.8	29.7	14.6	28.1	13.0
1951	.....	32.0	.....	23.0	10.5	33.1	.....	23.3	.....

standing and operating water levels measured during pump tests, together with results of the tests.

A complete series of measurements of static ground water levels at approximately 850 wells in the Sutter-Yuba Area was made in the spring and fall of each year during the period of investigation, beginning with the fall of 1947 and continuing through 1951. The wells were chosen to form a comprehensive grid covering the entire area. In addition, monthly measurements were made at approximately 90 control wells during the first half of 1948 and through 1949, in order to observe behavior of the ground water table under conditions of draft and recharge. Available records of depth to ground water at wells in or adjacent to the Sutter-Yuba Area are included as Appendix E to this report.

Depths to ground water throughout the Sutter-Yuba Area, as measured each fall from 1947 through 1951, were plotted on maps and lines of equal depth drawn. These are shown on Plates 7 to 11, inclusive, "Lines of Equal Depth to Ground Water." Plate 12, "Lines of Equal Elevation of Ground Water, Fall 1949," was prepared from the data used for Plate 9, depths to ground water being subtracted from elevations of the measuring points above sea level to obtain elevations of the water table.

Table 11 shows depths from the surface of the ground to the water table at selected representative wells in the several zones of the Sutter-Yuba Area during the fall of most years from 1929 through 1951. The measurements were made following the summer period of irrigation pumping draft and prior to recovery in ground water storage resulting from winter rains. The wells are numbered in accordance with the system utilized by the United States Geological Survey, and described in Appendix B. Fluctuations in depth to ground water at a representative well in each zone of the Sutter-Yuba Area are depicted graphically on Plate 13, "Measured Fall Depths to Ground Water at Representative Wells."

From study of all available well measurements, estimates were made of the approximate average depth to ground water in the Sutter-Yuba Area in the fall of each year from 1929 through 1951. These estimates, which constitute arithmetical averages of available measurements, are presented in Table 12 and are illustrated graphically in Plate 14, entitled "Average Fall Depth to Ground Water."

TABLE 12

ESTIMATED AVERAGE FALL DEPTH TO GROUND WATER IN SUTTER-YUBA AREA

(In feet)

Year	Depth to ground water	Year	Depth to ground water
1929	15.9	1940	12.3
		1941	12.0
1930	16.1	1942	11.9
1931	17.7	1943	11.6
1932	16.6	1944	13.1
1933	17.6		
1934	17.2	1945	14.2
		1946	16.2
1935	16.8	1947	17.6
1936	16.4	1948	18.3
1937	15.2	1949	19.8
1938	15.2		
1939	14.5	1950	21.7
		1951	21.8

It is indicated that a moderate lowering of the water table over the Sutter-Yuba Area occurred from 1929 until 1931, followed by a slight rise in 1932, and a lowering again in 1933. Although 1935 marked the end of a series of dry years, ground water levels rose in 1934 because of reduced pumping. The water table continued to rise during a generally wet series of years until 1943, and in that year the estimated average depth to ground water was the least during the entire period from 1929 through 1951. Since 1943, coincidental with dry years and expansion of irrigation, a continuous lowering of the water table has occurred, reaching its greatest average depth during the entire period in the fall of 1951.

In order to estimate weighted average changes in ground water elevations in the Sutter-Yuba Area during the nine-year base period and each investigational season, maps were drawn showing lines of equal change in elevation during these periods. An example of these maps is presented as Plate 15, "Lines of Equal Change in Ground Water Elevation from Fall of 1947 to Fall of 1951." By planimetering the areas between lines of equal change, the weighted average change in elevation of water levels was estimated for each zone of the Sutter-Yuba Area. The results of these estimates are presented in Table 13.

TABLE 13

ESTIMATED WEIGHTED AVERAGE SEASONAL CHANGES IN FALL GROUND WATER ELEVATION IN ZONES OF SUTTER-YUBA AREA

(In feet)

Zone	1939-40 to 1947-48	1947-48	1948-49
West Side			
Peach Bowl	−0.7	−0.7	−1.5
Outside Peach Bowl	+0.1	+0.1	−0.2
Northeast	+0.1	+0.3	−1.0
East Central	−0.7	−1.2	−2.3
South Side	−0.6	−1.3	−2.1

Change in Ground Water Storage

In an area of free ground water, the volume of soil unwatered or resaturated over a period of time, when multiplied by the specific yield, measures the change in ground water storage during that time. Available data on fluctuations of water levels at wells in the Sutter-Yuba Area were sufficient to estimate the volume of soil unwatered or resaturated during the base period, and during the two investigational seasons. Changes in ground water storage were estimated for each zone of the area by multiplying changes in elevation of ground water, presented in Table 13, by the area of each zone and by the average value of specific yield of 7.4 percent, found by the Geological Survey for the depth interval from 20 to 50 feet below ground surface. The results of these estimates are presented in Table 14.

TABLE 14

ESTIMATED WEIGHTED AVERAGE SEASONAL CHANGES IN GROUND WATER STORAGE IN ZONES OF SUTTER-YUBA AREA

(In acre-feet)

Zone	Area, in acres	1939-40 to 1947-48	1947-48	1948-49
West Side				
Peach Bowl	61,400	−3,000	−3,000	−7,000
Outside Peach Bowl	62,370	+500	0	−1,000
Northeast	42,860	+300	+1,000	−3,000
East Central	77,870	−4,000	−7,000	−13,000
South Side	82,460	−4,000	−8,000	−13,000
TOTALS	326,960	−10,200	−17,000	−37,000

It is indicated that an average seasonal net decrease in ground water storage in the Sutter-Yuba Area of about 10,000 acre-feet occurred during the nine-year base period, in which conditions of water supply and climate were approximately equivalent to conditions during the mean periods. The estimated net decrease in ground water storage during the two investigational seasons was approximately 17,000 acre-feet in 1947-48, and 37,000 acre-feet in 1948-49. It may be noted that the decrease in storage was substantial in the Peach Bowl portion of the West Side Zone, and in the East Central and South Side Zones. In the high water table lands of the Sutter Butte Canal service area in the West Side Zone, and in the Northeast Zone, changes in ground water storage were of minor importance.

Subsurface Inflow and Outflow

Lines of equal elevation of ground water in the Sutter-Yuba Area in the fall of 1949 are shown on Plate 12. Slopes of the water table as defined by these ground water contours, together with information on the permeabilities of the various subsurface geologic formations, indicate that the greater portion of subsurface inflow to the area probably came from the east, and a smaller amount from the north between Sutter Buttes and the eastern foothills. It is probable that about half of the subsurface inflow from the east entered from Placer County south of the historic Bear River flood plain, and that the other half moved across the investigational boundary from the east in Yuba

County, including the whole of the historic Bear River flood plain.

The ground water gradients shown on Plate 12 indicate that there was little subsurface outflow from the Sutter-Yuba Area during or immediately following the 1949 season of heavy pumping draft. Sufficient data were not available to depict ground water contours in the area during the wet years from 1939 to 1943, when there was substantial ground water replenishment and when subsurface outflow may have been significant. Study of available data, however, does show that average seasonal subsurface outflow from the Sutter-Yuba Area during the nine-year base period was probably small.

The ground water contours shown on Plate 12 indicate the presence of a depression cone in the water table extending approximately north and south through the Peach Bowl during 1949. There was a general convergence of ground water around the perimeter of the depression and into the trough, showing that such ground water movement as may have occurred was inflow to the cone, rather than outflow.

The northern and western portions of the West Side Zone, and adjacent areas outside of the Sutter-Yuba Area, are served with surface water supplies, and ground water levels have been fairly stable and close to the ground surface even in dry years. However, during dry years, ground water levels in the Peach Bowl have lowered as a result of increased pumping. These conditions have probably resulted in relatively greater subsurface inflow to the Peach Bowl during such dry years, owing to the steeper gradients existing in the water table.

An indirect method was used to estimate the net effect of subsurface inflow to and outflow from the Sutter-Yuba Area. This involved evaluation of the difference between subsurface inflow and outflow as the item necessary to effect a balance between water supply and disposal. The sum of the items comprising the water supply of a given hydrologic unit or area must be equal to the sum of the items of water disposal. This is a statement of what is referred to as the "equation of hydrologic equilibrium." In the case of the Sutter-Yuba Area, values for pertinent items other than the difference between subsurface inflow and outflow, including surface inflow and outflow, precipitation, change in ground water storage, and consumptive use of water, were quantitatively measured or estimated. Determination of values for consumptive use of water is explained in Chapter III. Retention of subsurface inflow, or the difference between subsurface inflow and outflow, was the remaining unknown quantity in the equation of hydrologic equilibrium. Table 15 sets forth this equation for the Sutter-Yuba Area.

Certain of the values in the equation of hydrologic equilibrium presented in Table 15 are of large magnitude as compared to the derived excess of subsurface inflow over subsurface outflow. Small percentage errors in these larger quantities might introduce relatively large errors in the derived remainders. In this connection, independent geologic analysis of the cross section of the perimeter of the Sutter-Yuba ground water basin, including consideration of the porosity of the aquifers, indicated that with existing slopes of the water table the derived values for net subsurface inflow might be excessive. However, study of disposal of water supplies in areas adjacent to the Sutter-Yuba Area tended to corroborate the derived values.

TABLE 15

ESTIMATED EXCESS OF SEASONAL SUBSURFACE INFLOW OVER SUBSURFACE OUTFLOW IN SUTTER-YUBA AREA

(In acre-feet)

Item	Average for 9-year base period 1939-40 through 1947-48	1947-48	1948-49
WATER SUPPLY			
Precipitation	635,000	529,000	448,000
Surface inflow	6,239,000	4,849,000	3,425,000
Decrease in ground water storage	10,000	17,000	37,000
TOTALS	6,884,000	5,395,000	3,910,000
WATER DISPOSAL			
Surface outflow	6,316,000	4,790,000	3,296,000
Consumptive use of water	710,000	764,000	794,000
TOTALS	7,026,000	5,554,000	4,090,000
REMAINDER — EXCESS OF SUBSURFACE INFLOW OVER SUBSURFACE OUTFLOW	142,000	159,000	180,000

Yield of Wells

Yield of wells is an important factor in the use of ground water in the Sutter-Yuba Area. In certain small portions of the area ground water is not utilized for irrigation because of inability to obtain wells of adequate capacity to meet the agricultural requirements. On the other hand, throughout most of the area adequate agricultural wells can generally be obtained.

Yield of wells in the Sutter-Yuba Area was analyzed by the United States Geological Survey, as reported in Appendix B, utilizing data obtained from well pumping tests made by the Pacific Gas and Electric Company during the period from 1933 through 1948. Results of the Geological Survey's analysis are summarized in Table 16, which shows for each zone of the Sutter-Yuba Area the number of wells tested, and their average discharge, specific capacity, depth, and yield factor. The term "specific capacity" refers to the number of gallons of water per minute produced by a pumping well per foot of drawdown. "Drawdown" refers to the lowering of the water level in a well caused by pumping, and is measured in feet. The "yield factor" reflects

the production of water per foot of depth of well, and is determined by multiplying the specific capacity by 100 and dividing by the depth of the well, in feet.

TABLE 16

ESTIMATED AVERAGE YIELD OF WELLS IN ZONES OF SUTTER-YUBA AREA

Zone	Number of wells tested	Average discharge, in gallons per minute	Average specific capacity, in gallons per minute per foot of drawdown	Average depth of wells, in feet	Average yield factor
West Side					
Peach Bowl	249	728	47	182	25.7
Outside Peach Bowl	48	878	54	320	16.8
Northeast	28	838	60	201	29.8
East Central	109	846	48	292	16.7
South Side	104	960	47	324	14.7

Insofar as may be determined from consideration of Table 16, it is indicated that the better wells of the Sutter-Yuba Area are located in the Peach Bowl and in the Northeast Zone. While wells of adequate capacity may generally be obtained throughout the remainder of the area, it is usually necessary to drill to greater depths for equivalent yields. However, although not apparent from the foregoing data, it was determined during the investigation that in the southeastern portion of the East Central Zone there is an area of approximately 3,400 acres of irrigable land upon which efforts to obtain wells of sufficient capacity to support irrigation demands have been unsuccessful.

High Water Table Areas

Under about 8,000 acres in the Northeast Zone, ground water was less than 10 feet from the ground surface continuously from November, 1947, through 1951, as was also the case under about 23,000 acres in the West Side Zone north of the East and West Intercepting Canals. Under about 1,000 acres of such lands in the Northeast Zone, and 4,500 acres in the West Side Zone, depth to the water table ranged from 0 to 5 feet from the ground surface.

The foregoing high water table lands were entirely irrigated by surface waters. It was indicated that the perennially high water table was largely caused by heavy applications of the abundant surface water supply to crops of rice and permanent pasture. The geologic investigations showed that the lands overlie good water-bearing formations which are capable of being developed by wells of relatively high yield, and that increase in use of ground water would probably result in lowering of ground water levels.

Studies indicated that the high water table lands would be suitable for a much wider range of crops than at present, if ground water levels were held at greater depths, and that an existing drainage problem would be eliminated. Furthermore, it is probable that consumptive use of water on these lands, as evidenced by heavy growth of native vegetation, is substantially in excess of such use on similar nearby lands where ground water levels are lower. The term "consumptive use of water," as used in this report, refers to water consumed by vegetative growth in transpiration and building of plant tissue, and to water evaporated from adjacent soil, from water surfaces, and from foliage. It also refers to water similarly consumed and evaporated by urban and nonvegetative types of culture.

Safe Ground Water Yield

The term "safe ground water yield" refers to the maximum rate of extraction of water from a ground water body which, if continued over an indefinitely long period of years, will result in the maintenance of certain desirable fixed conditions. Commonly, safe ground water yield is determined by one or more of the following criteria:

1. Mean seasonal extraction of water from the ground water body does not exceed mean seasonal replenishment to the body.

2. Water levels are not so lowered as to cause harmful impairment of the quality of the ground water by intrusion of other water of undesirable quality, or by accumulation and concentration of degradants or pollutants.

3. Water levels are not so lowered as to imperil the economy of ground water users by excessive costs of pumping from the ground water body.

Safe ground water yield, as derived in this report, was measured by net extraction of water from the Sutter-Yuba ground water basin, as differentiated from total pumpage from the basin. Since the Sutter-Yuba Area overlies a free ground water body, the unconsumed portion of total pumpage may return to the ground water body and become available for re-use. The net rate of extraction, therefore, was considered to be only that portion of total pumpage from the ground water basin which was consumptively used.

Under natural conditions, ground water is expended by consumptive use from seep lands and from lands where the water table is close to the ground surface, by effluent stream flow, and by subsurface outflow. Artificial development and utilization of ground water salvages all or a portion of such natural disposal, by lowering ground water levels. This, in turn, affords opportunity for additional replenishment of ground water.

With the present general patterns of water utilization in the Sutter-Yuba Area, the extraction of water from the ground water basin might be increased. Such increase in draft would undoubtedly be accompanied by recession of ground water levels in areas of pumping. However, this lowering of the water table would induce increased subsurface inflow to the areas of pumping and reduce natural disposal of the ground water, the probable effects of which would be to increase replenishment in an amount approximately equal to the increase in draft. This would probably hold true even in a series of dry years because of the continuous availability of large amounts of ground water in adjacent areas, maintained by percolation from relatively large surface water supplies. For this reason, the first of the foregoing criteria for determination of safe yield was not considered to be applicable in the Sutter-Yuba Area.

Because of expressed local concern over recent progressive lowering of pumping levels and deterioration in mineral quality of the ground water, the second and third of the foregoing criteria for determination of safe ground water yield were adopted as applicable to the Sutter-Yuba Area. It was therefore arbitrarily assumed that seasonal net extraction of ground water in 1948-49, with ground water levels prevailing at that time, defined the desirable limit beyond which net extraction should not be increased at the expense of further lowering of ground water levels.

As previously stated, consumptive use of ground water was considered to be equal to net extraction of water from the Sutter-Yuba ground water basin. An estimate of average seasonal consumptive use of ground water in the area during the nine-year base period is presented and explained in Chapter III. After correction for average seasonal change in ground water storage, this value was considered to represent average seasonal replenishment of the ground water basin during the base period. When further corrected for the increase in replenishment during 1948-49, over and above the base period average, as measured by increase in subsurface inflow, the value was considered to be equal to safe seasonal ground water yield.

The estimate of safe seasonal ground water yield is presented in Table 17.

Certain of the items included in the estimate of safe ground water yield are based on the assumption that present practice of irrigation by surface water supplies in and adjacent to the Sutter-Yuba Area will continue indefinitely. Under such circumstances adjacent ground water basins will remain the sources of sufficient subsurface inflow to areas of ground water pumping in the Sutter-Yuba Area to meet increases in pumping draft. While there is no assurance that surface irrigation practices will continue indefinitely as at present, there is reason to believe that any changes will not be of material significance to the estimated yield for many years in the future.

TABLE 17

ESTIMATED SAFE SEASONAL GROUND WATER YIELD IN SUTTER-YUBA AREA

Item	Acre-feet
Average seasonal consumptive use of ground water for 9-year base period, 1939-40 through 1947-48	158,100
Average seasonal decrement in ground water storage for base period	10,000
Average seasonal replenishment of ground water basin for base period	148,100
Increase in replenishment in 1948-49 over base period seasonal average	38,000
SAFE SEASONAL GROUND WATER YIELD	186,100

The foregoing estimate of safe seasonal ground water yield may be considered to represent the net seasonal extraction from the ground water basin that might be maintained without permanent lowering of the water table and degradation of mineral quality of the ground water beyond conditions prevailing in 1948-49. Having so chosen the determining criteria, estimated safe seasonal ground water yield may be considered to be a property of the ground water basin, not affected by changes in irrigation efficiency, patterns, or practices.

QUALITY OF WATER

The surface water supplies of the Sutter-Yuba Area are of excellent mineral quality and well suited from that standpoint for irrigation and other beneficial uses. With respect to ground water supplies, however, salinity sufficient to impair use of the ground water for irrigation, domestic, and many industrial uses has been observed at scattered wells throughout the area for many years. In the Peach Bowl, in the adjacent southern portion of the West Side Zone, and in the western portion of the South Side Zone this salinity of ground water has been general. The principal objectives of the water quality investigation, therefore, were to evaluate these conditions and to determine the extent of the area presently affected and the source of the saline ground waters.

It is desirable to define certain terms commonly used in connection with discussion of quality of water:

Contamination—This refers to impairment of the quality of water by sewage or industrial waste to a degree which creates a hazard to public health through poisoning or spread of disease.

Degradation—This refers to any impairment in the quality of water due to causes other than disposal of sewage and industrial wastes.

Pollution—This refers to impairment of the quality of water by sewage or industrial waste to a degree which does not create a hazard to public health, but which adversely and unreasonably affects such water for beneficial uses.

Quality of Water—This refers to those inherent characteristics of water affecting its suitability for beneficial uses.

The term "mineral analysis" refers to the quantitative determination of inorganic impurities or dissolved mineral constituents in the water. The complete mineral analysis included a determination of three cations, consisting of calcium, magnesium, and sodium; four anions, consisting of bicarbonate, chloride, sulphate, and nitrate; total soluble salts; boron; and computation of percent sodium. The partial analysis included determination of chlorides and total mineral solubles only.

With the exception of boron, the concentrations of cations and anions in a water sample are expressed in this report in terms of "equivalents per million." This was done because ions combine with each other on an equivalent basis, rather than on basis of weight, and a chemical equivalent unit of measurement provides a better and more convenient expression of concentration. This is especially true when it is desired to compare the composition of waters having variable concentration of mineral solubles. In the case of boron, concentrations are expressed on a weight basis of "parts per million" of water. In order to convert equivalents per million to parts per million, the concentration, expressed in equivalents per million, should be multiplied by the equivalent weight of the cation or the anion in question. Equivalent weights of the common cations and anions are presented in the following tabulation:

Cation	*Equivalent weight*	*Anion*	*Equivalent weight*
Calcium	20.0	Bicarbonate	61.0
Magnesium	12.2	Chloride	35.5
Sodium	23.0	Sulphate	48.0
		Nitrate	62.0

Data used to determine the quality of water in the Sutter-Yuba Area included complete mineral analyses of eight surface water samples and complete mineral analyses of water samples collected from 38 wells. The data also included partial analyses of water samples collected from 226 wells during the 1948 irrigation season and partial analyses of samples collected from 296 wells during the 1949 irrigation season. Other data used during the course of the investigation included well water analyses that were obtained from the Federal Land Bank in Berkeley and the Rubidoux Laboratory of the United States Department of Agriculture at Riverside, California.

Standards of Quality for Water

Investigation and study of the quality of surface and ground waters of the Sutter-Yuba Area, as reported herein, were largely limited to consideration of mineral constituents of the waters, with particular reference to their suitability for irrigation use. However, it may be noted that, within the limits of the mineral analyses herein reported, a water which is determined to be suitable for irrigation may also be considered as being either generally suitable for municipal and domestic use, or susceptible to such treatment as will render it suitable for that purpose.

The major criteria which were used as a guide to judgment in determining suitability of water for irrigation use comprised the following: (1) chloride concentration, (2) total soluble salts, (3) boron concentration, and (4) percent sodium.

1. The chloride anion is usually the most troublesome element in most irrigation waters. It is not considered essential to plant growth, and excessive concentrations will inhibit growth.

2. Total soluble salts furnishes an approximate indication of the over-all mineral quality of water. It may be approximated by multiplying specific electrical conductance ($Ec \times 10^6$ at 25° C.) by 0.7. The presence of excessive amounts of dissolved salts in irrigation water will result in reduced crop yields.

3. Crops are sensitive to boron concentration, but require a small amount (less than 0.1 per million) for growth. They will usually not tolerate more than 0.5 to 2 parts per million, depending on the crop in question.

4. Percent sodium reported in the analyses is the proportion of the sodium cation to the sum of all cations, and is obtained by dividing sodium by the sum of calcium, magnesium, and sodium, all expressed in equivalents per million, and multiplying by 100. Water containing a high percent sodium has an adverse effect upon the physical structure of the soil by dispersing the soil colloids and making the soil "tight," thus retarding movement of water through the soil, retarding the leaching of salts, and making the soil difficult to work.

The following excerpts from a paper by Dr. L. D. Doneen, of the Division of Irrigation of the University of California at Davis, may assist in interpreting water analyses from the standpoint of their suitability for irrigation:

"Because of diverse climatological conditions, crops, and soils in California, it has not been possible to establish rigid limits for all conditions involved. Instead, irrigation waters are divided into three broad classes based upon work done at the University of California, and at the Rubidoux, and Regional Salinity laboratories of the U. S. Department of Agriculture.

"Class 1. *Excellent to Good*—Regarded as safe and suitable for most plants under any condition of soil or climate.

"Class 2. *Good to Injurious*—Regarded as possibly harmful for certain crops under certain conditions of soil or climate, particularly in the higher ranges of this class.

"Class 3. *Injurious to Unsatisfactory*—Regarded as probably harmful to most crops and unsatisfactory for all but the most tolerant.

"Tentative standards for irrigation waters have taken into account four factors or constituents, as listed below.

Factor	*Class 1 excellent to good*	*Class 2 good to injurious*	*Class 3 injurious to unsatisfactory*
Conductance (Ec × 10⁶ at 25° C.)	Less than 1000	1000–3000	More than 3000
Boron, ppm	Less than 0.5	0.5–2.0	More than 2.0
Percent sodium	Less than 60	60–75	More than 75
Chloride, epm	Less than 5	5–10	More than 10

(End of quotation)

Quality of Surface Water

Analyses of surface water samples, collected in March, 1949, from the Feather River and four of its tributaries, showed that at that time the waters in these streams were of excellent mineral quality and well suited for irrigation and other beneficial uses. The waters were characterized by a very low content of total mineral solubles, chloride, and boron, and by low percent sodium. The occurrence of excellent quality water in the Feather River is also indicated by analyses of water from that stream which are presented in the Sacramento-San Joaquin Water Supervision Reports of the Division of Water Resources dating from 1946. Analyses of drainage water samples collected from Sutter By-pass and Snake Slough indicated that both drainage waters contain higher concentrations of mineral solubles than waters of Feather River and its tributaries, but that they are well within the limits of Class 1 irrigation waters. Analyses of representative surface waters of the Sutter-Yuba Area, sampled in 1949, are presented in Table 18.

Quality of Ground Water

Although in the course of the present investigation surveys were made of the mineral quality of ground water throughout the Sutter-Yuba Area, particular emphasis was placed on those areas where saline degradation has been general, and of a degree sufficient to limit beneficial use of the ground water. Results of the surveys are presented and discussed in this section under the headings "Area of Degraded Ground Water" and "Source of Ground Water Salinity."

Area of Degraded Ground Water. Two comprehensive surveys of the average mineral quality of ground water in the Sutter-Yuba Area were made during the irrigation seasons of 1948 and 1949. Both surveys involved the partial analysis of water samples collected from numerous wells to determine total mineral solubles and chlorides. Results of the two surveys are summarized in Table 19, and show that in 1948 and 1949 the mineral quality of native ground water supplies was excellent or good in all zones of the Sutter-Yuba Area, except in that portion of the West Side Zone south of Oswald Road where abnormally high concentrations of chloride were found in many of the well water samples. The 1949 survey embraced a larger area than the 1948, and included lands south and west of Sutter By-pass. Results of this extended survey showed that high chloride salinity of ground water also occurred locally near the town of Robbins, some seven miles westerly from Nicolaus.

The foregoing present areas of comparatively high chloride salinity are shown on Plate 16, "Lines of Equal Concentration of Chlorides in Ground Water, July 1949." It may be noted that the concentration of chlorides in the ground water decreased progressively with distance from both of the affected areas, in the

TABLE 18

COMPLETE MINERAL ANALYSES OF REPRESENTATIVE SURFACE WATERS OF SUTTER-YUBA AREA

	Date of sample	Conductance, Ec × 10⁶ at 25° C.	Boron, in ppm	Mineral constituents in equivalents per million							Percent sodium
				Ca	Mg	Na	HCO_3 + CO_3	Cl	SO_4	NO_3	
Tributary Streams											
Feather River at Rednal Road	3/15/49	99	0.0	0.39	0.47	0.27	0.91	0.06	0.09	Trace	24
Feather River at Nicolaus	3/14/49	92	0.0	0.43	0.46	0.40	0.77	0.03	0.20	0.09	31
South Honcut Creek at La Porte Road	3/15/49	124	0.0	0.43	0.62	0.36	1.08	0.12	0.15	Trace	26
Dry Creek near Waldo	3/21/49	164	0.0	0.71	0.85	0.40	1.37	0.13	0.31	Trace	20
Coon Creek at Highway 99E	3/14/49	175	0.0	0.70	0.93	0.36	1.51	0.16	0.32	0.06	18
Auburn Ravine at Highway 99E	3/14/49	143	0.0	0.54	0.69	0.39	1.04	0.16	0.28	0.10	24
Drainage Waters											
Sutter By-pass at Colusa Highway	7/19/49	400	0.09	1.49	1.79	1.35	3.94	0.52	0.21	Trace	28
Snake Slough at Sanders	7/19/49	380	0.09	1.29	1.80	1.80	3.88	0.38	0.08	Trace	26

TABLE 19

SUMMARY OF PARTIAL MINERAL ANALYSES OF GROUND WATERS IN ZONES OF SUTTER-YUBA AREA, SUMMERS OF 1948 AND 1949

Zone	Number of samples		Chlorides, in equivalents per million				Conductance, Ec × 10^6 at 25° C.	
			Average		Range			
	1948	1949	1948	1949	1948	1949	1948	1949
West Side								
North of Oswald Road	41	25	1.5	0.84	0.3- 4.8	0.3- 2.1	600	730
South of Oswald Road	129	159	5.13	6.10	0.3-28.7	0.3-62.5	1,010	1,300
Northeast	4	2	0.8	0.73	0.3- 1.1	0.3- 1.1	340	280
East Central	31	14	0.7	0.7	0.3- 1.7	0.3- 1.7	300	210
South Side	21	6	1.1	1.0	0.6- 4.8	0.5- 2.0	500	380

West Side Zone south of Oswald Road and near the town of Robbins. It may be inferred from this condition that, when hydraulic conditions are favorable, saline ground water from these two areas may move laterally, thus causing degradation in the mineral quality of remaining fresh ground water resources of surrounding areas.

The areas delimited by the lines of equal chloride concentration on Plate 16 indicate that at the present time wells on approximately 4,500 acres of land in the West Side Zone south of Oswald Road yield water containing chlorides in amounts exceeding 10 equivalents per million, which amount is considered to be the upper limit for safe irrigation use. When such saline waters are used for irrigation, quantities of water exceeding normal crop demands are commonly applied in order to dilute the soil solution and leach accumulations of excess salts away from the root zone.

Source of Ground Water Salinity. The presence of saline ground waters in and adjacent to the Sutter-Yuba Area has been observed to exist for many years, and was remarked upon in reports of salt balance studies conducted by the Division of Soil Management and Irrigation of the United States Department of Agriculture. These studies, which were made in cooperation with the Sutter Mutual Water Company during 1931, 1932, 1933, 1946, and 1947, showed that the amount of dissolved solids in water drained from lands adjacent to and west of the southern portion of the Sutter-Yuba Area greatly exceeded the amount brought onto the lands in irrigation water. The salt output during each of the five years, expressed as a proportion of the input, is reported to have ranged between 248 and 655 percent, and the average was about 407 percent.

The opinion was expressed in a report on the foregoing 1947 salt balance study that the salt in the drainage waters was probably derived from saline waters underlying the area. Preliminary studies made by the Division of Water Resources similarly indicated that the chloride salinity in many of the wells was due to admixture of deep-seated brines with native fresh ground waters. There is evidence that such brines may underlie aquifers of good quality water throughout large areas of the Sacramento and San Joaquin Valleys, and that they may have originated during past geologic time when the floor of the valley was inundated by the ocean. Such brines sometimes appear in water pumped from the deeper wells in the two valleys, or from areas wherein the fresh ground water levels are markedly lowered through overdraft. In many instances these relatively deep-seated brines are under considerable pressure and readily rise to the surface through defective, abandoned, or improperly constructed wells. A case in point is a natural gas well located near the town of Robbins which yields water under artesian and/or gas pressure, at a rate of about 200 gallons a minute. The water from this well, No. 12N/2E-18, has a conductivity of about 8,600, a chloride content of about 100 equivalents per million, and about 10.8 parts per million of boron.

A geochemical study was made to determine whether salinity of ground water in the Sutter-Yuba Area was caused principally by a common degradant, and whether the foregoing deep-seated brines constituted that degradant. The study to identify the degradant was made on the basis of complete mineral analyses of water samples collected from 38 scattered wells located in the West Side Zone south of Oswald Road and in adjacent lands to the west. These water samples were first classified into eight groups according to the range in concentration of total anions. For purposes of the study it was considered that native fresh ground waters contained total anions in amounts less than about 7 equivalents per million, chlorides in amounts less than about 2.5 equivalents per million, and that degradation had occurred if these amounts were ex-

ceeded. A discussion of the characteristics of each group follows:

Group 1. This comprised unaltered normal ground water. Four analyses were available for Group 1 water. The wells which yielded this water were located within the present zone of high chloride concentration, and the samples were taken and analyses made in 1934 and 1935 prior to recent degradation of ground water in the zone. The water had total anions ranging from 4.72 to 6.31 equivalents per million, and chlorides from 0.85 to 2.06 equivalents per million. Its mineral quality was excellent.

Group 2. This group comprised waters containing a trace of salinity. Total anions ranged from 8.95 to 10.68 equivalents per million, and chlorides from 5.45 to 6.39 equivalents per million. Four analyses repre-

TABLE 20

COMPLETE MINERAL ANALYSES OF GROUND WATERS IN AREA OF SALINE DEGRADATION IN AND ADJACENT TO SUTTER-YUBA AREA, GROUPED IN ACCORDANCE WITH TOTAL ANIONS

Ground water group	Well location or number	Date of sample	Conductance, Ec × 10⁶ at 25° C.	Boron, in ppm	Mineral constituents, in equivalents per million							Percent sodium
					Ca	Mg	Na	HCO_3 + CO_3	Cl	SO_4	NO_3	
1	N½ Sec. 9, T13N, R3E	5/31/34	483		1.40	1.81	1.51	3.30	1.33	0.09		32
	S½ Sec. 10, T14N, R3E	1/ 2/35	543		1.70	1.97	1.43	4.25	0.85	Trace		28
	NE¼ Sec. 15, T14N, R3E	1/15/35	515		1.50	2.13	1.54	3.70	1.47	Trace		30
	NW¼ Sec. 28, T14N, R3E	4/30/34	635		2.10	2.30	1.91	4.20	2.06	0.05		30
	Average		544		1.67	2.05	1.59	3.86	1.43	0.03		30
2	11N/3E-2B1	7/ /49	944	0.16	2.80	2.24	4.31	3.02	5.90	0.03	0.0	46
	13N/3E-3D1	7/ /49	980	0.09	3.59	5.02	2.05	4.20	6.39	0.09	0.0	19
	14N/3E-28R1	7/ /49	1,000	0.12	2.71	5.62	2.58	3.94	6.38	0.13	Trace	24
	14N/3E-33A2	7/ /49	1,037	0.0	2.98	4.29	3.32	5.09	5.45	0.03	0.0	31
	Average		990	0.09	3.02	4.29	3.06	4.06	6.03	0.07	Trace	30
3	13N/3E-2P3	7/ /49	1,317	0.17	3.13	3.39	6.46	3.78	9.21	0.04	0.0	50
	13N/3E-5K1	7/ /49	1,353	0.07	3.70	5.53	4.07	4.15	9.14	0.09	0.0	31
	13N/3E-10A1	7/ /49	1,190	0.05	4.40	5.83	2.13	3.91	8.06	0.22	0.0	17
	14N/3E-27E1	7/ /49	1,361	0.0	4.51	5.94	3.38	5.53	7.86	0.45	Trace	24
	14N/3E-29Q1	7/ /49	1,390	0.14	4.14	5.33	4.47	3.23	10.15	0.02	Trace	32
	14N/3E-34J1	7/ /49	1,087	0.0	4.05	5.76	2.57	6.84	3.40	2.01	0.10	21
	Average		1,283	0.07	3.99	5.31	3.85	4.54	7.97	0.14	0.02	29
4	13N/3E-2E1	7/ /49	1,503	0.49	2.96	3.05	8.75	3.78	11.11	0.03	0.0	59
	13N/3E-11D1	7/ /49	1,408	0.06	5.21	7.34	1.96	4.17	9.34	0.81	0.0	13
	13N/3E-14G1	7/ /49	1,307	0.06	4.43	6.85	3.44	6.20	7.49	0.71	0.06	23
	13N/3E-23H1	7/ /49	1,408	0.03	5.45	6.73	2.92	4.98	10.23	0.17	0.0	19
	13N/3E-24D1	7/ /49	1,460	1.64	3.23	2.15	9.05	3.90	11.68	0.03	0.0	63
	14N/3E-33A1	7/ /49	1,460	0.0	4.88	6.99	2.82	5.11	9.44	0.09	0.0	19
	Average		1,425	0.36	4.36	5.52	4.86	4.52	9.88	0.31	0.01	33
5	13N/3E-5C1	7/ /49	1,835	0.21	4.83	6.00	6.70	3.52	14.08	0.03	0.0	38
	13N/3E-11F1	7/ /49	1,710	0.85	3.29	4.51	9.40	3.26	13.04	0.28	0.0	55
	13N/3E-14J1	7/ /49	1,710	0.31	4.68	8.18	4.87	4.12	12.78	0.43	0.0	27
	14N/3E-28G2	7/ /49	1,653	0.0	5.18	6.92	4.51	5.21	10.95	0.37	0.0	27
	14N/3E-32F1	7/ /49	1,640	0.24	4.90	7.36	4.77	4.35	12.37	0.03	0.0	28
	Average		1,709	0.32	4.58	6.59	6.05	4.09	12.64	0.23	0.0	35
6	11N/3E-3B1	7/ /49	2,162	0.93	4.63	2.98	13.94	3.42	18.08	0.03	0.0	65
	13N/3E-2N1	7/ /49	1,802	0.07	5.71	6.31	6.02	4.63	13.61	0.15	Trace	33
	13N/3E-14R1	7/ /49	1,870	0.72	5.35	6.68	6.89	4.88	14.06	0.26	0.0	36
	13N/3E-16R1	7/ /49	2,222	0.03	5.96	8.25	7.27	4.24	17.42	0.03	0.0	34
	13N/3E-32L1	7/ /49	2,062	0.21	5.27	10.09	5.75	2.64	17.26	0.30	0.0	27
	Average		2,059	0.39	5.38	6.86	7.97	3.95	16.09	0.15	Trace	39
7	13N/3E-6K1	7/ /49	2,550	0.28	6.62	11.33	8.81	5.08	20.42	0.05	0.0	33
	13N/3E-23B1	7/ /49	3,390	0.0	11.83	16.80	6.71	5.50	29.04	0.34	Trace	19
	14N/3E-31J1	7/ /49	2,425	0.0	7.28	11.08	6.20	5.06	19.26	0.26	Trace	25
	14N/3E-31R1	7/ /49	2,552	0.07	7.36	11.09	6.97	4.98	20.44	0.12	0.0	27
	14N/3E-32L2	7/ /49	2,776	0.27	7.40	9.30	9.84	2.82	23.52	0.04	0.0	37
	14N/5E-21A1	8/ 3/49	2,702	1.71	10.78	4.17	12.60	1.72	22.94	2.01	Trace	46
	Average		2,732	0.39	8.55	10.63	8.52	4.19	22.60	0.47	Trace	31
8	SE¼ Sec. 2, T12N, R2E	7/ 9/49	10,000	0.60	30.37	35.30	39.90	4.10	99.45	0.05	0.0	38
	SW¼ Sec. 18, T12N, R2E	3/14/47	8,600	10.8	19.83	7.22	76.12	2.71	99.92	0.08		74
	Average		9,300	5.7	25.10	21.26	58.01	3.40	99.67	0.05		56

senting wells yielding Group 2 waters were available. These waters were classed as of good mineral quality and suitable for general irrigation use.

Group 3. This group comprised slightly saline ground waters. Total anions ranged from 12.19 to 13.40 equivalents per million, and chlorides ranged from 3.40 to 10.15 equivalents per million. Six analyses were available for wells yielding Group 3 waters. These waters were considered to be generally satisfactory for irrigation use.

Group 4. This group comprised moderately saline ground waters, with total anions ranging from 14.32 to 15.38 equivalents per million, and chlorides ranging from 7.49 to 11.68 equivalents per million. Six analyses were available for wells yielding Group 4 waters. These waters were classed as usable with caution for general irrigation under most conditions.

Group 5. This group comprised saline ground waters with total anions ranging from 16.53 to 17.63 equivalents per million, and chlorides ranging from 10.95 to 14.08 equivalents per million. Five analyses were available for wells yielding Group 5 waters. These waters would normally be considered usable for irrigation only after dilution with water of better mineral quality.

Group 6. This group comprised saline ground waters having total anions ranging from 18.35 to 21.69 equivalents per million, and chlorides ranging from 13.61 to 18.08 equivalents per million. Five analyses were available for wells yielding Group 6 water. This water was classed as unsuitable for irrigation use.

Group 7. This group comprised highly saline ground waters, having total anions ranging from 25.54 to 34.88 equivalents per million, and chlorides ranging from 19.26 to 29.04 equivalents per million. Analyses were available for six wells yielding Group 7 waters. These waters were not considered usable for irrigation or domestic purposes.

Group 8. This group comprised briny ground waters. Group 8 waters were yielded in June 1949 by a reputedly shallow well, and in April 1930 and March 1947 by a nearly 1500-foot abandoned gas well, both located near Robbins to the west of the Sutter-Yuba Area. These waters had total anions in excess of 100 equivalents per million. Chlorides accounted for about 95 per cent or more of the anions.

Results of complete mineral analyses of ground waters in the zone of degradation, segregated into the foregoing groups, are presented in Table 20.

The character formula of a water expresses the percent of each cation and anion of mineral constituents of the water with respect to their total, and is useful in comparing mineral quality characteristics of several waters. In order to compare the groups of saline ground waters in and adjacent to the Sutter-Yuba Area, the average equivalents per million of each cation and anion in unaltered normal ground water, represented by Group 1, were first subtracted from corresponding average mineral constituents in ground water of each of the other groups, with exception of those of Group 8. The character formulae of waters of Groups 2 to 7 were then derived as determined by use of these remainders. Both the character formulae of these differences and the mineral constituents are shown in Table 21. They may be considered to represent the mineral characteristics of the ground water degradant as they were prior to alteration through mingling of the degradant with fresh ground water, but after being subjected to base exchange during movement of the degradant from its source. It may be noted that both the concentration and composition of waters in Group 8 were taken directly from the average analysis presented in Table 20. This was done on the assumption that the brines of that group were not significantly diluted with fresh water.

TABLE 21

AVERAGE MINERAL CHARACTER AND CONSTITUENTS OF SALINE GROUND WATERS IN AND ADJACENT TO SUTTER-YUBA AREA

(Corrected for effects of dilution with unaltered normal ground water)

Ground water group	Mineral constituents in equivalents per million and character formulae in percent					
	Ca	Mg	Na	HCO_3	Cl	SO_4
2	1.35 13.3%	2.24 22.2%	1.47 14.5%	0.20 2.0%	4.60 47.6%	0.04 0.4%
3	2.32 14.0%	3.26 20.8%	2.26 14.4%	0.68 4.6%	6.54 44.6%	0.11 0.8%
4	2.69 14.3%	3.47 18.4%	3.27 17.3%	0.66 3.5%	8.45 45.0%	0.28 1.5%
5	2.91 12.2%	4.54 19.1%	4.46 18.7%	0.23 1.0%	11.21 48.1%	0.20 0.9%
6	3.71 13.7%	4.81 15.6%	6.38 20.7%	0.09 0.3%	14.66 49.3%	0.12 0.4%
7	6.88 15.4%	8.58 19.1%	6.93 15.5%	0.33 0.8%	21.17 48.2%	0.44 1.0%
8	25.10 21.0%	21.26 10.0%	58.01 28.0%	3.40 1.7%	99.67 48.0%	0.06 0.3%

Table 21 shows that, irrespective of variations in concentration, the character formula of the degradant in each of the ground water Groups 2 through 7 is strikingly similar to that of the brines comprising Group 8. This is especially true of the anions which are not subject to base exchange reactions. This similarity in composition, together with apparent absence of any other like degradant, indicates that degradation of the native ground waters is due to admixture of deep-seated brines of the type exemplified by Group 8.

Although the chloride content of water from wells in the area of saline ground water is generally high, it is quite variable with respect to the depth of wells. Examination of analyses of water from 33 wells of known depth in the West Side Zone south of Oswald Road did not indicate any correlation between chloride content of the water and depth. The wells studied for this purpose ranged in depth from about 50 to 300 feet, and the average depth was of the order of 145 feet. The lack of any significant correlation in this matter cannot be fully explained on the basis of data compiled during the course of the present investigation. However, it is probable that the explanation may lie in precise identification of the aquifers which contribute water to the respective wells. For example, wells pumping from both fresh and saline aquifers would probably yield water containing lower concentrations of chlorides than wells pumping only from saline aquifers. In this connection it is noted that additional more detailed investigation of the quality of the water resources of the Sutter-Yuba Area is in progress under the provisions of Section 229 of the Water Code. This work is being conducted by the Division of Water Resources in connection with its assigned responsibilities for a state-wide survey of quality of surface and ground waters, the results of which will be published at a later date.

Studies to date of saline ground water conditions in the Sutter-Yuba Area indicate that the brines of Group S may migrate upward into fresh water aquifers both through permeable zones in the alluvium and through unplugged test wells and abandoned, defective, or improperly constructed water wells. Furthermore, when the water table is lowered by heavy irrigation pumping, it is probable that upward movement of the brines is accelerated. Possible subsequent lateral movement of the brines may be inferred from the observed progressive decrease in ground water chloride concentrations with distance from the two areas of high chloride salinity, in the West Side Zone south of Oswald Road and near Robbins.

CHAPTER III

WATER UTILIZATION AND SUPPLEMENTAL REQUIREMENTS

The nature and extent of water utilization and requirements for supplemental water in the Sutter-Yuba Area, both at the present time and under probable conditions of ultimate development, are considered in this chapter. In connection with the discussion, the following terms are used as defined:

Water Utilization—This term refers to the sum of consumptive use of water and those irrecoverable losses of water incidental to its beneficial use.

Consumptive Use of Water—This term refers to water consumed by vegetative growth in transpiration and building of plant tissue, and to water evaporated from adjacent soil, from water surfaces, and from foliage. It also refers to water similarly consumed and evaporated by urban and nonvegetative types of culture.

Supplemental Requirement—This term refers to the amount of water, over and above the sum of safe ground water yield and safe surface water yield, which must be developed to satisfy water utilization.

Ultimate—This term refers to an unspecified but long period of years into the future when cultural development will be essentially stabilized. (It is realized that any present forecasts of the nature and extent of such ultimate cultural development, and resultant water utilization, are inherently subject to possible large errors in detail and appreciable error in the aggregate. However, such forecasts, when based upon best available data and present judgment, are of value in establishing long-range objectives for development of water resources. They are so used herein, with full knowledge that their re-evaluation after the experience of a period of years may result in considerable revision.)

Present water utilization in the Sutter-Yuba Area was estimated by the application of appropriate unit consumptive use of water factors to the present cultural pattern. Probable ultimate water utilization was similarly estimated, by the use of an ultimate cultural pattern projected from the present pattern on the basis of land classification data, the assumption being made that under ultimate conditions of cultural development all irrigable lands would be irrigated. As indicated by the foregoing definition, supplemental requirements for water were estimated as the differences between derived values of safe yield and utilization, under both present and ultimate conditions of cultural development.

Water utilization is considered and evaluated in this chapter under the general headings "Present Water Supply Development," "Land Use," "Unit Use of Water," "Past and Present Water Utilization," "Probable Ultimate Water Utilization," and "Demands for Water." Supplemental water requirements are similarly treated under the two general headings "Present Supplemental Requirements" and "Probable Ultimate Supplemental Requirements."

WATER UTILIZATION

Of the total amount of water presently utilized in the Sutter-Yuba Area, approximately 65 percent is consumed in the production of irrigated crops, while the remainder is consumed by dry-farmed crops and fallow lands, native vegetation, and miscellaneous culture including domestic and municipal. It is considered probable that the predominant importance of irrigated agriculture, as related to utilization of water in the area, will continue to prevail in the future.

Present Water Supply Development

Approximately two-thirds of the acreage under water service in the Sutter-Yuba Area is presently supplied by water pumped from the underlying ground water basin. Irrigated lands utilizing ground water are generally served by individually owned wells and pumps. Because of this fact and the extensive ground water utilization, the amount of water developed for irrigation use by individuals is larger than by organized agencies. As of April 1, 1949, there were 2,198 wells and pumping plants of heavy draft, powered with motors of more than five horsepower, and of this number 2,159 were used for irrigation. The 39 remaining wells supplied water for urban and industrial uses. A number of additional wells of light draft supplied limited amounts of water for noncommercial gardens and orchards, and for domestic purposes. Lands served principally with ground water comprise the Peach Bowl, the East Central Zone, and the portion of the South Side Zone adjacent to and south of Bear River.

Surface diversions for irrigation in the Sutter-Yuba Area are made from the Sacramento and Feather Rivers and tributary streams, and from the Wadsworth and Natomas Canals, various surface drains, and the Sutter By-pass. The major diversions are made by irrigation companies and districts, with service to the lands being largely by means of open ditch transmission and distribution systems. Minor surface diversions are made for the most part by individuals whose lands are adjacent to the surface supplies. The Sutter Butte Canal Company is the principal diverter of water from Feather River, serving lands in the West Side Zone outside of the Peach Bowl. The joint diversion of the Hallwood Irrigation Company and the

Cordua Irrigation District is the largest of a number of irrigation diversions from Yuba River, and serves water to lands in the Northeast Zone. The Nevada Irrigation District supplies some surface water to lands in the South Side Zone through ditches diverting from Auburn Ravine. Lands served principally by surface waters comprise the Northeast Zone, the West Side Zone outside the Peach Bowl, and the west portion of the South Side Zone.

Water used for municipal, industrial, and domestic purposes in the Sutter-Yuba Area is obtained almost entirely from wells. The greater part of such use is in the Cities of Marysville and Yuba City, and is scattered and of relatively minor significance throughout the remainder of the area.

The City of Marysville is served by the California Water Service Company, a public utility which pumps water from wells into storage tanks, from which it is delivered to consumers by gravity. Water services are metered. The quantity of water pumped for use in Marysville in the calendar year 1948 was 506,000,000 gallons, or 1,550 acre-feet. With an approximate population of 7,500 in July, 1948, the daily production averaged about 185 gallons per capita.

Yuba City is served by the Yuba City Municipal Water Works, which charges for water on a flat-rate basis. It was estimated that the quantity of water pumped for use in Yuba City in the calendar year 1948 was about 750,000,000 gallons, or 2,300 acre-feet. With an approximate population of 6,300 in March, 1948, the daily per capita production was about 330 gallons.

In addition to the foregoing figures regarding ground water pumped in 1948 under the municipal systems of Marysville and Yuba City, it was estimated that approximately 1,000 acre-feet was pumped and used by industries operating their own wells within the cities. Wheatland has a community water system that distributes water from a storage tank supplied by two wells. The estimated amount of water pumped in Wheatland during the calendar year 1948 was approximately 200 acre-feet. Assuming that the per capita water production in remaining small towns and communities in the Sutter-Yuba Area was about 200 gallons per day, it was estimated, on the basis of 1948 population estimates, that total annual pumpage from ground water for these communities was about 700 acre-feet.

The respective areas within the several zones of the Sutter-Yuba Area served by ground water and surface water are shown in Table 22. The data presented for the two investigational seasons resulted from field surveys during the current investigation, while the averages for the base period were largely based on records of crop surveys made by the Division of Water Resources in connection with the Sacramento-San Joaquin Water Supervision, and on pumping power consumption records furnished by the Pacific Gas and Electric Company.

TABLE 22

GROUND AND SURFACE WATER SERVICE AREAS IN ZONES OF SUTTER-YUBA AREA

(In acres)

Zone	Ground water		Surface water	
	1948	1949	1948	1949
West Side	48,990	44,650	18,750	21,590
Northeast	6,050	8,240	11,540	11,850
East Central	24,230	33,140	2,500	990
South Side	11,280	10,770	15,420	18,070
TOTALS	90,550	96,800	48,210	52,500
Averages for 9-year base period, 1939-40 through 1947-48	68,490		42,810	

Table 23 lists the principal water service agencies, together with notations on their sources of water supply, locations of service areas within the Sutter-Yuba Area, and acreages within the area irrigated by water served by each agency in 1948. Areas included within the boundaries of these agencies are shown on Plate 2.

TABLE 23

PRINCIPAL WATER SERVICE AGENCIES SUTTER-YUBA AREA

Agency	Source of water supply	Service area, by zones	Acreage irrigated in 1948
California Water Service Company	Ground water	Northeast	Municipal use in Marysville
Camp Far West Irrigation District	Bear River	East Central	1,580
Cordua Irrigation District	Yuba River	Northeast	4,736
Farm Lands Investment Company	Feather River	East Central	1,833
Feather River Water Company	Feather River	West Side	0
Garden Highway Mutual Water Company	Feather River	West Side	2,075
Hallwood Irrigation Company	Yuba River	Northeast	6,365
Natomas Central Mutual Water Company	Sacramento River	South Side	11,298
Natomas Northern Mutual Water Company	Sacramento River	South Side	*
Nevada Irrigation District	Yuba and Bear Rivers	South Side	1,240
Oswald Water District	Feather River	West Side	608
Sutter Butte Canal Company	Feather River	West Side	12,840
Sutter Extension Water District	Feather River	West Side	Formed in 1949
Yuba City Municipal Water Works	Ground water	West Side	Municipal use

* Included in acreage of Natomas Central Mutual Water Company.



Rice Field in Sutter-Yuba Area

Land Use

As a first step in estimating the amount of water utilization in the Sutter-Yuba Area during the base period and investigational seasons, determinations were made of the nature and extent of land use prevailing during these periods. Similarly, the probable nature and extent of ultimate land use, as related to water utilization, was forecast on the basis of land classification survey data which segregated lands of the area in accordance with their suitability for irrigated agriculture.

Past and Present Cultural Patterns. In connection with the Sacramento-San Joaquin Water Supervision, the Division of Water Resources for some 25 years has made annual crop surveys of those lands in the Sutter-Yuba Area utilizing surface water. In 1946 the United States Bureau of Reclamation made a complete crop survey of the area. A comprehensive cultural survey was made during the season of 1947-48 as a part of the current investigation. Additional data on culture were obtained in 1948-49 from a supplementary survey made in order to determine any changes in land use since the preceding season.

Data available from the foregoing surveys were sufficient to estimate the average cultural pattern in the Sutter-Yuba Area during the nine-year base period. For purposes of this report, the cultural pattern existing during the 1948-49 season was considered to represent "present" conditions of culture and development in the area, and is so referred to in subsequent discussion.

Summaries of the results of the cultural surveys of 1947-48 and 1948-49 and the estimated average cultural pattern for the base period are presented in Table 24. The Sutter Buttes, comprising some 22,300 acres of waste land in the West Side Zone, are not included in the tabulation. Lands irrigated in the Sutter-Yuba Area during the 1947-48 season are shown on Plate 17, "Irrigated and Irrigable Lands, 1948."

The most significant indicated recent trend in irrigated agriculture in the Sutter-Yuba Area is toward increased plantings of rice and permanent pasture. The data presented in Table 24 show that the area of rice increased from an estimated average of some 25,500 acres during the base period to over 44,000 acres in 1948-49. At the same time, permanent pasture increased from some 17,500 to 25,500 acres. Deciduous orchard, which had long been the largest irrigated crop in the area on an acreage basis, showed an increase of less than 3,000 acres in 1948-49 over the base period average, and was surpassed by the acreage of rice during the latter season. The foregoing increases in irrigated agriculture were largely reflected by corresponding decreases in acreage of dry-farmed and fallow lands. Table 24 shows that there was moderate increase in farmstead and urban development in 1948-49 over the base period averages, but no very significant changes in remaining types of culture in the Sutter-Yuba Area.

Probable Ultimate Cultural Pattern. Classification of lands of the Sutter-Yuba Area with respect to their suitability for irrigated agriculture was largely accomplished by other agencies prior to the Sutter-Yuba Counties Investigation. Many valuable data on land classification were available from and furnished by the United States Bureau of Reclamation. The available data were supplemented and checked as required in the course of field surveys conducted as a part of the investigation.

On the basis of their suitability for irrigation, agricultural lands of the Sutter-Yuba Area were segregated into the following five classes:

Class 1. This class comprises lands that are highly desirable in every respect for continuous irrigated agricultural use, and capable of producing all climatically adapted crops. The soils are deep, with good surface and subsoil drainage, of medium to fairly fine texture, and of good water-holding capacity. The soil structure is such as to permit easy penetration of roots, air, and water, and the land surface is smooth and gently sloping.

Class 2. This class comprises lands that are generally limited in their use to climatically adapted crops of medium root depths. Restrictive features with regard to use of the lands are soil depth and, to some extent, topography or drainage.

Class 3. This class comprises lands that are generally limited in their use to climatically adapted shallow-rooted crops, owing to deficiencies in soil depth, topography, or drainage characteristics. This class of lands is suitable for development under irrigation, but because of shallow soil depths, greater care and skill are required in the application of water than are necessary in the case of lands of Classes 1 and 2.

Class 4. This class comprises lands that fail to meet the standards of Classes 1, 2, and 3, as to topography, drainage, and depth of soil. These lands are generally suitable only for permanent pasture or similar crops.

Class 6. This class comprises all lands that do not meet the minimum requirements of suitability for irrigation use.

In addition to agricultural lands, 5,550 acres in the Sutter-Yuba Area were classified as urban, and 22,270 acres comprising the waste lands of the Sutter Buttes were not otherwise classified. Results of the land classification of the Sutter-Yuba Area, summarized by zones, are presented in Table 25.

By use of the land classification data a probable ultimate cultural pattern for the Sutter-Yuba Area was forecast. The general assumption was made that under

TABLE 24

PAST AND PRESENT CULTURAL PATTERNS IN ZONES OF SUTTER-YUBA AREA

(In acres)

Class and type of culture	West Side Zone			Northeast Zone			East Central Zone			South Side Zone			Totals		
	Estimated base period average, 1939-40 through 1947-48	1947-48	Present, 1948-49	Estimated base period average, 1939-40 through 1947-48	1947-48	Present, 1948-49	Estimated base period average, 1939-40 through 1947-48	1947-48	Present, 1948-49	Estimated base period average, 1939-40 through 1947-48	1947-48	Present, 1948-49	Estimated base period average, 1939-40 through 1947-48	1947-48	Present, 1948-49
Irrigated lands															
Deciduous orchard	30,610	32,660	31,820	3,830	4,380	4,410	3,190	3,970	4,080	3,050	3,220	3,190	40,680	44,230	43,500
Rice	9,200	13,480	13,120	1,170	3,440	4,320	3,350	7,800	12,080	11,800	13,630	14,920	25,520	38,350	44,440
Permanent pasture	5,750	8,760	8,530	5,030	6,710	7,580	3,860	5,130	5,860	2,800	3,330	3,560	17,440	23,940	25,530
Beans	3,470	3,610	3,700	1,270	1,460	1,140	3,640	4,190	5,680	1,330	1,390	1,870	9,700	10,650	12,390
Alfalfa	3,100	3,780	3,770	780	1,030	1,630	1,430	1,940	2,210	2,760	3,310	3,530	8,070	10,060	11,140
Truck	2,950	3,060	3,010	210	230	250	510	600	650	680	1,000	930	4,350	4,890	4,840
Tomatoes	980	1,020	1,000	70	80	140	180	210	600	320	70	140	1,550	1,370	1,880
Corn	350	370	300	190	220	270	310	350	550	370	390	410	1,230	1,330	1,530
Hops	520	540	540				560	650	650				1,080	1,190	1,190
Sugar beets	240	250	190	10	10	180	560	640	640	210		40	1,020	900	1,050
Olives	50	40	40	20	20	20	240	290	280				310	350	340
Vines	140	150	150				70	80	80		10	10	200	240	240
Miscellaneous	20	20	70			150	810	890	770	310	350	240	1,140	1,260	1,230
Subtotals	57,380	67,740	66,240	12,580	17,580	20,090	18,710	26,740	34,130	23,630	26,700	28,840	112,300	138,760	149,300
Dry-farmed and fallow lands	53,980	42,610	44,110	24,700	19,150	16,640	47,440	38,440	31,050	53,810	50,120	47,980	179,920	150,310	139,770
Native vegetation	3,580	3,580	3,580	2,750	2,750	2,750	5,280	5,280	5,280	1,400	1,400	1,400	13,010	13,010	13,010
Miscellaneous															
Farmsteads	2,320	2,690	2,690	460	590	590	1,080	1,460	1,460	1,070	1,380	1,380	4,930	6,120	6,120
Roads	2,320	2,690	2,690	460	590	590	1,080	1,460	1,460	1,070	1,380	1,380	4,930	6,120	6,120
Urban	1,840	2,110	2,110	900	1,190	1,190	1,850	2,060	2,060	190	190	190	4,780	5,550	5,550
Water surface	1,350	1,350	1,350	470	470	470	1,040	1,040	1,040	130	130	130	2,990	2,990	2,990
Railroads and highways	720	720	720	380	380	380	660	660	660	690	690	690	2,450	2,450	2,450
Airfields				160	160	160	590	590	590				750	750	750
By-pass overflow lands										470	470	470	470	470	470
Tules	160	160	160				20	20	20				180	180	180
By-pass levees	120	120	120										130	130	130
Waste lands							120	120	120				120	120	120
Subtotals	8,830	9,840	9,840	2,380	3,380	3,380	6,440	7,410	7,410	3,620	4,240	4,240	21,730	24,880	24,880
TOTALS	*123,770	*123,770	*123,770	42,860	42,860	42,860	77,870	77,870	77,870	82,460	82,460	82,460	*326,960	*326,960	*326,960

* Excluding 22,270 acres of waste lands in Sutter Buttes.

TABLE 25

CLASSIFICATION OF LANDS IN ZONES OF SUTTER-YUBA AREA

(In acres)

Zone	Land classes						
	1	2	3	4	6	Urban	Totals
West Side	45,520	41,040	27,440	220	7,440	2,110	*123,770
Northeast	4,240	18,420	13,190	190	5,630	1,190	42,860
East Central	8,330	14,070	44,450	1,270	7,690	2,060	77,870
South Side	10,200	30,880	36,770		4,420	190	82,460
TOTALS	68,290	104,410	121,850	1,680	25,180	5,550	*326,960

* Excluding 22,270 acres of waste lands in Sutter Buttes.

an increasing pressure of demand for agricultural products all irrigable but presently dry lands would eventually be provided with irrigation service. Provision was also made for probable increase in lands devoted to farmsteads, roads, urban, and other miscellaneous purposes under conditions of probable ultimate development.

The estimated ultimate cultural pattern of the Sutter-Yuba Area, summarized by general classes of culture and by zones of the area, is presented in Table 26. Irrigable lands, as determined by the land classification survey data and as indicated by the probable ultimate cultural pattern, are shown on Plate 17.

TABLE 26

PROBABLE ULTIMATE CULTURAL PATTERN IN ZONES OF SUTTER-YUBA AREA

(In acres)

Class of culture	West Side Zone	Northeast Zone	East Central Zone	South Side Zone	Totals
Irrigated lands	100,000	31,200	54,000	64,700	249,900
Dry-farmed lands	9,600	5,100	9,300	11,100	35,100
Native vegetation	3,600	2,700	5,300	1,400	13,000
Miscellaneous	10,600	3,900	9,300	5,200	29,000
TOTALS	*123,800	42,900	77,900	82,500	*327,000

* Excluding waste lands in Sutter Buttes.

Unit Use of Water

The second step in evaluation of water utilization involved the determination of unit values of consumptive use of water for each type of water consuming culture. Estimates of these unit values were largely based on the results of prior investigations and studies in other areas.

A procedure suggested by Harry F. Blaney and Wayne D. Criddle of the Soil Conservation Service, United States Department of Agriculture, in their reports entitled "A Method of Estimating Water Requirements in Irrigated Areas from Climatological Data," dated December, 1947, and "Determining Water Requirements in Irrigated Areas from Climatological and Irrigation Data," dated August, 1950, was generally utilized for adjustment of available data on unit consumptive use by irrigated crops in other localities to correspond with conditions existing in the Sutter-Yuba Area. This method involved correlation of the data on the basis of variations in average monthly temperatures, monthly percentages of annual daytime hours, precipitation, and lengths of growing season. It disregarded certain generally unmeasured factors such as wind movement, humidity, etc. Average monthly temperatures at Marysville were considered representative of the Sutter-Yuba Area. Monthly percentages of annual daytime hours were determined for latitude 39° N., which passes approximately through the center of the area.

The following is an outline of the procedure utilized for estimating unit values of consumptive use:

1. The unit value for each irrigated cultural type during its growing season was taken as the product of available heat and an appropriate coefficient of consumption, where: (a) the available heat was the product of average monthly temperature and monthly percent of daytime hours, and (b) the coefficient of consumption was one which had been selected as appropriate for California by Harry F. Blaney as a result of his studies for the Soil Conservation Service. Certain exceptions involved the use of coefficients estimated from consumptive use data available from other sources.

2. The unit value for each irrigated cultural type during its nongrowing season was taken as the amount of precipitation available, but not exceeding one to two inches of depth per month, depending upon the type of culture and cover crop.

3. The seasonal unit value for each irrigated cultural type was taken as the summation of values determined under items 1 and 2 for that type.

4. Unit seasonal values for native annual grasses were taken as equal to the available precipitation up to but not exceeding 1.3 feet in depth.

5. Unit seasonal values for native vegetation other than annual grasses were estimated on the basis of available data on corresponding consumptive use in similar localities, due consideration being given to density and type of vegetation and depth to ground water.

6. Unit seasonal values for free water surfaces were estimated from available records of evaporation at Gridley.

7. Unit seasonal values for remaining miscellaneous types of culture were estimated on the basis of available data on corresponding consumptive use in similar localities.

Estimated unit seasonal values of consumptive use of water in the Sutter-Yuba Area, including consumption of precipitation, are presented in Table 27. In view of the indicated water supply and climatological similarities of the mean and base periods, the estimated average unit seasonal values of consumptive use for the base period were considered to approximate corresponding values for the mean period.

TABLE 27

ESTIMATED UNIT VALUES OF SEASONAL CONSUMPTIVE USE OF WATER IN SUTTER-YUBA AREA

(In feet of depth)

Class and type of culture	Average for 9-year base period, 1939-40 through 1947-48	1947-48	1948-49
Irrigated lands			
Deciduous orchard	2.7	2.5	2.7
Rice	5.0	5.0	5.0
Permanent pasture	3.7	3.3	3.6
Beans	2.0	2.0	1.8
Alfalfa	4.0	3.6	3.9
Truck	2.3	2.3	2.2
Tomatoes	2.3	2.3	2.2
Corn	2.8	2.7	2.6
Hops	3.0	2.9	3.0
Sugar beets	3.1	3.0	3.0
Olives	2.7	2.5	2.7
Vines	2.0	2.0	1.9
Miscellaneous	2.4	2.3	2.2
Dry-farmed and fallow lands	1.3	1.3	1.2
Native vegetation			
Heavy brush, trees, grass	4.5	4.5	4.5
Medium brush, trees, grass	3.8	3.8	3.8
Light brush, grass	2.8	2.8	2.8
Sparse brush, grass	1.3	1.3	1.3
Miscellaneous			
Farmsteads	2.0	2.0	2.0
Roads	1.0	1.0	1.0
Urban	2.0	2.0	2.0
Water surfaces	5.0	5.0	5.0
Railroads, highways	1.0	1.0	1.0
Airfields	1.3	1.3	1.3
By-pass overflow lands	4.0	4.0	4.0
Tules	5.0	5.0	5.0
By-pass levees	1.0	1.0	1.0
Waste lands	0.5	0.5	0.5

Past and Present Water Utilization

The total amount of utilization of water in the Sutter-Yuba Area was estimated by multiplying the acreage of each type of culture by its respective unit value of consumptive use of water. The results of the estimates of seasonal water utilization during the base period and investigational seasons are presented in Table 28, summarized by general classes of culture. These estimates include consumptive use of precipitation.

TABLE 28

ESTIMATED SEASONAL UTILIZATION OF WATER IN SUTTER-YUBA AREA DURING BASE PERIOD AND INVESTIGATIONAL SEASONS

(In acre-feet)

Class of culture	Average for 9-year base period, 1939-40 through 1947-48	1947-48	1948-49
Irrigated lands	382,000	469,000	524,000
Dry-farmed and fallow lands	234,000	195,000	171,000
Native vegetation	49,000	49,000	49,000
Miscellaneous	45,000	51,000	50,000
TOTALS	710,000	764,000	794,000

Mean seasonal water utilization in the Sutter-Yuba Area was also estimated as it would be with present cultural development but under mean conditions of water supply and climate. The estimate was based on the cultural pattern determined by the 1949 survey, and on estimated average unit seasonal values of consumptive use of water for the nine-year base period which were considered to approximate those for the mean period. The estimate, which includes consumptive use of precipitation, is presented in Table 29, summarized for the four zones of the area and segregated by general cultural classes.

In order to facilitate certain phases of the analysis of ground water hydrology, presented in Chapter II, it was desirable to estimate seasonal utilization of ground water in the Sutter-Yuba Area. Unit seasonal values of consumptive use of ground water were derived by subtracting the amount of available precipitation, up to but not exceeding 1.3 feet of depth, from the appropriate unit seasonal values presented in Table 27. The corrected values were then multiplied by the acreages of each cultural type served by ground water during the respective periods. These included native vegetation in high water table areas. The 1949 cultural pattern was considered representative of present conditions, and average unit seasonal values of consumptive use for the base period were considered to be equal

to corresponding mean period values. The estimates of utilization of ground water are summarized by general classes of culture in Table 30.

TABLE 29

ESTIMATED MEAN SEASONAL UTILIZATION OF WATER IN ZONES OF SUTTER-YUBA AREA UNDER PRESENT CULTURAL DEVELOPMENT

(In acre-feet)

Class of culture	West Side Zone	Northeast Zone	East Central Zone	South Side Zone	Totals
Irrigated lands	219,100	73,400	125,500	120,100	538,100
Dry-farmed and fallow lands	57,300	21,600	40,400	62,400	181,700
Native vegetation	13,600	10,400	20,000	5,300	49,300
Miscellaneous	20,700	7,100	15,300	5,900	49,000
TOTALS	310,700	112,500	201,200	193,700	818,100

TABLE 30

ESTIMATED SEASONAL UTILIZATION OF GROUND WATER IN SUTTER-YUBA AREA

(In acre-feet)

Class of culture	Average for 9-year base period, 1939-40 through 1947-48	1947-48	1948-49	With present culture under mean conditions of water supply and climate
Irrigated lands	119,400	165,600	222,400	224,600
Native vegetation	31,900	31,900	31,900	31,900
Miscellaneous	6,800	8,200	8,200	8,200
TOTALS	158,100	205,700	262,500	264,700

Probable Ultimate Water Utilization

The total seasonal amount of water utilization in the Sutter-Yuba Area was estimated as it would be under probable ultimate conditions of cultural development and under mean conditions of water supply and climate. This was accomplished by multiplying acreages of cultural types derived in the forecast of the ultimate cultural pattern by corresponding average unit seasonal values of consumptive use of water for the base period. It was considered that unit consumptive use during the base period was equal to that under mean conditions of water supply and climate. The estimate of probable ultimate water utilization is summarized in Table 31 by general cultural classes and by zones of the Sutter-Yuba Area. The estimate includes consumptive use of precipitation.

TABLE 31

PROBABLE ULTIMATE MEAN SEASONAL UTILIZATION OF WATER IN ZONES OF SUTTER-YUBA AREA

(In acre-feet)

Class of culture	West Side Zone	Northeast Zone	East Central Zone	South Side Zone	Totals
Irrigated lands	336,300	111,500	205,000	249,300	902,100
Dry-farmed lands	12,400	6,700	12,100	14,400	45,600
Native vegetation	13,600	10,400	20,000	5,300	49,300
Miscellaneous	22,000	7,600	18,400	9,300	57,300
TOTALS	384,300	136,200	255,500	278,300	1,054,300

Demands for Water

The term "demands for water," as used in this report, refers to those factors pertaining to rates, times, and places of delivery of water, imposed by the control, development, and use of the water for any and all beneficial purposes. Certain possible present or future nonconsumptive demands for water in the Sutter-Yuba Area, such as those for hydroelectric power generation, flood control, conservation of fish and wildlife, recreation, etc., were considered to be outside the scope of the current investigation. Since they would have little significance in preliminary design of works to meet supplemental requirements for water in the Sutter-Yuba Area, they are not further discussed herein.

Irrigation practice in the Sutter-Yuba Area, as determined by rates of application, gross diversions, monthly demands, and permissible deficiencies in application of water, must be given consideration in preliminary design of works to meet supplemental water requirements. These demand factors, which were not measured or considered in the foregoing estimates of water utilization, are discussed in the following sections.

Application of Water. The term "applied water," as used in this report, refers to that water other than precipitation which is delivered to a farmer's headgate in the case of irrigation use, or to an individual's meter in the case of urban use, or its equivalent. During each of the two seasons of the investigation measurements were made of the amount of water applied for irrigation of selected plots of principal crops grown on various soil types in the Sutter-Yuba Area. Records of such application of water pumped from wells were obtained for 35 plots during 1948, and 21 plots during 1949. For each well the pump discharge, acreage of each type of crop irrigated, number of irrigations, periods of irrigation, and amounts of water applied in each irrigation were recorded. From these data, monthly and total seasonal applications of water to

each crop were determined. Results of these studies, which may be considered representative of prevailing irrigation practice in the Sutter-Yuba Area, are summarized in Table 32. Detailed results of the plot studies are presented in Appendix F, and location of the plots is indicated on Plate 17.

TABLE 32

MEASURED AVERAGE SEASONAL APPLICATION OF IRRIGATION WATER ON REPRESENTATIVE PLOTS OF PRINCIPAL CROPS IN SUTTER-YUBA AREA

Crop	Number of plots			Applied water, in feet of depth		
	1948	1949	Total	1948	1949	Weighted average for the two seasons
Alfalfa	2	3	5	5.69	6.14	5.98
Almonds	3	2	5	1.07	1.71	1.29
Beans	2	1	3	1.21	0.95	1.15
Cherries	2	0	2	2.29	--	2.29
Clover	1	0	1	4.29	--	4.29
Corn	1	1	2	2.62	1.76	1.91
Flax	1	0	1	0.87	--	0.87
Hops	1	1	2	0.92	0.87	0.89
Irrigated pasture	1	3	4	2.18	6.50	5.19
Peaches	9	5	14	2.46	2.68	2.53
Prunes	4	1	5	1.04	3.02	1.21
Rice	3	3	6	5.14	5.56	5.36
Sugar beets	1	0	1	1.45	--	1.45
Walnuts	4	1	5	2.04	1.90	2.00

Studies were made to determine the approximate average irrigation efficiency realized from application of ground water in the Sutter-Yuba Area during the 1947-48 season. "Irrigation efficiency" is defined as the ratio of consumptive use of applied water to the total amount of applied water, and is commonly expressed as a percentage.

In order to estimate the total amount of ground water applied for irrigation in the Sutter-Yuba Area in 1947-48, appropriate crop acreages, as mapped in the cultural survey, were multiplied by average seasonal values of depth of applied water for the several crops, as measured at the representative plots listed in Table 32. This computation resulted in an estimate of 347,000 acre-feet. As a check on this figure, the Pacific Gas and Electric Company furnished a corresponding estimate of 317,000 acre-feet based on records of electric power consumption for pumping. The company's estimate gave consideration to the relationship between pumping plant horsepower, drawdown, and power consumption per unit of water pumped at various lifts, as determined by pump performance tests conducted in the area by the company. In view of the nature of the basic data, the check furnished was believed to have been reasonably close.

By dividing the estimated value of 165,600 acre-feet for consumptive use of ground water on irrigated lands in the Sutter-Yuba Area in 1947-48, presented in Table 30, by the foregoing estimated value of 347,000 acre-feet, it was estimated that the irrigation efficiency realized from application of ground water in the Sutter-Yuba Area during 1947-48 was approximately 48 percent. This efficiency may be considered to be indicative of average irrigation practice in the Sacramento Valley. It was impracticable to make a corresponding estimate of irrigation efficiency realized from use of surface water in the Sutter-Yuba Area because of lack of sufficient data regarding application of surface water for irrigation purposes.

Gross Diversion of Water. The amount of the gross diversion for irrigation by ground water in the Sutter-Yuba Area was considered to be equivalent to the amount of applied ground water. As discussed in the preceding section, this was estimated to have totaled 347,000 acre-feet during 1947-48.

The gross diversion for irrigation by surface water in the Sutter-Yuba Area was estimated to have totaled about 362,000 acre-feet during 1947-48. This estimate was based on records of measurement of all surface diversions in the area, plus the estimate of importation by the Sutter Butte Canal system presented in Chapter II.

By subtracting from total consumptive use of water on irrigated lands the corresponding consumptive use of ground water and precipitation, the approximate amount of consumptive use of applied surface water was estimated. An estimate of total consumptive use of water on irrigated lands of the Sutter-Yuba Area in 1947-48, in the amount of 469,000 acre-feet, was presented in Table 28. Consumptive use of ground water on irrigated lands was estimated to have been 165,600 acre-feet in 1947-48, as shown in Table 30. It was further estimated that consumptive use of precipitation on the 138,700 acres of irrigated lands in the Sutter-Yuba Area in 1947-48 was equal to 1.3 feet of depth, or a total amount of 180,400 acre-feet. It follows that the estimated amount of consumptive use of surface water applied for irrigation in the area was approximately 123,000 acre-feet in 1947-48.

It is indicated from the foregoing that only about 123,000 acre-feet, or about 34 percent of the estimated 362,000 acre-feet of gross surface diversion for irrigation in the Sutter-Yuba Area in 1947-48, was actually consumed in production of crops. It should be noted that this figure is not comparable with estimated irrigation efficiency attained in connection with use of ground water in the area, evaluated in the preceding section, since it is based on the amount of gross diversion rather than the amount of applied water. Insufficient data were available to permit evaluation of transmission and other losses encountered in connection with use of surface water between points of diversion and places of use.

Monthly Demands for Irrigation Water. Because of the wide variety of crops produced in the Sutter-Yuba Area there is considerable variation in both rate and period of demand for irrigation water. On the

average, the irrigation demand occurs during the months of April through October. Studies of irrigation practice in the Sutter-Yuba Area indicated that for certain crops the maximum monthly demand might be as much as 45 percent of the seasonal total. Based on these studies, and on similar studies made in other areas, the estimated average monthly distribution of demand for irrigation water in the West Side Zone and in the remainder of the Sutter-Yuba Area is set forth in Table 33. Because of the predominance of orchard and truck crops in the West Side Zone, monthly distribution in that zone varies somewhat from that in the remainder of the area. Early applications to rice and irrigated pasture account for the greater part of the demand for water in April and May.

TABLE 33

ESTIMATED AVERAGE MONTHLY DISTRIBUTION OF DEMAND FOR IRRIGATION WATER IN SUTTER-YUBA AREA

(In percent of seasonal total)

	West Side Zone	Remainder of Sutter-Yuba Area
April	2	10
May	13	16
June	21	17
July	27	22
August	21	17
September	12	11
October	4	5
November		2
	100	100

Permissible Deficiencies in Application of Irrigation Water. Studies to determine deficiencies in the supply of irrigation water that might be endured without permanent injury to perennial crops were not made in connection with the Sutter-Yuba Counties Investigation. However, the results of past investigation and study of endurable deficiencies in the Sacramento River Basin are believed to be applicable to the Sutter-Yuba Area. In this respect, the following is quoted from Division of Water Resources Bulletin No. 26, "Sacramento River Basin," 1931.

"* * * A full irrigation supply furnishes water not only for the consumptive use of the plant but also for evaporation from the surface during application and from the moist ground surface, and for water which is lost through percolation to depths beyond the reach of the plant roots. Less water can be used in years of deficiency in supply by careful application and by more thorough cultivation to conserve the ground moisture. In these ways the plant can be furnished its full consumptive use with much smaller amounts of water than those ordinarily applied and the yield will not be decreased. If the supply is too deficient to provide the full consumptive use, the plant can sustain life on smaller amounts but the crop yield will probably be less than normal.

"It is believed from a study of such data as are available that a maximum deficiency of 35 per cent of the full seasonal requirement can be endured, if the deficiency occurs only at relatively long intervals. It is also believed that small deficiencies occurring at relatively frequent intervals can be endured. * * *"

SUPPLEMENTAL WATER REQUIREMENTS

The previously presented data, estimates, and discussion regarding water supply and utilization in the Sutter-Yuba Area indicate that present and probable future water problems of the area are largely limited to those connected with ground water and that their effects are largely related to irrigated agriculture. It is further indicated that ground water problems, including those created in various portions of the area by progressive lowering of water levels, degradation of mineral quality of ground water, and low yield of wells, may be eliminated or prevented if adequate supplemental water supplies are developed and utilized in the area. The estimated present and probable ultimate requirements for supplemental water in the Sutter-Yuba Area are discussed and evaluated in the following sections. As previously defined, requirement for supplemental water refers to the amount of water, over and above the sum of safe ground water yield and safe surface water yield, which must be developed to satisfy water utilization. Water utilization in turn refers to the sum of consumptive use of water and those irrecoverable losses of water incidental to its beneficial use.

Present Supplemental Requirement

The present requirement for supplemental water in the Sutter-Yuba Area was evaluated as the difference between safe yield of ground water and present consumptive use of ground water. It might be argued that this evaluation fails to give consideration to possible inadequacies in service of surface water to portions of the area. However, in the solution of the equation of hydrologic equilibrium, presented in Table 15, upon which the estimate of safe ground water yield was based, the unit consumptive use factors chosen assumed a full and sufficient application of water on all irrigated lands whether from surface sources or ground water. It follows that any possible present inadequacy in surface water service was taken into account and provided for in the estimate of safe ground water yield.

It was estimated in Chapter II that safe seasonal ground water yield in the Sutter-Yuba Area amounted to 186,100 acre-feet. This was determined as the seasonal net extraction of water from the ground water basin that might be maintained, under mean conditions of water supply and climate, without further progressive lowering of the water table below levels prevailing in 1948-49. Seasonal consumptive use of ground water in the area, with present culture and under mean conditions of water supply and climate, was estimated to be 264,700 acre-feet, as shown in Table 30. The estimated present requirement for supplemental water in the Sutter-Yuba Area, therefore, is 78,600 acre-feet per season. This estimate is presented in Table 34, which shows distribution of the supple-

mental water requirement among the several zones of the area. The distribution was based on the assumption that lowering of water levels which occurred during the season of 1948-49 would have been proportionately the same had mean water supply and climatic conditions prevailed.

TABLE 34

ESTIMATED PRESENT MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENT IN ZONES OF SUTTER-YUBA AREA

Zone	Acre-feet
West Side	
Peach Bowl	14,900
Outside Peach Bowl	2,100
Northeast	6,400
East Central	27,600
South Side	27,600
TOTAL	78,600

It was shown in Chapter II that an area of about 4,500 acres in the West Side Zone south of Oswald Road was irrigated in the summer of 1950 with ground water containing chlorides at or above the upper limit of safe use for irrigation. A substitute water supply is presently required for these lands, the amount of which may be determined by the required amount of applied water. This is true because any unconsumed portion of applied water would be so degraded after percolating to the underlying saline ground water as to preclude its re-use. Seasonal application of water to the orchard and truck crops grown in the Peach Bowl averages about 3.0 feet of depth, as determined by plot studies conducted during the investigation. However, if water of good mineral quality were substituted for the inferior ground water now used, leaching irrigations would not be required. It was estimated that under such conditions the seasonal application of water would be about 2.5 feet of depth, corresponding to average good practice in the Sutter-Yuba Area for irrigation of orchard and truck crops. On this basis the estimated amount of the substitute water supply presently required in the West Side Zone in lieu of ground water of excessive salinity is about 11,300 acre-feet per season. This is less than the estimated present supplemental requirement of 17,000 acre-feet per season required to prevent progressive and permanent lowering of water levels in the West Side Zone. Therefore, by furnishing a supplemental surface water supply to the West Side Zone sufficient to prevent progressive and permanent lowering of the water table, the present problem with respect to inferior mineral quality of the ground water would be eliminated.

Probable Ultimate Supplemental Requirement

The probable ultimate requirement for supplemental water in the Sutter-Yuba Area was evaluated as the difference between present and probable ultimate utilization of water, plus the present requirement for supplemental water. Development and utilization of a supplemental water supply in the amount of this forecast would assure an adequate supply of water for lands presently irrigated in the area, as well as for those irrigable lands not presently served with water. Furthermore, present problems resulting from progressive and permanent lowering of water levels, degradation of mineral quality of ground water, and low yield of wells would be eliminated.

Estimates of present and probable ultimate utilization of water in the Sutter-Yuba Area, under mean conditions of water supply and climate, were presented in Tables 29 and 31, respectively, and a corresponding estimate of the present requirement for supplemental water was developed in the preceding section. Utilizing these estimates, the forecast of probable ultimate seasonal requirement for supplemental water by zones of the Sutter-Yuba Area, under mean conditions of water supply and climate, is presented in Table 35.

TABLE 35

PROBABLE ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENT IN ZONES OF SUTTER-YUBA AREA

(In acre-feet)

Zone	1	2	3	4	5
	Present water utilization	Probable ultimate water utilization	Probable increase in water utilization (2 — 1)	Present supplemental water requirement	Probable ultimate supplemental water requirement (3 + 4)
West Side	310,700	384,300	73,600	17,000	90,600
Northeast	112,500	136,200	23,700	6,400	30,100
East Central	201,200	255,500	54,300	27,600	81,900
South Side	193,700	278,300	84,600	27,600	112,200
TOTALS	818,100	1,054,300	236,200	78,600	314,800

CHAPTER IV

PLANS FOR WATER DEVELOPMENT

It has been shown heretofore that the present basic water problems in the Sutter-Yuba Area are progressive and permanent lowering of ground water levels and attendant degradation of mineral quality of the ground water. Elimination of these problems, prevention of their recurrence in the future, and irrigation of irrigable lands not presently served with water will require further conservation development of available water supplies. In the preceding chapter, estimates were presented as to the amount of supplemental water required for these purposes both at the present time and under probable ultimate conditions of cultural development.

It has been shown that large surplus flows of water are presently available to the Sutter-Yuba Area from the highly productive watershed of the Feather River system, including the Yuba and Bear Rivers and minor tributary streams. This surface water is available during the snowmelt period of every season, and, in all but very dry seasons, flows sufficient to meet present supplemental requirements of the area are available into the summer months. Studies which are described in this chapter indicate that the surplus flows, if properly controlled and regulated, would more than supply the probable ultimate water requirements of the Sutter-Yuba Area.

As was stated in Chapter I, the Division of Water Resources is presently conducting surveys and studies for the State-wide Water Resources Investigation, under direction of the State Water Resources Board. This investigation has as its objective the formulation of The California Water Plan, for full conservation, control, and utilization of the State's water resources, to meet present and future water needs for all beneficial purposes and uses in all parts of the State, insofar as practicable. Surveys and studies are also being conducted by the Division of Water Resources for the Survey of Mountainous Areas. This investigation, which is coordinated with the state-wide investigation, has as its primary objective the determination of probable ultimate water requirements of certain counties of the Sierra Nevada, and the formulation of plans for projects which will meet those requirements. Although these investigations are still in progress, they are sufficiently advanced to permit tentative description of certain major features of The California Water Plan which would provide supplemental water to meet the probable ultimate requirements of the Sutter-Yuba Area. The projects would also provide supplemental water supplies for other water-deficient areas of California. In addition, benefits from the projects would include hydroelectric power, flood and salinity control, mining debris storage, and incidental benefits in the interests of recreation and the preservation of fish and wildlife.

In general, the major features of The California Water Plan, which were mentioned in the preceding paragraph, would be large multipurpose projects requiring relatively large capital expenditures. Their scope, with regard to both location of the works and benefits derived from their operation, would not be limited to the Sutter-Yuba Area, but would embrace other portions of California. Much additional study will be required to estimate costs and to determine possible means of financing these large projects. Under the Sutter-Yuba Counties Investigation, therefore, numerous surveys and studies were made in order to estimate costs of supplemental water supplies for the Sutter-Yuba Area under more localized plans that might be suitable for current financing, construction, and operation by appropriate local public agencies. These plans for initial development generally are such that the works could be integrated into future major projects. Their purposes are largely limited to conservation of new water supplies sufficient to meet the present requirements of the Sutter-Yuba Area and to provide for limited future growth in water demands of the area.

Major features of The California Water Plan which would be pertinent to solution of the ultimate water problems of the Sutter-Yuba Area are described in general terms in this chapter under the heading "The California Water Plan." These projects will be more specifically described in future reports of the State Water Resources Board. The several plans for possible initial local development of supplemental water supplies which were given consideration in connection with the Sutter-Yuba Counties Investigation are described in this chapter under the heading "Plans for Initial Local Development." All such plans considered would be subject to vested rights. Specific plans are presented for the more favorable of these local projects, together with estimates of capital and annual costs and unit costs of the developed supplemental water supplies. Location of the principal features of the several possible plans, for both initial and future construction, are shown on Plate 18, "Potential Water Storage Developments."

THE CALIFORNIA WATER PLAN

The Feather River Project, an adopted feature of The California Water Plan, is described in the following section, where it is shown that it will provide supplemental water to meet the probable ultimate

requirement of the West Side Zone. Several other major projects, which would involve multipurpose water resources developments on the Yuba and Bear Rivers and other tributaries of the Feather River, are briefly described in an ensuing section. These latter projects would provide supplemental water to meet the probable ultimate requirements of the Northeast, East Central, and South Side Zones, and are tentatively being considered as possible features of The California Water Plan.

Feather River Project

The probable ultimate supplemental water requirement in the West Side Zone could be met under a plan which would provide upstream regulatory storage on the Feather River to enhance and firm the summer flow of the stream. Such storage will be made available by construction of Oroville Dam and Reservoir, units of the Feather River Project, which are described in detail in a publication of the State Water Resources Board entitled "Report on Feasibility of Feather River Project and Sacramento-San Joaquin Delta Diversion Projects Proposed as Features of The California Water Plan," dated May, 1951. These projects were authorized and adopted by the 1951 Legislature in an act which authorized their construction, operation, and maintenance by the Water Project Authority of the State of California. Provision was made in the authorizing act for financing construction of the proposed works through issuance and sale of revenue bonds and through receipt of contributions from other sources. In May, 1952, the Legislature provided $800,000, by budgetary appropriation to the Division of Water Resources, for necessary investigations, surveys, and studies, and preparation of plans and specifications for the Feather River and Sacramento-San Joaquin Delta Diversion Projects.

The multipurpose Feather River Project contemplates construction of a gravity concrete dam, 710 feet in height above stream bed, at a point on the Feather River 1.7 miles below the junction of the North and Middle Forks and 5.5 miles above the City of Oroville. The dam will have an overpour spillway. It will create a reservoir of 3,500,000 acre-foot storage capacity, and will provide a large measure of control of the runoff of the Feather River for purposes of conservation, flood control, hydroelectric power generation, and other beneficial uses. Provision will be made for a power plant located at the dam, of 440,000 kilowatt capacity, and for an afterbay dam, and power plant of 25,000 kilowatt capacity, located four miles downstream from the main dam. The foregoing features of the Feather River Project are shown on Plate 18. The project also includes construction of a power transmission line from the Oroville power plants to Bethany, near Tracy in San Joaquin County, and a switch yard at the terminal. A channel crossing of the Sacramento-San Joaquin Delta will be required to carry Oroville Reservoir releases from the Sacramento River to the San Joaquin River Delta for subsequent transmission to water-deficient areas in other parts of California.

In studies for the cited feasibility report of the State Water Resources Board, Oroville Reservoir was operated to first meet the water requirements of the Feather River Service Area, shown on Plate 18. The West Side Zone of the Sutter-Yuba Area is contained within the described Feather River Service Area.

Under the plan of operation of Oroville Reservoir described in the foregoing feasibility report, releases of water would be made sufficient to meet gross demands of the Feather River Service Area under ultimate conditions of irrigation development. The estimate of seasonal gross demand for water under such conditions was 970,000 acre-feet, which, with an assumed irrigation efficiency of 65 percent, would provide for consumptive use of water, over and above effective rainfall, in the amount of 631,000 acre-feet per season. Of this estimated ultimate consumptive use of applied water in the Feather River Service Area, 311,000 acre-feet per season would be new water over and above present utilization. Studies indicate that the probable ultimate supplemental water requirement of the West Side Zone, estimated to be some 90,000 acre-feet per season, could readily be supplied from the foregoing 311,000 acre-feet of new water from Oroville Reservoir.

Detailed estimates of cost of the Feather River Project are presented in the feasibility report. A summary of estimated capital costs of the project is given in Table 36. The estimates of capital cost were based on prices prevailing in 1951, and included allowances of 10 percent for administration and engineering, 15 percent for contingencies, and 3 percent for interest during one-half of the estimated construction period.

TABLE 36

SUMMARY OF ESTIMATED CAPITAL COSTS OF FEATHER RIVER PROJECT

Oroville Dam and Reservoir	$342,626,000
Oroville Power Plant	64,509,000
Oroville Afterbay and Power Plant	14,146,000
Oroville Transmission Line	17,124,000
Terminal Switchyard	2,610,000
Delta Cross Channel	3,798,000
TOTAL	$444,813,000

It was assumed in the cost analyses presented in the feasibility report that the Federal Government would contribute to the Feather River Project the sum of $50,000,000, without reimbursement, in the interest of flood control. Substantial flood control benefits to land

and communities along the Feather River would result from operation of the project. There is well-established federal policy for such financial participation in projects of this character. It was also assumed that the State of California would contribute to the Feather River Project the sum of $86,926,000 in the interests of flood control and water development. This contribution would likewise be without reimbursement, and would be accomplished by assuming the costs of lands and improvements flooded and of necessary relocation of utilities. Such financial participation by the State would be justified under the policy set forth in the State Water Resources Act of 1945, as amended. If these federal and state contributions to the Feather River Project were forthcoming, capital costs shown in Table 36 would be reduced to $307,887,000. Based on this estimated capital cost, it was further estimated that annual costs of the project would be about $14,791,000 based upon 2 percent interest, and about $16,272,000 based on 3 percent interest. The annual costs included interest, repayment, replacement, operation and maintenance, insurance, and general expenses. In the cost analysis it was shown that annual costs based upon the 2 percent interest rate could be met under the schedule of revenues shown in the following tabulation, but that an annual deficit of some $1,426,000 would occur with the 3 percent rate.

Item	*Unit charge*	*Annual revenue*
311,000 acre-feet of new water delivered to Feather River Service Area (includes West Side Zone)	$1.00	$311,000
2,845,000 acre-feet of new water delivered to Delta	1.00	2,845,000
1,670,000,000 kilowatt-hours of electrical energy at terminal substation	0.007	11,690,000
TOTAL		$14,846,000

Based on the foregoing assumptions, the estimated cost of water from the Feather River Project to water users in the West Side Zone would be about $1 per acre-foot at the streamside. This estimate does not include costs for diverting the water from the Feather River and conveying it to and distributing it in areas of use in the West Side Zone. Studies indicate that a practicable means for diverting the water from the river would be by pumping plants strategically located along the river, discharging into appropriate conveyance and distribution systems. Diversion also could be made by gravity with construction of a diversion weir and headgates at a suitable upstream site.

Other Major Projects Under Consideration

Surveys and studies in connection with the Statewide Water Resources Investigation and the Survey of Mountainous Areas indicate that it would be feasible from the engineering standpoint to so regulate and conserve the relatively large flood flows of the Yuba and Bear Rivers and other tributaries of the Feather River as to yield firm water supplies considerably in excess of the probable ultimate supplemental water requirements of the Northeast, East Central, and South Side Zones. Existing water resources developments on these streams, together with tentative locations of possible future dams and reservoirs, are shown on Plate 18.

In addition to the studies by the Division of Water Resources, the Oroville-Wyandotte Irrigation District is currently investigating a plan for multipurpose development of the water resources of the South Fork of the Feather River. Principal features of this project, which is in an advanced planning phase, are delineated on Plate 19, "Plans for Development of South Fork of Feather River." The district is considering the diversion of waters of both the South Fork of the Feather River and Slate Creek through tunnels to the proposed Lost-Sly Creek Reservoir, to be created by construction of a dam immediately above the flow line of the existing Lost Creek Reservoir on the stream of that name. Conservation and regulatory storage would be created on the South Fork by construction of Little Grass Valley Reservoir, and on Slate Creek by construction of the small Slate Creek Reservoir. Water released from Lost-Sly Creek Reservoir would flow into Lost Creek Reservoir, and then through a proposed pressure tunnel to the penstock of the proposed Woodleaf Power House, to be located on the South Fork about one mile below its junction with Lost Creek. From the afterbay of this plant the water would flow through another tunnel to the penstock of the proposed Forbestown Power House, also to be located on the South Fork. Construction of a canal is proposed from the Forbestown Power House afterbay along the left or south bank of the South Fork of the Feather River to a point about two miles west of Lake Wyandotte, to serve lands of the Oroville-Wyandotte Irrigation District to the west of the canal. It is feasible from an engineering standpoint to extend the canal in a southerly direction a distance of some 25 miles to South Honcut Creek.

As a possible alternative to the Oroville-Wyandotte Irrigation District's project, the Division of Water Resources is studying another plan for multipurpose development of the South Fork of the Feather River. This plan contemplates construction of the proposed Little Grass Valley Reservoir on the South Fork, and diversion of the conserved water at a point about 1½ miles below the dam through a tunnel to Fall River. Water would also be diverted from South Branch of Middle Fork of Feather River to Fall River through a tunnel. A dam on Fall River would divert its own flows and water from the two foregoing diversions through a tunnel to the penstock of the proposed Lumpkin Power House on the South Fork of Feather River. A tunnel would convey the water from the afterbay of this plant to an enlarged Lost Creek Reservoir, which

would be created by construction of a higher dam approximately at the site of the existing structure. The plan also contemplates construction of a small reservoir on Canyon Creek, and a diversion tunnel to the proposed Slate Creek Diversion Dam. From this dam the Slate Creek water and water from Canyon Creek would be diverted through a tunnel to a point on Lost Creek above the proposed enlarged reservoir. Releases from Lost Creek Reservoir would be made through a tunnel to a diversion dam on Grizzly Creek and from this dam through a canal and siphons to the penstock of the proposed Golden Gate Power House, to be located on Golden Gate Canyon at the headwaters of French Dry Creek. From the afterbay of this plant, a conduit, including canal and siphon sections, would lead to the penstock of the proposed Brownsville Power House, to be located on French Dry Creek at Brownsville. A canal would lead from the afterbay of the Brownsville plant to a saddle between the drainage areas of French Dry and South Honcut Creeks. At this point the canal would divide, with one branch bearing generally westerly and discharging into the existing Forbestown Ditch and thence into Lake Wyandotte. The other branch would bear southwesterly and terminate at the penstock of the proposed Honcut Power House, to be located on South Honcut Creek below its confluence with Natchez Creek. From the afterbay of the Honcut Power House a canal would extend along the right bank of South Honcut Creek and then bear northerly, terminating east of Oroville. This canal would serve lands of the Oroville-Wyandotte Irrigation District and adjacent irrigable lands lying to the west of the canal. Construction of a dam on South Honcut Creek is contemplated under the plan to create a reservoir the flow line of which would extend to the Honcut Power House afterbay. Water released from South Honcut Creek Reservoir would be diverted at appropriate downstream points on South Honcut Creek to serve lands in Browns Valley and on the Sacramento Valley floor east of the Feather River. Other diversions for irrigation and other beneficial uses in remaining water service areas between the Feather and Yuba Rivers could be made from the system.

Tentative plans for ultimate development of the Yuba River contemplate increasing the storage capacity of the existing Bullards Bar Reservoir on the North Yuba River, or providing equivalent increased capacity upstream at Kellys Bar, together with hydroelectric power development of the upper North Yuba River. Construction of a dam and reservoir on the Middle Yuba River at Granite Point is also under consideration, together with a diversion tunnel to the existing afterbay of the Bullards Bar Power House. Waters of the South Yuba River would be diverted at Edwards Crossing and conveyed by a proposed tunnel to the Granite Point Reservoir. Both the Middle and South Yuba Rivers offer possibilities for construction of dams and reservoirs, principally in the interests of mining debris storage and flood control.

The State Water Plan, as adopted by the Legislature in 1941, contemplates a storage capacity in the Englebright Reservoir on the Yuba River of about 850,000 acre-feet, as compared to the 70,000 acre-foot capacity of the existing Englebright Reservoir. This additional capacity would provide substantial conservation, flood control, and hydroelectric power, but would inundate the existing Colgate Power House, recently enlarged by the Pacific Gas and Electric Company. As a possible alternative, construction of offstream storage for waters of the Yuba River at the Waldo site, on Dry Creek, about nine miles northeast of Wheatland, is under consideration. This plan would involve construction of a conduit, diverting from Englebright Reservoir at the spillway elevation, to convey flood waters of the Yuba River to the proposed Waldo Reservoir. Under the plan, Waldo Reservoir in turn would spill into the proposed enlarged Camp Far West Reservoir on Bear River, which is hereinafter described. Consideration is also being given to possible construction of one or more additional reservoirs at the Garden Bar, Parker, or Rollins sites, upstream from the Camp Far West site on the Bear River, to effect more complete conservation of flood waters of that stream.

Studies indicate that the Northeast Zone could be served with an ultimate supplemental water supply either from the South Fork of the Feather River under the plan of development hereinbefore described, or from the Yuba River. Service from the Yuba River could be made by enlargement of the existing Hallwood-Cordua system or by diversion from the Yuba River at a suitable site in the vicinity of Parks Bar, and distribution by gravity from a main conduit bearing in a northerly direction roughly along the eastern boundary of the zone. It has been estimated that the amount of the probable ultimate mean seasonal supplemental water requirement of the Northeast Zone will be about 30,000 acre-feet. A water supply in this amount, under an appropriate schedule of demands, could be made available to the Northeast Zone by construction of one or more of the previously described major upstream projects.

It is indicated that under ultimate conditions of development the East Central Zone could also be served with supplemental water from the Yuba River. It has been estimated that the amount of the probable ultimate mean seasonal water requirement of the zone will be about 82,000 acre-feet. A portion of the required supplemental supply could be diverted, under an appropriate schedule of demands, directly from the Yuba River above Hammonton, and conveyed in a southerly direction to Hutchinson Creek, by rehabilitation and extension of the abandoned Yuba River Ditch of the Yuba Consolidated Gold Fields. Conserved water of the Yuba River to meet the remainder of the ultimate

supplemental water requirement of the East Central Zone could be released from the proposed Waldo Reservoir for downstream diversion and conveyance to areas of use.

Studies also indicate that under ultimate conditions of development the South Side Zone could be served with a supplemental water supply released, under an appropriate schedule of demands, from the proposed Camp Far West Reservoir. It has been estimated that the amount of the probable ultimate mean seasonal supplemental water requirement of the zone will be about 112,000 acre-feet. A supply in this amount would be available in Camp Far West Reservoir, and would consist of waters of the Yuba and Bear Rivers and Dry Creek conserved jointly by the proposed Waldo Reservoir, Camp Far West Reservoir, and upstream reservoirs on the Bear River. It could be conveyed to points of use in the South Side Zone by an enlarged system similar to that described hereinafter in connection with the Camp Far West Project.

PLANS FOR INITIAL LOCAL DEVELOPMENT

Possible plans for initial local development of supplemental water supplies for the Sutter-Yuba Area, together with cost estimates, are described in this section. Design of features of the plans was necessarily of a preliminary nature and primarily for cost estimating purposes. More detailed investigation, which would be required in order to prepare plans and specifications, might result in designs differing in detail from those presented in this report. However, it is believed that such changes would not be significant.

Capital costs of dams, reservoirs, diversion works, conduits, pumping plants, and appurtenances, included in the considered conservation, conveyance, and distribution systems, were estimated from preliminary designs based largely on data from surveys made during the current investigation. Approximate construction quantities were estimated from these preliminary designs. Unit prices of construction items were determined from recent bid data on projects similar to those in question, or from manufacturers' cost lists, and are considered representative of prices prevailing in April, 1952. The estimates of capital cost included costs of rights of way and construction, and interest during one-half of the estimated construction period at 3 percent per annum, plus 10 percent for engineering, and 15 percent of construction costs for contingencies. Estimates of annual costs included interest on the capital investment at 3 percent, amortization over a 50-year period on a 3 percent sinking fund basis, replacement, operation, and maintenance costs, and costs of electrical energy for pumping.

Because of geographical considerations, and respective types of water service and water supplies in the several zones of the Sutter-Yuba Area, possible plans for initial water development are presented in this section separately for the West Side, Northeast, East Central, and South Side Zones.

West Side Zone

In Chapter III it was shown that the present requirement for supplemental water in the West Side Zone is about 17,000 acre-feet per season. However, in the design of projects for initial local development to meet this requirement, it was considered desirable to provide some capacity for future growth in water demand which would occur through development of irrigable lands not presently irrigated. This additional capacity was estimated at about 7,000 acre-feet per season, giving consideration to the extent of undeveloped irrigable lands that might readily be served, and to the available sources of water supply. For reasons hereinafter discussed it was considered that the new water supply would be applied to about 7,000 acres of land in the Peach Bowl, of which about 4,500 acres are presently irrigated by ground water containing chlorides at or above the safe limit for irrigation use, and 2,500 acres are irrigable lands not presently served with water. These lands are contained within a service area lying generally to the south of Oswald Road, and delineated on Plate 20, "Peach Bowl Project."

Three possible alternative plans of works for initial construction to provide supplemental water to the West Side Zone were considered. For reasons hereinafter mentioned, after preliminary investigation and study the first two plans were given no further consideration for present cost estimating purposes, but may warrant future study. The third plan is described in some detail later in this section.

Alternative Plans Considered. The first of the alternative plans considered for initial construction included salvage of water in high water table lands of the Sutter Butte Canal service area, and its conveyance to and use in the Peach Bowl. This would involve the installation of batteries of wells in the high water table area, conveyance of the pumped ground water to the Peach Bowl either in conduits or in the channel of the Feather River, and distribution of the water in a strategically situated service area of heavy ground water pumping draft in the Peach Bowl. The new water supply would largely replace ground water presently used in the Peach Bowl service area, thereby preventing progressive and permanent lowering of ground water levels and attendant degradation of mineral quality of the ground water throughout the Peach Bowl and adjacent ground water service areas. However, preliminary investigation and study indicated that changes in the crop pattern and in irrigation practice in the Sutter Butte Canal service area, which would be necessary for consummation of this plan, would be difficult to effect, and that cost of the salvaged water would be greater than for water yielded under the third plan



Feather River in the Vicinity of Starr Bend, Looking Upstream

herein described. For these reasons, this plan was given no further present consideration.

Consideration was also given to the provision of a supplemental water supply to the Peach Bowl service area from the Feather River, by extension of the conveyance and distribution system of the Sutter Butte Canal. As in the case of the first plan described, use of the new surface water supply would prevent progressive and permanent lowering of water levels, and attendant degradation of mineral quality of ground water, in the area served and in adjacent areas. Preliminary investigation and study of this second plan for initial construction indicated that existing diversion facilities might be adequate for such purpose, but that conveyance facilities would require enlargement. Furthermore, a canal to serve lands requiring supplemental water in the Peach Bowl would have to be constructed on a relatively flat slope over a long distance through highly developed orchard lands. The canal would also pass through urban areas lying immediately south and west of Yuba City. It was indicated from investigation and study that cost of the new water supply would be greater than under the third plan hereinafter described. For these reasons, this plan was given no further present consideration.

The third of the alternative plans considered for initial construction would provide for the present supplemental water requirement in the West Side Zone, and for growth in water utilization for a number of years in the future. It would include the construction of facilities for pumping water directly from the Feather River and for its conveyance to and distribution in the service area in the Peach Bowl. As in the case of the two previous plans, use of the new surface water supply would prevent progressive and permanent lowering of ground water levels and degradation of mineral quality of the ground water, in the area served and in adjacent areas. This plan is hereinafter referred to as the "Peach Bowl Project," and its principal features are delineated on Plate 20.

Peach Bowl Project. Satisfactory sites for a pumping plant to divert flow of the Feather River exist on the right or west bank of the river along the reach one-half mile north and south of the prolongation of Hutchinson Road. The site selected for cost estimating purposes is at a point about four miles south of Shanghai Bend, near the center of Section 26, Township 13 North, Range 3 East, M.D.B. & M. Conveyance and distribution of water pumped from the Feather River to the area of use would be accomplished by means of a combination system including lined and unlined canals, and ditches, and the utilization of existing individual distribution systems insofar as possible. The lands which would be irrigated with the new water supply comprise the aforementioned 7,000 acres within the service area shown on Plate 20, ranging in elevation from approximately 45 feet at the north boundary to approximately 30 feet in the southerly portion.

Since the Peach Bowl constitutes a free ground water area, water losses in conveyance and distribution of the new water supply would largely percolate to the ground water. For this reason it was assumed that these losses, plus the unconsumed portion of the new water supply applied to irrigation would be effective in preventing progressive and permanent lowering of ground water levels and degradation of mineral quality of the ground water. The acreage to be irrigated by the supplemental supply would depend on the amount of the gross diversion, water losses encountered in conveyance and distribution, and the requirement for application of water to the lands irrigated.

For cost estimating purposes the Peach Bowl Project was designed to provide a gross seasonal supplemental surface water supply of approximately 24,000 acre-feet, of which about 17,000 acre-feet is necessary to meet the present supplemental requirement, and the remainder would be available for additional development of irrigable lands. An estimate of the monthly distribution of demand for irrigation water in the West Side Zone was presented in Table 33. Based on these data, the monthly gross demand for water for the Peach Bowl Project would be as shown in Table 37.

TABLE 37

ESTIMATED MONTHLY DISTRIBUTION OF GROSS DEMAND FOR WATER FOR THE PEACH BOWL PROJECT

Month	Percent of seasonal total	Demand for water, in acre-feet
April	2	480
May	13	3,120
June	21	5,040
July	27	6,480
August	21	5,040
September	12	2,880
October	4	960
TOTALS	100	24,000

Based upon known soil characteristics in the Peach Bowl and upon irrigation experience elsewhere, it was assumed that water losses in conveyance and distribution of a new surface water supply would amount to about 25 percent of the gross diversion, leaving about 18,000 acre-feet per season for application to irrigated lands. Lands in the Peach Bowl to be served with the new water supply and presently irrigated by ground water comprise about 4,500 acres of highly developed orchard. From results of the plot studies of water application described in Chapter III, it was estimated that these orchard lands would require a

seasonal application of irrigation water in an amount of about 2.5 acre-feet per acre, or a total of about 11,000 acre-feet. The remaining 7,000 acre-feet of water per season available under the Peach Bowl Project, as designed, would serve about 2,500 acres of irrigable lands, presently not served with water, lying to the west of the foregoing orchard lands. If developed, it was considered that these irrigable lands would probably largely be devoted to truck and general row crops, with limited amounts of rice and irrigated pasture. Based on results of the cited plot studies, it was estimated that these lands would require a seasonal application of irrigation water in an amount of about 2.8 acre-feet per acre.

No record was available of flow in the Feather River at the proposed point of pumping diversion. However, records were available of monthly flow at Shanghai Bend some four miles upstream from the proposed diversion point, and at Nicolaus some 11 miles downstream therefrom. The Shanghai Bend record dated from 1940, while that for Nicolaus was continuous since 1921, although prior to 1939 records of stream flow at the latter station were obtained only during summer months of low flow. Studies were made of these records and of measurements of diversions from the Feather River in the reach between the two stations. These studies indicated that during the irrigation season probable flow at the proposed diversion for the Peach Bowl Project was greater than recorded flow in the Feather River at Nicolaus. Therefore, the assumption that flows available for the pumping diversion were equal to those measured at Nicolaus was considered to be conservative.

It was determined that during the critical months of July, August, and September, tributary inflow to the Feather River from the Bear River was negligible. For this reason, any future conservation development on this tributary would not adversely affect the assumption as to flow in the Feather River at the proposed point of diversion during the critical summer months. Furthermore, records of the Sacramento-San Joaquin Water Supervision indicated that the amount of existing diversions from the Feather River between Nicolaus and the confluence with the Sacramento River, during the critical summer months of low flow, is insufficient to materially affect the estimates of water supply available in the Feather River for diversion to the Peach Bowl.

Available records of monthly stream flow of the Feather River at Nicolaus during the irrigation season are presented in Table 38. Comparison of these recorded flows with the estimated monthly gross demands of the Peach Bowl Project, presented in Table 37, indicates that during the period from 1921 through 1950 ample water was available from the Feather River to meet demands of the project, as designed, except during the two seasons of 1924 and 1931. During these seasons irrigation deficiencies of approximately 40 and 25 percent, respectively, would have occurred. From past experience in the Sacramento Valley, it is considered probable that such deficiencies could be endured without permanent damage.

TABLE 38

MEASURED MONTHLY FLOW OF FEATHER RIVER AT NICOLAUS DURING THE IRRIGATION SEASON, 1921 THROUGH 1950

(In acre-feet)

Year	Runoff index	April	May	June	July	August	September	October
1921	129				61,870	23,195	25,035	49,140
1922	109				181,000	48,300	49,200	49,200
1923	67				111,000	52,100	72,000	126,000
1924	28			6,780	1,780	609	20,900	93,500
1925	67				55,600	33,400	49,000	106,000
1926	67			57,500	24,900	24,300	60,100	109,000
1927	122				99,000	43,600	61,300	131,000
1928	90			89,300	54,800	30,700	60,700	104,000
1929	40		371,000	160,000	49,700	70,100	104,000	132,000
1930	85		536,000	183,000	52,000	57,300	112,000	163,000
1931	32		68,900	17,700	935	5,070	32,800	68,200
1932	72		904,000	453,000	75,600	29,900	26,700	40,100
1933	42		418,000	331,000	34,900	18,300	25,100	61,100
1934	44		114,000	40,500	21,800	19,600	39,200	67,710
1935	93				84,430	69,850	70,070	123,400
1936	94			385,200	81,780	63,020	82,050	110,000
1937	69				66,950	18,130	38,780	129,000
1938	186				217,000	83,360	90,100	149,800
1939	41	359,700	107,800	27,070	9,870	19,660	57,700	77,200
1940	123	1,593,900	711,200	200,100	43,700	36,760	92,230	128,700
1941	141	1,416,200	1,467,000	548,000	191,300	52,800	54,500	99,400
1942	145	1,480,000	1,254,000	793,600	166,500	44,140	67,200	137,600
1943	122	1,220,600	663,300	314,800	57,350	22,040	32,360	119,000
1944	61	597,600	633,000	179,800	33,300	13,280	32,190	83,300
1945	82	726,800	736,100	262,900	40,890	27,620	53,160	106,800
1946	90	836,000	679,900	171,900	38,500	30,040	53,690	87,650
1947	55	573,300	124,000	74,330	16,780	24,640	40,820	135,600
1948	74	1,326,000	1,091,000	590,200	73,600	16,170	48,190	132,900
1949	57	809,700	533,500	98,060	13,920	9,230	27,480	39,430
1950	84	1,099,000	834,900	327,200	40,030	18,230	71,500	163,500

Studies indicated that the maximum monthly diversion for the Peach Bowl Project would occur in July, and that it would amount to about 27 percent of the total seasonal diversion of 24,000 acre-feet, equivalent to a continuous flow of about 105 second-feet throughout the month. For cost estimating purposes the pumping plant for the project was designed with a total pumping capacity of 135 second-feet. This installation would meet the estimated maximum rate of demand, provide additional capacity for shorter-term peaking in excess of the average monthly rate, and provide stand-by capacity to assure continuous service in case of breakdown.

Features of the pumping plant considered for the Peach Bowl Project are shown on Plate 20. In order to permit flexibility in operation of the project, design of the pumping plant was based on the installation of three electrically driven vertical axial-flow propellor type pumping units. Each of the units would comprise a 36-inch diameter pump with capacity of 45 second-feet, driven by a 100-horsepower motor. The pumps would operate at a maximum pumping head of about 15 feet, pumping from an estimated minimum water surface elevation in the river of about 31 feet to a discharge elevation of about 46 feet. The pumping units would be of the all-weather type, mounted on steel beams, and supported on concrete piles driven into the stream bed at the toe of the river face of the right bank levee of the Feather River. The battery of pumps would be operated from a corrugated metal control house, also mounted on the concrete piles, and would be served by a steel trestle from the levee crest. The units would pump from a reinforced-concrete sump into three 30-inch diameter steel pipes supported by ring girders and reinforced-concrete piers on the slopes of the levee. The pipes would pass through the levee five feet beneath the crest, and discharge into a reinforced-concrete sand trap at the landward base of the levee.

From the sand trap the water would be conveyed by gravity to areas of use by the system of lined and unlined canals shown on Plate 20. The main canal extending in a southerly direction along the levee would be concrete-lined, in order to prevent seepage which might otherwise damage orchards or the toe of the Feather River levee. This canal would be approximately 6.1 miles in length, and would be of trapezoidal section, with 1.5:1 side slopes, bottom width of 8.0 feet, depth of 3.4 feet, and 1.0 foot freeboard. The slope would be approximately 1.0 foot per mile, the velocity about 2.5 feet per second, and the capacity would be 100 second-feet. A second main canal would extend from the sand trap in a westerly direction a distance of approximately 0.7 mile to a concrete division box near the Southern Pacific Railroad right of way. This canal would have characteristics similar to the one already described. From the division box a lateral would extend south along the railroad right of way a distance of approximately 4.8 miles. This lateral would also be concrete-lined, to prevent possible damage by seepage to adjacent orchards and to the railroad. It would be of trapezoidal section, with 1.5:1 side slopes, bottom width of 6.0 feet, depth of 2.4 feet, and freeboard of 1.0 foot. The slope would be approximately 1.5 feet per mile, the velocity about 2.3 feet per second, and the capacity 50 second-feet. A second lateral from the division box would extend in a westerly and then southerly direction a distance of approximately 5.2 miles. This canal would be unlined, since seepage from it would probably result in no damage. The canal would be of trapezoidal section, with 2:1 side slopes, bottom width of 6.0 feet, depth of 3.2 feet, and freeboard of 1.0 foot. Its slope would be approximately 1.5 feet per mile, its velocity about 1.3 feet per second, and its capacity 50 second-feet. Cost estimates for the conveyance canals were based on preliminary designs utilizing data from field location surveys.

Detailed design of works for distribution of water from the conveyance canals was considered to be outside the scope of the current investigation. Existing pressure irrigation systems of individuals and agencies could be adapted to use of the new surface water supply by means of gravity diversions or individual low-head pumps, as required. Cost estimates for the distribution systems were based on known costs of similar irrigation works elsewhere in California, adjusted to correspond with conditions prevailing in the Sutter-Yuba Area.

Pertinent data with respect to general features of the Peach Bowl Project, as designed for cost estimating purposes, are presented in Table 39.

TABLE 39

GENERAL FEATURES OF PEACH BOWL PROJECT

Pumping Plant

- Pumps—3 each, vertical, propeller type, axial-flow, 45 second-foot capacity
- Estimated minimum water surface elevation in Feather River—31 feet
- Discharge elevation—46 feet
- Estimated maximum pumping head—15 feet
- Installed pumping capacity—135 second-feet
- Estimated maximum monthly demand—105 second-feet
- Estimated gross seasonal diversion—24,000 acre-feet
- Motors—3 each, all-weather type, 100 horsepower
- Pump support—steel beams on concrete pile structure
- Pumping sump—reinforced-concrete, 13 feet by 65 feet, 5 feet deep, equipped with trash racks
- Discharge lines—3 each, 30-inch diameter, welded-steel, supported on concrete piers by ring girders
- Sand trap—reinforced-concrete, 10 feet by 40 feet, 6 feet deep, equipped with baffles and sluice gates

Conveyance System

	Main canals	Central lateral	West lateral
Type	Trapezoidal, concrete-lined	Trapezoidal, concrete-lined	Trapezoidal, unlined
Length, in miles	6.8	4.8	5.2
Side slopes	1.5:1	1.5:1	2:1
Bottom width, in feet	8.0	6.0	6.0
Depth, in feet	3.4	2.4	3.2
Freeboard, in feet	1.0	1.0	1.0
Slope, in feet per mile	1.0	1.5	1.5
Velocity, in feet per second	2.5	2.3	1.3
Capacity, in second-feet	100	50	50



Daguerre Point Weir on Yuba River

Capital cost of the Peach Bowl Project, based on prices prevailing in April, 1952, was estimated to be about $1,384,900. Corresponding annual costs of the Peach Bowl Project were estimated to be about $100,900. Resultant estimated average unit cost of the 24,000 acre-feet of water per season diverted at the river was about $4.20 per acre-foot. The estimated average unit cost of the 18,000 acre-feet of water per season actually applied for irrigation was about $5.60 per acre-foot.

Estimated capital and annual costs of the Peach Bowl Project are summarized in the following tabulation. Detailed cost estimates are presented in Appendix H.

	Estimated costs	
	Capital	*Annual*
Pumping plant	$107,900	$16,000
Conveyance system	813,900	43,800
Distribution system	463,100	41,100
TOTALS	$1,384,900	$100,900

Northeast Zone

In Chapter III it was shown that the present requirement for supplemental water in the Northeast Zone is about 6,000 acre-feet per season. However, in the design of projects for initial local development to meet this requirement, it was considered desirable to provide some capacity for future growth in water demand which would occur through development of irrigable lands not presently irrigated. This additional capacity was estimated at about 6,000 acre-feet per season, giving consideration to the extent of undeveloped irrigable lands that might readily be served, and to the available sources of water supply as determined by engineering and economic limitations on size of the proposed conservation works. For reasons hereinafter discussed, it was considered that the new water supply would be applied to about 2,300 acres in the Northeast Zone, of which about 1,700 acres are presently irrigated by ground water and 600 acres are irrigable lands not presently served with water. These lands are contained within a service area adjoining and lying to the east and north of the Cordua Irrigation District, and delineated on Plate 21, "South Honcut Creek Project."

Three possible alternative plans of works for initial construction to provide supplemental water to the Northeast Zone were considered. For reasons hereinafter mentioned, after preliminary investigation and study, the first two plans were given no further consideration for present cost estimating purposes, but may warrant future study. The third plan is described in some detail in this section.

Alternative Plans Considered. The first of the alternative plans considered for initial construction involved the substitution of surface water from the Yuba River to replace ground water presently utilized in the foregoing service area. The substitute supply would be furnished by extension and enlargement of portions of the Cordua Irrigation District canal system. Its use would prevent progressive and permanent lowering of ground water levels in the described service area and in adjacent areas. The Cordua Irrigation District and the Hallwood Canal Company jointly divert from the Yuba River through a 1,200-foot tunnel with capacity of 325 second-feet, heading at the northwest end of the Daguerre Point Weir. Surface flow in the Yuba River at Daguerre Point during the peak of the irrigation season is generally not greater than present demands of the Cordua and Hallwood systems, and at times these demands cannot be met. Much of the surface flow in the Yuba River during such periods as measured at Marysville does not occur on the surface at the Daguerre Point Weir. Measurements indicate that this water is lost to surface flow by percolation in an extensive area of dredger tailings above the weir, and reappears at the Marysville gaging station. For this reason, a preliminary survey was made to determine the feasibility of diverting the Cordua-Hallwood water supply from the Yuba River at a site upstream from the area of dredger tailings. This would be excessively expensive because of the necessity for increasing capacity of the Cordua-Hallwood system, providing a diversion structure, and providing a closed conduit for the diverted water for a considerable distance until stable bank could be reached. For these reasons, and because of uncertainty regarding the available water supply, this plan was given no further present consideration.

The second of the alternative plans considered for initial construction involved the purchase of Feather River water from the Oroville-Wyandotte Irrigation District at a point of delivery on South Honcut Creek, diversion of the water from South Honcut Creek, and its conveyance to and distribution in the Northeast Zone. As in the case of the first plan described, use of the new surface water supply would prevent progressive and permanent lowering of ground water levels in the area served and in adjacent areas. The water purchased and utilized would be a portion of that which the district proposes to develop on the South Fork of the Feather River under the multipurpose project described earlier in this chapter, principal features of which are shown on Plate 19. The water would be delivered to South Honcut Creek at an elevation of about 600 feet, by the district. The amount of water that might be made available to the Northeast Zone would depend upon design of features of the proposed Oroville-Wyandotte Irrigation District project, and in turn upon the outcome of possible negotiations between the district and an agency representing interests of the Northeast Zone. For these reasons, features of the plan were not surveyed and studied in detail, nor estimates of cost prepared.

The third plan considered for initial construction would include the construction of a dam and reservoir on South Honcut Creek, facilities for diversion of flood



South Honcut Creek Dam Site Viewed From Point Within Reservoir Area

waters of French Dry Creek to the reservoir, and facilities for diversion of the conserved waters from South Honcut Creek below the dam, and for their conveyance to and distribution in both the Northeast Zone and the Browns Valley service area. This latter area, lying to the east of the Northeast Zone, is also in need of a supplemental water supply and could be advantageously served as indicated. As in the case of the two previous plans, use of the new surface water supply would prevent progressive and permanent lowering of ground water levels in the area served in the Northeast Zone and in adjacent areas. This plan is hereinafter referred to as the "South Honcut Creek Project," and its principal features are delineated on Plate 21.

South Honcut Creek Project. The proposed dam would be an earthfill structure with side channel spillway, located on South Honcut Creek near Sugar Loaf, in Section 25, Township 18 North, Range 5 East, M. D. B. & M., some 20 miles upstream from the confluence of Honcut Creek with the Feather River. The stream bed elevation at this point is about 730 feet. Flood waters of French Dry Creek would be diverted at a point on that stream at an elevation of approximately 2,125 feet, about one-half mile below Brownsville, and conveyed a distance of about two miles in a canal, discharging into a tributary of South Honcut Creek above the reservoir. The conserved waters of both South Honcut and French Dry Creeks, after release from the reservoir, would be diverted from South Honcut Creek at a point about two miles downstream from the dam and 300 feet downstream from the county bridge southeast of Bangor, at an elevation of about 600 feet. From this diversion point the waters would be conveyed by a conduit a distance of about 4.7 miles to a point about one mile northeast of Loma Rica, where the elevation is about 500 feet. Diversions could be made for the Browns Valley service area along the conduit and at its terminus. Water for the Northeast Zone would be conveyed from this terminus in a natural drainage channel, a short canal section, and the natural channel of Prairie Creek to a diversion point for the Northeast Zone on Prairie Creek about one mile upstream from its confluence with South Honcut Creek, at an elevation of approximately 135 feet. From this point the waters would be conveyed to and distributed in the Northeast Zone by means of an unlined canal and ditch system. The lands which would be served by the new water supply comprise the aforementioned 2,300 acres contained within the service area shown on Plate 21, ranging in elevation from about 150 feet along its eastern boundary to about 75 feet on the west.

As a first step in determination of size of the project, estimates were made of yield of the proposed works for various reservoir storage capacities. It was estimated that mean seasonal runoff of South Honcut Creek, from the approximately 24 square miles of watershed above the dam site, was about 23,400 acre-feet. Estimated mean seasonal runoff of French Dry Creek at the proposed point of diversion to South Honcut Creek was about 27,100 acre-feet, from some 22 square miles of watershed. Of these French Dry Creek waters, studies indicated that flood flows in an estimated mean seasonal amount of about 22,000 acre-feet could be diverted to the proposed South Honcut Creek Reservoir through a 200 second-foot capacity conduit, during the months from November to April, inclusive.

Based upon records and estimates of runoff during the critical dry period which occurred in the Sacramento Valley from 1920-21 through 1934-35, yield studies were made for five sizes of reservoir at the South Honcut Creek site. It was assumed that a seasonal irrigation deficiency up to 35 percent could be endured in one season of the period. Monthly demands on the reservoir were assumed to be proportional to the estimated distribution of irrigation demands in the Sutter-Yuba Area, as presented in Table 33. A summary of results of the yield studies is presented in Table 40.

TABLE 40

ESTIMATED SAFE SEASONAL YIELD OF SOUTH HONCUT CREEK RESERVOIR WITH FRENCH DRY CREEK DIVERSION, BASED ON CRITICAL DRY PERIOD FROM 1920-21 THROUGH 1934-35

(In acre-feet)

Reservoir storage capacity	Safe seasonal yield
12,000	12,800
20,000	16,400
30,000	20,900
38,000	24,300
70,000	27,100

After consideration of the results of the yield studies, together with topography of the dam site and cost analyses hereinafter discussed, a reservoir of 38,000 acre-foot storage capacity, with estimated safe seasonal yield of 24,300 acre-feet, was chosen for purposes of cost estimates to be presented in this report. The yield study for this size of reservoir is included in Appendix G.

Although the estimate of the present requirement for supplemental water in the Northeast Zone was only about 6,000 acre-feet per season, essentially all irrigable but presently nonirrigated lands in the zone would be physically susceptible of irrigation under the South Honcut Creek Project. However, a substantial acreage of irrigable lands lying in the Browns Valley service area could be developed with water from the South Honcut Creek Project. For this reason, studies of present utilization of water from the South

Honcut Creek Project were based on an assumed release of water for the Northeast Zone equal to approximately one-half of the estimated safe yield of the project. It was assumed that remaining safe yield of the project would be made available to the Browns Valley service area.

For design purposes it was assumed that minor losses of water released from South Honcut Creek Reservoir would occur in the stream channel between the dam and the downstream point of diversion and in the lined canal leading to the point of release north of Loma Rica, and would amount to about 300 acre-feet per season. Thus a gross supplemental water supply of approximately 12,000 acre-feet per season would be made available to the Browns Valley service area. It was estimated that losses in conveyance and distribution of this supply would be about 25 percent, leaving some 9,000 acre-feet per season for application to irrigation. On the assumption that the imported water would be largely used on irrigated pasture, with an estimated average unit seasonal application of about 3.5 acre-feet per acre, about 2,600 acres of irrigable but presently nonirrigated lands in the Browns Valley service area could be served by the new water supply.

It was assumed that seasonal losses by transpiration, evaporation, and percolation in conveying the new water supply to the point of diversion on Prairie Creek would be about 10 percent of the gross reservoir release, or about 1,200 acre-feet, leaving approximately 10,800 acre-feet for distribution in the zone. Since the Northeast Zone constitutes a free ground water area, water losses in the unlined canal and ditch system would largely percolate to the ground water. For this reason it was assumed that these losses, plus the unconsumed portion of the new water supply applied to irrigation, would be effective in preventing progressive and permanent lowering of ground water levels.

The acreage to be irrigated by the supplemental supply in the Northeast Zone would depend on the gross amount of the import, water losses encountered in conveyance and distribution, and the requirement for application of water to the lands irrigated. It was assumed that losses to be encountered in conveyance and distribution within the zone would be 25 percent of the gross import, or about 2,700 acre-feet per season, leaving some 8,100 acre-feet for application to irrigated lands. It was also assumed that water imported to the Northeast Zone would largely be used on irrigated pasture, and that the average seasonal application of the new water would be 3.5 acre-feet per acre. On this basis it was estimated that the imported supply would be applied to some 2,300 acres in a service area adjoining and lying to the east and north of the Cordua Irrigation District. Of the lands which would be served with the new water supply, about 1,700 acres are presently irrigated by ground water and 600 acres are irrigable lands not presently irrigated.

An estimate of the monthly distribution of demand for irrigation water in the Sutter-Yuba Area was presented in Table 33. Based on these data, the monthly demand on the South Honcut Creek Project would be as shown in Table 41.

TABLE 41

ESTIMATED MONTHLY DISTRIBUTION OF DEMAND FOR WATER FROM SOUTH HONCUT CREEK PROJECT

(In acre-feet)

Month	Percent of seasonal total	Reservoir release	Gross import to Northeast Zone	Gross import to Browns Valley
April	10	2,430	1,080	1,200
May	16	3,890	1,730	1,920
June	17	4,130	1,830	2,040
July	22	5,350	2,380	2,640
August	17	4,130	1,830	2,040
September	11	2,670	1,190	1,320
October	5	1,210	540	600
November	2	490	220	240
TOTALS	100	24,300	10,800	12,000

Plane table topographic surveys were made of the South Honcut Creek dam and reservoir sites by the Division of Water Resources in 1949. The reservoir site was mapped at a scale of 1 inch to 400 feet, and the dam site at a scale of 1 inch to 100 feet, both with 10-foot contour intervals. Storage capacities of South Honcut Creek Reservoir at various stages of water surface elevation are given in Table 42.

Based upon preliminary geological reconnaissance, the South Honcut Creek dam site is considered suitable for an earthfill dam of any height up to a maximum of 200 feet. Foundation rock at the site consists of a slightly metamorphosed series of igneous rocks, chiefly of volcanic origin. The original nature of the rocks ranged from basalt to gabbro. The bulk of the material is a blue-gray, hard, very slightly metamorphosed basalt. The entire mass has been intruded by a number of small dikes, of later origin, consisting of unmetamorphosed andesite and/or basalt. The foundation bedrock as a whole is relatively hard and unweathered where exposed in outcrops. Joints are prominently developed in several sets. The predominant set has a strike approximately parallel to the stream course and apparently controls the primary drainage pattern in the vicinity. Small shears are common throughout the rock mass but these have generally been recemented. Some of the joints also have been recemented by deposition of minerals from percolating waters. Seepage may be observed from remaining open seams in the bedrock in several places.

TABLE 42

AREAS AND CAPACITIES OF SOUTH HONCUT CREEK RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum, in feet	Water surafce area, in acres	Storage capacity, in acre-feet
0	730	0	0
20	750	3	25
40	770	26	226
60	790	62	1,090
80	810	132	2,980
100	830	256	6,530
119	849	344	12,000
120	850	355	12,300
138	868	484	20,000
140	870	512	20,900
156	886	634	30,000
160	890	691	32,800
168	898	720	38,000
180	910	801	47,600
200	930	933	65,000
205	935	976	70,000
220	950	1,070	85,100

Three hundred feet downstream from the axis a fault zone is encountered which follows the base of the right abutment longitudinally for an additional 200 feet before lensing out. The plane of this fault apparently has a dip of 55 degrees into the left abutment. The zone appears to die out rapidly in both upstream and downstream directions but at the point of maximum development it is eight feet in width. There is some gouge and much crushed rock along this fault. The inconsistency of the zone on the surface would seem to indicate that it may also lens out vertically at a relatively shallow depth. Indications are that there has been no recent movement on the fault. Special treatment of the dam foundation in the area of this fault would undoubtedly be necessary.

Stripping for the foundation of an earthfill type of dam at this site should not exceed, for the right abutment, five feet of overburden, consisting chiefly of soil, plus three feet of weathered bedrock, and for the left abutment, three feet of overburden plus three feet of weathered bedrock. These estimates apply only under the impervious section of an earthfill type of dam and are for any height of dam up to a maximum of 200 feet. Only the overburden would have to be stripped from under the pervious sections of such a dam. The stated depths are estimated normal to the surface. Stripping in the channel section should consist of about two feet of gravel and one foot of weathered bedrock.

A satisfactory location for a spillway for an earthfill dam at this site would be around the end of the structure, with the excavation being largely in hard bedrock. The material from such excavation, as well as the weathered rock stripped from the abutments, should prove about 80 percent recoverable for construction use as pervious fill, rockfill, or riprap. Tailings from former hydraulic mining operations which choke the channel one mile upstream from the dam site could also be used as pervious fill material. A small quantity of concrete aggregate could be recovered locally for use in appurtenant structures for an earthen dam, but large amounts would either have to be crushed at the site or imported. Soil suitable for use in the construction of an impervious embankment is available in limited quantities from sloping flats of the reservoir area. Although the depth of this material is probably not great, it is believed that enough could be obtained from this source to provide for a minimum impervious earth section.

As a result of yield studies, geologic reconnaissance, and preliminary economic analysis, an earthfill dam, 168 feet in height from stream bed to spillway lip, and with a crest elevation of 910 feet, was selected to illustrate estimates of cost of the South Honcut Creek Project. The dam would have a crest length of about 670 feet and a crest width of 30 feet, and 2.5:1 upstream and down-stream slopes. The central impervious core would have a top width of 10 feet and 0.8:1 slopes, and would be blanketed with sand and gravel filters. The outer pervious zones of the dam would consist of dredger tailings and materials excavated in construction of the spillway. The volume of the fill would be an estimated 919,000 cubic yards. The maximum depth of water above the spillway lip would be 8 feet, and an additional 4 feet of freeboard would be provided. The spillway would be of the side channel type, excavated from rock of the right abutment and concrete-lined. It would have a capacity of 10,000 second-feet, required for an assumed discharge of 400 second-feet per square mile of drainage area, and would discharge into South Honcut Creek below the dam. Outlet works would consist of a 42-inch diameter steel pipe placed in a trench excavated in rock beneath the dam, and encased in concrete. Releases from the dam would be controlled at the upstream end by two 30-inch hydraulically controlled high pressure slide gates located at a submerged inlet upstream from the dam, and operated by hydraulic controls from the crest of the dam. The outlet would be controlled at the downstream end by a Howell-Bunger valve.

The diversion works on French Dry Creek would be located approximately at the site of a former diversion weir, portions of which are still in existence. The site was examined and cross sections taken during the

course of the investigation. The proposed diversion weir would consist of a concrete gravity overpour section and apron, 7 feet in height above stream bed and some 55 feet in length. An opening at the right end of the weir would provide entrance to a side channel leading downstream about 100 feet to the headworks of the diversion canal. The side channel would have a concrete gravity parapet wall of the overpour type, and a 5- by 4-foot sluice gate would be provided for sand clearance. The headworks would consist of a concrete headwall across the end of the side channel, in which there would be two 5- by 4-foot slide gates. The diversion canal, which for a portion of its route would be aligned roughly along an abandoned canal, would be about 2.0 miles in length, discharging into an unnamed tributary of South Honcut Creek. Location of the canal was based on a map study, and was checked in the field. The canal chosen for cost estimating purposes would have a capacity of 200 second-feet, a shotcrete-lined trapezoidal section with 1:1 side slopes, bottom width and depth of 4.0 feet, and freeboard of 1.0 foot, and a slope of approximately 7.0 feet per mile. The velocity would be about 6.3 feet per second.

The diversion works on South Honcut Creek to serve Browns Valley and the Northeast Zone would be similar to those described for the French Dry Creek diversion, except that the weir would be 9 feet high and 84 feet in length, and the headworks would be located at the left end of the weir. The site was examined and cross-sectioned during the course of the investigation. The diversion conduit chosen for cost estimating purposes would have a capacity of 150 second-feet and would bear in a general southerly direction a distance of approximately 4.7 miles. Location of the conduit was based on a map study, and was checked in the field. For the most part the conduit would consist of a shotcrete-lined canal, but would include a steel pipe siphon, 5.5 feet in diameter and about 1,500 feet in length, across Tennessee Creek. The canal portion would have a trapezoidal section with 1:1 side slopes, bottom width of 5.0 feet, depth of 4.0 feet, and freeboard of 1.0 foot. Its slope would be approximately 4.0 feet per mile, and the velocity would be about 4.2 feet per second. Releases of water for use in Browns Valley could be made along the conduit and at its terminus.

From the terminus, about one mile northeast of Loma Rica, water for the Northeast Zone would be released to flow southerly in a tributary of Little Dry Creek for about 6,000 feet, and then would be diverted by temporary earthen works into a short unlined canal leading westerly and discharging into an unnamed tributary of Prairie Creek. The water would flow in Prairie Creek and its tributary a distance of about six miles to the point of diversion for the Northeast Zone. This diversion site and the route of the conduit to serve the Northeast Zone were surveyed during the course of the investigation. The diversion works would consist merely of a temporary earthen structure, replaced each season. The conduit from the diversion to the Northeast Zone would bear in a general southerly direction a distance of approximately 6.3 miles, terminating in a tributary of Nigger Jack Slough. It would be an unlined canal, having capacities of 75 second-feet at the diversion point and 25 second-feet at the terminus. At the diversion point the canal would have a trapezoidal section with 2:1 side slopes, bottom width of 4.0 feet,

TABLE 43

GENERAL FEATURES OF SOUTH HONCUT CREEK PROJECT

Earthfill Dam
- Crest elevation—910 feet
- Crest length—670 feet
- Crest width—30 feet
- Height, spillway lip above stream bed—168 feet
- Side slopes—2.5:1
- Freeboard, above spillway lip—12 feet
- Elevation of stream bed—730 feet
- Volume of fill—919,000 cubic yards

Reservoir
- Surface area at spillway lip—720 acres
- Capacity at spillway lip—38,000 acre-feet
- Drainage area
  - Honcut Creek—24 square miles
  - French Dry Creek—22 square miles
- Estimated mean seasonal runoff
  - Honcut Creek—23,400 acre-feet
  - French Dry Creek—27,100 acre-feet
- Estimated mean seasonal diversion from French Dry Creek—22,000 acre-feet
- Estimated safe seasonal yield—24,300 acre-feet
- Type of spillway—Side channel, concrete-lined
- Spillway capacity—10,000 second-feet
- Type of outlet—42-inch diameter steel pipe beneath dam

Diversion Works
- French Dry Creek—Concrete gravity weir, with ogee overpour section, 55 feet in length, and 7 feet high above stream bed elevation of about 2,125 feet; side channel diversion box, with overpour parapet wall, and 5- by 4-foot slide sluice gate; two 5- by 4-foot slide headgates in concrete headwall.
- South Honcut Creek—Concrete gravity weir, with ogee overpour section, 84 feet in length, and 9 feet high above stream bed elevation of 600 feet; side channel diversion box, with overpour parapet wall, and 5- by 4-foot slide sluice gate; two 5- by 4-foot slide headgates in concrete headwall.
- Prairie Creek—Temporary earthen structure, at stream bed elevation of 135 feet.

Conduits

	French Dry Creek Diversion	South Honcut Creek Diversion	Prairie Creek Diversion
Type	Trapezoidal, shotcrete-lined canal	Trapezoidal, shotcrete-lined canal, and 1,500 feet of 5.5-foot diameter steel pipe siphon	Trapezoidal, unlined canal
Length, in miles	2.0	4.7	6.3
Side slopes	1:1	1:1	2:1
Bottom width, in feet	4.0	4.0	1.0 (maximum)
Depth, in feet	4.0	5.0	3.7 (maximum)
Freeboard, in feet	1.0	1.0	1.0
Slope, in feet per mile	7.0	4.0	2.5
Velocity, in feet per second	6.3	4.2	1.7
Capacity, in second-feet	200	150	75 to 25

depth of 3.7 feet, and freeboard of 1.0 foot. Its slope would be approximately 2.5 feet per mile, and the velocity would be about 1.7 feet per second.

Cost estimates for the canals to convey water to the service areas in Browns Valley and the Northeast Zone were based on designs utilizing data obtained by reconnaissance field location surveys. Detailed design of the distribution systems in Browns Valley and the Northeast Zone, however, was considered to be outside the scope of the current investigation. Cost estimates for the systems were based on known costs of similar irrigation works elsewhere in California, adjusted to correspond with conditions prevailing in the Sutter-Yuba Area.

Pertinent data with respect to the general features of the South Honcut Creek Project, as designed for cost estimating purposes, are presented in Table 43.

The capital cost of the South Honcut Creek Project, based on prices prevailing in April, 1952, was estimated to be about $3,009,600. Corresponding annual costs of the South Honcut Creek Project were estimated to be about $154,200. The resultant estimated average unit cost of the 24,300 acre-feet of water per season conserved by South Honcut Creek Reservoir was about $6.40 per acre-foot. The estimated unit costs of water applied for irrigation in the Northeast Zone and in the Browns Valley service area were about $9.70 and $8.40 per acre-foot, respectively.

Estimated capital and annual costs of the South Honcut Creek Project are summarized in the following tabulation. Detailed cost estimates are presented in Appendix H.

	Estimated costs	
	Capital	*Annual*
Dam and reservoir	$2,225,600	$94,400
French Dry Creek diversion and conduit	151,100	8,100
South Honcut Creek diversion and conduit	379,100	20,500
Prairie Creek diversion and conduit	131,300	7,100
Browns Valley distribution system	65,000	14,400
Northeast Zone distribution system	57,500	9,700
TOTALS	$3,009,600	$154,200

East Central Zone

In Chapter III it was shown that the present requirement for supplemental water in the East Central Zone is about 28,000 acre-feet per season. However, in the design of projects for initial local development to meet this requirement, it was considered desirable to provide some capacity for future growth in water demand which would occur through development of irrigable lands not presently irrigated. This additional capacity was estimated at about 12,000 acre-feet per season, giving consideration to the extent of undeveloped irrigable lands that might readily be served, and to the available sources of water supply. For reasons hereinafter discussed it was considered that the new water supply would be applied to about 8,500 acres in the East Central Zone, of which about 3,300 acres are presently irrigated by ground water and 5,200 acres are irrigable lands not presently served with water. These lands are contained within a service area lying generally south of Hutchinson Creek and east of the Western Pacific Railroad, and delineated on Plate 22, "Camp Far West Project."

Four possible alternative plans of works for initial construction to provide supplemental water to the East Central Zone were considered. For reasons hereinafter mentioned, after preliminary investigation and study the first three plans were given no further consideration for present cost estimating purposes, but may warrant future study. The fourth plan is described in some detail in this section.

Alternative Plans Considered. The first of the alternative plans considered for initial construction involved the substitution of surface water from the Yuba River to replace ground water presently utilized in an area in the East Central Zone. The substitute supply would be diverted at a point on the Yuba River about four miles upstream from Daguerre Point by means of existing headworks of the Yuba River Ditch, owned by the Yuba Consolidated Gold Fields. The Yuba River Ditch, an abandoned canal some four miles in length, with a designed capacity of approximately 115 second-feet, would be rehabilitated and extended in a southerly direction to Hutchinson Creek. Use of the new surface water supply would prevent progressive and permanent lowering of ground water levels in the area served and in adjacent areas. During study of the plan it was determined that surplus flows are available in the Yuba River at the proposed point of diversion during the snowmelt period and into summer months in all but the driest years. However, during the peak of the irrigation season in many years, flows at the diversion point are no more than adequate to maintain the required downstream diversion at Daguerre Point for the Cordua and Hallwood systems. Until such time as additional upstream conservation storage and regulation of flood flows of the Yuba River are accomplished, excessive irrigation deficiencies would be experienced under this plan. For this reason the plan was given no further present consideration for initial construction.

The second of the alternative plans considered for initial construction would include the construction of a dam and reservoir at the Waldo site on Dry Creek, facilities for release of the conserved waters from the reservoir, and facilities for their downstream diversion, conveyance, and distribution in the East Central Zone. Preliminary studies indicated that this plan would not provide sufficient yield to meet the present requirement for supplemental water in the East Central Zone, and that the unit cost of the conserved water would be greater than the corresponding unit cost with the fourth plan described in this section. For these reasons the plan was given no further present consideration. Studies were also made of a plan which included a



Existing Camp Far West Dam and Reservoir

larger dam and reservoir at the Waldo site, together with facilities for diversion of flood waters of Yuba River to the larger reservoir. Yield studies and preliminary cost estimates indicated that this plan should probably be deferred for future development. It was indicated that only a portion of the yield of the enlarged project could be readily utilized in the Sutter-Yuba Area at the present time. The capital cost of the larger project would be more than twice that of the fourth plan for initial construction described in this section. Costs of developed water would be excessive until such time as the major portion of the yield could be put to beneficial use. For these reasons this plan was given no further present consideration for initial construction.

The third of the alternative plans considered for initial construction involved the possible purchase of water from the Nevada Irrigation District and conveyance to places of use in the natural channel of Dry Creek. Preliminary studies indicated that additional water could be supplied to the East Central Zone by development and extension of existing facilities of the district, including the China and Tarr Ditches. As in the case of the first plan described, use of the new surface supply would prevent progressive and permanent lowering of ground water levels in the area served and in adjacent areas. The amount of water that might be made available to the East Central Zone would depend upon construction and enlargement of works of the Nevada Irrigation District, and, in turn, upon the outcome of possible negotiations between the district and an agency representing interests of the Northeast Zone. For these reasons, features of the plan were not surveyed and studied in detail, nor estimates of cost prepared.

The fourth plan considered for initial construction would provide for the present supplemental water requirement in the East Central Zone and for growth in water utilization for a number of years in the future. In addition, it would provide corresponding benefits to the South Side Zone. The plan would include the construction of a larger dam and reservoir on the Bear River at the site of the existing Camp Far West Dam and Reservoir, and facilities for conveyance of the conserved water to and its distribution in both the East Central and South Side Zones. Use of the new surface water supply would prevent progressive and permanent lowering of ground water levels in the areas served and in adjacent areas. This plan is hereinafter referred to as the "Camp Far West Project," and its principal features are delineated on Plate 22.

Camp Far West Project. The proposed dam would be an earthfill structure with chute spillway, located on the Bear River, in Section 21, Township 14 North, Range 6 East, M. D. B. & M., some 16 miles upstream from the confluence with the Feather River, and 6.6 miles upstream from Highway 99E. Stream bed elevation at the site is 145 feet. The proposed dam would be superimposed upon an existing curved concrete gravity dam, 62 feet in height from stream bed to dam crest, which creates a reservoir of about 5,000 acre-foot capacity, and is owned by the Camp Far West Irrigation District. Flood waters of the Bear River conserved by the proposed reservoir would be released at an elevation of approximately 180 feet to canals serving the East Central and South Side Zones, respectively. The lands which would be served by the new water supply comprise the aforementioned 8,500 acres in the East Central Zone, and an additional 8,500 acres in the South Side Zone, in the respective service areas shown on Plate 22. Both service areas range in elevation from about 150 feet along their eastern boundaries to about 50 feet on the west.

In Chapter III it was estimated that the present requirement for supplemental water in the East Central Zone is about 28,000 acre-feet per season and in the South Side Zone an additional 28,000 acre-feet, a total of about 56,000 acre-feet per season. In the design of the Camp Far West Project for cost estimating purposes, it was considered necessary to provide about 10,000 acre-feet of water per season for the Camp Far West Irrigation District to replace yield of the existing reservoir. Based upon the area of lands irrigated by the district, this estimate is believed to be adequate. As has been stated, it was also considered desirable to provide some capacity for future growth in demand on the project, which would occur through development of irrigable lands not presently irrigated.

As a first step in determination of size of the project, estimates were made of yield of the proposed works for various storage capacities. It was estimated that mean seasonal runoff of the Bear River, from the approximately 280 square miles above the dam site, was 347,000 acre-feet. Based upon records and estimates of runoff during the critical dry period which occurred in the Sacramento Valley from 1920-21 through 1934-35, yield studies were made for three sizes of reservoirs at the Camp Far West site. It was assumed that a seasonal irrigation deficiency up to 35 percent could be endured in one season of the period. A summary of results of the yield studies is presented in Table 44.

TABLE 44

ESTIMATED SAFE SEASONAL YIELD OF CAMP FAR WEST RESERVOIR, BASED ON CRITICAL DRY PERIOD FROM 1920-21 THROUGH 1934-35

(In acre-feet)

Reservoir storage capacity	Safe seasonal yield
55,000	55,000
104,000	90,000
151,000	122,000

After consideration of the results of the yield studies, together with topography of the dam site and cost analyses hereinafter discussed, a reservoir of 104,000 acre-foot storage capacity, with estimated safe seasonal yield of 90,000 acre-feet was chosen for purposes of cost estimates to be presented in this report. The yield study for this size of reservoir is included in Appendix G.

For cost estimating purposes a tentative distribution of yield of the proposed Camp Far West Reservoir was made. Of the estimated 90,000 acre-feet of safe seasonal yield, 10,000 acre-feet per season was assigned to the Camp Far West Irrigation District. The remaining yield was divided equally between the East Central and South Side Zones, in the amount of 40,000 acre-feet per season to each zone.

Since the East Central Zone constitutes a free ground water area, water losses in the proposed canal and ditch system would largely percolate to the ground water. For this reason it was assumed that these losses, plus the unconsumed portion of the new water supply applied to irrigation would be effective in preventing progressive and permanent lowering of ground water levels. It was estimated that losses in conveyance and distribution of the 40,000 acre-feet of safe seasonal yield assigned to the East Central Zone would be about 25 percent, leaving some 30,000 acre-feet per season for application to irrigation. It was also assumed that water imported to the East Central Zone would be used largely on irrigated pasture, and that the average seasonal application of the new water would be 3.5 acre-feet per acre. On this basis it was estimated that the imported supply would be applied to some 8,500 acres in a service area lying generally south of Hutchinson Creek and east of the Western Pacific Railroad. Of the lands which would be served with the new water supply, about 3,300 acres are presently irrigated by ground water and about 5,200 acres are irrigable lands not presently irrigated.

An estimate of the monthly distribution of demand for irrigation water in the Sutter-Yuba Area was presented in Table 33. Based on these data, monthly demands on the Camp Far West Project would be as shown in Table 45.

A topographic survey of the Camp Far West reservoir site up to an elevation of 225 feet was made by the Camp Far West Irrigation District in 1922. This survey was extended to an elevation of 320 feet by the Division of Water Resources in 1930, and a map was drawn from both surveys at a scale of 1 inch equals 500 feet, with a contour interval of 10 feet. Storage capacities of the Camp Far West Reservoir at various stages of water surface elevation are given in Table 46.

Based upon preliminary geological reconnaissance, the Camp Far West dam site is considered suitable for an earthfill dam of any height up to a maximum of 180 feet. Bedrock at the site consists of a slightly

TABLE 45

ESTIMATED MONTHLY DISTRIBUTION OF DEMAND FOR WATER FROM CAMP FAR WEST PROJECT

Month	Percent of seasonal total	Gross release to Camp Far West Irrigation District, in acre-feet	Gross import to East Central Zone, in acre-feet	Gross import to South Side Zone, in acre-feet
April	10	1,000	4,000	4,000
May	16	1,600	6,400	6,400
June	17	1,700	6,800	6,800
July	22	2,200	8,800	8,800
August	17	1,700	6,800	6,800
September	11	1,100	4,400	4,400
October	5	500	2,000	2,000
November	2	200	800	800
TOTALS	100	10,000	40,000	40,000

TABLE 46

AREAS AND CAPACITIES OF CAMP FAR WEST RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	145	0	0
25	170	100	1,400
45	190	180	4,200
65	210	380	9,800
85	230	600	19,400
105	250	890	34,200
125	270	1,260	55,500
145	290	1,750	85,600
155	300	2,020	104,400
165	310	2,330	126,100
175	320	2,620	151,000

porphyritic, compact, and massive dark greenstone with gradations into coarse-grained phutonic rock. A complex joint system exists in this vicinity with joint cracks opened a few inches on the surface by weathering. The joints probably do not persist to appreciable depths other than as hairline cracks in the rock. However, some moderate grouting would be necessary. Shears are not abundant in the bedrock, and no serpentine was found locally. While slopes up to an elevation of about 160 feet above stream bed on

both abutments consist essentially of barren bedrock with scattered patches of overlying soil, the abutment slopes above 100 feet show only occasional bedrock outcrops with a much heavier mantle of overburden. Stripping under the impervious section of an earthfill type of dam at this site should not exceed four feet of depth of loose material up to 100 feet above stream bed on both abutments, and eight feet of depth above 100 feet on the abutments. Topographic considerations indicate that the spillway should be located across the ridge forming the right abutment of the dam, utilizing a natural saddle and drainage channel.

The material stripped from the foundation and abutments and excavated from the spillway should prove largely recoverable for construction use as pervious fill, rockfill, or riprap. Deposits of dredger tailings about two miles downstream from the dam, as well as sands and gravels accumulated in the existing reservoir, could be used as pervious fill material for the proposed dam. Soil suitable for use in the construction of an impervious embankment is available in limited quantities within a radius of about two miles from the dam. Although the depth of this material is probably not great, it is believed that enough could be obtained from several sources to provide for a minimum impervious earth section.

As a result of yield studies, geologic reconnaissance, and preliminary economic analysis, an earthfill dam, 155 feet in height from stream bed to spillway lip, and with a crest elevation of 311 feet, was selected to illustrate estimates of costs of the Camp Far West Project. The dam would have a crest length of about 2,980 feet and a crest width of 30 feet, and 3 :1 upstream and 2.5 :1 downstream slopes. The central impervious core would have a top width of 10 feet and 0.8 :1 slopes. The outer pervious zones of the dam would consist of stream bed gravels, dredger tailings, and salvaged material from stripping and excavation. A 3-foot blanket of gravel riprap would protect the upstream face of the dam. The volume of the fill would be an estimated 2,070,000 cubic yards. The spillway would be of the chute type, located across the ridge forming the right abutment, and concrete-lined. The maximum depth of water above the spillway lip would be 7 feet, and an additional 4 feet of freeboard would be provided. The spillway would have a capacity of 60,000 second-feet, required for an assumed discharge of 215 second-feet per square mile of drainage area. The spillway would discharge into a draw that joins the Bear River about 900 feet downstream from the toe of the dam. The outlet works would include a horseshoe type tunnel, 10 feet in diameter and 880 feet in length, excavated through the left abutment and concrete-lined. The tunnel would be used to divert flow of the Bear River during the construction period. After completion of the dam a concrete plug would be placed in the tunnel at the axis of the dam, and a 5- by 5-foot high pressure slide gate would be installed to control releases from the reservoir. A 66-inch diameter steel pipe, with capacity of 440 second-feet, would convey the water through the tunnel and terminate in a 60-inch diameter needle valve at a location about 250 feet downstream from the tunnel portal. This needle valve would discharge into a concrete-lined stilling basin, from which water would enter a concrete-lined canal at an elevation of 187 feet. Another needle valve, of 36-inch diameter, would be installed in the steel outlet pipe just outside of the tunnel portal, and would discharge directly into the Bear River.

The canal from the stilling basin would be of trapezoidal section, with 1 :1 side slopes, bottom width of 7.0 feet, depth of 6.0 feet, and freeboard of 1.0 foot. Its slope would be about 2.5 feet per mile, its velocity about 5.1 feet per second, and its capacity 400 second-feet. The canal would extend along the left bank of the Bear River a distance of about 8,000 feet, terminating in a concrete division box at an elevation of 183 feet. From this structure a steel pipe siphon, 66 inches in diameter and about 800 feet in length, with capacity of 200 second-feet, would convey water across the Bear River, discharging into a canal to serve the East Central Zone. The division box would also contain an outlet to a canal to serve the South Side Zone, and another outlet to a wasteway emptying into the Bear River.

The canals to serve both the East Central and South Side Zones would have capacities at their intakes of 200 second-feet. The canal to serve the East Central Zone would extend from the siphon outlet in a northwesterly direction a distance of approximately 3.6 miles, where about one-half of the water would be discharged into the channel of South Dry Creek to be diverted by downstream users. The remaining water would be carried a distance of about 0.8 mile and discharged into the channel of North Dry Creek for similar downstream rediversion. For an initial distance of about 3,500 feet from the Bear River siphon the canal would be shotcrete-lined and of trapezoidal section, with 1 :1 side slopes, bottom width of 6.0 feet, depth of 4.5 feet, and freeboard of 1.0 foot. The slope would be about 2.5 feet per mile, and the velocity about 4.3 feet per second. For the remainder of the distance to South Dry Creek the canal would be unlined and of trapezoidal section, with 2 :1 side slopes, bottom width of 8.0 feet, depth of 5.0 feet, and freeboard of 1.0 foot. The slope would be about 2.5 feet per mile, and the velocity about 2.2 feet per second. From South Dry Creek to North Dry Creek the canal would be unlined and of trapezoidal section, with 2 :1 side slopes, bottom width of 7.0 feet, depth of 3.7 feet, and freeboard of 1.0 foot. The slope would be about 2.5 feet per mile, and the velocity about 1.9 feet per second. Capacity of this portion of the canal would be 100 second-feet.

The canal to serve the South Side Zone would extend from the division box in a southerly direction a distance

of approximately 10.0 miles to Coon Creek, where about one-half of the flow would be discharged for rediversion by downstream users. The remaining water would be carried in a canal with capacity reduced to 100 second-feet, a distance of about 5.5 miles in a general southerly direction, where it would be similarly discharged into and conveyed in the natural channel of Markham Ravine for a distance of about 1.1 miles. The conserved water would be diverted from Markham Ravine by a flashboard dam and conveyed in a canal for a distance of about 1.2 miles where it would be discharged into Auburn Ravine for rediversion by downstream users. For an initial distance of about 1.0 mile from the division box the canal would be shotcrete-lined and of trapezoidal section, with 1:1 side slopes, bottom width of 6.0 feet, depth of 4.5 feet, and freeboard of 1.0 foot. The slope would be about 2.5 feet per mile, and the velocity about 4.3 feet per second. For the remainder of the distance to Coon Creek the canal would be unlined. It would be of trapezoidal section, with 2:1 side slopes, bottom width of 8.0 feet, depth of 5.0 feet, and freeboard of 1.0 foot. Its slope would be about 2.5 feet per mile, and its velocity about 2.2 feet per second. From Coon Creek to Auburn Ravine the constructed canal would be unlined and of trapezoidal section, with 2:1 side slopes, bottom width of 7.0 feet, depth of 3.7 feet, and freeboard of 1.0 foot. Its slopes would be about 2.5 feet per mile, and its velocity about 1.9 feet per second.

TABLE 47

GENERAL FEATURES OF CAMP FAR WEST PROJECT

Earthfill Dam
- Crest elevation—311 feet
- Crest length—2,980 feet
- Crest width—30 feet
- Height, spillway lip above stream bed—155 feet
- Side slopes—3:1 upstream; 2.5:1 downstream
- Freeboard, above spillway lip—11 feet
- Elevation of stream bed—145 feet
- Volume of fill—2,070,000 cubic yards

Reservoir
- Surface area at spillway lip—2,020 acres
- Capacity at spillway lip—104,000 acre-feet
- Drainage area—280 square miles
- Estimated mean seasonal runoff—347,000 acre-feet
- Estimated safe seasonal yield—80,000 acre-feet
- Type of spillway—Chute, concrete-lined
- Spillway capacity—60,000 second-feet
- Type of outlet—10-foot diameter pressure tunnel and 66-inch diameter steel pipe through left abutment

Conduits

	Outlet	Bear River Canal	Bear River Siphon	East Central Zone Conduit			South Side Zone Conduit		
Type	66-inch diameter steel pipe	Trapezoidal, concrete-lined	66-inch diameter	Trapezoidal			Trapezoidal		
				Lined section	Unlined section		Lined section	Unlined section	
Length, in miles	0.21	1.5	0.15	0.7	2.9	0.8	1.0	10.0	6.7
Side slopes		1:1		1:1	2:1	2:1	1:1	1:1	2:1
Bottom width, in feet		7.0		6.0	8.0	7.0	6.0	8.0	7.0
Depth, in feet		6.0		4.5	5.0	3.7	4.5	5.0	3.7
Freeboard, in feet		1.0		1.0	1.0	1.0	1.0	1.0	1.0
Slope, in feet per mile		2.5		2.5	2.5	2.5	2.5	2.5	2.5
Velocity, in feet per second	18.5	5.1	8.4	4.3	2.2	1.9	4.3	2.2	1.9
Capacity, in second-feet	440	100	200	200	200	100	200	200	100

Cost estimates for the canals to convey water to the service areas in the East Central and South Side Zones were based on designs utilizing data obtained by field location surveys. Detailed design of the distribution systems in the East Central and South Side Zones, however, was considered to be outside the scope of the current investigation. Cost estimates for the distribution systems were based on known costs of similar irrigation works elsewhere in California, adjusted to correspond with conditions prevailing in the Sutter-Yuba Area.

Pertinent data with respect to general features of the Camp Far West Project, as designed for cost estimating purposes, are presented in Table 47.

The capital cost of the Camp Far West Project, based on prices prevailing in April, 1952, was estimated to be about $5,592,900. The corresponding annual costs of the Camp Far West Project were estimated to be about $299,600. The resultant estimated unit cost of the 80,000 acre-feet per season of new water conserved by the Camp Far West Reservoir was about $3.70 per acre-foot. The estimated unit cost of water applied for irrigation in the East Central Zone was about $4.70 per acre-foot, and the estimate for water applied for irrigation in the South Side Zone was about $5.30 per acre-foot.

Estimated capital and annual costs of the Camp Far West Project are summarized in the following tabulation. Detailed cost estimates are presented in Appendix H.

	Estimated costs	
	Capital	*Annual*
Dam and reservoir	$3,979,900	$170,000
Bear River canal	233,000	12,600
East Central Zone canal and siphon	286,600	15,400
South Side Zone canal	668,400	36,000
East Central Zone distribution system	212,500	32,800
South Side Zone distribution system	212,500	32,800
TOTALS	$5,592,900	$299,600

South Side Zone

Three possible alternative plans of works for initial construction to provide supplemental water to the South Side Zone were considered. The first of these plans was the Camp Far West Project, which, as described in the preceding section, would provide supplemental water for both the East Central and South Side Zones. The second of the alternative plans con-

sidered for initial construction involved the possible purchase of water from the Nevada Irrigation District and conveyance to places of use in the natural channels of Coon Creek and Auburn Ravine. The amount of water that might be made available to the South Side Zone would depend upon design and construction of additional works of the Nevada Irrigation District, and in turn upon the outcome of possible negotiations between the district and an agency representing interests of the South Side Zone. For these reasons, features of the plan were not surveyed and studied in detail, nor estimates of cost prepared.

The third of the plans involved the construction of a dam and reservoir on Coon Creek, at a site approximately seven miles northeast of Lincoln, the utilization of an existing diversion works and ditch to convey flood flows of the Bear River to the reservoir, the reconstruction of existing abandoned facilities for diversion of the conserved waters from Coon Creek below the dam, and the construction of facilities for conveyance of the waters to and their distribution in the South Side Zone. This plan is hereinafter referred to as the "Coon Creek Project," and its principal features are delineated on Plate 23, "Coon Creek Project."

Under each of the alternative plans use of the new surface water supplies would prevent progressive and permanent lowering of ground water levels in the areas served and in adjacent areas. Each plan would provide for the present supplemental water requirement of the South Side Zone and for growth in water utilization for a number of years in the future.

Camp Far West Project. In the earlier description of the Camp Far West Project a reservoir of 104,000 acre-foot capacity, with estimated safe seasonal yield of 90,000 acre-feet, was chosen at the Camp Far West site on the Bear River for cost estimating purposes. A tentative distribution of this yield was made that would provide 40,000 acre-feet per season to the South Side Zone, some 12,000 acre-feet per season greater than the present requirement for supplemental water in the zone, which was estimated in Chapter III to be about 28,000 acre-feet per season. The 12,000 acre-feet per season of indicated present surplus yield was assigned to irrigation of irrigable lands not now served with water.

Since the South Side Zone constitutes a free ground water area, water losses in the proposed conveyance and distribution system for the new water supply would largely percolate to the ground water. For this reason it was assumed that these losses, plus the unconsumed portion of the new water supply applied to irrigation, would be effective in preventing progressive and permanent lowering of ground water levels. It was assumed that losses in conveyance and distribution of the 40,000 acre-feet per season of safe seasonal yield assigned to the South Side Zone would be about 25 percent, leaving some 30,000 acre-feet per season for application to irrigation. It was also assumed that water imported to the South Side Zone would largely be used on irrigated pasture and that the average seasonal application of the new water would be 3.5 acre-feet per acre. On this basis it was estimated that the imported supply would be applied to some 8,500 acres in a service area lying generally adjacent to Coon Creek and Auburn Ravine and easterly of the boundaries of Reclamation Districts 1000 and 1001. Elevation of this service area ranges from about 150 feet along the eastern boundary to about 50 feet on the west. Of the lands which would be served with the new water supply, about 3,300 acres are presently irrigated by ground water, and 5,200 acres are irrigable lands not presently irrigated. An estimate of monthly distribution of demand for the 40,000 acre-feet of gross seasonal import to the South Side Zone from the Camp Far West Project was presented in Table 45.

As described in the preceding section, direct releases would be made from Camp Far West Reservoir to the intake of a canal to serve the South Side Zone. The intake would be at a concrete division box, located on the left bank of the Bear River, about 1.5 miles downstream from Camp Far West Dam, at an elevation of 183 feet. From the intake the canal, with capacity of 200 second-feet, would extend in a southerly direction approximately 10.0 miles to Coon Creek. At this point about one-half of the flow would be discharged into Coon Creek for rediversion by downstream users. The remaining water would be carried in a general southerly direction an additional 5.5 miles, in a canal with capacity reduced to 100 second-feet, where it would be similarly discharged into and conveyed in the natural channel of Markham Ravine for a distance of about 1.1 miles. The conserved water would be diverted from Markham Ravine by a flashboard dam and conveyed in a canal for a distance of about 1.2 miles where it would be discharged into Auburn Ravine for rediversion by downstream users. Additional pertinent data with respect to general features of the Camp Far West Project, as designed for cost estimating purposes, were presented in Table 47.

The cost estimate for the canal to convey water to the South Side Zone was based on designs utilizing data obtained by field location surveys. Detailed design of the distribution system for the South Side Zone was considered to be outside the scope of the current investigation. The cost estimate for the distribution system was based on known costs of similar irrigation works elsewhere in California, adjusted to correspond with conditions prevailing in the Sutter-Yuba Area.

As stated in the preceding section, the capital cost of the Camp Far West Project, based on prices prevailing in April, 1952, was estimated to be about $5,592,900. Corresponding annual costs of the Camp Far West Project were estimated to be about $299,600. The resultant estimated unit cost of new water conserved by Camp Far West Reservoir was about $3.70 per acre-foot of safe seasonal yield. The estimated unit cost of

water applied for irrigation in the South Side Zone was about $5.30 per acre-foot, and the estimate for water applied for irrigation in the East Central Zone was about $4.70 per acre-foot. Detailed cost estimates for the Camp Far West Project are presented in Appendix H.

Coon Creek Project. The proposed Coon Creek Dam would be an earthfill structure, with two earthen auxiliary saddle dikes and a chute spillway. It would be located in Sections 8 and 17, Township 13 North, Range 6 East, M.B.D. & M., at a site on Coon Creek some 7.5 miles northeast of Lincoln and 8.3 miles upstream from Highway 99E. Stream bed elevation at this site is 345 feet. For cost estimating purposes, it was assumed that flood waters of the Bear River would be diverted by existing works, conveyed in the existing Upper Gold Hill and Combie-Ophir Canals for a distance of about 2.4 miles, and discharged into a tributary of Coon Creek above the proposed reservoir. These diversion works and the canals belong to the Nevada Irrigation District. The conserved waters of both Coon Creek and Bear River, after release from the proposed reservoir, would flow down Coon Creek for a distance of approximately six miles to an existing abandoned diversion structure. At this point about one-half of the released water would be diverted into a canal, and conveyed in a general southerly direction for a distance of some 5.5 miles where it would be discharged into and conveyed in the natural channel of Markham Ravine for a distance of about 1.1 miles. The conserved water would be diverted from Markham Ravine by a flashboard dam and conveyed in a canal for a distance of about 1.2 miles where it would be discharged into Auburn Ravine. The new water supply would be available in the natural channels of Coon Creek and Markham and Auburn Ravines for downstream diversion and use.

The lands which would be served by the new water supply comprise some 12,000 acres in a service area lying generally adjacent to Coon Creek and Auburn Ravine and easterly of the boundaries of Reclamation Districts 1000 and 1001. A portion of this service area, shown on Plate 23, is in Placer County and outside of the Sutter-Yuba Area. For reasons hereinafter discussed, it was assumed that water yielded by the Coon Creek Project would be entirely applied to irrigable lands not presently served with water. Use of the new surface water supply would prevent progressive and permanent lowering of ground water levels in the area served and in adjacent areas in the South Side Zone.

In Chapter III it was estimated that the present requirement for supplemental water in the South Side Zone is about 28,000 acre-feet per season. However, in design of projects for initial local development to meet this requirement, it was considered desirable to provide some capacity for future growth in water demand which would occur through development of irrigable lands not presently irrigated. In the case of the Camp Far West Project, described in the preceding section, this additional capacity was estimated to be 12,000 acre-feet per season. However, in connection with the Coon Creek Project, giving consideration to the extent of undeveloped irrigable lands that might readily be served, and to the available source of water supply, the corresponding additional capacity was estimated to be 28,000 acre-feet per season.

As a first step in determination of the size of the Coon Creek Project, estimates were made of yield of the proposed works for various reservoir storage capacities. It was estimated that mean seasonal runoff of Coon Creek, from the approximately 40 square miles of watershed above the dam site, was about 32,800 acre-feet. Of the Bear River waters, studies indicated that flood flows in an estimated mean seasonal amount of about 35,700 acre-feet could be diverted to the proposed Coon Creek Reservoir, through the existing Combie-Ophir Canal of about 106 second-foot capacity, during the months of November through April.

Based on records and estimates of runoff during the critical dry period which occurred in the Sacramento Valley from 1920-21 through 1934-35, yield studies were made of two sizes of reservoir at the Coon Creek site. The limited number of yield studies was largely determined by topographic considerations. It was assumed that a seasonal irrigation deficiency up to 35 percent could be endured in one season of the period. Monthly demands on the reservoir were assumed to be proportional to the estimated distribution of irrigation demands in the Sutter-Yuba Area, as presented in Table 33. A summary of the results of the yield studies is presented in Table 48.

TABLE 48

ESTIMATED SAFE SEASONAL YIELD OF COON CREEK RESERVOIR WITH BEAR RIVER DIVERSION, BASED ON CRITICAL DRY PERIOD FROM 1920-21 THROUGH 1934-35

(In acre-feet)

Reservoir storage capacity	Safe seasonal yield
25,500	34,000
59,000	56,000

After consideration of the results of the yield studies, together with topography of the dam site and cost analyses hereinafter discussed, a reservoir of 59,000 acre-foot capacity with estimated safe seasonal yield of 56,000 acre-feet was chosen for purposes of cost estimates to be presented in this report. The yield study for this size of reservoir is included in Appendix G.

Since the considered service area constitutes a free ground water area, water losses in the proposed canal

and ditch system would largely percolate to the ground water. For this reason it was assumed that these losses, plus the unconsumed portion of the new water supply applied to irrigation, would be effective in preventing progressive and permanent lowering of ground water levels in the area served and in adjacent areas in the South Side Zone.

It was assumed that seasonal losses in conveyance and distribution of the 56,000 acre-feet of safe seasonal yield would be about 25 percent, or 14,000 acre-feet, leaving some 42,000 acre-feet for application to irrigation. It was also assumed that the new water supply from the Coon Creek Project would largely be used on irrigated pasture, and that the average seasonal application of water would be 3.5 acre-feet per acre. On this basis it was estimated that the imported supply would be applied to some 12,000 acres in a service area lying generally adjacent to Coon Creek and Auburn Ravine and easterly of the boundaries of Reclamation Districts 1000 and 1001. Of the assumed average seasonal application of 3.5 acre-feet per acre, it was estimated that seasonal consumptive use would be about 2.3 acre-feet per acre, and that about 1.2 acre-feet per acre would be unconsumed. This unconsumed portion would aggregate about 14,400 acre-feet per season for the 12,000 acres which would be irrigated.

From the foregoing it was estimated that losses in conveyance and distribution of the new water supply, plus the unconsumed portion of the water actually applied to irrigation, both of which would largely percolate to ground water, would total about 28,400 acre-feet per season. Since the estimated present seasonal water requirement to prevent progressive and permanent lowering of ground water levels in the South Side Zone is about 28,000 acre-feet per season, no substitute water supply would have to be furnished lands presently irrigated by ground water in order to prevent such lowering. It was assumed, therefore, that lands to which the water supply from the Coon Creek Project would be applied would consist entirely of irrigable lands not presently served with water. In this connection, certain irrigable but unirrigated lands in Placer County lying immediately adjacent to the South Side Zone could readily and logically be served with water from the Coon Creek Project. For this reason the water service area shown on Plate 23 was extended outside the South Side Zone to include these lands.

An estimate of the monthly distribution of demand for irrigation water in the Sutter-Yuba Area was presented in Table 33. Based on these data, monthly demands on the Coon Creek Project would be as shown in Table 49.

TABLE 49

ESTIMATED MONTHLY DISTRIBUTION OF DEMAND FOR WATER FROM COON CREEK PROJECT

Month	Percent of seasonal total	Gross release to South Side Zone, in acre-feet
April	10	5,600
May	16	9,000
June	17	9,500
July	22	12,300
August	17	9,500
September	11	6,200
October	5	2,800
November	2	1,100
TOTALS	100	56,000

A topographic map of the Coon Creek dam and reservoir sites, at a scale of 1 inch equals 425 feet, with contour interval of 20 feet, was made by the Division of Water Resources in 1951, using photogrammetric methods. Topography of the dam site was shown on the map up to an elevation of 580 feet, while topography of the reservoir site was shown up to an elevation of 500 feet. Reservoir topography above that elevation was estimated. Storage capacities of Coon Creek Reservoir at various stages of water surface elevation are given in Table 50.

TABLE 50

AREAS AND CAPACITIES OF COON CREEK RESERVOIR

Depth of water at dam, in feet	Water surface elevation, USGS datum, in feet	Water surface area, in acres	Storage capacity, in acre-feet
0	345	0	0
15	360	5	50
35	380	25	300
55	400	65	1,200
75	420	110	3,000
95	440	180	5,800
115	460	260	10,300
135	480	360	16,600
155	500	500	25,500
175	520	610	37,600
195	540	740	51,000
205	550	810	58,000
207	552	820	59,000
215	560	880	65,000

Based upon preliminary geological reconnaissance, the Coon Creek dam site is considered suitable for an earthfill dam of any height up to a maximum of 220 feet. Foundation rock at the site consists essentially of

amphibolite schist. In the vicinity of the site the rock varies between schistose and massive material, striking across the channel and dipping vertically. The foundation bedrock as a whole is relatively hard and unweathered where exposed in outcrops. Joints are prominently developed in several sets, with a horizontal joint set predominating. Minor faulting may be involved at this site, as evidenced by the sharp change in attitude of the joint sets of the rock slightly downstream from the tentative axis position. The trend of such a possible fault may strike obliquely upstream into the right abutment where considerable talus material exists. There are no indications of recent movement in this area.

The stream at this site has cut through the resistant rib of rock, forming a narrow gorge with steep side slopes to an elevation of about 150 feet above stream bed. A dam of the height considered for cost estimating purposes would require a dike across the saddle south of the left abutment, and two dikes across smaller saddles north and east of the right abutment. However, it is indicated that the spillway could be located across the ridge forming the right abutment of the dam, utilizing one of the saddles and eliminating the need for construction of a dike therein.

It is probable that stripping under the impervious section of an earthfill dam at the Coon Creek site would be relatively heavy, due to the jointed blocky nature of the rock. On the left abutment no removal of overburden would be required for a height of about 50 feet above stream bed, while above that height stripping of overburden, consisting of earth and loose rock, should not exceed two feet of depth. On the right abutment for a height of about 60 feet above stream bed stripping of overburden, consisting of loose talus rocks but including occasional blocks in place, should not exceed 15 feet of depth. Above that height on the right abutment stripping of overburden, consisting of loose rock and earth, should not exceed three feet of depth. Beneath the described overburden on both abutments it is anticipated that required stripping would involve the removal of blocky hard rock to a maximum of 20 feet of depth.

For an earthfill dam at this site, a large proportion of the material obtained from stripping operations could be salvaged for use in the pervious sections of the dam or as riprap. Aggregates, particularly fines, are lacking in the area and might require hauling from the vicinity of the Bear River. Soil suitable for use in the construction of an impervious core is available in only limited quantities. Deposits of residual clay overburden are scattered and thin in the vicinity. However, based on a preliminary sampling program, sufficient material is believed to be available within two to three miles of the dam site to provide for a minimum impervious earth section. Materials for the pervious sections of the dam could be obtained from salvage from stripping, and from stream bed gravels of Coon Creek and the Bear River.

As a result of yield studies, geologic reconnaissance, and preliminary economic analysis, an earthfill dam 207 feet in height from stream bed to spillway lip, and with a crest elevation of 560 feet, was selected to illustrate estimates of cost of the Coon Creek Project. The dam would consist of three earthfill structures, a main dam across Coon Creek and two auxiliary saddle dams. The main dam would have a crest length of about 1,420 feet, a crest width of 30 feet, and 3:1 upstream and 2.5:1 downstream slopes. The south saddle dam would have a crest length of about 1,450 feet and a maximum height of about 64 feet. The north saddle dam would have a crest length of about 550 feet and a maximum height of about 39 feet. Both saddle dams would have crest widths of 20 feet, and 2.5:1 upstream and downstream slopes. The central impervious cores of all dams would have top widths of 10 feet and 0.8:1 slopes, and would be blanketed with sand and gravel filters. The outer pervious zones of the dams would consist of stream bed gravels and materials salvaged from stripping and excavation. The upstream face of the main dam would be protected by a 3-foot blanket of riprap, and similar blankets 2 feet in depth would protect the upstream faces of the saddle dams. The main dam would have an estimated volume of fill of 2,201,000 cubic yards, and the estimated volume of fill of the two saddle dams would be 449,000 cubic yards.

The concrete spillway would be of the ogee weir type, located in a saddle between the main dam and the north saddle dam. It would have a capacity of 14,000 second-feet, required for an assumed discharge of 350 second-feet per square mile of drainage area, and would discharge into a tributary of Coon Creek. The maximum depth of water above the spillway lip would be 4 feet, and an additional 4 feet of freeboard would be provided. Outlet works would consist of a 48-inch diameter steel pipe placed in a trench excavated in rock beneath the dam, and encased in concrete. Releases from the reservoir would be controlled at the upstream end by two 30-inch hydraulically controlled high-pressure slide gates, located at a submerged inlet upstream from the dam, and operated by hydraulic controls from a house on the left abutment. The outlet would be controlled at the downstream end by a Howell-Bunger valve.

The proposed diversion works on Coon Creek would incorporate remaining features of an abandoned diversion structure at a site approximately 3.3 miles upstream from Highway 99E. The site was examined and surveyed during the course of the investigation. The existing works consist of a concrete gate structure with concrete abutments. An earthen dike which formerly completed stream closure of the left abutment has been destroyed. Stream bed elevation at the site is 140 feet, and the gate structure is 17 feet in height above stream

bed. The gate opening is 35 feet in width, and contains seven bays to hold flashboards, each with an opening four feet in width.

For cost estimating purposes, it was planned to utilize the old concrete gate structure by installing removable flashboards to a height of 7 feet above stream bed elevation. The earthen dike would be replaced from the left abutment of the gate structure to the natural bank of Coon Creek, a distance of about 100 feet, to complete the stream closure. This embankment would be approximately 10 feet in height, with 2:1 side slopes and a crest elevation of 150 feet. A similar dike with crest elevation of 155 feet, portions of which are already in place, would extend upstream along the low left bank of Coon Creek for a distance of approximately 1,000 feet. At a point about 50 feet upstream from the main axis of the diversion structure a concrete headwall would be placed in the left side embankment, containing a 4- by 4-foot slide gate to control releases into a proposed canal. It was estimated that spillway capacity of the existing gate structure, after removal of the flashboards, would be in excess of 2,000 second-feet. It was considered that infrequent flood flows in Coon Creek in excess of this amount would wash out the closing earth embankment, and that the embankment would have to be replaced after such floods.

The proposed canal, with a capacity of 100 second-feet, would extend from the headgate in a general southerly direction a distance of approximately 5.5 miles to Markham Ravine. The conserved water would be conveyed in the natural channel of Markham Ravine for a distance of about 1.1 miles where it would be diverted by a flashboard dam and conveyed in a canal for a distance of about 1.2 miles and discharged into Auburn Ravine. For an initial distance of about 0.5 mile from the headgate the canal would be shotcrete-lined and of trapezoidal section, with 1:1 side slopes, bottom width of 4.0 feet, depth of 4.0 feet, and freeboard of 1.0 foot. Its slope would be approximately 2.5 feet per mile, and the velocity would be about 3.5 feet per second. The remaining portion of the constructed canal would be of an unlined trapezoidal section, with 2:1 side slopes, bottom width of 7.0 feet, depth of 3.7 feet, and freeboard of 1.0 foot. Its slope would be approximately 2.5 feet per mile, and the velocity would be about 1.9 feet per second. At a distance of about 1.3 miles before reaching Markham Ravine the conduit would cross Highway 99E and the Southern Pacific Railroad. The structure to carry the water underneath the highway and railroad tracks would be a steel pipe 48 inches in diameter.

Cost estimates for the canal were based on designs utilizing data obtained by a reconnaissance field location survey. Detailed design of the distribution system, however, was considered to be outside the scope of the current investigation. Cost estimates for the system were based on known costs of similar irrigation works elsewhere in California, adjusted to correspond with conditions prevailing in the Sutter-Yuba Area.

Pertinent data with respect to general features of the Coon Creek Project, as designed for cost estimating purposes, are presented in Table 51.

TABLE 51

GENERAL FEATURES OF COON CREEK PROJECT

Main Earthfill Dam
- Crest elevation—560 feet
- Crest length—1,420 feet
- Crest width—30 feet
- Height, spillway lip above stream bed—207 feet
- Side slopes—3:1 upstream
  2.5:1 downstream
- Freeboard, above spillway lip—8 feet
- Elevation of stream bed—345 feet
- Volume of fill—2,201,000 cubic yards

Auxiliary Earthfill Dams
- South saddle dam
  - Crest length—1,450 feet
  - Crest width—20 feet
  - Side slopes—2.5:1
  - Maximum height—64 feet
- North saddle dam
  - Crest length—550 feet
  - Crest width—20 feet
  - Side slopes—2.5:1
  - Maximum height—39 feet
- Volume of fill, both dams—449,000 cubic yards

Reservoir
- Surface area at spillway lip—820 acres
- Capacity at spillway lip—59,000 acre-feet
- Drainage area, Coon Creek—40 square miles
- Estimated mean seasonal runoff, Coon Creek—32,800 acre-feet
- Estimated seasonal diversion of Bear River water through Combie-Ophir Canal—35,700 acre-feet
- Estimated safe seasonal yield—56,000 acre-feet
- Type of spillway—Ogee weir, concrete-lined
- Spillway capacity—14,000 second-feet
- Type of outlet—48-inch diameter steel pipe beneath dam

Diversion Works
- Bear River—Existing concrete gravity weir, with overpour section, approximately 300 feet in length, and approximately 15 feet high above stream bed elevation of about 1,500 feet; side channel diversion box, with overpour parapet wall and sluice gate; headgates in concrete headwall.
- Coon Creek—Existing concrete diversion structure for flashboard control, with opening 35 feet in width and 17 feet in height above stream bed elevation of 140 feet; to be rehabilitated by installation of flashboards to height of 7 feet, construction of auxiliary earthen dikes, and installation of concrete headwall and 4- by 4-foot slide headgate.

Conduits
- Bear River Diversion—Existing conduit with estimated capacity of 106 second-feet, 2.4 miles in length, comprised of concrete-lined and unlined canal sections, wooden flume, and steel pipe siphons.

Coon Creek Diversion

Type	Trapezoidal, shotcrete-lined canal	Trapezoidal, unlined canal
Length, in miles	0.5	5.0
Side slopes	1:1	2:1
Bottom width, in feet	4.0	7.0
Depth, in feet	4.0	3.7
Freeboard, in feet	1.0	1.0
Slope, in feet per mile	2.5	2.5
Velocity, in feet per second	3.5	1.9
Capacity, in second-feet	100	100

The capital cost of the Coon Creek Project, based on prices prevailing in April, 1952, was estimated to be $5,303,500. The corresponding annual cost of the Coon

Creek Project was estimated to be about $254,100. The resultant estimated average unit cost of the 56,000 acre-feet per season of new water conserved by the Coon Creek Reservoir was about $4.50 per acre-foot. The estimated unit cost of water applied for irrigation in the service area considered for cost estimating purposes was about $6.10 per acre-foot. These estimates of cost do not include possible charges for use of the existing diversion works on the Bear River and the canals of the Nevada Irrigation District. They do, however, include estimated costs for acquiring the existing abandoned diversion structure on Coon Creek below the dam.

Estimated capital and annual costs of the Coon Creek Project are summarized in the following tabulation. Detailed cost estimates are presented in Appendix H.

	Estimated costs	
	Capital	*Annual*
Dam and reservoir	$4,773,700	$196,200
Coon Creek diversion and conduit	229,800	12,300
Distribution system	300,000	45,600
TOTALS	$5,303,500	$254,100

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

As a result of field investigation, and study and analyses of available data on the water resources and water problems of the Sutter-Yuba Area, the following conclusions and recommendations are made.

CONCLUSIONS

It is concluded that:

1. The present basic water problems in the Sutter-Yuba Area are progressive and permanent lowering of ground water levels and attendant degradation of mineral quality of ground water. Elimination of these problems, prevention of their recurrence in the future, and irrigation of irrigable lands not presently served with water will require further development of available water supplies.

2. Mean seasonal depth of precipitation over the Sutter-Yuba Area is about 20.7 inches, and precipitation contributes water to the area in a mean seasonal amount of about 590,000 acre-feet.

3. The highly productive tributary watersheds of the Sierra Nevada constitute the most important source of water supply available to the Sutter-Yuba Area, and mean seasonal surface inflow of water to the area from these sources is about 6,240,000 acre-feet.

4. The ground water basin underlying the Sutter-Yuba Area functions as a natural regulatory reservoir, and at the present time about two-thirds of the lands irrigated in the area are irrigated with water pumped from this reservoir. The gross extraction of ground water in the Sutter-Yuba Area during 1948 was about 350,000 acre-feet.

5. The storage capacity of the ground water basin underlying the Sutter-Yuba Area is about 3,890,000 acre-feet between the levels of 20 and 200 feet below the ground surface.

6. Because of the continuing development and extensive use of ground water in the Sutter-Yuba Area, a substantial cone of depression exists in the ground water plane, and the average level of ground water has fallen about 10 feet since 1943. This lowering of the ground water level has resulted in increased agricultural production costs, and in saline degradation of the ground water in portions of the area.

7. Hydraulic gradients existing in the plane of ground water at the present time result in a seasonal excess of subsurface inflow over subsurface outflow from the Sutter-Yuba Area of about 180,000 acre-feet. This water is an important source of replenishment to the ground water basin.

8. Satisfactory wells with yields sufficient for irrigation purposes may be obtained in all but certain small portions of the Sutter-Yuba Area.

9. High water table lands in certain portions of the Sutter-Yuba Area served with surface water would be suitable for a wider range of crops than at present if ground water levels were held at greater depths. Furthermore, existing drainage problems in these areas would be eliminated and some salvage of water now excessively consumed would result.

10. Safe seasonal yield of the ground water basin underlying the Sutter-Yuba Area, with average maintenance of ground water levels prevailing in 1949, is about 190,000 acre-feet.

11. The surface water supplies of the Sutter-Yuba Area are of excellent mineral quality.

12. The ground water supplies of the Sutter-Yuba Area are generally of excellent to good mineral quality. However, salinity sufficient to impair use of ground water for irrigation, domestic, and many industrial uses, has been observed at scattered wells throughout the area for many years. This condition is particularly prevalent in the Peach Bowl. Saline degradation of ground water in the Sutter-Yuba Area probably results from the upward migration and diffusion of deep saline brines through permeable zones in the alluvium, and through unplugged test wells and abandoned, defective, or improperly constructed wells. This upward and lateral movement of degraded water is probably accelerated when the ground water plane is lowered by heavy irrigation pumping.

13. Due to geographic and water service considerations, the Sutter-Yuba Area is naturally divided into four principal zones. These have been designated "West Side Zone," "Northeast Zone," "East Central Zone," and "South Side Zone," and are shown on Plate 2.

14. At the present time there are approximately 150,000 acres of irrigated land in the Sutter-Yuba Area. The present distribution of the irrigated land among the several zones is as follows: West Side Zone, 66,200 acres; Northeast Zone, 20,100 acres; East Central Zone, 34,100 acres; and South Side Zone, 28,800 acres.

15. The probable ultimate cultural pattern of the Sutter-Yuba Area will include about 250,000 acres of irrigated land. The probable ultimate distribution of irrigated land among the several zones is as follows: West Side Zone, 100,000 acres; Northeast Zone, 31,000 acres; East Central Zone, 54,000 acres; and South Side

Zone, 65,000 acres. This and subsequent conclusions set forth with reference to future conditions are based upon the general assumptions that: (a) All irrigable lands in the Sutter-Yuba Area will ultimately be brought under irrigation; (b) The type of irrigated crops and irrigation practice will not alter materially; (c) There will be no significant changes in irrigation practice in adjacent areas served with surface supplies; (d) Rainfall, water supply, and climatic conditions will have annual and secular variations as in the past.

16. Of the total amount of water, including rainfall, presently utilized in the Sutter-Yuba Area, approximately 65 percent is consumed in the production of irrigated crops. Dry-farmed and fallow lands, native vegetation, and miscellaneous culture including urban areas, consume the remaining 35 percent. At the present time mean seasonal utilization of water in the area is about 820,000 acre-feet. The estimated distribution of seasonal water utilization among the several zones is as follows: West Side Zone, 311,000 acre-feet; Northeast Zone, 113,000 acre-feet; East Central Zone, 201,000 acre-feet; and South Side Zone, 194,000 acre-feet.

17. Under conditions of ultimate development the mean seasonal utilization of water will probably increase to about 1,050,000 acre-feet. The probable distribution of this use among the several zones is as follows: West Side Zone, 384,000 acre-feet; Northeast Zone, 136,000 acre-feet; East Central Zone, 256,000 acre-feet; and South Side Zone, 278,000 acre-feet.

18. The present requirement for supplemental water in the Sutter-Yuba Area, in order to prevent progressive and permanent lowering of ground water levels and attendant degradation of mineral quality of the ground water, is about 79,000 acre-feet per season. The estimated distribution of the supplemental seasonal water requirement among the several zones is as follows: West Side Zone, 17,000 acre-feet; Northeast Zone, 6,400 acre-feet; East Central Zone, 27,600 acre-feet; and South Side Zone, 27,600 acre-feet. The distribution among the zones was based on the assumption that lowering of water levels which occurred during the season of 1948-49 would have been proportionately the same had mean water supply and climatic conditions prevailed.

19. Under ultimate conditions of development the corresponding requirement for supplemental water probably will be about 315,000 acre-feet per season. The estimated distribution of ultimate mean seasonal supplemental water requirement among the several zones is as follows: West Side Zone, 90,600 acre-feet; Northeast Zone, 30,100 acre-feet; East Central Zone, 81,900 acre-feet; and South Side Zone, 112,200 acre-feet. The estimate for each zone was determined as the sum of the probable increase in water utilization and the present supplemental water requirement.

20. Major features of The California Water Plan, which is presently being formulated under direction of the State Water Resources Board, will provide supplemental water to meet the probable ultimate requirements of the Sutter-Yuba Area. The Feather River Project, an adopted feature of The California Water Plan, will provide supplemental water to meet the probable ultimate supplemental water requirements of the West Side Zone. It is feasible from an engineering standpoint to so regulate and conserve the relatively large flood flows of the Yuba and Bear Rivers and other tributaries of the Feather River as to yield firm water supplies considerably in excess of the probable ultimate supplemental water requirements of the Northeast, East Central, and South Side Zones.

21. New water sufficient to meet the present supplemental requirement of the West Side Zone, together with additional water for growth in water demand for a number of years in the future, could be furnished by construction of facilities for pumping water directly from the Feather River and for its conveyance to and distribution in the Peach Bowl. Cost estimates indicate that the average unit cost of water diverted at the river would be about $4.20 per acre-foot, and that applied to irrigation would be about $5.60 per acre-foot.

22. Preliminary studies indicate that supplemental water could be furnished the Northeast Zone from a multipurpose development of the South Fork of the Feather River and tributaries of the North Fork of the Yuba River.

23. New water sufficient to meet the present supplemental requirement of the Northeast Zone, together with additional water for growth in water demands for a number of years in the future in both the Northeast Zone and the Browns Valley service area, could be furnished by construction of a dam and reservoir on South Honcut Creek, facilities for diversion of flood waters of French Dry Creek to the reservoir, and facilities for conveyance to and distribution of the conserved waters in the Northeast Zone and the Browns Valley service area. The estimated average unit cost of the water so developed and applied to irrigation would be about $9.70 per acre-foot in the Northeast Zone, and about $8.40 per acre-foot in the Browns Valley service area.

24. Preliminary studies indicate that supplemental water could be furnished both the East Central and South Side Zones from a development involving enlargement and extension of facilities of the Nevada Irrigation District.

25. New water sufficient to meet the present supplemental requirements of the East Central and South Side Zones, together with additional water for growth in water demands for a number of years in the future, could be furnished by construction of a larger dam and reservoir on the Bear River at the site of the existing Camp Far West Dam and Reservoir, and

facilities for conveyance of the conserved water to and its distribution in both the East Central and South Side Zones. The estimated average unit cost of the water so developed and applied to irrigation would be about $4.70 per acre-foot in the East Central Zone, and about $5.30 per acre-foot in the South Side Zone.

26. New water sufficient to meet the present supplemental requirement of the South Side Zone, together with additional water for growth in water demand for a number of years in the future, could be furnished by construction of a dam and reservoir on Coon Creek, utilization of existing facilities of the Nevada Irrigation District for diversion of flood waters of the Bear River to the proposed reservoir, and facilities for conveyance to and distribution of the new water in the South Side Zone. The estimated average unit cost of the water so developed and applied to irrigation would be about $6.10 per acre-foot.

27. The unit costs of water as given in the foregoing paragraphs are based on current prices of construction, and are illustrative of the cost of new water for the various zones of the Sutter-Yuba Area developed by works exclusively for water conservation purposes. The costs exceed that of surface water presently served within the area, and it is probable that under present conditions ground water pumping costs are somewhat less than the estimated costs of water developed by the considered conservation projects. It is indicated that in order to obtain new water at lower unit costs in the Sutter-Yuba Area, multipurpose developments providing other benefits and revenues in addition to water conservation will be required.

RECOMMENDATIONS

It is recommended that:

1. Public districts endowed with appropriate powers be created for the purposes of proceeding with further study of the local water problems and with financing, construction, and operation of projects found financially feasible.

2. Local development of water resources be accomplished by an orderly progression of phases of development, and in accordance with The California Water Plan. Successive steps in proposed plans should first develop those projects with indicated lowest capital and unit cost of water, and thence proceed in order of expense to phases of greater unit cost.

3. Additional engineering investigation and study be made for design, financing, and construction of the Peach Bowl Project.

4. Additional engineering investigation and study be made as required for design, financing, and construction of other local projects for initial development outlined in this report, when the financial feasibility of these projects has been determined.

5. A program be initiated for the acquisition of lands, easements, and rights of way necessary for construction of required local water conservation works.

6. Consideration be given to the implementation of plans for securing a firm ultimate supplemental water supply for the West Side Zone from the Feather River Project.

7. Continuing support be given to the investigation and study of major multipurpose developments under The California Water Plan, including those on the Feather, Yuba, and Bear river systems.

APPENDIX A

AGREEMENT, AND ITS SUPPLEMENT, BETWEEN THE STATE WATER RESOURCES BOARD, THE COUNTIES OF SUTTER AND YUBA, AND THE DEPARTMENT OF PUBLIC WORKS

AGREEMENT BETWEEN THE STATE WATER RESOURCES BOARD, THE COUNTIES OF SUTTER AND YUBA, AND THE DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in quintuplicate, entered into by the State Water Resources Board, hereinafter referred to as the "Board"; the Counties of Sutter and Yuba, hereinafter referred to as the "Counties"; and the Department of Public Works, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer."

WITNESSETH:

WHEREAS, in the State Water Resources Act of 1945, as amended, the Board is authorized to make investigations, studies, surveys, hold hearings, prepare plans and estimates, and make recommendations to the Legislature in regard to water development projects, including flood control plans and projects; and

WHEREAS, by said act, the State Engineer is authorized to cooperate with any county, city, State agency or public district on flood control and other water problems and when requested by any thereof may enter into a cooperative agreement to expend money in behalf of any thereof to accomplish the purposes of said act; and

WHEREAS, each of the Counties desires and hereby requests the Board to enter into a cooperative agreement for the making of an investigation and report on the underground water supply of the valley floor lands in the Counties of Sutter and Yuba, including quality, replenishment and utilization thereof, and if possible, to incorporate findings in said report as to a method or methods of solving the problems involved; and

WHEREAS, the Board hereby requests the State Engineer to cooperate in making an investigation and report on the underground water supply of said valley floor lands in said Counties, including quality, replenishment and utilization thereof, and, if possible, to incorporate in said report a method or methods of solving the problems involved;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the Counties, and the State Engineer do hereby mutally agree as follows:

ARTICLE I—WORK TO BE PERFORMED:

The work to be performed under this agreement shall consist of investigation and report on the underground water supply of the valley floor lands in the Counties of Sutter and Yuba, including quality, replenishment and utilization thereof, and, if possible, a method or methods of solving the problems involved.

The Board by this agreement authorizes and directs the State Engineer to cooperate by making said investigation and report and by otherwise advising and assisting in making an evaluation of present and ultimate underground water problems in the valley floor lands of said Counties, and in formulating a solution or solutions of said problems.

During the progress of said investigation and report all maps, plans, information, data and records pertaining thereto which are in the possession of any party hereto shall be made fully available to any other party for the due and proper accomplishment of the purposes and objects hereof.

The work under this agreement shall be diligently prosecuted with the objective of completion of the investigation and report on or before December 31, 1949, or as nearly thereafter as possible.

ARTICLE II—FUNDS:

Each of the Counties, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Five Thousand Dollars ($5,000) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund (also known as the Water Resources Fund) in the State Treasury, for expenditure by the State Engineer in performance of the work provided for in this agreement. Also, upon execution of this agreement by the Board, the Director of Finance is requested to approve the transfer of the sum of Ten Thousand Dollars ($10,000) from funds appropriated either by the Budget Act of 1947, or by Chapter 1541, Statutes of 1947, or in part from each of said appropriations, to said Water Resources Board for expenditure by the State Engineer in performance of the work provided for in this agreement and the State Controller is requested to make such transfer.

If the Director of Finance, within thirty (30) days after receipt by the State Engineer of said sums from the Counties, shall not have approved the deposit thereof into said Water Resources Revolving Fund, together with the transfer of said sum of Ten Thousand Dollars ($10,000) from funds appropriated to said Board either by the Budget Act of 1947, or by Chapter 1541, Statutes of 1947, or in part from each of said appropriations, said Water Resources Revolving Fund for expenditure by the State Engineer in performance of the work provided for in this agreement, said sums contributed by said Counties shall be returned thereto by the State Engineer.

It is understood by and between the parties hereto that the sum of Twenty Thousand Dollars ($20,000) to be made available as hereinbefore provided is adequate to perform approximately half of the above specified work and it is the present intention of each of said Counties to make a further sum of Five Thousand Dollars ($5,000) available at the commencement of the second year of said investigation which will be subject to a matching or contribution in equal sums by said Board for the completion of said investigation and report.

The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for under this agreement any amount in excess of the sum of Twenty Thousand Dollars ($20,000) as made available hereunder and when said funds are exhausted, the Board and the State Engineer may discontinue the work provided for in this agreement and shall not be liable or responsible for the resumption and completion thereof until the further sums as specified in the preceding paragraph are made available.

Approved:

/s/ C. H. Purcell
Director of Public Works

Approval Recommended:

/s/ Spencer Burroughs
Principal Attorney
Division of Water Resources

Approved as to Form:

/s/ Loyd E. Hewitt
District Attorney
County of Sutter

/s/ Joseph L. Hennan
District Attorney
County of Yuba

Approved:

/s/ James S. Dean
Director of Finance

Approved as to Legality:

/s/ C. C. Carleton
Chief Attorney
Department of Public Works

Upon completion of and final payment for the work provided for in this agreement, the State Engineer shall furnish the Board and each of the Counties a statement of all expenditures made under this agreement. One-half of the total amount of all said expenditures shall be deducted from the sum advanced from funds appropriated to said Board, and one-fourth of the total amount of all said expenditures shall be deducted respectively, from the sum advanced by each of the Counties and any balances which may remain shall be returned to the Board, and to the counties, respectively.

ARTICLE III—EFFECTIVE DATE

This agreement shall become effective immediately upon its execution by all the parties hereto.

In Witness Whereof, the parties hereunto have affixed their signatures, the County of Sutter on the 22nd day of September, 1947, the County of Yuba on the 22nd day of September, 1947, the Board on the 6th day of October, 1947, and the State Engineer on the 7th day of October, 1947.

COUNTY OF SUTTER

By /s/ Ed. F. DaCosse
Chairman, Board of Supervisors

/s/ Albert B. Brown
Clerk, Board of Supervisors

COUNTY OF YUBA

By /s/ James R. Brown
Chairman, Board of Supervisors

/s/ Adrienne Conley
Clerk, Board of Supervisors

STATE WATER RESOURCES BOARD

By /s/ Royal Miller
Chairman

DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA

By /s/ Edward Hyatt
State Engineer

(Initialled)
LJK HA

Form	Budget	Value	Descript.

DEPARTMENT OF FINANCE
APPROVED
Oct. 23, 1947

SUPPLEMENTAL AGREEMENT BETWEEN THE STATE WATER RESOURCES BOARD, THE COUNTIES OF SUTTER AND YUBA, AND THE DEPARTMENT OF PUBLIC WORKS

THIS AGREEMENT, executed in sextuplicate, entered into by the State Water Resources Board, hereinafter referred to as the "Board"; the Counties of Sutter and Yuba, hereinafter referred to as the "Counties"; and the Department of Public Works of the State of California, acting through the agency of the State Engineer, hereinafter referred to as the "State Engineer":

WITNESSETH:

WHEREAS, by agreement heretofore entered into by and between the parties hereto, executed by the Counties on the 22nd day of September, 1947, by the Board on the 6th day of October, 1947, and by the State Engineer on the 7th day of October, 1947, the making by the State Engineer of an investigation and report on the underground water supply of the valley floor lands in the Counties of Sutter and Yuba, including quality, replenishment and utilization thereof and, if possible, a method or methods of solving the problems involved, was provided for; and

WHEREAS, it was the expressed intention in said agreement that at the commencement of the second year of said investigation said Counties would make available in equal proportion a further sum of Ten Thousand Dollars ($10,000) subject to a matching or contribution in equal amount by the Board for the completion of said investigation and report; and

WHEREAS, said additional funds are required to complete said investigation and report, and it is the desire of the parties hereto that an additional sum of Twenty Thousand Dollars ($20,000) shall be provided, Five Thousand Dollars ($5,000) by each of the Counties, and Ten Thousand Dollars ($10,000) by the Board;

NOW THEREFORE, in consideration of the premises and of the several promises to be faithfully performed by each as hereinafter set forth, the Board, the Counties, and the State Engineer do hereby mutually agree as follows:

1. Each of the Counties, upon execution by it of this agreement, shall transmit to the State Engineer the sum of Five Thousand Dollars ($5,000) for deposit, subject to the approval of the Director of Finance, into the Water Resources Revolving Fund in the State Treasury for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental.

2. Upon execution of this agreement by the Board, the Director of Finance will be requested to approve the transfer of the sum of Ten Thousand Dollars ($10,000) from funds appropriated to the Board by Item 335 of the Budget Act of 1948 for expenditure by the State Engineer in continuing performance of the work provided for in said prior agreement to which this agreement is supplemental, and the State Controller will be requested to make such transfer.

3. The Board and the State Engineer shall under no circumstances be obligated to expend for or on account of the work provided for in said prior agreement to which this agreement is supplemental any amount in excess of the sum of Forty Thousand Dollars ($40,000) as made available under said prior agreement and this supplemental agreement and if funds are exhausted before completion of said work the Board and the State Engineer may discontinue said work and shall not be liable or responsible for the completion thereof.

4. In so far as consistent herewith and to the extent adaptable hereto, all of the terms and provisions of said prior agreement to which this agreement is supplemental are hereby made applicable to this agreement and are hereby confirmed, ratified, and continued in effect.

5. This agreement shall become effective immediately upon its execution by all of the parties hereto.

In Witness Whereof, the parties hereunto have affixed their signatures, the County of Sutter on the 4th day of October, 1948, the County of Yuba on the 22nd day of November, 1948, the Board on the 3rd day of December, 1948, and the State Engineer on the 30th day of November, 1948.

Approved as to form:

/s/ Loyd E. Hewitt
District Attorney
County of Sutter

/s/ Joseph L. Hennan
District Attorney
County of Yuba

Approval Recommended:

/s/ Spencer Burroughs
Principal Attorney
Division of Water Resources

Approved as to Legality:

/s/ C. C. Carleton
Chief Attorney
Department of Public Works

Approved:

/s/ James S. Dean
Director of Finance

COUNTY OF SUTTER

By /s/ Ed. F. DaCosse
Chairman, Board of Supervisors

/s/ Albert B. Brown
Clerk, Board of Supervisors

COUNTY OF YUBA

By /s/ James P. Brown
Chairman, Board of Supervisors

/s/ Adrienne Conley
Clerk, Board of Supervisors

STATE WATER RESOURCES BOARD

By /s/ C. A. Griffith
Vice-Chairman

DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA

By /s/ C. H. Purcell
Director of Public Works

/s/ Edward Hyatt
State Engineer

APPENDIX B

GEOLOGIC FEATURES AND GROUND-WATER STORAGE CAPACITY OF THE SUTTER-YUBA AREA, CALIFORNIA

By G. H. Davis and F. H. Olmsted, under the direction of J. F. Poland, District Geologist

Ground Water Branch, Water Resources Division
UNITED STATES GEOLOGICAL SURVEY

Prepared in cooperation with the California Department of Public Works, Division of Water Resources

Dated May, 1950

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B-1. Geologic Map of Sutter-Yuba Area ..... following page 104

B-2. Geologis Cross Sections A-A'-A'' and B-B' ..... following page 104

B-3. Geologic Cross Sections C-C'' and D-D' ..... following page 104

B-4. Ground Water Storage Units in Sutter and Yuba Counties ..... following page 104

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GROUND WATER BRANCH
2520 Marconi Avenue
SACRAMENTO 21, CALIFORNIA

May 22, 1950

Mr. A. D. EDMONSTON, *State Engineer*
Division of Water Resources
P. O. Box 1079, Sacramento 5, California

DEAR SIR: I take pleasure in transmitting herewith a report on "Geologic features and ground-water storage capacity of the Sutter-Yuba area, California" by G. H. Davis and F. H. Olmsted. This report has been prepared by the Geological Survey as a part of the program of cooperative ground-water investigations with the California Division of Water Resources.

The report has been approved by the Director of the Geological Survey for publication by the State Water Resources Board as an appendix to its Bulletin No. 6 entitled "Sutter-Yuba Counties Investigation."

Very truly yours,

(Signed) JOSEPH F. POLAND
District Geologist

GEOLOGIC FEATURES AND GROUND-WATER STORAGE CAPACITY OF THE SUTTER-YUBA AREA, CALIFORNIA

By G. H. Davis and F. H. Olmsted

INTRODUCTION

Purpose and Scope of Report

The Sutter-Yuba Area, as identified in this report, includes the parts of Sutter and Yuba Counties that are within the Sacramento Valley and the lower foothills of the Sierra Nevada, an area of 750 square miles. Its general physical and geomorphic features are shown by Plate 1. It is bounded on the east by the rugged Sierra Nevada, on the west by the Sacramento River, and is divided into two nearly equal parts by the southward flowing Feather River. Its importance as an agricultural area and its dependence on surface-water and ground-water supplies for existence and future development have been discussed in the main report by the California Division of Water Resources.

This report on the geology and ground-water storage capacity of the Sutter-Yuba Area has been prepared at the request of the Division of Water Resources, as one of the investigations of ground-water basins of the State now being made by the Geological Survey in accordance with the cooperative agreement with the State Water Resources Board entered into in March, 1948.

The geologic investigation of the Sutter-Yuba Area is in essence a part of a broader reconnaissance investigation of the geology and ground-water storage capacity of the Sacramento Valley which was begun by the Geological Survey in the spring of 1948 at the request of and in cooperation with the California Division of Water Resources. The findings of the valley-wide study are to be published in a separate bulletin under the title of "Geologic features and ground-water storage capacity of the Sacramento Valley, California." That bulletin is now being written.

This appendix has two principal purposes:

First, to describe the geology and general water-bearing character of the rocks. Treatment of the older, nonwater-bearing rocks is general and brief, but is a necessary element of the story because the sediments making up the water-bearing rocks are derived from the weathering and erosion of these older rocks and from their transportation from the Sierra Nevada to the Sacramento Valley. The water-bearing rocks of Tertiary and Quaternary age are described in considerable detail; those deposits are the important sources of ground water. Furthermore, certain geologic events which have uplifted, tilted, or folded the rocks or have produced volcanic deposits have been described because they have caused changes in the texture of sediments being transported to the valley by streams, by mud flows, or through the atmosphere, and thus have been primary factors in deposition of the coarse-grained water-bearing deposits.

Second, to describe the methods used and the results obtained in estimating the water-holding capacity of the water-bearing deposits considered to be within ultimate economic limits for pumping—that is, the deposits constituting the part of the underground reservoir that may be capable of dewatering and resaturation.

This appendix does not treat ground-water occurrence and movement, perennial yield, or chemical character of the ground waters because the hydrologic and water-quality phases of the problem have been carried out entirely by the State Division of Water Resources.

The investigation, which began in October, 1949, has been under the general direction of A. N. Sayre, geologist in charge of the Ground Water Branch, and under the immediate supervision of J. F. Poland, district geologist for California. The field work by the Geological Survey in the Sutter-Yuba area was confined chiefly to geologic mapping, which was done by G. H. Davis and F. H. Olmsted in October and November 1949. The geologic contacts actually traced in the field include the boundaries of the basement complex and of the Tertiary and Quaternary deposits near the basement-complex outcrop. The boundaries of the alluvial deposits of late Tertiary and Quaternary age were mostly drawn or modified on the basis of physiography, and from significant soil-type boundaries mapped by the United States Department of Agriculture, Bureau of Soils. The geology of the Sutter Buttes was taken from H. R. Johnson (1943) * "Marysville Buttes (Sutter Buttes) gas field."

Most of the information on subsurface geology and ground-water storage capacity of the water-bearing deposits was obtained from about 700 logs of water wells supplied by well drillers to the Bureau of Reclamation and the Geological Survey. The logs were turned over to the Division of Water Resources for field location. The cooperation of the well drillers in making available the well logs is greatly appreciated.

Numbers Applied to Wells

In its recent cooperative programs in California, the Geological Survey commonly has assigned well numbers that indicate locations according to the rectangular land surveys. For well 15 N 3E-21C1, for example, the

* References are listed at the end of this appendix alphabetically by the author's name and the year of publication.

first part of the number indicates the township and range (T. 15 N., R. 3 E., Mt. Diablo base line and meridian), the two digits following the hyphen indicate the section (Sec. 21), and the letter indicates the 40-acre subdivision as shown on the accompanying diagram.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Within each 40-acre tract the wells are numbered serially as indicated by the final digit or digits of the number. Thus well 21C1 is in the NE ¼ NW ¼ Sec. 21 and is the first well in that tract to be listed.

In the parts of the area that once were public lands, the official Federal land survey is followed. In the few areas that never were Federally surveyed, the net is projected.

GEOLOGY

General Features

North-central California, which includes the Sutter-Yuba Area, comprises parts of four geomorphic provinces as delimited by Jenkins (1943, pp. 83-88): the Great Valley of California, the Sierra Nevada, the Coast Ranges, and the Cascade Range. The area described in this report lies mostly within the Great Valley of California province, but includes a narrow strip of the Sierra Nevada province to the east. The southernmost extension of the Cascade Range lies more than 20 miles to the north, and the eastern margin of the Coast Ranges lies 20 miles to the west of the Sutter-Yuba Area.

The rocks exposed in the area range from Recent alluvial deposits to Mesozoic and Paleozoic crystalline rocks. Their areal extent is shown on Plate B-1 and their subsurface character on Plates B-2, B-3, and B-4. Their stratigraphy and physical and water-bearing character are summarized in the following table. These rocks may be assigned to two broad categories: the basement complex and the superjacent rocks. The basement complex is exposed in the Sierra Nevada and extends beneath the superjacent rocks in the Sacramento Valley. The superjacent rocks cap many of the interstream divides in the Sierra and comprise the thick and extensive deposits of the valley. The water-bearing rocks considered in this report are entirely within the superjacent rocks, although the basement complex yields small amounts of water to wells in weathered and fractured zones.

Pre-Cretaceous Crystalline Rocks

The basement complex consists of metamorphosed igneous and sedimentary rocks of late Paleozoic and early Mesozoic age and a series of igneous rocks ranging in composition from granite to peridotite which were intruded during the late Jurassic or early Cretaceous Nevadan orogeny.

The rocks exposed immediately east of the Sutter-Yuba Area are predominantly greenstones that probably are metamorphosed basic igneous rocks.

Cretaceous and Tertiary Nonwater-bearing Rocks

The older superjacent rocks are Upper Cretaceous and early Tertiary sediments. A section of unnamed Upper Cretaceous siltstone and sandstone totaling 4,350 feet thick crops out in the Sutter Buttes and has been found in gas wells in the Sacramento Valley. These sediments were deposited in a sea which at times extended eastward to or beyond the present western edge of the basement complex outcrop.

Eocene and possible Paleocene sediments underlie most of the Sutter-Yuba Area. A lower and middle Eocene marine section is exposed in the Sutter Buttes. Stewart (1949) has assigned the 300 feet of lower Eocene in the Buttes to the Meganos formation, and the 130 feet of middle Eocene to the Ione formation. The Ione formation, described in some detail by Allen (1929) is exposed in places along the east side of the valley. There it is usually a brackish-water or deltaic deposit consisting largely of light-colored anauxitic clays and sands, dark reddish or brownish ferruginous sandstones, and minor amounts of lignitic material.

The Ione formation interfingers to the east with river gravels deposited by old Sierra Nevada streams. The ancient Yuba River was the main stream entering the Sutter-Yuba Area in Eocene time.

About 250 to 300 feet of upper Eocene or Oligocene rocks, called the Wheatland formation by Clark and Anderson (1938), are exposed along the southeast bank of the Dry Creek flood plain northeast of Wheatland. A fossiliferous conglomerate containing andesitic pebbles is near the base of the formation which lies unconformably on basement complex. Some of the finer-grained sediments above the conglomerate also contain volcanic detritus.

The Upper Cretaceous and Eocene sediments are not significant as ground-water reservoirs in the Sutter-Yuba Area. Probably none of the water wells in the area penetrates Upper Cretaceous rocks. Several water wells near Wheatland apparently penetrate Eocene rocks, but impermeable shale, siltstone, and sandstone predominate, and the water in the more permeable zones is generally of poor quality. How much of the chloride contamination in parts of the area comes from connate waters in the Eocene rocks is not known. In

STRATIGRAPHY OF THE SUTTER-YUBA AREA AND VICINITY, CALIFORNIA

(Generalized section[1])

Geologic age		Rock unit and symbol on pl. B-1		Thickness (feet)	Physical and water-bearing character
QUATERNARY	Recent	Young alluvial deposits	Stream-channel deposits (Qrc)	0 - 130	Sand, gravel, and silt, in large part well-sorted, in present stream channels and beneath flood plains; yield water in large quantities to irrigation wells. Where the Feather and Sacramento Rivers border the Sutter Basin, they have constructed natural levees composed largely of silt and fine sand deposited during flood stages.
			Basin deposits (Qrb)	0 - 100±	Largely impervious clays and silts deposited in the overflow basins during flood stages of the Feather and Sacramento Rivers. Thin, discontinuous sands supply small domestic and stock wells in the northern part of Sutter Basin; in the southern part of the basin brackish waters are likely to be encountered in wells of any depth.
			Alluvial fans of the Sutter Buttes (Qrf)	0 - 80	Poorly sorted alluvial deposits of gravel and clay, sandy clay, or silt, of low to moderate permeability; yield small supplies of good quality water to stock and domestic wells along the flanks of Sutter Buttes.
	Pleistocene	Local unconformity			
		Intermediate alluvial deposits (Qpal)		0 - 110+	Silt, sand, and gravel, in part well-sorted; moderately permeable throughout. Tongues and layers of fluviatile sand and gravel are highly permeable and supply large quantities of irrigation water. Deposits are coarsest and most permeable near the present major streams and along abandoned Pleistocene channels of the Yuba and Feather Rivers.
		Unconformity			
		Old alluvial deposits (TQal)		0 - 350±	Poorly-sorted silt, clay, sand, and gravel of moderate to low permeability supply water of good chemical quality to domestic, stock, and a few small irrigation wells. Essentially impervious strata of cemented sand and gravel are common. Well-sorted permeable alluvial materials are rare.
TERTIARY	Pliocene	Volcanic rocks of the Sutter Buttes	Andesite tuff-breccia (Tat)	0 - 800±	Andesitic tuffs and tuff-breccias, unsorted and generally of low permeability; some beds may be impermeable. Permeable tongues and stringers of volcanic sand and gravel interbedded with mudflow tuffs and tuff-breccias yield water of good quality to irrigation wells in the Pennington and Sutter City areas.
			Unconformity		
			Rhyolite and andesite (Tra)		Impervious, hard lavas forming core of Sutter Buttes; possibly could provide small water supplies from fractured zones. No wells are known in these rocks.
			Unconformity		
	Pliocene Miocene Oligocene	Volcanic rocks from the Sierra Nevada (Tfa)		0 - 1,800±	Andesitic and rhyolitic tuffs, tuff-breccias, conglomerates, sands, and gravels deposited by inter-volcanic streams from the Sierra Nevada. Sands and gravels yield water of good quality to deep wells in the Marysville and Bear River areas. Fluviatile "black sands" are prolific water producers at many places in the Sacramento Valley. Tuff and tuff-breccia have low permeability and yield little water.
		Unconformity			
	Eocene	Undivided Eocene sediments (Te)		0 - 700±	Marine and non-marine clay, shale and sandstone beneath the Sacramento Valley interfingering along the eastern margin of the valley with Eocene river gravels. These gravels ordinarily are cemented and partially decomposed and probably would yield little water. Coarser sediments in southern Yuba and northwestern Placer counties yield saline waters of probable marine origin to some deep wells. In structurally high positions the marine connate waters have been flushed out of the permeable strata and fresh water is found.
		Unconformity			
CRETACEOUS	Upper Cretaceous	Unnamed Upper Cretaceous sediments (Ku)		0 - 4,350	Sandstone, siltstone, and shale; not penetrated by water wells in Sutter-Yuba area. Connate marine water high in chloride could be expected in wells penetrating these sediments in the Sacramento Valley.
		Unconformity			
PRE-CRETACEOUS		Pre-Cretaceous crystalline rocks (pK)			Hard, impervious metamorphic and igneous rocks. Stock and domestic wells produce small supplies of water of good chemical quality from fractured and partly decomposed zones near the land surface.

[1] Dotted lines are used to separate units that are considered to be contemporaneous.

structurally high positions, for example just west of the outcrops of Wheatland formation, the marine connate waters have been flushed out, and fresh water is found in the more permeable strata.

Tertiary and Quaternary Water-bearing Rocks

Volcanic Rocks From the Sierra Nevada (Eocene-Pliocene)

Tertiary fragmental volcanic rocks having a source near the present crest of the northern Sierra Nevada are exposed at several localities and are encountered in many of the deep wells in the Sutter-Yuba Area. The exposures are found at three principal localities: south of the Yuba River and about 10 miles east of Marysville, on the Camp Beale Military Reservation; at the clay quarries one to two miles northwest of Lincoln; and in an extensive area east of the Southern Pacific railroad and U. S. Highway 99E between Lincoln and Roseville. The last two areas are in Placer County.

Tertiary volcanic rocks do not crop out in the foothill region between Lincoln and the Camp Beale exposure south of the Yuba River. However, many water wells farther west penetrate volcanic rocks, and the original eastward extent of those volcanics was probably greater than it is at present.

GEOLOGIC EVENTS IN SIERRA NEVADA AND ON EAST SIDE OF SACRAMENTO VALLEY

(Read from bottom up)

Recent	Hydraulic mining in Sierra Nevada in late 19th century chokes channels of Feather, Yuba and Bear Rivers with debris. Deposition of stream-channel, alluvial-fan, and basin deposits contemporaneous with mild dissection of intermediate alluvial deposits (Qpal).
Pleistocene	Deposition of intermediate alluvial deposits (Qpal), contemporaneous with moderate to severe dissection of old alluvial deposits (TQal). Several stages of glaciation in Sierra. Truncation and planation of Pliocene alluvial deposits and older rocks, and deposition of thin blanket of course gravel in many areas adjacent to the Sierra Nevada (uppermost part of TQal). Last major uplift of Sierra Nevada with additional regional westward tilting.
Pliocene	Eruptions of Sutter Buttes volcano cover slopes with tuff-breccia deposits from mud-flows. Deposition of old alluvium from Sierra continues. Deposition of old alluvial deposits by streams of low gradient from Sierra Nevada. May be in part contemporaneous with deposition of uppermost Sutter formation and with subsequent volcanic activity at Sutter Buttes. Intrusion of Sutter Buttes central area as plug of plastic andesite porphyry. Andesite mass subsequently intruded by rhyolite porphyry. Valley sediments pierced by volcanic plug are folded and fractured around central area. Great andesitic volcanic activity in Sierra wanes; consequent streams erode volcanic materials and deposit them in Sacramento Valley.
Miocene and Oligocene	Great mud flows of andesitic detritus originating near the crest of the Sierra cover most of the western slope. Old drainage in Sierra almost completely disrupted. Streams begin to erode detritus and deposit it in valley. Faulting and westward tilting of Sierra block during andesite eruptions. Volcanic eruptions near present Sierra crest continue; rhyolitic debris moves westward down canyons, locally damming and diverting streams. Deposition of Sutter formation (non-marine) begins in Sacramento Valley; continues until uplift of Sutter Buttes.
Oligocene or Eocene	Earliest volcanic activity in Sierra Nevada (andesitic and some rhyolitic); sea finally withdraws from Sacramento Valley after extending as far northeast as Wheatland during uppermost Eocene or Oligocene.
Eocene	Marine sedimentation in Sacramento Valley during middle and lower Eocene. Middle Eocene Ione formation, largely non-marine clay and quartzose sand, deposited on the lower slopes of the Sierra Nevada and as deltaic deposits in Sacramento Valley embayment. Moderate uplift of Sierra Nevada or change of base level causes dissection of weathered rocks on west slope of Sierra. Tropical climate and gentle slopes cause deep weathering of rocks in place on west slope of Sierra Nevada.
Upper Cretaceous	Regional upwarping at end of Upper Cretaceous interrupts marine deposition on east side of Sacramento Valley. Great erosion in Sierra Nevada; shallow-water marine deposition in Sacramento Valley.
Lower Cretaceous	At end of Lower Cretaceous—ancestral Coast Ranges formed by folding, faulting, and uplift; Sacramento Valley trough first outlined, though axis somewhat west of present valley. Erosion in ancestral Sierra Nevada.
Lower Cretaceous and/or Upper Jurassic	Formation of folded mountain range of great height, the ancestral Sierra Nevada, by Nevadan orogeny.

The volcanic deposits are chiefly andesitic stream-laid conglomerate and sandstone, and tuff-breccia of mud-flow origin, together with some fine-grained rhyolitic material, all from the Sierra Nevada. As encountered in wells, the conglomerate and sandstone often are loosely consolidated and in such cases are logged by drillers as gravel and sand.

The large area of volcanic rocks at Camp Beale is underlain by andesitic conglomerate, sandstone, and tuff-breccia with interbedded rhyolitic ash. The age of these deposits is probably Eocene, which is somewhat older than most of the other volcanic deposits in the Sutter-Yuba Area on the east side of the Sacramento Valley (Clark and Anderson, 1938).

Andesite tuff-breccia one mile northwest of Lincoln overlies altered rhyolitic ash, and also clay of the Ione formation. The extensive volcanic surface east of U. S. Highway 99E between Lincoln and Roseville is underlain by the same andesite tuff-breccia interbedded with andesitic sandstone and conglomerate. The age of these deposits is not certainly known, but they are believed to be equivalent in age to andesitic deposits in the Mokelumne River Area (the Mehrten formation), which is probably Miocene and may be in part Pliocene (Piper and others, 1939).

The Sutter formation of the Sutter Buttes unconformably overlies Eocene rocks and is in turn overlain unconformably by andesitic and rhyolitic tuffs and breccias of Pliocene age derived from the Buttes volcano. The lower part of the Sutter formation is probably correlative with the volcanic rocks from the Sierra Nevada, although the upper portion may consist of later reworked deposits. The maximum exposed thickness of the Sutter formation is approximately 1,800 feet (Johnson, 1943, p. 614)—considerably thicker than the volcanics from the Sierra Nevada farther east which are probably not over 250 feet thick in outcrop (see Plate B-1). The Sutter rocks are thin-bedded to massive tuff, conglomerate, sand, and clay.

The permeable sand and gravel in the volcanic rocks from the Sierra Nevada probably yield water to deep wells in the Sutter-Yuba Area. Deep wells in Marysville obtain some water from the volcanic sediments, and wells on the Camp Beale Military Reservation 10 miles east of Marysville obtain yields of several hundred gallons a minute from volcanic sands and gravel. Several wells south of the Bear River also produce water from the volcanic rocks from the Sierra Nevada.

Volcanic Rocks of the Sutter Buttes (Pliocene)

The Pliocene volcanic rocks of the Sutter Buttes may be divided into two principal groups: the intrusive rhyolite and andesite and the vent tuffs of the central core; and the andesitic and rhyolitic tuff-breccia that forms the ring encircling the core.

The rocks of the first group are principally porphyritic rhyolite and andesite. These rocks form the sharp peaks in the central area. They are unimportant as a source of ground water.

The tuff-breccia consists of angular blocks of rhyolite and andesite that were swept down the slopes of the old volcano in great mud flows. Many water wells near the periphery of the Buttes encounter the tuff-breccia and intercalated volcanic sediments (see Plates B-1 and B-2). The estimated maximum thickness of the deposits is about 800 feet.

In general, the volcanic sand and gravel yields some water, but the tuff-breccia is tight and nonwater-bearing. North of the Buttes, in the vicinity of Pennington, irrigation wells obtain part of their yield from the volcanic sands and gravels.

Old Alluvial Deposits (Pliocene-Pleistocene)

Location and Extent. The old alluvial deposits, which overlie the volcanics from the Sierra Nevada and older rocks, are exposed in a semicontinuous belt along the east side of the valley, between the outcrop of the basement complex and the volcanics to the east and the younger sediments to the west. A few scattered outliers of old alluvium extend west of the main outcrop from the northern edge of the Sutter-Yuba Area to Wheatland.

Physical Character. The old alluvial deposits are identified physiographically as dissected uplands near the eastern valley margin. Peculiar "hog wallow" topography, consisting of small mounds and undrained or poorly drained depressions often less than 100 feet across, is a common and striking characteristic.

A capping gravel, presumably early Pleistocene in age, and seldom more than 30 feet thick, is extensive near the eastern edge of the outcrops of old alluvium. The underlying silts and sands are presumably Pliocene in age and may be correlative with the Laguna formation to the south, in the Mokelumne Area, described by Gale (Piper and others, 1939).

The gravels almost always have a silty or fine sandy matrix with a distinctive reddish color. Silty and fine-sandy loams, usually with a hardpan layer, are typical soils.

The old alluvial deposits are extremely heterogeneous, and it is difficult to distinguish them in most well logs from younger and older sediments.

Reddish to yellowish-brown silt and silty sand are abundant, but light-gray moderately well-bedded indurated siltstone and fine sandstone are more distinctive and diagnostic. Many of the sand and gravel beds are cross-bedded, indicating fluviatile origin. The gravel is rarely clean or well-sorted; the silty matrix greatly reduces the permeability and porosity. This gravel may be distinguished from that in the underlying volcanics from the Sierra Nevada by the relative scarcity of volcanic rocks, but this distinction is often hard to make, and many drillers do not mention the composition of the pebbles and cobbles.

Water-bearing Character. The poorly-sorted sediments of the old alluvium generally do not yield as much water as the younger deposits. Cementation of the sand and gravel strata is a common feature and many wells are left uncased in the older alluvium; the cemented silt, sand, and gravel strata being sufficiently consolidated to stand without support.

Throughout the Sutter-Yuba Area, enough water can be obtained from the old alluvial deposits to supply domestic and stock wells. It is doubtful, however, that large-capacity irrigation wells could be developed in these deposits. Few wells tap only the old alluvium for sure and yields of these are not known. In the area between the Bear and Yuba Rivers, several irrigation wells produce between 1,000 and 2,000 gallons a minute, but these wells are several hundred feet deep and penetrate the intermediate alluvium, the old alluvium, and presumably the volcanic deposits from the Sierra Nevada. It is believed that the bulk of their yield comes from the volcanic deposits below and the intermediate alluvium above.

Intermediate Alluvial Deposits (Pleistocene)

Location and Extent. The intermediate alluvial deposits which rest on the old alluvium and in places are overlain by the young alluvium of Recent age crop out along a broad belt between the old alluvium on the east and the basin deposits on the west. A few small outliers of intermediate alluvium occur in the American Basin east of the Feather-Sacramento junction.

Physical Character. Topographically these deposits underlie moderately to slightly dissected low plains with a gentle westerly to southwesterly slope. Soils are quite variable but all have some hardpan development. The soils adjacent to the flood basins are fine-grained and dark in color. Soils farther east are coarser, frequently reddish, but almost never gravelly. (See soil surveys, U. S. Dept. Agriculture, in references.)

The intermediate alluvium consists of sand, silt, and gravel, in part well-sorted and well-stratified, deposited by the Feather River and its tributaries in building the low alluvial planes. These deposits are heterogeneous and lenticular in character because of their extremely varied mode of formation. In the eastern part of the area they are largely of alluvial-fan origin; the coarse sand and gravel beds extending 3 to 5 miles west from the present course of the Feather River are probably Pleistocene (Feather) river-channel deposits; and the predominantly fine-grained deposits farther west are chiefly of flood basin or lacustrine origin. Well logs indicate that the material penetrated in the top 100 feet becomes progressively finer toward the Sutter and Butte Basins. Sand and gravel give way to sandy clays and clays, and dark colors predominate. The proportion of sand and gravel to fine sediments in the upper 50 feet decreases from maxima of 80 to 90 percent to 5 to 10 percent. The proportion of blue and dark-gray fine-grained materials—indicative of a non-oxidizing environment—possibly flood-basin or lacustrine deposition—becomes greater as the proportion of fine sediments increases.

In general, the intermediate alluvium is not appreciably consolidated. The beds that are indurated have a high proportion of clay and silt which act as a binder. Hardpan layers, representing buried soil zones, are encountered at various depths. These hard layers usually are cemented with hydrous iron and aluminum silicates, although calcareous cementation is common in areas of high water table adjacent to the flood basins.

The intermediate alluvial deposits are inferred to be correlative with the Victor formation of Pleistocene age in the Mokelumne area described by Gale and Piper (Piper and others, 1939).

Thickness. From drillers' logs, it is inferred that the intermediate alluvial deposits do not exceed 110 feet in thickness in the Sutter-Yuba Area. West of the Feather River, these deposits consist of 50 to 110 feet of sandy clay, sand, and gravel. (See Plate B-2, Section B-B1.) North of Yuba City they overlie brown cemented sands and hard brown clays of the old alluvium. South of Yuba City and in the Marysville area the underlying old alluvium usually is blue clay.

In the area east of the Feather River and north of the Yuba River the intermediate alluvium reaches thicknesses of 70 to 100 feet and rests upon cemented sand, gravel, and clay of the old alluvium that crop out in the dissected uplands to the east.

Few wells penetrate the intermediate alluvium south of the Yuba River but the thickness does not appear to exceed 50 feet.

Water-bearing Character. The intermediate alluvium is moderately permeable throughout, but the tongues and layers of well-sorted sand and gravel are highly permeable and yield large quantities of water to wells. Nearly all the domestic and many small irrigation wells located on the low plains are completed in these deposits. Large wells for irrigation and municipal supply obtain much of their water from this material, but also obtain water from the older deposits at greater depths.

Deposits of this age are coarsest and most permeable near the Yuba and Feather Rivers, and less permeable close to the flood basins where dark colored silt and clay predominate.

Young Alluvial Deposits (Recent)

The Recent deposits of the Sacramento Valley may be defined as those sediments that are still accumulating, or would be accumulating under natural conditions. These deposits would include: silt, sand, and gravel laid down in stream channels during times of decreasing flood flow; silt and sand deposited on natural levees at times of overflow; silt and clay deposited in the flood basins; detritus of the alluvial fans surrounding the Sutter Buttes. In this report, the natural levee sediments are grouped with the stream-channel

deposits. The other two types of sediments are called "basin deposits" and "alluvial-fan deposits," respectively. Each of these subdivisions of the Recent sediments has certain unique physiographic, lithologic, and hydrologic characteristics which are discussed below.

Alluvial-fan Deposits of the Sutter Buttes. Alluvial fans of Pleistocene and Recent age form a ring surrounding the Sutter Buttes and extending toward their center in narrow valleys cut into andesite tuff-breccia. Small isolated patches of alluvium occupy valleys high in the Buttes. This alluvium is probably thin and is not continuous with the deposits farther down the flanks.

The fan material consists of volcanic and sedimentary detritus eroded from the Buttes and deposited around their perimeter. The deposits are usually poorly sorted and contain many volcanic fragments as large as boulder size. An average of several logs of wells near Pennington and Sutter City indicates the following proportion of materials: "clay," 70 percent; clay and gravel (including clay and volcanics), 20 percent; sand and gravel, 10 percent. The "clay" is usually yellow and is probably largely silt and fine sand.

Most of the alluvial-fan deposits are poorly sorted and ground-water yields are low. Moderately permeable sand strata yield water of good quality to wells near Pennington and Sutter City, but chances for developing large irrigation wells are generally poor.

Basin Deposits. The basins are nearly flat, poorly drained lands subject to natural overflow of the Sacramento and Feather Rivers during floods. The deposits have formed from the accumulation of silt and clay that were carried in suspension by the flood waters and settled slowly when the current slackened.

Dark-gray clays and clay adobes, often with more than 50 percent clay-size particles, are the chief basin soils. Depth of the soils is usually from three to six feet, and the underlying material is stratified and of lighter color.

Few water wells have been drilled in the basins, so it is difficult to work out the pattern of the subsurface geology from the meager data. Only eight water-well logs were available in Sutter Basin and four logs in the American Basin.

In Sutter Basin soil and yellow clay as much as 48 feet thick are reported above blue clay, blue sand, gray clay, or gravel. The change in color from yellow to blue indicates that the deeper sediments have been in a non-oxidizing environment since deposition. If the blue clay and coarse-grained deposits are Pleistocene in age the basin deposits of Recent age attain a thickness of at least 48 feet in the Sutter Basin and 100 feet in the American Basin.

The Recent basin deposits nearly all consist of relatively impermeable clay and silt. The older sediments, usually at least 50 to 100 feet below land surface, frequently include thin sand and gravel strata which yield moderate amounts of water. Generally, yields from the Sutter Basin deposits are too small to permit economic use of the ground-water for irrigation; and even in the deep wells penetrating permeable strata, poor quality (high chloride content) precludes use of the water. Locally, however, satisfactory deep wells might be developed by casing off strata containing the high-chloride water. Wells in the northern part of the American Basin get fair yields from deep permeable strata (probably in the intermediate alluvial deposits) and apparently do not encounter the chloride contamination present in the Sutter Basin.

Stream-channel Deposits. The stream-channel deposits comprise those sediments which under natural conditions of stream flow would still be in the process of accumulation. They include the sand and gravel deposited in the river channels during times of decreasing flow and the fine sediments deposited on the flood plains and natural levees during floods. The stream-channel deposits range in width from less than one mile to as much as six miles and extend as narrow bands along the major streams of the area.

The river channels are floored with sand and gravel, the flood plains by sand and silt. During stages of moderate flow the rivers occupy only their channels and roll sand and gravel along their beds. During floods muddy water spreads over the flood plain and deposits fine sediments. Flood channels, abandoned river channels, and lakes characterize the flood-plain surface. Natural levees bordering the Sacramento and lower Feather Rivers were deposited during flood stages along the boundary between high velocity flows in the river channels and still waters occupying the flood basins.

The Yuba and Bear Rivers offer a special case. The natural channel deposits of both streams have been completely buried by 15 to 20 feet of hydraulic mining debris deposited since 1870. Levees now confine this debris, which stands as raised channelways subdivided into braided gravelly channels. (See Pl. B-3.) Large quantities of debris choke the lower Feather below the Yuba junction, although the flood plain has not been altered to the same extent as those of the Yuba and Bear Rivers.

Well defined channels of coarse gravel, deposited in trenches excavated in the intermediate alluvial deposits and older sediments, underlie the flood plains of the Feather, Yuba, and Bear Rivers. Coarse gravel deposits from one to two miles in width can be traced beneath the Feather River flood plain from Oroville south 10 miles to the highway bridge east of Gridley. The depth of the base of the gravel is about 30 feet near Oroville, increasing to 105 feet at the Gridley bridge. No subsurface information is available on the river channel deposits between the Gridley bridge and the Feather-Yuba junction. Wells on the Feather River flood plain south of the Yuba-Feather junction en-

counter gravel between depths of 35 and 90 feet that may correspond to the Recent gravel deposits upstream.

Records of wells drilled on the Yuba River flood plain two miles east of Marysville show coarse gravel deposits to a depth of 110 to 130 feet. (See Pl. B-3.)

Sand and gravel underlies the Bear River flood plain for eight miles downstream from the canyon mouth. This gravel deposit which occurs between 25 and 65 feet beneath the surface near Wheatland is terminated rather abruptly about three miles southeast of Wheatland.

Little is known of the subsurface extent of the Recent deposits of the Sacramento River. Wells drilled on the natural levees pass through varicolored sand, gravel, silt, and clay. Well logs show no systematic changes either laterally or vertically. Lateral discontinuity of beds is a marked feature—even closely spaced wells penetrate completely different sections.

Clean, well-sorted sand and gravel of the stream-channel deposits yield water in large quantity and of good chemical quality to irrigation wells on the flood plains of the Feather, Yuba, and Bear Rivers. A few irrigation wells are bottomed in the Recent deposits but wells of large capacity commonly penetrate older sediments as well.

Wells drilled in the natural-levee deposits of the Feather and Sacramento Rivers obtain large supplies of water from thin, discontinuous tongues of gravel and sand which are buried stream-channel deposits. The fine sand and silt of these deposits supply some small stock and domestic wells.

Yields of Wells

Data on yields of wells in the Sutter-Yuba Area for the period 1933 to 1949 have been furnished by the Pacific Gas and Electric Company. The results of tests are summarized in the following table, which shows averages of discharge and specific capacity for 595 wells in five areas within the area. Specific capacity is obtained by dividing the yield in gallons per minute by the drawdown from static to pumping level in feet. It is a measure of the productivity of the well per foot of drawdown.

Area	*Average discharge (gpm)*	*Average specific capacity (gpm/ft. dd)*	*Number of wells*
1. Eastern Sutter County	728	47	261
2. Northwestern Sutter County	878	54	82
3. Southeastern Sutter County	960	47	121
4. Southern Yuba County	846	48	108
5. Northern Yuba County	838	60	23

The table shows that the wells having the highest specific capacities are in areas two and five. A hasty conclusion (based on this relation) might be drawn that the best irrigation wells are to be obtained in the areas of highest average specific capacity. However, a study of well depths in relation to specific capacity changes the picture somewhat. Drillers' logs of 528 irrigation wells were used to obtain a yield factor that would give a reasonable idea of production per foot of well. The yield factor was computed by the following formula:

$$\text{Yield factor} = \frac{\text{Average specific capacity} \times 100.}{\text{Average well depth}}$$

The results are summarized in the following table.

Area	*Number of irrigation wells*	*Total footage drilled*	*Average depth (feet)*	*Yield factor*
1	249	45,270	182	25.7
2	48	15,341	320	16.8
3	104	33,709	324	14.7
4	109	31,828	292	16.7
5	28	5,623	201	29.8

It can be seen from comparison of yield factors that the ratio of well production to depth of wells is higher in areas 1 and 5 than in areas 2, 3, and 4. Plate B-4, showing ground-water storage units, and well-yield areas indicates that areas 1 and 5 lie largely in group A (river flood-plain and channel deposits). Area 2 comprises the Sutter Buttes, the alluvial fans surrounding the Buttes (storage group B) and a large area of basin deposits (storage group D). Only a small part of this area is within storage group A. Most of the wells in area 2 are in the Pennington-Live Oak district, where many wells are 500 feet or more deep.

The other two areas with low yield factors are areas 3 and 4 east of the Feather River in southeastern Sutter and southern Yuba Counties; they embrace extensive areas of low alluvial-plain deposits (storage group B), and smaller areas of basin deposits (storage group D) and dissected alluvial deposits (storage group C). Although area 4 includes large areas of river flood-plain deposits (storage group A) the yield factor approximates that of the poor-yield areas rather than that of high-yield areas as might be expected.

In conclusion, generally speaking, areas of high-yield factor generally correspond to areas of high specific yield as determined from statistical analysis of drillers' logs.

GROUND-WATER STORAGE CAPACITY

Most of the information on ground-water storage capacity of the Sutter-Yuba Area was derived from well logs obtained from water well drillers. In connection with their Sutter-Yuba investigation the Division of Water Resources located in the field about 700 water wells for which drillers' logs were available. The Geological Survey located about 50 wells in western and northwestern Sutter County.

Clay, gravel, sand, and volcanic rocks are usually recognized in the drillers' logs, and the more complete logs mention color, hardness, degree of cementation, and other readily identified lithologic features.

A peg model based on drillers' logs was used to subdivide the shallow sediments of the area into hydro-

logic units. In constructing the model only the deeper well records were used where wells were located within 1,500 feet of each other. In this way 576 well logs were selected. In order to smooth out the effect of close well spacing in residential districts supplied by domestic wells, only the wells selected for the peg model were used in computing storage capacity.

Selection of Depth Zones

The storage capacity of the Sutter-Yuba Area has been estimated for three depth zones: 20 to 50 feet, 50 to 100 feet, and 100 to 200 feet below the land surface. The only exception to this three-zone treatment was in the area south of Yuba City between the natural levee deposits of the Sacramento River and the channel of the Feather River (storage units A 5 and D 2). Water of poor quality underlies that area at relatively shallow depths, and the California Division of Water Resources believes that it would be impractical in general to draw down the water level below 100 feet without causing saline intrusion. Accordingly, in that area the storage capacity was calculated only for the deposits between depths of 20 and 100 feet.

It is believed that for the Sutter-Yuba Area it would be inefficient to store water in the deposits less than 20 feet below land surface, even where permeable. Also, for economic reasons, it is unlikely that water levels will be lowered below 200 feet. In the near future, drawdown of the water table in the Sutter-Yuba Area probably will not extend below the 100-foot depth.

Classification of Materials in Drillers' Logs

In order to estimate the ground-water storage capacity of the water-bearing deposits it was necessary to classify the drillers' logs into a few general categories to which specific-yield values could be assigned. Although many logs reported only gravel, sand, and clay or gradations between these units, some logs reported as many as 10 to 20 different types of materials. It was decided to group the sediments logged into five general classes, namely: (1) gravel; (2) sand, including gravelly sand and gravel and sand; (3) tight sand, hard sand, sandstone and other materials of similar hydrologic character; (4) cemented gravel, clay and gravel, etc.; and (5) "clay," which included silt, clay, shale, and related materials of low permeability including "lava."

Assignment of Specific-yield Values

The specific yield of a rock is the ratio of (1) the volume of water which, after being saturated, it will yield by gravity to (2) its own volume. This ratio is customarily expressed in percent. The procedure followed in assigning specific-yield values to the various types of material classified in the well logs of the Sacramento Valley is discussed in detail in the valley-wide report now in preparation and has been summarized in an appendix to Bulletin 1 of the State Water Resources Board (Poland and others, 1950). The table below indicates the values assigned:

Material	*Specific yield (percent)*
Gravel	25
Sand, including sand and gravel, and gravel and sand	20
Fine sand, hard sand, tight sand, sandstone, and related deposits	10
Clay and gravel, gravel and clay, cemented gravel, and related deposits	5
"Clay," silt, sandy clay, lava rock, and related fine-grained deposits	3

Subdivision of Sutter-Yuba Area Into Storage Units

For the purpose of estimating underground storage capacity, the Sutter-Yuba Area was divided into four storage groups, and these in turn were subdivided into 14 storage units. (See Pl. B-4). Boundaries of the storage units were first drawn on significant soil and physiographic changes, then were modified on the basis of the subsurface character of the deposits above a depth of 200 feet below land surface. Special emphasis was placed on the hydrologic character of the sediments in the top 100 feet. There are three reasons for this. First, it is believed that the storage units should be representative for the depth range most widely subject to unwatering or resaturation under present conditions. Second, for nearly all the storage units in the valley except the basin deposits, the specific yield is greater above the 100-foot depth than below it. Lastly, with reference to natural or artificial recharge at or near the land surface, the distribution of water-bearing beds in the near-surface deposits is of primary importance. In this respect, the coarse sand and gravel tongues or blankets that are so well defined at shallow depths beneath or near the channels of the Feather, Yuba, and Bear Rivers are noteworthy.

In the table summarizing the ground-water storage capacity of the Sutter-Yuba Area, the 14 storage units have been assembled within the four groups. Briefly summarized, the groups are:

A. River Flood-plain and Channel Deposits. These deposits contain a high proportion of sand and gravel deposited by streams mostly during the Pleistocene and Recent epochs, although some of the sands and gravels in the 100- to 200-foot depth zone may be of Pliocene age. In general, the river flood-plain and channel deposits have the highest specific yield of the four groups in all three depth zones. The specific yield decreases markedly in the 100- to 200-foot depth zone, but still is higher than in the other three storage groups.

B. Low Alluvial-plain and Alluvial-fan Deposits. These deposits are variable in physical character but are generally much less permeable than the river flood-plain and channel deposits, particularly in the top two depth zones. The near-surface sediments in this group include the alluvial fans of the Sutter Buttes, intermediate alluvial deposits (Pleistocene), old alluvial deposits (Pliocene and Pleistocene) and smaller areas of

Recent stream-channel deposits. Most of the low alluvial-plain deposits above the 200-foot depth are old and intermediate alluvial deposits, however.

C. Dissected Alluvial Deposits. This group is represented in Sutter and Yuba Counties by two widely separated small areas—the northern between Honcut Creek and the Yuba River on the east margin of the valley, and the southern in Sutter County east of the American Basin. The specific yield and physical character of the dissected alluvial deposits and the low alluvial-plain and alluvial-fan deposits are similar, and the geologic units contained are essentially the same, although the dissected alluvial deposits contain a somewhat greater percentage of old alluvium.

D. Basin Deposits. These sediments to a depth of 200 feet include the Recent basin deposits, the intermediate alluvial deposits of Pleistocene age and probably some old alluvium. Silt and clay predominate and permeability and specific yield are correspondingly low. The 100- to 200-foot depth zone in the northern part of the American Basin (D1) contains a rather high proportion of sand which may represent buried Sacramento River channels, but the deep zone in the Butte Basin (D3) has fine-grained material of low permeability. The specific yield of the deep zone in the Sutter Basin (D2) was not calculated because of salt-water contamination, but the well logs record mostly fine-grained material.

Summary of Results

The following table summarizes the estimated ground-water storage capacity of the Sutter-Yuba Area for the four storage groups. This summary is followed by a tabulation of storage capacity for each of the 14 storage units, listed by groups.

The summary for the Sutter-Yuba Area by storage groups first gives total storage capacities for all deposits, including those beneath the basin lands. The totals are then given with the storage capacity of the basin deposits eliminated. There are several reasons for omitting the storage capacity of these deposits from consideration. The deposits in the Sutter and Butte Basins are relatively impermeable in all three depth zones, and those in the American Basin in the top two depth zones. Therefore, well yields would be low and it would be difficult to draw down the water level extensively within the basins unless many closely spaced wells were drilled. Although the basin water levels are close to the surface, the altitude of land surface in the basins is lower than that in all the surrounding lands. Because of the low altitude and the low permeability of the basin deposits, it is believed there would not be appreciable dewatering by lateral drainage to adjacent pumped areas. For the same reasons, recharging the basin deposits would be slow and costly. Because of low well yields and the availability of surface water, it is ordinarily more economical to use surface water than ground water for irrigation of the basin lands.

Excluding the basin storage, the estimated ground-water storage capacity for the Sutter-Yuba Area between limits of 20 and 200 feet below the land surface is about 3,900,000 acre-feet. More than half this storage is in the deposits 20 to 100 feet below the surface. As discussed previously, how much of this ground-water storage capacity is economically usable is not known.

ESTIMATED TOTAL GROUND-WATER STORAGE CAPACITY OF SUTTER-YUBA AREA IN ACRE-FEET

Storage unit	Area[1] (acres)	Depth zone: 20-50 feet		50-100 feet		100-200 feet		All zones 20-200 feet	
		Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)
A. River flood-plain and channel deposits	204,590 (164,430)	10.4	640,000	9.4	960,000	7.0	1,140,000	8.4	2,740,000
B. Low alluvial-plain and alluvial-fan deposits	101,590	5.4	160,000	4.9	250,000	4.7	470,000	4.9	880,000
C. Dissected alluvial deposits	30,600	4.5	40,000	5.5	80,000	4.7	150,000	4.9	270,000
D. Basin deposits	143,590 (29,080)	5.4	230,000	5.1	370,000	6.4	180,000	5.4	780,000
TOTALS	480,370 (325,700)	7.4	1,070,000	6.9	1,660,000	6.0	1,940,000	6.6	4,670,000
Percent of total			22.9		35.5		41.6		

ESTIMATED GROUND-WATER STORAGE CAPACITY, EXCLUDING BASIN DEPOSITS

Total (A+B+C)	336,780 (296,620)	840,000	1,290,000	1,760,000	3,890,000
Percent of total		21.6	33.2	45.2	

[1] Figures in parentheses indicate acreage utilized for computing storage in zone 100 to 200 feet below land surface.

SUTTER AND YUBA COUNTIES
ESTIMATED GROUND-WATER STORAGE CAPACITY OF RIVER FLOOD-PLAIN AND CHANNEL DEPOSITS (A)

Storage unit	Area[1] (acres)	Depth zone: 20-50 feet		50-100 feet		100-200 feet		All zones 20-200 feet	
		Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)
1. Sacramento River	35,680	9.0	96,000	9.8	176,000	8.6	308,000	9.0	580,000
2. East of Feather River north of Yuba River	39,240	10.3	121,000	8.7	170,000	6.0	235,000	7.5	526,000
3. West side Feather River north of Yuba City	35,920	9.8	105,000	8.4	151,000	5.9	214,000	7.3	470,000
4. East side Feather River south of Yuba River and Bear River	53,590	11.8	189,000	10.8	289,000	7.2	384,000	8.9	862,000
5. West of Feather River south of Yuba City	(40,160)	10.4	126,000	8.9	179,000			9.5	305,000
TOTALS	204,590 (164,430)	10.4	637,000	9.4	965,000	7.0	1,143,000	8.4	2,744,000

[1] Figures in parentheses indicate acreage utilized for computing storage in zone 100 to 200 feet below land surface.

SUTTER AND YUBA COUNTIES
ESTIMATED GROUND-WATER STORAGE CAPACITY OF LOW ALLUVIAL-PLAIN AND ALLUVIAL-FAN DEPOSITS (B)

Storage unit	Area (acres)	Depth zone: 20-50 feet		50-100 feet		100-200 feet		All zones 20-200 feet	
		Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)
1. Low plains south of Bear River	36,030	6.5	70,000	5.2	93,000	4.2	151,000	4.8	314,000
2. Low plains north of Bear River	47,070	4.7	67,000	4.5	105,000	5.4	253,000	5.0	425,000
3. Low plains west of Feather River	2,560	5.2	4,000	5.6	7,000	4.0	10,000	4.6	21,000
4. Alluvial plains enclosing Sutter Buttes	15,930	4.8	23,000	5.8	46,000	3.7	59,000	4.5	128,000
TOTALS	101,590	5.4	164,000	4.9	251,000	4.7	473,000	4.9	888,000

SUTTER AND YUBA COUNTIES
ESTIMATED GROUND-WATER STORAGE CAPACITY OF DISSECTED ALLUVIAL DEPOSITS (C)

Storage unit	Area (acres)	Depth zone: 20-50 feet		50-100 feet		100-200 feet		All zones 20-200 feet	
		Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)
1. Deposits between American and Bear Rivers	20,070	4.8	29,000	4.8	48,000	5.2	105,000	5.0	182,000
2. Deposits south of Oroville	10,530	3.9	12,000	7.0	37,000	3.8	40,000	4.7	89,000
TOTALS	30,600	4.5	41,000	5.6	85,000	4.7	145,000	4.9	271,000

SUTTER AND YUBA COUNTIES
ESTIMATED GROUND-WATER STORAGE CAPACITY OF BASIN DEPOSITS (D)

Storage unit	Area[1] (acres)	Depth zone						All zones 20-200 feet	
		20-50 feet		50-100 feet		100-200 feet			
		Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)	Specific yield (percent)	Storage (acre-feet)
1. American Basin	17,860	4.6	25,000	5.0	45,000	7.7	137,000	6.4	207,000
2. Sutter Basin	114,510 (0)	5.5	189,000	5.2	295,000			5.3	484,000
3. Butte Basin	11,220	5.1	17,000	4.6	26,000	4.3	48,000	4.8	91,000
TOTALS	143,590 (29,080)	5.4	231,000	5.1	366,000	6.4	185,000	5.4	782,000

[1] Figures in parentheses indicate acreage utilized for computing storage in zone 100 to 200 feet below land surface.

Best Areas for Ground-water Storage

As can be seen from the ground-water storage table, the best areas for storing water underground are the five river flood-plain and channel deposits units. Excluding basin deposits, about 70 percent of the total storage capacity is in these five areas which include about 40 percent of the Sutter-Yuba Area, and most of the soils and near-surface sediments are sufficiently permeable to permit recharge from the surface. Sand and gravel beds are most continuous in the river-channel deposits of the Feather River, and the deposits west of the river from Yuba City south to the vicinity of Nicolaus seem to be especially favorable for storing ground-water (See Pl. B-2). Unfortunately, however, this area is contaminated with salt water in the lower depth zone, and storage in this zone may not be practicable.

The low alluvial-plain and alluvial-fan deposits and the dissected alluvial deposits are both rather unfavorable for ground-water storage. Soils are generally tight and impervious hardpan is prevalent, and recharge from land surface would be difficult.

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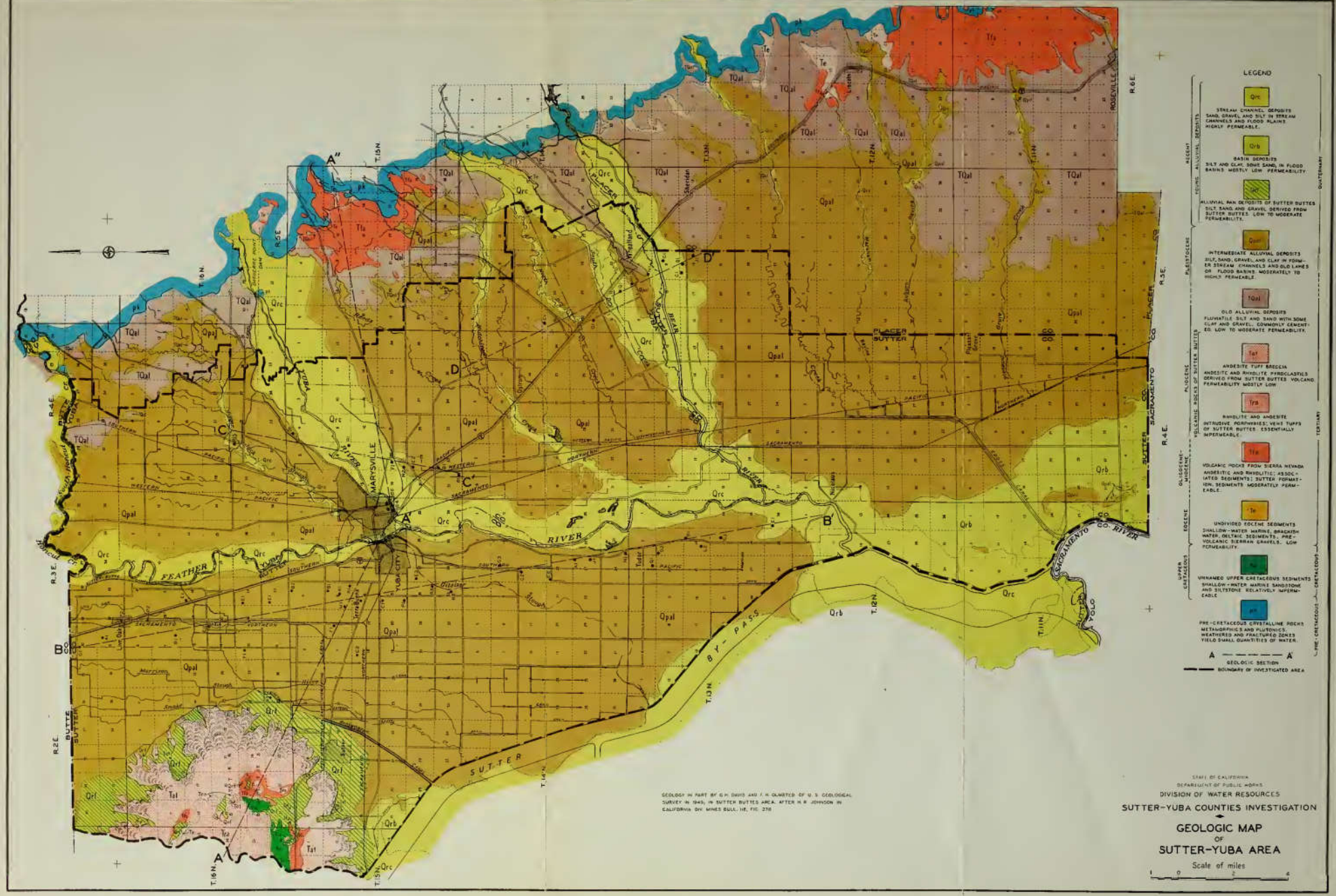
PLATE B-1



GEOLOGY IN PART BY G.H. DAVIS AND J.H. OLMSTED OF U.S. GEOLOGICAL SURVEY IN 1949, IN SUTTER BUTTES AREA. AFTER H.R. JOHNSON IN CALIFORNIA DIV. MINES BULL. 118, FIG. 270

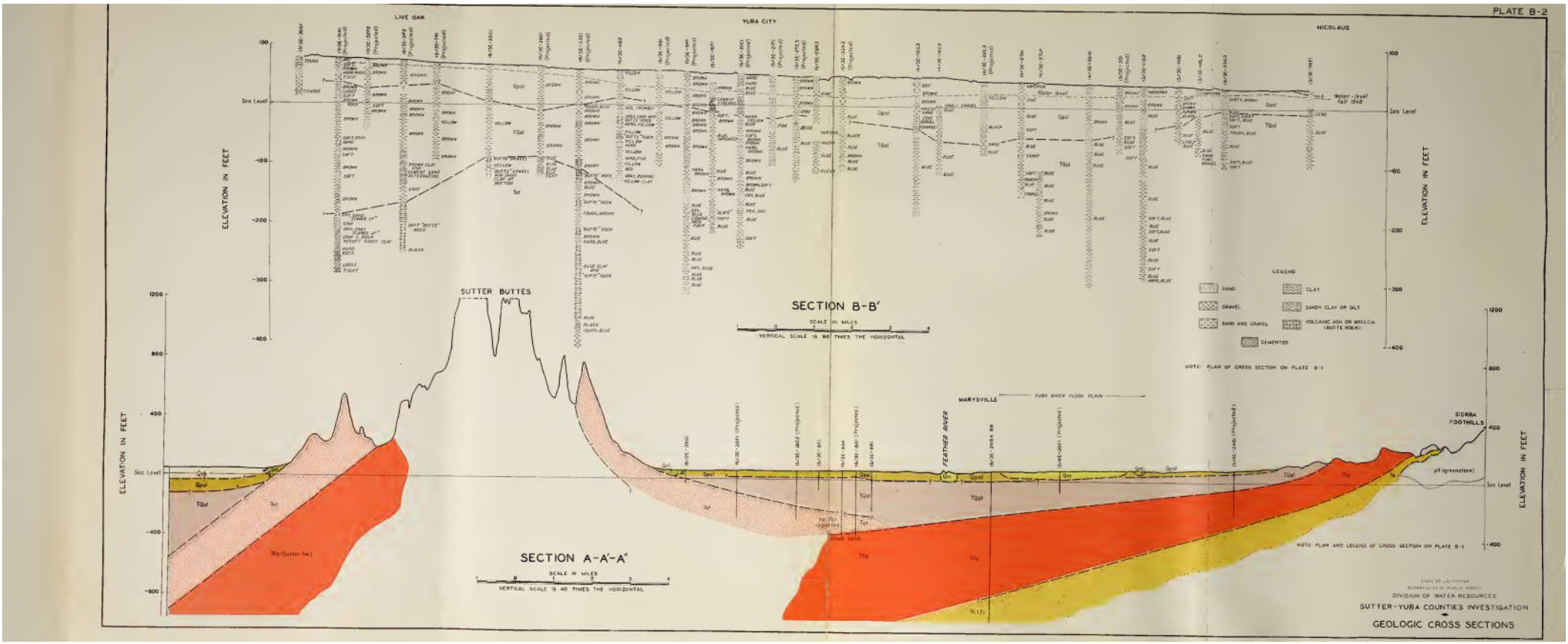
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION

GEOLOGIC MAP OF SUTTER-YUBA AREA

Scale of miles

1 0 2 4

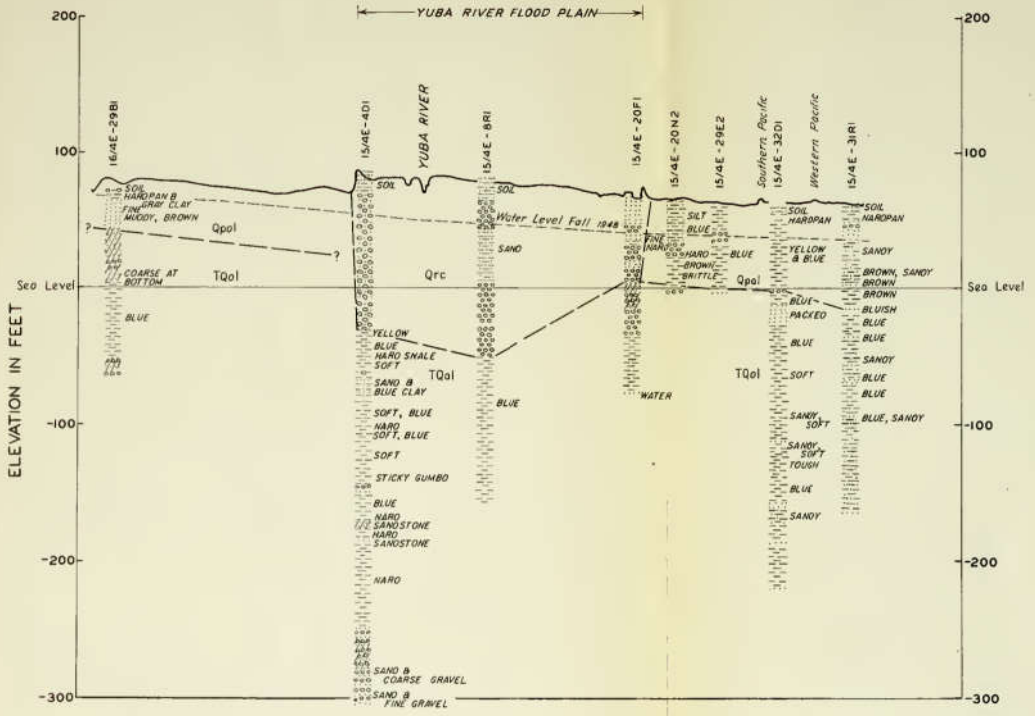
PLATE B-2



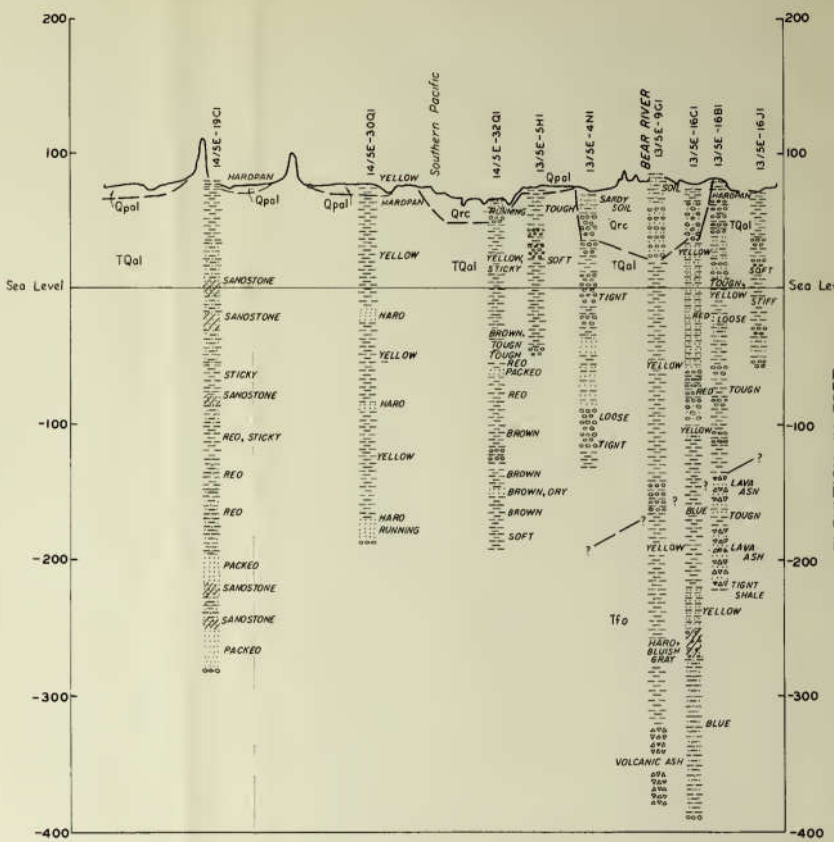
DIVISION OF WATER RESOURCES

SUTTER-YUBA COUNTIES INVESTIGATION

GEOLOGIC CROSS SECTIONS



SECTION C-C'



SECTION D-D'

LEGEND

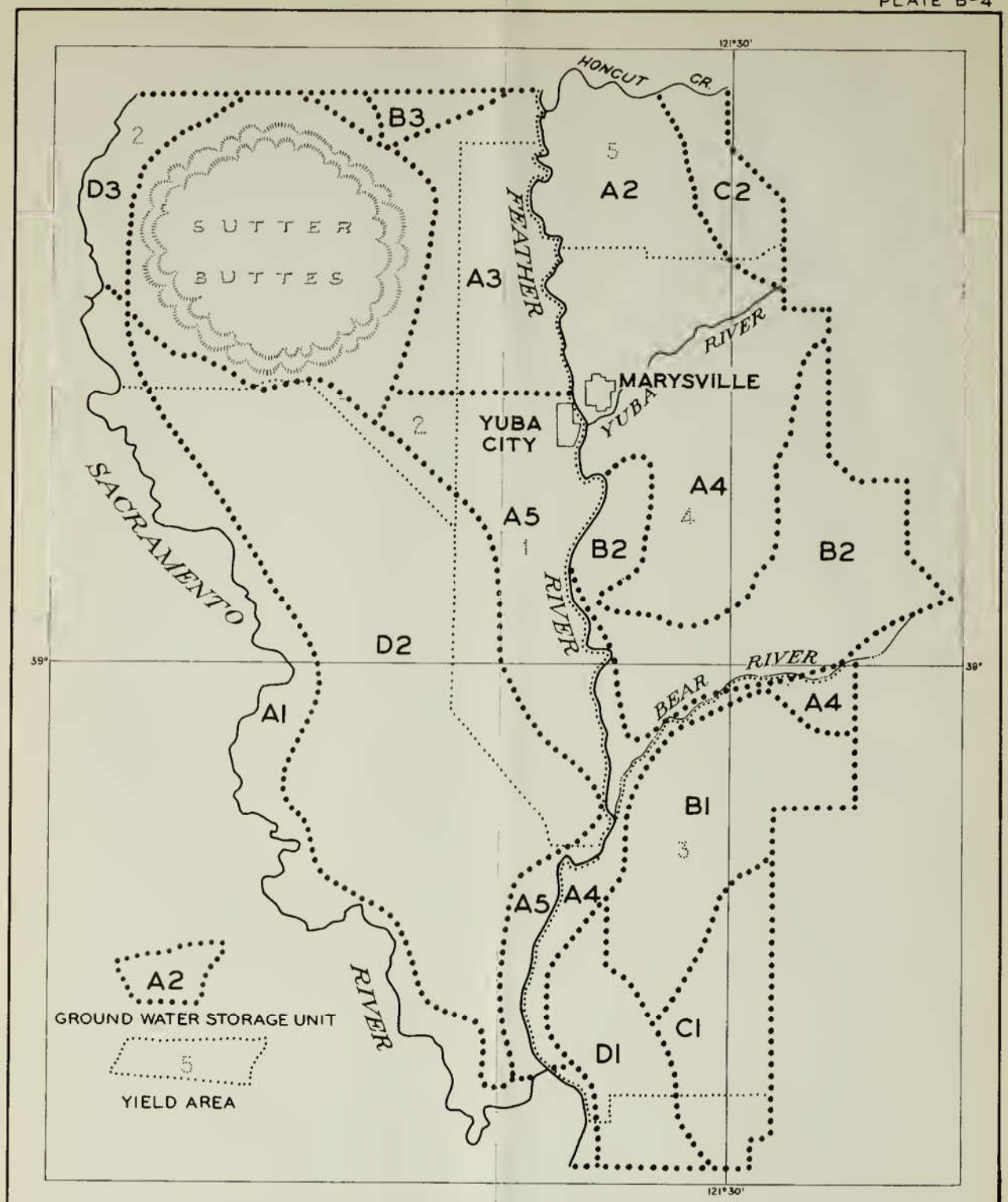
SAND
CLAY
GRAVEL
SANDY CLAY OR SILT
SAND AND GRAVEL
VOLCANIC ASH OR BRECCIA (BUTTE ROCK)
CEMENTED

NOTE: PLAN OF CROSS SECTIONS ON PLATE B-1

SCALE OF MILES
1 0 1 2 3 4
VERTICAL SCALE IS 80 TIMES THE HORIZONTAL

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION

GEOLOGIC CROSS SECTIONS



GROUND WATER STORAGE UNITS IN SUTTER AND YUBA COUNTIES

APPENDIX C

RECORD OF MONTHLY PRECIPITATION AT ROBBINS, CALIFORNIA

RECORD OF MONTHLY PRECIPITATION AT ROBBINS, CALIFORNIA

County: Sutter
Date established: 1926
Type of gage: Not recording
Elevation: 20 feet, U.S.G.S. datum

Latitude: 38° 52'
Longitude: 121° 43'
Record obtained from: Reclamation District 1500, Kirkville

(In inches)

Season	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Total
1925-26											0.55		
1926-27		0.05	Tr.	1.58	7.43	0.81	2.43	5.39	1.69	0.96	0.34	0.45	21.13
1927-28		Tr.	Tr.	1.81	2.05	0.68	1.72	1.61	3.68	0.64	0.03	0.05	12.27
1928-29				0.26	2.51	2.61	0.73	2.01	1.20	0.55	Tr.	1.51	11.38
1929-30				0.10	0.00	4.53	4.12	1.43	2.64	1.07	0.52		14.41
1930-31			0.19	0.42	1.21	1.50	2.65	1.25	0.97	0.20	1.04	0.87	10.30
1931-32		0.02		0.26	2.69	7.65	1.72	1.52	0.49	0.88	0.70		15.93
1932-33	0.05			Tr.	0.27	2.59	3.13	0.65	1.69	0.10	0.48		8.96
1933-34			Tr.	0.76	0.00	5.90	0.24	2.73	0.33	0.54	0.16	0.22	10.88
1934-35			Tr.	1.06	2.62	2.29	5.46	1.56	2.77	3.95	Tr.		19.71
1935-36	Tr.			0.89	1.05	1.71	2.95	5.90	1.01	1.24	0.42	0.43	15.60
1936-37				0.30	0.06	2.50	2.78	5.96	5.39	0.48	0.00	0.14	17.61
1937-38				0.56	2.58	2.97	3.76	7.27	3.77	1.89	0.14	0.05	22.99
1938-39			0.59	1.19	0.58	1.25	2.69	0.63	2.14	0.16	0.44		9.67
1939-40	Tr.		0.27	0.67	0.04	1.71	6.24	7.06	4.11	0.86	0.81		21.77
1940-41			0.06	0.92	1.41	7.76	6.04	6.49	3.31	3.90	2.04	Tr.	31.93
1941-42	Tr.		0.02	1.54	1.77	6.25	4.00	3.75	3.28	5.12	0.59		26.32
1942-43				0.38	2.08	2.87	5.72	2.36	2.73	1.94	0.06	0.05	18.19
1943-44				0.24	0.80	2.42	2.22	7.29	0.55	1.53	1.00	0.01	16.06
1944-45				0.94	4.13	2.31	2.02	1.86	2.97	0.08	0.88	0.16	15.35
1945-46				3.29	2.19	4.75	0.91	0.95	1.64	0.08	0.36		14.17
1946-47	0.09		0.20	0.28	2.27	3.03	0.36	2.24	2.35	0.30	0.29	0.51	11.92
1947-48				2.06	1.06	1.01	0.90	1.41	3.32	3.92	1.82	0.57	16.07
1948-49		0.03	0.30	1.11	0.49	3.97	1.26	1.19	4.67		1.17		14.16
1949-50				0.01	0.70	1.18	3.51	3.28	0.86	1.00	0.15	0.11	10.83
1950-51			0.22	2.48	3.49	4.58	2.24	2.04	0.53	0.76	0.76		17.10
1951-52				0.11	3.01	3.96	3.03	6.57	1.35	2.36	1.05	Tr.	0.43	21.87

APPENDIX D

RECORDS OF DAILY RUNOFF IN SUTTER-YUBA AREA NOT PREVIOUSLY PUBLISHED

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COON CREEK AT HIGHWAY 99E
1947 AND 1948

(Daily mean flow, in second-feet)

Date	1947		1948										
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1		14	12	15	21	34	76	64	6	6	9	24	21	26
2		14	16	15	18	33	54	40	6	6	10	24	42	18
3		13	39	17	15	77	47	31	7	6	10	22	58	30
4		13	32	18	16	80	38	33	8	5	10	22	65	44
5	26	14	30	21	15	113	34	35	10	5	10	22	52	34
6	22	15	29	49	12	125	30	34	15	4	10	26	50	57
7	21	15	46	56	12	49	22	32	12	4	10	21	46	38
8	20	14	178	34	12	55	28	31	17	5	9	21	43	44
9	18	13	54	72	15	101	28	34	21	7	8	21	44	39
10	17	13	42	87	18	490	36	31	27	10	9	24	43	31
11	16	12	34	44	12	157	29	25	25	7	8	24	40	26
12	15	13	29	34	12	96	19	23	22	13	9	31	37	23
13	14	13	25	29	34	71	20	22	20	10	9	31	34	68
14	14	13	22	25	89	65	37	21	13	10	8	30	34	95
15	18	14	21	25	81	58	42	19	7	10	7	32	37	67
16	23	15	20	25	64	61	38	18	7	9	10	33	44	47
17	22	18	18	24	89	156	31	16	7	8	12	30	44	138
18	19	20	13	23	57	81	38	14	8	7	12	21	45	92
19	17	20	18	23	86	55	46	13	9	9	19	17	45	53
20	16	18	17	21	63	44	96	11	7	10	18	14	41	43
21	15	19	16	21	48	42	160	10	6	10	18	15	38	38
22	14	18	16	19	39	96	115	9	4	10	20	15	34	33
23	14	17	15	17	54	57	86	8	3	13	23	15	31	30
24	15	15	18	16	719	43	71	7	4	12	23	15	19	28
25	18	11	17	15	299	36	61	8	6	10	24	11	18	29
26	17	11	15	15	108	32	43	10	7	10	24	11	18	46
27	15	12	15	16	74	30	32	9	6	10	22	11	17	240
28	14	15	15	21	55	31	32	10	5	10	22	12	17	123
29	13	14	15	25	50	57	33	9	5	16	26	12	18	67
30	13	13	15		43	107	31	7	4	18	24	13	26	50
31		13	15		38		46		5	9		17		47
Mean		14.6	28.2	28.4	73.2	84.4	48.4	21.1	10.0	9.0	14.4	10.6	36.8	56.3
Runoff, in acre-feet		897	1,730	1,630	4,499	5,022	2,973	1,258	613	553	859	1,263	2,184	3,459

AUBURN RAVINE AT HIGHWAY 99E
1947 AND 1948

(Daily mean flow, in second-feet)

Date	1947		1948											
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1		7	36	54	57	81	37	85	69	69	62	11	12	12
2		7	49	52	62	85	15	70	76	76	62	12	17	25
3		7	56	52	56	117	9	54	71	67	62	9	21	39
4		9	42	57	51	118	16	55	66	67	62	7	13	39
5		11	42	66	55	98	15	51	65	67	62	8	10	31
6		11	43	96	50	80	10	52	61	67	72	6	11	47
7		11	75	74	45	62	9	48	60	67	62	3	10	31
8		12	133	64	49	51	14	48	62	69	62	2	10	44
9		14	81	98	54	66	12	52	57	68	63	2	9	31
10		11	78	81	50	64	11	60	60	67	63	2	9	29
11		11	72	68	48	61	7	63	65	68	63	4	8	27
12		11	68	66	48	54	16	56	70	69	62	6	9	28
13	7	9	62	64	68	56	52	47	82	68	61	5	9	70
14	9	8	62	62	86	54	61	49	80	66	61	5	6	32
15	22	8	58	61	89	63	70	57	79	67	63	5	11	71
16	22	8	58	61	86	46	68	58	78	67	62	4	9	52
17	14	44	56	61	82	66	67	62	77	67	50	4	16	108
18	12	42	54	61	70	44	80	62	79	66	51	3	11	70
19	11	37	53	59	102	38	107	66	78	63	52	8	11	51
20	11	44	54	56	77	35	115	62	75	59	45	16	11	47
21	10	44	55	53	61	32	53	58	71	58	24	17	11	43
22	11	40	56	54	55	62	44	55	70	60	22	15	10	41
23	11	38	55	51	56	38	58	63	70	50	23	6	13	40
24	11	35	52	52	289	29	57	55	69	59	22	5	25	40
25	9	32	51	55	192	26	54	59	70	58	15	8	23	38
26	7	33	48	54	117	23	50	71	70	58	16	8	22	52
27	8	33	51	54	83	20	48	67	69	58	15	7	26	108
28	6	33	51	68	53	20	50	67	70	58	12	11	27	70
29	6	34	51	58	82	55	56	66	70	60	11	9	23	54
30	6	35	50		104	56	61	63	69	62	13	9	13	54
31		35	52		92		89		69	62		11		51
Mean	10.7	23.0	58.3	62.5	79.8	56.9	45.5	59.3	70.2	64.3	45.5	7.4	13.4	47.6
Runoff, in acre-feet	386	1,416	3,578	3,594	4,897	3,382	2,799	3,531	4,318	3,947	2,707	452	825	2,926

DRY CREEK NEAR WALDO
1947 AND 1948

(Daily mean flow, in second-feet)

Date	1947		1948										
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1		2	2	5	16	37	95	36				e 1	14	8
2		2	33	5	10	32	67	30				e 2	26	8
3		2	62	5	9	28	58	28				e 3	24	9
4		2	20	6	9	27	51	28				e 4	28	16
5		2	43	6	9	44	43	28				e 5	14	13
6		2	20	26	9	156	38	25				e 6	12	35
7		2	388	28	9	105	34	20				e 7	9	24
8		2	312	11	9	80	37	19				e 7	8	22
9		2	78	66	9	130	38	16				e 8	7	37
10	5	2	37	84	9	556	36	16				e 8	7	23
11	5	3	26	37	9	292	30	16				e 9	7	18
12	5	4	20	24	9	146	27	16				e 9	7	14
13	5	5	18	19	107	100	23	e16				e10	7	73
14	5	6	15	16	189	90	20	e15				e10	7	106
15	5	7	14	14	146	89	20	e14				e11	7	57
16	5	9	13	14	136	101	19	e13	NO FLOW	NO FLOW	NO FLOW	e11	7	42
17	4	9	12	13	159	407	18	e12				e12	7	79
18	4	8	11	13	88	156	33	e11				e12	7	115
19	3	7	10	13	136	100	64	e10				12	7	42
20	3	6	10	12	86	84	103	e10				12	7	23
21	2	5	9	12	56	67	73	e 9				12	7	17
22	2	4	9	11	39	222	44	e 8				12	6	14
23	2	3	8	10	131	174	38	e 7				12	6	12
24	2	2	7	10	727	95	30	e 6				12	6	10
25	2	2	6	9	316	74	28	e 5				12	7	10
26	2	2	6	9	142	67	28	e 4				12	7	10
27	2	2	6	9	92	58	26	e 3				12	7	138
28	2	2	5	9	71	59	26	e 2				12	7	132
29	2	2	5	12	58	112	28	e 1				12	8	48
30	2	2	5		44	130	67	e 1				12	8	30
31		2	5		41		49					12		24
Mean		13.6	39.2	18.1	93.0	127.0	41.7	14.2				9.4	9.6	38.9
Runoff, in acre-feet		222	2,410	1,008	5,712	7,575	2,561	843				577	571	2,398

e—Estimated.

DRY CREEK NEAR WALDO—1949

(Daily mean flow, in second-feet)

Date	January	February	March	April	May	Date	January	February	March	April	May
1	57	15	34	51	16	16	11	36	162	8	NO RECORD
2	80	15	187	38	12	17	10	33	120	7	
3	40	17	580	32	16	18	10	32	86	4	
4	28	26	475	18		19	11	28	171	4	
5	23	130	390	14		20	18	28	137	4	
6	19	112	335	35		21	17	38	103	5	
7	18	147	220	37		22	53	32	122	5	
8	16	132	154	16		23	63	57	148	5	
9	14	78	171	15		24	37	67	187	5	
10	13	71	780	12		25	29	59	137	4	
11	12	306	780	8		26	26	44	122	3	
12	12	130	278	5		27	24	57	119	4	
13	12	73	187	5		28	22	48	114	4	
14	12	52	137	5		29	20		103	5	
15	11	42	120	6		30	17		68	9	
						31	15		51		
						Mean	24.2	69.9	222.9	12.6	
						Runoff, in acre-feet	1,488	3,878	13,756	728	

SOUTH HONCUT CREEK AT LA PORTE ROAD

1947 AND 1948

(Daily mean flow, in second-feet)

Date	1947		1948										
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1		5	6	5	16	46	118	47	NO FLOW	NO FLOW	NO FLOW		25	5
2		5	122	9	17	38	90	38					54	5
3		6	104	10	14	95	78	34					66	13
4		11	114	11	11	122	70	37					32	34
5		15	132	24	10	147	65	44					15	31
6		11	61	50	9	132	61	38					9	90
7		8	472	46	7	80	52	34					8	48
8	6	7	224	28	4	73	48	28					6	67
9	7	7	77	48	12	430	43	25					5	46
10	6	8	130	70	9	580	40	23					5	27
11	5	8	38	44	3	271	35	22					5	19
12	5	8	34	33	2	158	32	21				8	4	15
13	5	7	30	28	50	118	27	20				5	4	78
14	6	8	27	24	252	115	27	19				3	3	89
15	9	9	25	23	122	132	26	18				4	12	61
16	11	10	24	22	168	127	26	17				5	27	49
17	13	20	22	21	342	406	26	16				6	27	66
18	10	27	21	20	171	158	40	15				7	24	82
19	6	18	20	18	171	115	69	14				6	17	47
20	5	12	19	17	93	95	104	13				6	15	34
21	5	15	19	16	69	85	81	12				5	12	28
22	5	17	25	15	51	250	52	11				5	9	24
23	5	16	21	11	120	143	40	10				5	8	22
24	5	13	21	10	619	101	34	9				5	7	20
25	5	12	21	10	283	81	34	8				5	7	17
26	1	10	13	10	136	70	32	7				6	6	25
27	1	10	12	10	95	64	27	6				5	6	216
28	5	10	11	15	73	73	35	5				3	6	113
29	1	10	10	28	64	132	34	3				5	7	61
30	1	8	7		54	184	63	1				9	7	46
31		7	5		16		69					10		38
Mean	6.2	10.9	60.2	24.1	94.5	154.2	51.0	19.9				5.7	14.6	49.0
Runoff, in acre-feet	284	670	3,703	1,341	5,796	9,166	3,130	1,180				226	869	3,007

APPENDIX E

RECORDS OF DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

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RECORDS OF DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

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The wells are numbered in accordance with a system adopted by the United States Geological Survey. The numbering system indicates the well locations according to the rectangular land surveys. An explanation of the numbering system is given on page 93 of Appendix B.

Reference point elevations given to the nearest foot have been estimated from United States Geological Survey topographic maps. Reference point elevations given to the nearest 0.1 foot have been established by field surveys.

TABLE 1

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Made by Division of Water Resources
(Depths to woter in feet meosured from reference point)

10N/3E-1A1—Reference point—top of 12-inch casing, elevation 23 feet. West side of Garden Highway at toe of levee, 0.75 mile southwest of Riego Road. 12/7/48, 15.1; 4/6/49, 10.7; 11/30/49, 15.7; 3/30/50, 6.4; 11/9/50, 15.6; 4/5/51, 10.2; 12/4/51, 14.0; 4/4/52, 0.0.

10N/4E-6K1—Reference point—top of 14-inch casing under pump, elevation 20 feet, 0.06 mile south of Riego Road, 0.47 mile west of Power Line Road. 12/23/47, 10.9; 3/4/48, 11.0; 12/7/48, 10.0; 4/6/49, 5.0; 12/1/49, 8.2; 3/30/50, 6.9; 1/9/50, 8.0; 12/4/51, 7.7; 4/4/52, 6.3.

10N/4E-12A1—Reference point—top of casing, elevation 43.1 feet, 0.10 mile west of Pleasant Grove Road, 0.70 mile south of Riego Road. 12/23/47, 22.0; 3/3/48, 20.6; 12/7/48, 28.1; 4/6/49, 23.2; 11/23/49, 36.1; 12/1/49, 27.2; 3/15/50, 29.5; 3/30/50, 28.7; 11/9/50, 35.0; 4/5/51, 25.9; 12/5/51, 26.7; 4/4/52, 24.4.

10N/5E-6J1—Reference point—top of wooden shoring for pit, 12.5 feet above casing, elevation 46 feet, 0.12 mile south of Riego Road, 0.82 mile east of Pleasant Grove Road. 12/24/47, 27.1; 3/3/48, 27.0; 12/7/48, 33.9 (operating); 4/6/49, 29.6; 12/1/49, 33.6; 3/30/50, 34.9; 11/9/50, 40.3; 4/5/51, 38.2; 12/5/51, 33.1; 4/8/52, 42.4 (operating).

10N/5E-8N1—Reference point—top of casing, elevation 37 feet, 1.5 miles south of Riego Road, 1.06 miles east of Pleasant Grove Road. 12/24/47, 25.3.

11N/3E-1D1—Reference point—hole in side of pump base, elevation 25.6 feet. South side of West Catlett Road, 0.18 mile east of Garwood Road. 12/19/47, 12.0; 3/4/48, 11.6; 12/15/48, 11.0; 3/30/49, 6.5; 5/26/49, 20.1; 6/29/49, 23.4; 7/28/49, 23.1; 8/26/49, 23.4; 12/5/49, 14.5; 3/24/50, 8.3; 11/16/51, 12.5; 4/7/52, 5.9.

11N/3E-2B1—Reference point—top of concrete base, elevation 23.8 feet. South side of West Catlett Road, 0.37 mile west of Garwood Road. 12/19/47, 11.0; 3/4/48, 10.8; 12/15/48, 12.3; 3/3/49, 5.9; 12/5/49, 14.1; 3/24/50, 7.4; 11/6/50, 12.4; 4/2/51, 5.1; 11/16/51, 11.7; 4/8/52, 6.1.

11N/3E-2Q1—Reference point—top of casing, elevation 20 feet, 0.50 mile east of Vernon Road, 0.89 mile south of West Catlett Road. 12/9/48, 11.9; 4/6/49, 5.7; 11/28/49, 14.0; 3/30/50, 7.1; 11/8/50, 11.2; 4/3/51, 5.1; 12/5/51, 11.0.

11N/3E-3C2—Reference point—west side of pump base, elevation 26.1 feet. South side of West Catlett Road, 1.57 miles north of Garwood Road. 12/19/48, 13.4; 3/4/48, 11.4; 12/15/48, 13.1; 3/30/49, 7.5; 12/5/49, 15.2; 3/34/50, 7.6; 11/6/50, 13.0; 4/2/51, 5.0; 4/8/52, 1.7.

11N/3E-3N1—Reference point—hole in pump base, elevation 25 feet, 0.85 mile west of Vernon Road, 0.93 mile south of West Catlett Road. 12/9/48, 13.1; 3/31/49, 6.2; 11/28/49, 14.9; 3/30/50, 5.9; 11/18/50, 13.1; 4/1/52, 0.0.

11N/3E-3P1—Reference point—hole in pump base, elevation 22 feet, 0.74 mile west of Vernon Road, 0.82 mile south of West Catlett Road. 12/9/48, 12.4; 11/8/50, 13.1; 4/3/51, 6.2, 12/5/51, 11.9; 4/1/52, 5.3.

11N/3E-10N1—Reference point—pipe in pump base, elevation 26 feet, 0.80 mile west of Vernon Road, 1.75 miles south of West Catlett Road. 3/31/49, 11.3; 11/28/49, 19.1.

11N/3E-11D1—Reference point—top of casing, elevation 21 feet, 0.14 mile east of Vernon Road, 1.08 miles south of West Catlett Road. 12/9/48, 8.3; 4/6/49, 4.5; 11/28/49, 12.2; 3/30/50, 4.9; 11/8/50, 7.7; 4/3/51, 2.7; 4/2/52, 1.9.

11N/3E-13A1—Reference point—top of casing, elevation 20 feet, 0.70 mile north of north levee of Natomas Cross Canal, 1.15 miles northeast of Garden Highway. 12/9/48, 7.6; 4/6/49, 3.3; 11/29/49, 9.4; 3/30/50, 3.6; 11/8/50, 10.0; 4/2/51, 3.0; 12/5/51, 9.5.

11N/3E-13D1—Reference point—hole in pump base, elevation 20 feet, 1.10 miles north of north levee of Natomas Cross Canal, 0.86 mile northeast of Garden Highway. 12/9/48, 11.9; 4/6/49, 7.4; 11/29/49, 13.0; 3/30/50, 8.5; 11/8/50, 13.5; 4/2/51, 7.5; 12/5/51, 13.0.

11N/3E-13F1—Reference point—hole in pump base, elevation 20 feet, 0.75 mile north of north levee of Natomas Cross Canal, 1.13 miles northeast of Garden Highway. 12/9/48, 12.5; 4/6/49, 8.3; 14/29/49, 14.2.

11N/3E-13P1—Reference point—hole in pump base, elevation 20 feet. At toe of north levee of Natomas Cross Canal, 1.37 miles northeast of Garden Highway. 4/6/49, 7.7; 11/29/49, 11.8.

11N/3E-14N1—Reference point—hole in pump base, elevation 25 feet, 0.14 mile east of Vernon Road, 0.60 mile north of Garden Highway. 12/9/48, 12.7.

11N/3E-15C1—Reference point—hole in pump base, elevation 25 feet, 1.50 miles north of Garden Highway, 0.78 miles west of Vernon Road. 12/24/47, 16.9; 3/4/48, 16.2; 12/9/48, 16.1; 3/31/49, 9.9; 11/28/49, 17.9; 3/30/50, 7.9; 11/8/50, 16.1; 4/3/51, 10.3; 12/4/51, 15.0; 4/1/52, 1.1.

11N/3E-22H1—Reference point—top of casing, elevation 27 feet. North side of Garden Highway, 0.23 mile northwest of Verona. 12/24/47, 18.8; 3/4/48, 18.2; 12/9/48, 18.0; 3/31/49, 11.6; 11/28/49, 18.2; 3/30/50, 9.9; 11/8/50, 16.2; 4/3/51, 11.4; 12/5/51, 15.7; 4/1/52, 3.3.

11N/3E-22H2—Reference point—top of casing, elevation 29 feet. Northeast side of Garden Highway, east side of Vernon Road. 11/7/29, 24.3; 9/27/30, 24.3; 12/15/31, 24.3; 11/23/32, 25.2; 12/21/33, 21.6; 10/27/34, 27.3; 11/28/34, 20.3; 11/25/36, 24.8; 11/6/37, 23.8; 1/10/39, 20.8.

11N/3E-22H3—Reference point—top of casing, elevation 29 feet, 300 feet north of Garden Highway, west side of Vernon Road. 12/20/40, 19.9.

11N/3E-23E2—Reference point—top of casing, elevation 27 feet, 100 feet north of Garden Highway, 0.07 mile east of Vernon Road. 11/11/47, 19.7; 12/16/48, 19.0; 12/9/49, 19.0; 11/13/50, 19.3; 12/6/51, 5.9.

11N/3E-23L1—Reference point—top of casing, elevation 29 feet, 0.12 mile north of Garden Highway, 0.47 mile southeast of Vernon Road. 12/23/47, 12.3; 3/4/48, 11.9; 12/9/48, 10.9; 3/31/49, 3.9; 11/28/49, 12.9.

11N/3E-23R1—Reference point—top of casing, elevation 20 feet. At toe of south levee of Natomas Cross Canal, 0.11 mile north of Garden Highway. 12/23/47, 12.1; 3/4/48, 16.0; 12/8/48, 15.2; 3/31/49, 6.9; 11/28/49, 16.1.

11N/3E-25C1—Reference point—top of casing, elevation 23 feet, 0.24 mile south of Sankey Road, 0.44 mile east of Garden Highway. 12/9/48, 11.3; 4/6/49, 7.3; 3/30/50, 7.6; 11/9/50, 10.9; 4/5/51, 5.6; 12/5/51, 11.3; 4/4/52, 4.4.

11N/3E-25P1—Reference point—top of casing, elevation 25 feet, 265 feet northwest of Garden Highway, 1.27 miles north of Riego Road. 11/7/29, 19.0; 9/27/30, 19.3; 12/15/31, 19.5; 11/23/32, 20.2; 12/21/33, 16.6; 10/27/34, 18.1; 11/28/34, 15.6; 11/25/36, 19.2; 11/6/37, 14.7; 1/10/39, 15.6; 12/20/40, 15.0; 11/11/47, 15.5; 12/23/47, 16.6; 3/4/48, 16.0; 12/1/49, 15.6; 4/6/49, 11.9; 11/13/50, 13.5; 12/6/51, 8.3.

11N/4E-1F1—Reference point—top of casing, elevation 49.3 feet, 0.80 mile south of Catlett Road, 0.25 mile east of Pleasant Grove Road. 12/22/47, 21.5; 3/22/48, 19.3; 12/18/48, 23.3; 3/29/49, 19.5; 12/2/49, 25.9; 3/27/50, 22.8; 11/8/50, 27.0; 11/16/51, 27.0; 4/8/52, 17.5.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

11N/4E-1M1—Reference point—concrete floor of pump house, elevation 45 feet, 0.55 mile north of Howsley Road, 0.12 mile east of Pleasant Grove Road. 11/8/29, 13.8; 9/26/30, 13.3; 12/10/31, 14.9; 11/23/32, 14.3; 12/20/33, 15.9; 10/27/34, 16.2; 11/23/36, 13.9; 11/1/37, 12.3; 1/10/39, 11.3; 1/4/41, 11.4; 11/11/47, 22.9; 12/16/48, 22.1; 12/9/49, 24.4; 11/13/50, 24.2; 12/6/51, 27.8.

11N/4E-1R1—Reference point—joint in cover plate around casing, elevation 50 feet. North side of Howsley Road, 1.0 mile east of Pleasant Grove Road. 12/23/47, 24.7; 3/3/48, 22.6; 12/8/48, 25.1; 3/31/49, 22.8; 11/30/49, 25.9; 11/14/50, 28.7.

11N/4E-2M1—Reference point—top of casing, elevation 40 feet, West side of Western Pacific Railroad, 0.29 mile north of Howsley Road. 3/15/48, 11.9; 12/8/48, 15.5; 3/29/49, 9.5; 12/2/49, 16.4.

11N/4E-3P1—Reference point—hole in base of pump, elevation 33 feet, 0.15 mile north of Howsley Road, 0.47 mile east of Pacific Avenue. 12/22/47, 19.8; 3/15/48, 18.1; 12/18/48, 21.1; 3/29/49, 14.4; 12/2/49, 21.3; 3/24/50, 16.3; 11/8/50, 21.6; 4/2/51, 12.3; 11/19/51, 20.8; 4/8/52, 13.2.

11N/4E-4R1—Reference point—top of casing, elevation 30 feet, 0.03 mile north of Howsley Road, 0.16 mile west of Pacific Avenue. 12/23/47, 14.7; 3/15/48, 13.1; 12/15/48, 10.2; 2/30/49, 3.9; 12/2/49, 15.9; 3/24/50, 9.8; 11/8/50, 16.0; 4/2/51, 8.0; 11/19/51, 14.7; 4/6/52, 6.1.

11N/4E-5A1—Reference point—top of casing, elevation 27 feet, 1.10 miles north of Natomas Cross Canal. 12/18/47, 9.9; 12/15/48, 9.9; 3/30/49, 3.8; 5/26/49, 18.1; 7/29/49, 20.1.

11N/4E-6B1—Reference point—hole in pump base, elevation 30 feet. South side of West Catlett Road, 1.50 miles west of Electric Avenue. 12/18/47, 11.5; 12/15/48, 15.1; 3/24/50, 7.9; 11/19/51, 14.0.

11N/4E-7H1—Reference point—edge of pump base, elevation 23 feet, 0.47 mile north of Natomas Cross Canal, 3 miles northeast of Garden Highway. 4/6/49, 10.1; 11/30/49, 12.3; 3/30/50, 10.6; 11/8/50, 14.5; 4/2/51, 9.3.

11N/4E-9C1—Reference point—top of casing, elevation 27 feet, 0.56 mile west of Sacramento Northern Railroad, 0.21 mile south of Howsley Road. 5/5/48, 37.0 (operating); 5/31/48, 10.8; 7/2/48, 49.0 (operating); 7/23/48, 50.5 (operating); 4/6/49, 7.7; 11/30/49, 14.0.

11N/4E-9L1—Reference point—top of casing, elevation 26 feet, 0.45 mile west of Sacramento Northern Railroad crossing on Howsley Road, 0.57 mile south of Howsley Road. 5/5/48, 48.2 (operating) 5/31/48, 12.7; 7/23/48, 50.5 (operating); 4/6/49, 8.8; 11/30/49, 14.2.

11N/4E-11C1—Reference point—top of casing, elevation 41 feet, 0.35 mile east of Western Pacific Railroad, 0.16 mile south of Howsley Road. 3/3/48, 19.9; 3/31/49, 18.8.

11N/4E-11C2—Reference point—top of casing, elevation 45 feet, 0.18 mile south of Howsley Road, 0.40 mile east of Western Pacific Railroad. 12/22/47, 23.1; 12/8/48, 25.1; 3/31/49, 21.0; 11/30/49, 25.8; 3/30/50, 21.2; 11/9/50, 28.1; 4/5/51, 19.2; 12/4/51, 27.1; 1/4/52, 17.6.

11N/4E-11N1—Reference point—top of casing, elevation 38 feet. North side of Fifield Road, west side of Western Pacific Railroad. 12/23/47, 21.2; 3/3/48, 18.6; 12/8/48, 25.5; 4/6/49, 18.0; 11/30/49, 25.1.

11N/4E-12C1—Reference point—top of casing, elevation 46 feet, 0.03 mile east of Pleasant Grove Road, 0.03 mile south of Howsley Road. 11/26/48, 27.2.

11N/4E-12C2—Reference point—top of casing, elevation 50.0 feet, 0.12 mile east of Pleasant Grove Road, 0.02 mile south of Howsley Road. 12/22/47, 23.4; 3/3/48, 20.9; 12/8/48, 23.6; 3/31/49, 22.1; 11/30/49, 23.9.

11N/4E-12H1—Reference point—top of casing, elevation 56.8 feet, 0.76 mile east of Pleasant Grove Road, 0.57 mile south of Howsley Road. 12/7/48, 27.8.

11N/4E-12J2—Reference point—top of casing, elevation 56.8 feet, 0.58 mile south of Howsley Road, 0.78 mile east of Pleasant Grove Road. 12/23/47, 27.3; 3/3/48, 25.2; 12/8/48, 28.2; 3/31/49, 24.7; 11/17/49, 30.8; 11/30/49, 28.9; 3/30/50, 28.0; 4/11/50, 26.9; 11/8/50, 32.5; 11/14/50, 32.4; 4/5/51, 28.9; 11/15/51, 34.0; 4/3/52, 29.2; 4/4/52, 29.6.

11N/4E-12M1—Reference point—slot in base, elevation 44.7 feet, 0.62 mile south of Howsley Road, 0.07 mile west of Pleasant Grove Road. 12/23/47, 22.8; 3/3/48, 19.8; 12/8/48, 24.6; 3/31/49, 20.4; 5/26/49, 26.2; 6/29/49, 25.1; 7/28/49, 32.8; 11/30/49, 27.2; 3/30/50, 23.1; 11/6/50, 28.2; 4/10/51, 23.5; 11/14/51, 35.0; 4/4/52, 23.2.

11N/4E-13D1—Reference point—top of casing, elevation 47.6 feet. West side of Pleasant Grove Road, 0.09 mile south of Fifield Road. 12/8/48, 28.5; 4/6/49, 18.0; 11/30/49, 27.0; 3/15/50, 23.3; 3/30/50, 24.1; 11/8/50, 30.1; 4/5/51, 25.0; 11/14/51, 32.6; 4/4/52, 29.5; 4/10/52, 25.2.

11N/4E-13M1—Reference point—top of casing in pit, elevation 46 feet, 0.12 mile west of Pleasant Grove Road, 0.37 mile north of Keys Road. 12/23/47, 15.9; 12/8/48, 19.1; 3/31/49, 14.0; 11/30/49, 21.7.

11N/4E-14B1—Reference point—top of casing, elevation 40 feet, 0.10 mile south of Howsley Road, 0.52 mile west of Pleasant Grove Road. 12/23/47, 25.8; 3/3/48, 21.8; 12/8/48, 27.8; 3/31/49, 21.1; 11/30/49, 29.6.

11N/4E-14D1—Reference point—top of casing, elevation 36.5 feet, 0.21 mile west of Western Pacific Railroad, 0.26 mile south of Fifield Road. 12/23/47, 21.2; 3/3/48, 18.6; 12/8/48, 25.5; 4/6/49, 18.0; 11/30/49, 25.1.

11N/4E-15C1—Reference point—top of casing, elevation 31.2 feet. South side of Fifield Road, 0.11 mile west of Sacramento Northern Railroad. 12/23/47, 16.9; 3/3/48, 14.9; 12/8/48, 20.0; 4/6/49, 12.9; 11/30/49, 18.8; 3/30/50, 14.4; 11/8/50, 19.5; 4/3/51, 11.0; 12/4/51, 19.1; 4/4/52, 7.2.

11N/4E-15Q1—Reference point—hole in pump base, elevation 33.6 feet, 0.80 mile west of Sacramento Northern Railroad, 0.22 mile north of Keys Road. 12/23/47, 18.5; 3/3/48, 16.8; 12/8/48, 23.5; 4/6/49, 16.0; 11/30/49, 22.2; 3/30/50, 17.9; 11/8/50, 23.5; 4/3/51, 14.7; 12/5/51, 23.0; 4/4/52, 12.6.

11N/4E-21R1—Reference point—top of casing, elevation 24.9 feet, 1.06 miles east of Burns Road, 0.22 mile north of Sankey Road. 12/23/47, 9.9; 3/3/48, 9.6; 12/8/48, 12.3; 4/6/49, 8.0.

11N/4E-22A1—Reference point—top of casing, elevation 32.7 feet, 0.18 mile west of Sacramento Northern Railroad crossing. 12/8/48, 23.5; 4/6/49, 15.2; 11/30/49, 22.6.

11N/4E-23C1—Reference point—top of casing, elevation 37 feet, 0.09 mile south of Keys Road, 0.09 mile east of Western Pacific Railroad. 12/23/47, 21.0; 3/3/48, 18.6; 11/30/49, 26.6; 3/30/50, 22.1; 11/8/50, 28.7; 4/3/51, 20.3; 12/4/51, 28.0; 4/4/52, 20.1.

11N/4E-23H1—Reference point—top of casing, elevation 53.1 feet, 0.02 mile west of Pleasant Grove Road, 0.46 mile south of Keys Road. 12/23/47, 19.5; 3/3/48, 18.0; 12/8/48, 24.1; 4/6/49, 19.8; 11/30/49, 32.2; 3/30/50, 24.6; 11/8/50, 30.7; 4/5/51, 21.6; 12/4/51, 29.2.

11N/4E-23N1—Reference point—top of concrete pit wall, elevation 33 feet, 0.06 mile west of Sacramento Northern Railroad, 0.11 mile north of Sankey Road. 12/23/47, 21.3.

11N/4E-25M1—Reference point—hole in base, elevation 37 feet, 0.58 mile south of Sankey Road, 0.06 mile east of Pleasant Grove Road. 12/23/47, 19.0; 3/3/48, 20.2; 12/8/48, 24.9; 4/6/49, 21.0; 12/1/49, 34.6; 3/30/50, 29.9; 4/4/50, 34.9.

11N/4E-26F1—Reference point—hole in base of pump, elevation 37 feet, 0.40 mile south of Sankey Road, 0.05 mile west of Sacramento Northern Railroad. 12/8/48, 28.0; 4/6/49, 23.0; 12/8/48, 119; 3/30/50, 29.9; 11/9/50, 29.1; 12/6/51, 37.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

11N/4E-28J1—Reference point—top of casing, elevation 34.3 feet, 0.70 mile south of Sankey Road, 0.40 mile west of Pacific Avenue. 3/4/48, 20.4; 12/8/48, 23.6; 4/6/49, 19.2; 12/1/49, 25.3; 3/30/50, 22.5; 11/9/50, 29.1; 4/5/51, 21.4; 12/6/51, 30.5; 4/4/52, 22.8.

11N/4E-33J1—Reference point—top of casing, elevation 25.6 feet, 0.03 mile west of Pacific Avenue, 0.28 mile north of Riego Road. 3/4/48, 13.4; 12/7/48, 15.7; 4/6/49, 12.2; 5/26/40, 11.0; 12/1/49, 17.4; 3/30/50, 14.0; 11/9/50, 14.6; 4/5/51, 12.7; 12/6/51, 14.1; 4/4/52, 14.9.

11N/4E-36E1—Reference point—top of concrete pit wall, elevation 39 feet, 0.07 mile east of Pleasant Grove Road, 0.70 mile north of Riego Road. 12/24/47, 22.3; 3/3/48, 23.0; 12/7/48, 28.9; 4/6/49, 24.9; 12/1/49, 38.7; 3/30/50, 23.2; 11/9/50, 44.4; 4/4/52, 19.0.

11N/5E-6N1—Reference point— top of casing, elevation 59 feet. North side Howsley Road, 0.80 mile east of Pleasant Grove Road. 12/23/47, 24.7; 3/3/48, 22.6; 12/8/48, 25.1; 3/31/49, 22.8; 11/30/49, 25.9; 11/14/50, 28.7; 3/22/51, 26.2.

11N/5E-18N1—Reference point— top of casing, elevation 50 feet. North side of Keys Road, 0.85 mile east of Pleasant Grove Road. 12/24/47, 27.3; 3/3/48, 26.5; 12/8/48, 30.1; 11/30/49, 31.8; 11/14/50, 33.1; 3/22/51, 31.2.

11N/5E-30M1—Reference point—top of casing, elevation 47 feet, 1.05 miles east of Pleasant Grove Road, 0.59 mile south of Sankey Road. 12/24/47, 18.8; 3/3/48, 18.7; 12/8/48, 22.4; 12/1/49, 23.4; 3/30/50, 24.4; 11/9/50, 23.4; 12/5/51, 23.4; 4/4/52, 32.5.

12N/3E-1E1—Reference point—top of casing, elevation 33 feet, 0.10 mile northeast of Garden Highway, 0.20 mile northwest of Sutter Avenue. 12/4/47, 13.6; 3/10/48, 10.0; 12/11/48, 13.2; 3/16/49, 8.3; 12/6/49, 12.6; 3/29/50, 7.5; 11/15/51, 11.1; 4/4/52, 5.9.

12N/3E-1L1—Reference point—top of casing, elevation 31 feet, 150 feet northwest of Sutter Avenue, 0.12 mile northeast of Garden Highway. 12/4/47, 12.6; 3/10/48, 12.1; 12/11/48, 12.9; 3/16/49, 8.0; 12/6/49, 12.5; 11/3/50, 13.2; 4/2/51, 5.3; 11/3/51, 13.2; 4/4/52, 3.3.

12N/3E-2B1—Reference point—top of casing, elevation 31 feet, 0.08 mile east of Garden Highway, 0.49 mile north of Chandler Road. 12/4/47, 9.1; 3/10/48, 9.4; 12/11/48, 9.7; 3/16/49, 6.5; 12/6/49, 8.6.

12N/3E-2E1—Reference point—top of casing, elevation 29 feet, North side of Chandler Road, 0.48 mile west of Garden Highway. 12/4/47, 9.9; 3/10/48, 5.8; 5/11/48, 4.7; 12/11/48, 8.8; 3/16/49, 4.1; 5/26/49, 3.1; 6/29/49, 3.2; 7/27/49, 2.6; 8/25/49, 3.3. Well destroyed.

12N/3E-2J1—Reference point—top of casing, elevation 30 feet, South side of Garden Highway, 0.30 mile northwest of Sutter Avenue. 12/4/47, 12.2; 3/10/48, 8.9; 12/11/48, 12.8; 3/16/49, 8.3; 12/6/49, 11.7.

12N/3E-2K1—Reference point—top of casing, elevation 30 feet, South side of Garden Highway, 0.54 mile west of Sutter Avenue. 12/4/47, 12.2; 3/10/48, 4.9; 5/11/48, 6.7; 3/16/49, 4.8; 12/6/49, 7.5.

12N/3E-3K1—Reference point—top of casing, elevation 25 feet, 0.89 mile west of Garden Highway, 0.08 mile south of Chandler Road. 11/7/29, 8.0; 9/27/30, 6.4; 12/12/31, 6.5; 11/25/32, 10.1; 12/20/33, 8.3; 11/10/34, 9.1; 11/25/36, 10.8; 11/24/37, 5.9; 1/25/39, 9.6; 1/13/41, 4.6; 11/7/47, 8.5; 12/15/48, 8.3; 12/6/49, 9.2.

12N/3E-3K2—Reference point—top of casing, elevation 25 feet, 0.20 mile south of Chandler Road, 0.89 mile west of Garden Highway. 11/13/50, 24.7; 12/6/51, 3.9.

12N/3E-3Q1—Reference point—hole in base of pump, elevation 32 feet, 0.32 mile south of Chandler Road, 0.89 mile west of Garden Highway. 11/6/50, 27.4; 4-2-51, 4.8.

12N/3E-12C1—Reference point—top of casing, elevation 30 feet, 0.15 mile southwest of west end of Nicolaus bridge. 12/9/47, 14.9; 3/11/48, 11.9; 12/11/48, 15.0; 12/6/49, 14.7.

12N/3E-13G1—Reference point—top of casing, elevation 30 feet, 0.68 mile north of Lee Road, 0.38 mile southeast of Garden Highway. 12/5/47, 14.3; 3/15/48, 12.4; 12/14/48, 13.8; well destroyed.

12N/3E-13M1—Reference point—top of pit wall, elevation 29 feet, 0.45 mile southwest of Garden Highway, 0.37 mile northwest of Lee Road. 12/5/47, 14.4; 3/11/48, 13.8; 3/25/49, 12.5; well destroyed.

12N/3E-14H1—Reference point—top of pit wall, elevation 30 feet. East side of Garden Highway, 0.99 mile northeast of Lee Road. 12/5/47, 14.7; 3/15/48, 14.2; 12/11/48, 15.0; 3/25/49, 10.1; 12/6/49, 16.1.

12N/3E-14Q1—Reference point—top of casing, elevation 26 feet, South side of Lee Road, 0.12 mile southeast of Garden Highway. 12/5/47, 14.2; 3/11/48, 13.1; 12/11/48, 14.1; 3/25/49, 9.3; 12/6/49, 14.7; 3/29/50, 9.8.

12N/3E-22R1—Reference point—top of casing, elevation 26 feet, East side of Garden Highway, 1.30 miles south of Lee Road. 11/7/29, 12.0; 9/27/30, 12.7; 12/15/31, 13.0; 11/25/32, 14.9; 12/21/33, 11.3; 10/27/34, 14.5; 11/25/36, 14.1; 11/6/37, 13.5; 1/10/39, 11.1; 12/20/40, 8.4; 11/10/47, 14.1.

12N/3E-22R2—Reference point—top of casing, elevation 26 feet, East side of Garden Highway, 1.30 miles south of Lee Road. 12/16/48, 12.3; 12/9/49, 14.0.

12N/3E-22R3—Reference point—top of casing, elevation 26 feet, 0.15 mile southeast of Garden Highway, 1.30 miles south of Lee Road. 11/13/50, 12.8; 12/6/51, 5.5.

12N/3E-23N1—Reference point—top of casing, elevation 25 feet, 0.09 mile east of Garden Highway, 1.10 miles south of Lee Road. 12/19/47, 12.6; 3/4/48, 11.2; 12/15/48, 12.3; 3/30/49, 6.6; 12/5/49, 15.9; 3/24/50, 5.8; 11/6/50, 12.6; 4/2/51, 6.6; 11/16/51, 11.4.

12N/3E-24A1—Reference point—top of casing, elevation 25 feet, South side of Lee Road, 0.58 mile west of Power Line Road. 12/5/47, 12.4; 3/11/48, 11.2; 12/11/48, 12.6; 3/25/49, 9.4; 12/6/49, 13.3.

12N/3E-24Q1—Reference point—top of casing, elevation 25 feet, 0.10 mile north of Striplin Road, 0.30 mile east of Garwood Road. 12/18/47, 11.6; 3/4/48, 10.8; 12/15/48, 12.9; 3/30/49, 7.9; 12/5/49, 14.1; 3/24/50, 9.1; 11/8/50, 12.1; 4/2/51, 4.3; 11/16/51, 12.8; 4/7/52, 3.5.

12N/3E-26N1—Reference point—lower end of flange around discharge pipe, elevation 22 feet, 0.08 mile southwest of Worth Road, 0.90 mile west of Garwood Road. 12/19/47, 11.1; 3/4/48, 9.9; 12/15/48, 14.1; 3/30/49, 7.9; well destroyed.

12N/3E-27Q1—Reference point—hole in base of pump, elevation 22 feet, 0.10 mile east of Garden Highway, 1.30 miles north of Catlett Road. 11/6/50, 12.5; 4/2/51, 7.0.

12N/4E-1B1—Reference point—top of casing, elevation 58 feet, South side of Cornelius Avenue, 0.54 mile east of Pleasant Grove Road. 12/22/47, 21.7; 3/11/48, 20.0; 12/15/48, 21.4; 3/18/49, 20.3; 12/7/49, 26.2.

12N/4E-2B1—Reference point—hole in base of pump, elevation 53 feet, 0.05 mile south of Cornelius Avenue, 0.50 mile north of Pleasant Grove Road. 12/22/47, 19.8; 3/11/48, 21.8; 12/13/48, 27.2; 3/29/49, 20.8; 12/7/49, 26.2; 3/27/50, 22.1; 11/6/50, 30.9; 4/5/51, 24.0; 4/4/52, 24.0.

12N/4E-2Q1—Reference point—hole in base of pump, elevation 51 feet, 0.46 mile north of Trowbridge Road, 0.34 mile west of Pleasant Grove Road. 3/11/48, 15.7; 5/5/48, 13.3; 5/31/48, 14.7; 6/17/48, 35.2; 6/23/48, 38.0; 7/2/48, 20.3; 12/15/48, 17.9; 3/28/49, 11.6; 5/26/49, 19.5; 6/29/49, 20.9; 7/28/49, 21.7; 8/26/49, 21.2; 12/7/49, 19.0; 3/27/50, 15.4; 11/6/50, 23.9; 4/5/51, 15.5; 4/4/52, 13.2.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Mode by Division of Woter Resources
(Depths to woter in feet meosured from reference point)

12N/4E-3A1—Reference point—top of casing, elevation 52.4 feet. Southwest corner of intersection of Cornelius Avenue and Pleasant Grove Road. 3/11/48, 19.9; 12/14/48, 22.5; 3/29/49, 19.8; 12/7/49, 24.5.

12N/4E-3B1—Reference point—top of casing, elevation 49 feet. South side of Cornelius Avenue, 0.55 mile east of Pacific Avenue. 12/22/47, 21.4; 12/14/48, 23.7; 3/29/49, 19.9; 12/7/49, 24.2.

12N/4E-4A1—Reference point—top of casing, elevation 47 feet. Southwest corner of intersection of Cornelius Avenue and Pacific Avenue. 12/21/40, 19.1; 12/4/47, 24.5; 12/16/48, 26.0; 12/8/51, 31.4.

12N/4E-4A2—Reference point—top of casing, elevation 47 feet. 70.0 feet south of southwest corner of Cornelius Avenue and Pacific Avenue. 11/7/47, 23.7; 12/16/48, 24.8; 12/9/49, 26.0; 11/10/50, 30.0; 12/8/51, 29.8.

12N/4E-4D1—Reference point—top of casing, elevation 42 feet. 0.06 mile south of Cornelius Avenue, 0.12 mile east of Electric Avenue. 12/9/47, 24.1; 3/11/48, 24.2; 5/11/48, 22.4; 12/14/48, 24.9; 3/28/49, 23.4; 12/6/49, 25.8.

12N/4E-4M1—Reference point—top of casing, elevation 40 feet. 0.24 mile east of Electric Avenue, 0.25 mile north of Watts Avenue. 3/11/48, 21.9; 12/14/48, 24.6; 3/28/49, 21.8; 12/7/49, 24.8.

12N/4E-5B1—Reference point—top of wooden pit, elevation 38 feet. South side of Cornelius Avenue, 0.36 mile west of Electric Avenue. 12/9/47, 20.9; 3/11/48, 20.8; 12/14/48, 22.1; 3/28/49, 19.4; 12/6/49, 22.5.

12N/4E-6B1—Reference point—top of wooden pit, elevation 32 feet, 0.29 mile west, 0.14 mile south of west end of Cornelius Avenue. 12/8/47, 14.2; 3/25/48, 12.0; 12/18/48, 13.9; 3/28/49, 8.4; 12/7/49, 15.2.

12N/4E-6Q1—Reference point—top of casing, elevation 30 feet, 1.50 miles west of Electric Avenue, 0.18 mile north of Nicolaus Avenue. 12/8/47, 15.7; 3/25/48, 14.1; 3/16/49, 12.9; 12/6/49, 16.8.

12N/4E-6R1—Reference point—top of casing, elevation 36 feet, 0.22 mile north of Nicolaus Avenue, 1.16 miles west of Electric Avenue. 12/8/47, 6.8; 12/14/48, 7.5; 3/16/49, 4.7; 12/6/49, 8.7.

12N/4E-7B1—Reference point—hole in base of pump, elevation 30 feet. South side of Nicolaus Avenue, 1.41 miles west of Electric Avenue. 12/8/47, 14.8; 5/11/48, 9.8; 12/13/48, 14.5; 3/16/49, 11.4; 6/30/49, 15.0; 7/27/49, 17.1; 12/6/49, 15.8; 3/25/50, 11.1; 11/6/50, 16.5; 4/2/51, 6.6; 11/16/51, 15.7; 4/4/52, 5.5.

12N/4E-7N2—Reference point—bottom of 6" x 14" plank bridge over pit, elevation 30 feet, 0.41 mile southeast of Garden Highway, 0.19 mile southwest of Markham Road. 12/5/47, 14.6; 3/15/48, 12.8; 12/11/48, 14.3; 3/25/49, 10.8; 12/6/49, 15.0.

12N/4E-7P2—Reference point—top of wooden pit, elevation 28 feet, 0.67 mile southeast of Garden Highway, 0.06 mile southwest of Markham Road. 12/5/47, 11.1; 3/11/48, 13.0; 5/11/48, 11.1; 12/11/48, 14.2; 3/25/49, 11.0; 12/6/49, 15.0.

12N/4E-8A1—Reference point—top of casing, elevation 37 feet. South side of Nicolaus Avenue, 0.07 mile west of Electric Avenue. 12/8/47, 19.2; 3/11/48, 17.4; 12/14/48, 19.6; 3/16/49, 17.4; 12/6/49, 20.4.

12N/4E-8C1—Reference point—top of casing, elevation 36 feet, 0.05 mile south of Nicolaus Avenue, 0.50 mile west of Electric Avenue. 12/8/47, 18.6; 3/11/48, 17.3; 5/11/48, 16.0; 12/14/48, 19.0; 3/16/49, 17.1; 12/6/49, 20.2; 3/29/50, 17.0; 11/6/50, 23.1; 1/2/51, 13.8; 11/16/51, 22.2; 1/1/52, 13.1.

12N/4E-8D1—Reference point—hole in base of pump, elevation 32 feet, 0.16 mile south of Nicolaus Avenue, 0.80 mile west of Electric Avenue. 12/8/47, 20.8; 3/25/48, 18.2; 12/11/48, 22.0.

12N/4E-9A1—Reference point—top of casing, elevation 44 feet. West side of Pacific Avenue, 0.24 mile south of Nicolaus Avenue. 12/23/47, 19.4; 3/11/48, 18.1; 12/14/48, 20.9; 3/28/49, 16.6; 12/7/49, 20.3; 3/27/50, 17.5; 11/6/50, 27.6; 4/2/51, 16.7; 11/16/51, 26.0; 4/4/52, 16.6.

12N/4E-9D1—Reference point—hole in pump base, elevation 40 feet. South side of Nicolaus Avenue, 0.13 mile east of Electric Avenue. 3/11/48, 17.9; 12/14/48, 20.0; 3/28/49, 17.3; 5/25/49, 21.0; 6/29/49, 22.7; 7/27/49, 23.9; 8/31/49, 25.1; 12/7/49, 20.6; 3/27/50, 18.2; 11/6/50, 24.8; 4/2/51, 16.1; 11/16/51, 24.0; 4/4/52, 15.8.

12N/4E-9J1—Reference point—top of casing, elevation 42 feet, 0.11 mile west of Pacific Avenue, 0.53 mile south of Nicolaus Avenue. 3/11/48, 18.7; 12/14/48, 21.1; 3/28/49, 16.7; 12/7/49, 20.5.

12N/4E-9J2—Reference point—top of casing, elevation 42 feet, 0.13 mile west of Pacific Avenue, 0.53 mile south of Nicolaus Avenue. 3/11/48, 19.1; 12/14/48, 21.4; 3/28/49, 16.9; 12/7/49, 20.8.

12N/4E-10A1—Reference point—hole in base of pump, elevation 50 feet, 0.09 mile south of Nicolaus Avenue, 0.90 mile east of Pacific Avenue. 3/11/48, 17.4; 4/2/48, 15.8; 5/5/48, 15.6; 5/31/48, 17.0; 6/17/48, 42.5; 7/2/48, 23.2; 12/15/48, 20.0; 3/28/49, 14.1; 7/1/49, 46.7 (operating); 8/1/49, 47.0 (operating); 8/31/49, 46.8 (operating); 12/7/49, 20.6; 3/27/50, 15.3; 11/6/50, 26.1; 4/5/51, 17.5; 4/4/52, 17.5.

12N/4E-10C1—Reference point—top of casing, elevation 47 feet. South side of Nicolaus Avenue, 0.51 mile east of Pacific Avenue. 3/11/48, 18.6; 12/14/48, 21.3; 3/28/49, 16.6; 12/7/49, 21.1.

12N/4E-11H1—Reference point—hole in base of pump, elevation 46 feet, 0.04 mile south of Trowbridge Road, 0.20 mile west of Pleasant Grove Road. 11/19/51, 22.9.

12N/4E-12D1—Reference point—top of casing, elevation 52 feet. West side of Pleasant Grove Road, 0.24 mile north of Trowbridge Road. 12/22/47, 13.4; 3/11/48, 12.5; 12/14/48, 14.0; 3/28/49, 6.9; 12/7/49, 15.8.

12N/4E-13C1—Reference point—hole in base of pump, elevation 51 feet, 0.11 mile south of Marcum Road, 0.53 mile east of Pleasant Grove Road. 3/11/48, 13.4; 12/14/48, 14.3; 12/22/48, 12.6; 3/29/49, 9.3; 11/10/49, 18.0; 3/15/50, 13.9; 3/27/50, 13.8; 4/10/50, 13.4; 11/6/50, 19.6; 11/14/50, 19.9; 3/23/51, 12.3; 11/19/51, 23.5; 4/4/52, 14.6; 4/10/52, 14.6.

12N/4E-13D1—Reference point—top of casing, elevation 50 feet. Southeast of intersection of Pleasant Grove Road and Marcum Road. 12/22/47, 12.1; 3/11/48, 12.3; 12/14/48, 12.2; 3/29/49, 6.6; 2/7/49, 13.9.

12N/4E-14P1—Reference point—top of casing, elevation 43 feet, 1.72 miles south of Trowbridge Road, 0.53 mile west of Pleasant Grove Road. 3/11/48, 9.1; 12/18/48, 8.8; 3/29/49, 3.3; 12/7/49, 10.8; 3/27/50, 7.1; 11/6/50, 4.3; 4/5/51, 5.3; 4/4/52, 4.3.

12N/4E-16A2—Reference point—top of casing, elevation 40 feet, 0.07 mile west of Pacific Avenue, 1.30 miles south of Nicolaus Avenue. 12/23/47, 16.1; 3/11/48, 15.2; 5/11/48, 17.7; 12/14/48, 16.5; 3/28/49, 12.0; 3/27/50, 13.8; 11/6/50, 22.6; 4/2/51, 11.8; 11/16/51, 26.6; 4/4/52, 11.6.

12N/4E-16L1—Reference point—top of 16-inch casing, elevation 34 feet, 0.50 mile east of Electric Avenue, 0.60 mile south of Markham Road. 3/11/48, 13.1; 12/14/48, 12.9; 3/28/49, 8.7; 12/7/49, 16.1; 11/6/50, 19.9; 4/2/51, 8.4.

12N/4E-16L2—Reference point—top of casing, elevation 34 feet, 0.25 mile east of Electric Avenue, 0.50 mile south of Markham Road. 3/11/48, 11.0; 12/13/48, 21.6; 3/28/49, 7.2; 12/7/49, 13.9.

12N/4E-17C1—Reference point—top of 16-inch casing under pump, elevation 35 feet, 0.25 mile south of Markham Road, 0.50 mile west of Electric Avenue. 12/8/47, 16.5; 3/25/48, 15.0; 12/11/48, 16.1; 3/28/49, 13.1; 12/7/49, 17.5.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Divisian of Water Resaurces
(Depths to water in feet measured from reference paint)

12N/4E-17J1—Reference point—top of 16-inch casing, elevation 32 feet. 300 feet west of Electric Avenue, 0.52 mile south of Markham Road. 12/8/47, 13.0; 3/11/48, 12.6; 5/11/48, 12.6; 12/11/48, 13.2; 3/28/49, 9.1; 5/26/49, 14.2; 6/29/49, 15.7; 7/27/49, 16.4; 8/26/49, 17.2; 12/7/49, 15.3; 11/16/51, 18.2; 4/4/52, 6.1.

12N/4E-18A1—Reference point—top of 12-inch casing under pump, elevation 30 feet. 600 feet south of Markham Road, 0.50 mile east of Power Line Road. 12/5/47, 14.3; 3/11/48, 14.9; 12/11/48, 14.7; 3/28/49, 12.4; 12/7/49, 15.6; 3/29/50, 13.3; 11/6/50, 17.1; 4/2/51, 6.4; 11/16/51, 16.4; 4/4/52, —3.0.

12N/4E-18D1—Reference point—top of concrete pit wall, south side, elevation 30 feet, 0.56 mile southeast of Garden Highway, 300 feet southwest of road. 12/5/47, 16.2; 12/11/48, 15.9; 3/25/49, 13.1; 12/6/49, 16.5; 11/6/50, 18.1; 4/2/51, 6.4.

12N/4E-18P1—Reference point—bottom of 4" x 12" plank across wooden pit, elevation 25 feet, 0.27 mile west of Power Line Road, 460 feet north of Lee Road. 12/5/47, 13.4; 3/11/48, 12.2; 12/11/48, 15.2; 3/25/49, 10.8; 12/6/49, 13.9.

12N/4E-19A1—Reference point—top of 14-inch casing, elevation 28 feet, 0.44 mile east of junction of Power Line and Lee Roads. 12/5/47, 12.9; 3/15/48, 12.1; 12/11/48, 13.1; 3/28/49, 10.0; 12/6/49, 14.2; 3/29/50, 11.9; 11/6/50, 13.1; 4/2/51, 4.5; 11/16/51, 15.5.

12N/4E-19C1—Reference point—hole in pump base, elevation 25 feet, 100 feet south of Lee Road, 200 feet west of Power Line Road. 12/5/47, 15.6; 3/11/48, 14.3; 3/25/49, 11.8; 12/6/49, 14.8.

12N/4E-19F1—Reference point—top of casing, elevation 27 feet, 300 feet west of Power Line Road, 0.40 mile south of Lee Road. 12/20/47, 14.6; 3/4/48, 14.0; 12/15/48, 14.8; 3/31/49, 11.3; 12/5/49, 15.9.

12N/4E-20A1—Reference point—top of casing, elevation 30 feet, 150 feet east of Electric Avenue, 0.76 mile north of Striplin Road. 12/20/47, 12.6; 3/4/48, 12.5; 12/15/48, 13.8; 3/30/49, 8.1; 12/2/49, 19.3.

12N/4E-20J1—Reference point—slot in concrete base, elevation 30 feet, 100 feet west of Electric Avenue, 0.42 mile north of Striplin Road. 5/5/48, 11.9; 5/31/48, 63.0 (operating); 7/2/48, 62.0 (operating); 12/15/48, 12.8; 4/13/49, 8.5; 6/30/49, 31.4; 8/1/49, 57.0 (operating); 8/31/49, 56.0 (operating); 12/7/49, 16.6; 3/24/50, 12.3; 11/8/50, 19.6; 4/2/51, 8.2; 11/19/51, 19.0; 4/7/52, 5.7.

12N/4E-20Q1—Reference point—top of 14-inch casing, elevation 30 feet, 0.35 mile west of Electric Avenue on Striplin Road. 5/5/48, 9.9; 5/31/48, 16.2; 12/15/48, 10.8; 4/13/49, 7.0; 6/2/49, 20.6; 8/1/49, 47.6 (operating); 8/31/49, 62.0 (operating); 12/7/49, 14.9.

12N/4E-20R1—Reference point—slot in concrete base, elevation 30 feet, 100 feet west of Electric Avenue, 0.21 mile west of Striplin Road. 5/5/48, 12.4; 5/31/48, 42.0 (operating); 7/2/48, 43.0 (operating); 12/15/48, 13.3; 4/13/49, 9.6; 6/2/49, 28.9; 6/30/49, 33.3; 8/1/49, 52.0 (operating); 8/31/49, 66.0 (operating); 12/7/49, 18.6.

12N/4E-21M1—Reference point—top of 16-inch casing outside of pump house, elevation 32 feet, 0.25 mile east of Electric Avenue, 0.80 mile north of Striplin Road. 12/23/47, 12.4; 3/15/48, 12.4; 12/15/48, 12.8; 3/30/49, 6.7; 12/2/49, 17.9.

12N/4E-24A1—Reference point—top of 14-inch casing, elevation 56 feet, South side of Lee Road, 0.5 mile west of Power Line Road. 12/20/48, 16.5; 4/1/49, 13.4; 11/10/49, 21.8; 3/15/50, 18.0; 4/10/50, 17.8; 10/2/50, 29.5; 11/13/50, 23.8; 3/21/51, 17.8; 5/9/51, 26.6; 11/14/51, 27.9; 3/13/52, 21.1.

12N/4E-24F1—Reference point—top of 14-inch casing, elevation 49 feet, 0.50 mile east of Pleasant Grove Road, 0.75 mile north of Striplin Road. 5/31/48, 11.3; 12/18/48, 13.1; 3/29/49, 8.7; 12/2/49, 16.2; 4/10/50, 13.2; 11/13/50, 18.2; 3/21/51, 11.7; 11/16/51, 21.4.

12N/4E-24M1—Reference point—top of 14-inch casing, elevation 50.9 feet, 75 feet east of Pleasant Grove Road, 0.25 mile north of Striplin Road. 12/22/47, 12.9; 3/22/48, 13.1; 12/18/48, 14.2; 3/29/49, 9.2; 5/26/49, 14.0; 6/29/49, 19.4; 7/28/49, 17.6; 8/26/49, 18.0; 12/2/49, 17.2; 3/15/50, 14.4; 3/27/50, 14.6, 11/6/50, 18.8; 4/5/51, 12.1; 11/16/51, 20.9; 11/19/51, 20.9; 4/8/52, 12.5; 4/10/52, 12.2.

12N/4E-25F1—Reference point—top of 16-inch casing, elevation 50 feet, 0.50 mile east of Pleasant Grove Road, 0.44 mile south of Striplin Road. 11/16/51, 27.1.

12N/4E-25M1—Reference point—hole in pump base, elevation 51.3 feet, 250 feet east of Pleasant Grove Road, 0.70 mile south of Striplin Road. 12/22/47, 15.7, 3/22/48, 15.1; 12/18/48, 17.4; 3/29/49, 13.3; 12/2/49, 20.6; 3/27/50, 17.5; 11/8/50, 22.8; 4/5/51, 15.7; 11/19/51, 29.0; 4/8/52, 19.8.

12N/4E-26M1—Reference point—hole in pump base, elevation 41 feet, 0.75 mile west of Pleasant Grove Road, 1.0 mile north of Catlett Road. 3/22/48, 12.9; 12/18/48, 14.8; 3/29/49, 10.6; 12/2/49, 18.5; 11/8/50, 19.4; 4/5/51, 12.7; 4/8/52, 11.3.

12N/4E-28F1—Reference point—hole in pump base, elevation 32 feet, 0.50 mile west of Pacific Avenue, 0.36 mile south of Striplin Road. 3/15/48, 11.0; 12/18/48, 12.5.

12N/4E-28H1—Reference point—hole in top of discharge pipe, elevation 36 feet. West of Pacific Avenue, 0.36 mile south of Striplin Road. 12/22/47, 11.1; 3/15/48, 11.0; 12/18/48, 11.2; 3/24/50, 11.1; 11/8/50, 15.7; 4/2/51, 8.1; 11/19/51, 11.9; 4/7/52, 8.0.

12N/4E-29A1—Reference point—north side base of pump, elevation 31 feet, 200 feet south of Striplin Avenue, 450 feet west of Electric Avenue. 12/18/47, 12.3; 3/14/48, 12.7; 12/15/48, 11.7; 3/30/49, 6.2; 12/2/49, 17.6; 3/24/50, 12.4; 11/8/50, 18.2; 4/2/51, 9.4; 11/19/51, 19.9; 4/7/52, 4.9.

12N/4E-29R1—Reference point—pump base at hole in concrete, elevation 30 feet, 300 feet west of Electric Avenue, 0.75 mile north of Catlett Road. 12/18/47, 10.2; 3/4/48, 10.8; 12/5/49, 20.8; 3/24/50, 8.0; 11/8/50, 13.5; 4/2/51, 5.6; 11/19/51, 14.0; 4/7/52, 3.9.

12N/4E-30F1—Reference point—pump base, elevation 25 feet, 100 feet east of Power Line Road, 0.50 mile south of Striplin Road. 12/20/47, 11.1; 3/4/48, 10.4; 12/15/48, 11.8; 3/30/49, 4.9; 12/5/49, 12.2; 3/27/50, 8.1; 11/8/50, 10.6; 4/2/51, 3.7; 11/16/51, 10.9; 4/8/52, 4.8.

12N/4E-32K1—Reference point—top of 16-inch casiug, elevation 28 feet, 1,500 feet west of Electric Avenue, 0.52 mile north of West Catlett Road. 3/30/49, 3.2.

12N/4E-33E1—Reference point—top of 18-inch casing, elevation 30 feet, 150 feet north of Catlett Road, 1,000 feet east of Electric Avenue. 3/15/48, 10.6; 12/18/48, 10.4.

12N/4E-33L3—Reference point—top of casing, elevation 31 feet. At dwelling south side of road, 300 feet east of Catlett Station, Sacramento Northern Railroad. 11/8/29, 15.4; 9/28/30, 16.0; 12/10/31, 16.4; 12/5/32, 12.2; 12/20/33, 15.6; 9/27/34, 16.3; 11/23/36, 12.5; 11/24/37, 9.4; 1/10/39, 8.9; 1/13/41, 3.4; 11/10/47, 11.5; 12/16/48, 11.0; 12/9/49, 13.4; 11/10/50, 13.0; 12/6/51, 12.0.

12N/4E-33R1—Reference point—top of 8-inch casing, elevation 31 feet, 100 feet west of Pacific Avenue, 0.32 mile south of Catlett Road. 12/22/47, 11.2; 3/18/48, 10.9; 12/18/48, 11.9; 3/30/49, 6.0; 12/2/49, 13.2; 3/24/50, 9.3; 11/8/50, 12.7; 4/2/51, 7.9; 11/19/51, 13.9; 4/8/52, 5.1.

12N/4E-34J1—Reference point—top of 4-inch casing, elevation 36 feet. Windmill 100 feet south of Catlett Road, 1.0 mile east of Pacific Avenue. 12/22/47, 14.8; 3/22/48, 13.7; 12/18/48, 15.9; 3/29/49, 9.8; 12/2/49, 17.9; 3/27/50, 13.8; 11/8/50, 16.7; 4/5/51, 10.2; 11/19/51, 22.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Mode by Division of Woter Resources
(Depths to woter in feet meosured from reference point)

12N 4E-35H1—Reference point—top of 16-inch casing, elevation 48.8 feet, 0.1 mile west of Pleasant Grove Road, 0.2 mile north of Catlett Road. 12/22/47, 13.3; 3/22/48, 12.0; 12/18/48, 15.2; 3/29/49, 12.0; 12/2/49, 18.3; 3/27/50, 16.4; 11/8/50, 20.1; 4/5/51, 13.3; 5/10/51, 16.7; 7/11/51, 25.1; 8/22/51, 28.2; 9/26/51, 27.3; 11/16/51, 22.2; 11/19/51, 24.7; 4/8/52, 15.2; 4/10/52, 13.6.

12N 4E-36Q1—Reference point—top of casing in bottom of pit, elevation 48 feet, ground surface, 0.47 mile south of Catlett Road, 0.63 mile east of Pleasant Grove Road. 4/11/51, 22.0; 11/16/51, 28.9.

12N 5E-18P1—Reference point—top of 14-inch casing, elevation 61 feet, 0.50 mile west of Brewer Road, 1.0 mile south of Mareum Road. 3/22/48, 15.4.

13N 3E-2C1—Reference point—top of air gage hole, elevation 42.7 feet, 50 feet west of Garden Highway, 0.25 mile north of Tudor Road. 11/13/47, 25.6; 3/24/48, 21.0; 3/29/48, 19.7; 11/10/48, 20.4; 1/24/49, 19.2; 3/23/49, 16.9; 6/30/49, 30.3; 7/27/49, 29.0; 8/25/49, 25.2; 12/6/49, 21.2; 3/29/50, 17.5; 11/7/50, 23.1; 3/25/51, 12.2; 11/15/51, 22.6; 4/3/52, 9.1.

13N 3E-2H1—Reference point—hole in pump base, elevation 43.4 feet, 150 feet south of Shannon Road, 0.5 mile east of Garden Highway. 11/13/47, 21.4; 3/8/48, 19.4; 11/10/48, 18.0; 3/23/49, 14.5; 12/6/49, 19.5; 3/29/50, 13.4; 11/7/50, 19.0; 3/29/51, 12.2; 11/15/51, 18.3; 4/3/52, 6.2.

13N 3E-2L1—Reference point—top of 10-inch casing, elevation 41.2 feet, 0.5 mile west of Garden Highway, 0.1 mile south of Tudor Road. 1/19/48, 18.3; 5/6/48, 15.9; 6/1/48, 15.1; 6/3/48, 25.8; 8/2/48, 16.1; 9/1-48, 21.8; 3/23/49, 16.9.

13N 3E-2P1—Reference point—hole in pump base, elevation 39.9 feet, 200 feet west of Garden Highway, 0.3 mile south of Tudor Road. 11/13/47, 19.9; 3/8/48, 26.0; 11/10/48, 18.0; 3/23/48, 15.9; 12/6/49, 19.8.

13N 3E-3D1—Reference point—hole in pump base, elevation 38.9 feet, 50 feet east of State Highway 24, 0.3 mile north of Tudor Road. 11/14/47, 20.9; 3/8/48, 20.8; 3/29/48, 19.5; 11/10/48, 21.1; 1/24/49, 19.7; 3/25/49, 18.1; 6/1/49, 28.6; 6/28/49, 25.4; 7/29/49, 32.3; 8/30/49, 26.1; 12/6/49, 23.3.

13N 3E-3F1—Reference point—hole in pump base, elevation 38.9 feet, 0.15 mile north of Tudor Road, 0.4 mile east of State Highway 24. 11/14/47, 20.8; 3/18/48, 22.9; 11/10/48, 21.3; 3/25/49, 19.2; 12/6/49, 23.4; 3/29/50, 20.6; 11/7/50, 24.6; 3/29/51, 19.0; 11/15/51, 22.9; 4/3/52, 9.0.

13N 3E-4B1—Reference point—top of wood pit east edge, elevation 36 feet, 0.45 mile west of State Highway 24, 0.4 mile north of Tudor Road. 11/14/47, 18.1; 3/8/48, 14.8; 11/10/48, 20.7; 3/25/49, 17.5; 12/6/49, 23.1.

13N 3E-4P1—Reference point—top of 12-inch casing, elevation 34.7 feet, 0.05 mile west of Hobbs Road, 0.3 mile south of Tudor Road. 12/12/47, 14.6; 3/10/48, 14.7; 3/12/48, 14.6; 11/18/48, 16.5; 3/24/49, 13.8; 3/29/50, 15.9.

13N 3E-4P2—Reference point—top of casing, elevation 34 feet, 100 feet west of Hobbs Road, 0.4 mile south of Tudor Road. 11/7/50, 22.9; 3/29/51, 15.8.

13N 3E-5B1—Reference point—top of 4" x 12" plank bridge over earth pit, elevation 39.1 feet, 50 feet east of Bailey Road, 750 feet south of Tudor Road. 12/12/47, 14.3; 3/10/48, 16.9; 3/12/48, 17.1; 3/29/48, 16.7; 11/8/48, 18.3; 3/24/49, 15.4; 12/5/49, 18.6.

13N 3E-5E1—Reference point—top of 2" x 6" sill, north wall of wooden pit, elevation 38.1 feet, 300 feet east of George Washington Boulevard, 1,000 feet north of Tudor Road. 12/12/47, 14.2; 3/10/48, 11.8; 11/8/48, 13.0; 3/24/49, 12.5; 3/29/50, 12.5; 11/7/50, 17.8; 3/29/51, 13.1; 11/15/51, 15.8; 4/3/52, 10.1.

13N 3E-5J1—Reference point—top of 16-inch casing, elevation 27 feet, 0.1 mile south of Tudor Road, 0.5 mile west of Hobbs Road. 12/12/47, 13.7; 3/10/48, 12.8; 3/12/48, 12.8; 12/5/49, 17.0.

13N 3E-5L1—Reference point—top of 12-inch casing, elevation 37.4 feet, 50 feet south of State Highway 24, 650 feet west of Bailey Road. 12/12/47, 15.6; 3/10/48, 15.6; 3/12/48, 15.6; 5/12/48, 15.1; 11/8/48, 16.3; 1/19/49, 14.8; 3/24/49, 14.9; 6/1/49, 16.7; 6/28/49, 21.2; 7/27/49, 22.0; 8/25/49, 20.4; 12/2/49, 17.3.

13N 3E-6K1—Reference point—top of 16-inch casing, elevation 34 feet, South side of Tudor Road, 0.5 mile west of George Washington Boulevard. 12/15/48, 9.0; 12/9/49, 9.7; 11/10/50, 12.7; 12/6/51, 13.3.

13N 3E-6M1—Reference point—top of 12-inch casing, elevation 34 feet, 400 feet south of Tudor Road, 0.34 mile east of Roberts Road. 12/11/47, 9.9; 3/10/48, 8.2; 3/12/48, 8.3; 11/8/48, 6.2; 3/24/49, 6.6; 12/2/49, 9.0.

13N 3E-7A1—Reference point—top of casing, 20 feet north of pump house, elevation 35.2 feet, 250 feet south of Thompson Road, 300 feet west of State Highway 24. 12/12/47, 10.8; 3/10/48, 11.1; 3/12/48, 11.2; 11/8/48, 11.7; 3/24/49, 10.5; 12/2/49, 12.3.

13N 3E-7J1—Reference point—top of 8-inch casing, elevation 35.1 feet, 0.45 mile north of Everglade Road, 0.15 mile west of George Washington Boulevard, 250 feet south to well. 12/11/47, 9.7; 3/10/48, 10.5; 3/12/48, 10.7; 11/3/48, 12.0; 1/24/49, 11.7; 3/24/49, 10.3; 12/2/49, 12.8.

13N 3E-8B1—Reference point—top of 16-inch casing, elevation 35 feet, 0.05 mile south of Thompson Road, 0.8 mile west of Hobbs Road. 12/12/47, 10.8; 3/10/48, 13.9; 3/12/48, 14.0; 11/18/48, 15.1; 3/25/49, 13.0; 12/5/49, 17.1.

13N 3E-8M1—Reference point—top of wood floor under pump, elevation 35.9 feet, 0.2 mile east of George Washington Boulevard, 0.7 mile south of Thompson Road. 12/11/47, 10.3; 3/10/48, 10.8; 3/12/48, 10.8; 11/8/48, 13.1; 3/24/49, 11.0; 12/2/49, 13.8.

13N 3E-9C1—Reference point—hole in pump base, elevation 36.2 feet, 150 feet west of Hobbs Road, 0.60 mile south of State Highway 24. 12/12/47, 15.4; 3/10/48, 15.8; 3/12/48, 15.7; 11/8/48, 17.7; 1/24/49, 16.3; 3/24/49, 14.8; 6/1/49, 19.1; 6/28/49, 20.9; 7/27/49, 21.8; 8/30/49, 22.4; 12/5/49, 19.8.

13N 3E-9H1—Reference point—top of east wall of concrete pit, elevation 35 feet, 200 feet west of Sawtelle Avenue, 0.57 mile south of Tudor Road. 12/12/47, 16.8; 3/10/48, 17.9; 3/17/48, 18.0; 11/8/48, 19.2; 3/24/49, 16.3.

13N 3E-11A1—Reference point—hole in pump base, elevation 40 feet, 350 feet north of O'Conner Road, 0.55 mile east of Garden Highway. 11/13/47, 20.1; 3/8/48, 20.8; 11/10/48, 19.0; 1/24/49, 18.6; 3/23/49, 15.5; 12/5/49, 20.7.

13N 3E-11L1—Reference point—top of casing, elevation 38 feet, 0.05 mile west of Garden Highway, 1.1 miles south of Tudor Road. 11/14/47, 16.4.

13N 3E-11M1—Reference point—top of casing, elevation 36 feet, 0.4 mile west of Garden Highway, 0.2 mile north of Wilkie Avenue. 1/20/48, 17.5.

13N 3E-11Q2—Reference point—hole in pump base, elevation 39.3 feet, 50 feet west of Garden Highway, 0.15 mile south of Wilkie Avenue. 11/19/47, 16.5; 3/9/48, 19.8; 5/11/48, 13.4; 11/4/48, 16.1; 1/19/49, 15.3; 3/8/49, 14.8; 6/1/49, 17.2; 6/29/49, 23.9; 8/3/49, 23.7; 8/25/49, 19.1; 12/8/49, 17.2.

13N 3E-12L1—Reference point—hole in pump base, elevation 41 feet, 300 feet north of Wilkie Avenue, 0.7 mile east of Garden Highway. 11/14/47, 18.2; 3/8/48, 19.0; 11/10/48, 16.7; 3/23/49, 12.1; 12/5/49, 17.9; 11/7/50, 17.1; 3/29/51, 11.3; 11/15/51, 16.3; 4/3/52, 6.9.

13N 3E-12N1—Reference point—top of casing, elevation 39.5 feet, 0.2 mile south of Wilkie Avenue, 0.45 mile east of Garden Highway. 11/19/47, 15.4; 3/9/48, 18.2; 5/12/48, 10.3; 11/4/48, 16.3; 3/8/49, 13.7; 12/8/49, 16.2.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

13N/3E-13C1—Reference point—hole in pump base, elevation 42.3 feet, 0.7 mile east of Garden Highway, 0.25 mile south of Wilkie Avenue. 11/19/47, 16.9; 3/9/48, 20.3; 11/4/48, 17.0; 3/8/49, 13.8; 12/8/49, 17.9; 3/29/50, 10.8; 11/7/50, 17.1; 3/29/51, 16.7; 11/15/51, 16.7; 4/2/52, 7.3.

13N/3E-13D1—Reference point— edge of pump base, elevation 39 feet, 0.55 mile east of Garden Highway, 0.25 mile south of Wilkie Avenue. 5/5/48, 9.4; 6/1/48, 9.3; 2/6/52, 6.0.

13N/3E-13E1—Reference point—hole in pump base, elevation 37 feet, 0.5 mile east of Garden Highway, 0.75 mile south of Wilkie Avenue. 11/19/47, 15.4; 3/25/48, 14.7; 11/4/48, 15.1; 3/8/49, 13.3; 12/8/49, 15.9.

13N/3E-13L1—Reference point—top of casing, elevation 38 feet, 0.75 mile east of Garden Highway, 0.95 mile south of Wilkie Avenue. 11/19/47, 15.5; 3/9/48, 19.0; 11/4/48, 14.1; 3/8/49, 13.3; 12/7/49, 16.0.

13N/3E-14C1—Reference point—hole in pump base, elevation 35 feet, 0.25 mile west of Garden Highway, 0.35 mile south of Wilkie Avenue. 11/26/29, 15.4; 9/27/30, 15.6; 12/12/31, 15.4; 12/2/32, 15.2; 12/20/33, 16.3; 11/10/34, 16.7; 11/25/36, 13.4; 11/24/37, 11.8; 1/25/39, 10.8; 1/13/41, 8.2; 11/6/47, 15.3; 11/19/47, 15.9; 5/12/48, 13.9; 11/4/48, 15.7; 12/16/48, 14.7; 3/8/49, 14.9; 12/8/49, 16.6; 12/9/49, 16.0; 11/10/50, 16.0; 12/6/51, 13.4.

13N/3E-14G1—Reference point—hole in pump base, elevation 30.8 feet, 50 feet west of Garden Highway, 0.65 mile south of Wilkie Avenue. 3/25/48, 8.8; 11/4/48, 8.9; 3/8/49, 7.9; 12/8/49, 9.9; 3/29/50, 7.5; 11/7/50, 10.3; 3/39/51, 6.7; 11/15/51, 8.9; 4/2/52, 0.2.

13N/3E-14L3—Reference point—hole in pump base, elevation 34.9 feet, 50 feet south of Wilson Road, 0.1 mile west of Garden Highway. 11/19/47, 12.1; 3/25/48, 12.2; 11/4/48, 10.2; 3/8/49, 10.9; 12/7/49, 13.0; 4/2/52, 3.8.

13N/3E-14M2—Reference point—hole in pump base, elevation 35.7 feet, 0.1 mile south of Wilson Road, 0.4 mile west of Garden Highway. 11/19/47, 16.9; 3/9/48, 16.2; 11/5/48, 14.1; 3/8/49, 12.9; 12/7/49, 14.8.

13N/3E-14P1—Reference point—top of casing, elevation 35.6 feet, 0.25 mile west of Garden Highway, 0.4 mile south of Wilson Road. 11/19/47, 11.1; 3/9/48, 14.1; 11/4/48, 12.9; 3/8/49, 11.7; 12/7/49, 13.8.

13N/3E-14Q1—Reference point—top of casing, elevation 35.1 feet, 350 feet west of Garden Highway, 0.45 mile south of Wilson Road. 11/19/47, 14.9; 3/8/49, 11.0; 12/7/49, 12.8.

13N/3E-14R1—Reference point—hole in pump base, elevation 38.4 feet, 0.4 mile east of Garden Highway, 1.0 mile south of Wilkie Avenue. 11/19/47, 15.9; 3/9/48, 17.8; 11/4/48, 14.2; 3/8/49, 12.5; 12/7/49, 14.8.

13N/3E-15C2—Reference point—top of casing, elevation 36.1 feet, 0.3 mile north of Wilson Road, 100 feet west of Southern Pacific Railroad tracks. 12/18/47, 15.1; 3/11/48, 15.6; 11/4/48, 18.2; 3/16/49, 15.0.

13N/3E-15H1—Reference point—top of wooden pit, north side, elevation 37.8 feet, 0.2 mile north of Wilson Road, 0.6 mile west of Garden Highway. 12/18/47, 16.2; 3/11/48, 17.8; 11/4/48, 17.0; 3/8/49, 15.5.

13N/3E-15P1—Reference point—bottom of 2" x 12" over pit, elevation 34.0 feet, 0.25 mile east of Sawtelle Avenue, 100 feet southeast of most southerly corner of Wilson Road. 12/18/47, 13.2; 3/11/48, 13.0; 11/4/48, 6.7; 3/8/49, 12.9; 12/7/49, 14.7; 3/29/50, 12.8. Well destroyed.

13N/3E-15Q1—Reference point—top of casing, elevation 37 feet, 0.15 mile east of Southern Pacific Railroad tracks, 0.5 mile south of Wilson Road. 3/11/48, 13.2; 11/4/48, 13.6; 3/16/49, 11.7; 12/7/49, 13.1.

13N/3E-15R1—Reference point—top of plug in "T" discharge pipe, elevation 36 feet, 0.65 mile west of Garden Highway, 0.5 mile south of Wilson Road. 3/11/48, 14.5; 11/4/48, 13.6; 3/16/49, 13.2; 12/7/49, 14.3.

13N/3E-16A1—Reference point—top of casing, elevation 35 feet. South of Everglade Road, west of Sawtelle Avenue at intersection. 12/12/47, 15.7; 3/10/48, 14.7; 3/12/48, 14.7; 11/8/48, 17.1; 3/25/49, 14.6; 12/5/49, 16.3; 3/29/50, 15.1; 11/7/50, 17.0; 3/29/51, 11.7; 11/15/51, 15.4; 4/3/52, 9.5.

13N/3E-16H1—Reference point—hole in pump base, elevation 36.8 feet, 0.25 mile south of Everglade Road on west side of Sawtelle Ave. 12/18/47, 16.6; 3/4/48, 17.8; 11/4/48, 18.7; 1/24/49, 16.5; 3/8/49, 15.7; 12/7/49, 18.2.

13N/3E-16R1—Reference point—hole in pump base, elevation 38.1 feet, 60 feet west of Sawtelle Avenue, 0.9 mile south of Everglade Road. 12/18/47, 16.4; 3/11/48, 17.3; 11/4/48, 16.3; 3/16/49, 15.2; 12/7/49, 17.7; 3/29/50, 14.7; 11/7/50, 15.2; 3/29/51, 10.8; 11/15/51, 14.0; 4/2/52, 8.0.

13N/3E-17A1—Reference point—top of casing, elevation 31 feet, 0.1 mile south of Everglade Road, 0.9 mile east of George Washington Boulevard. 12/18/47, 9.4; 3/11/48, 9.8; 11/4/48, 8.3; 3/16/49, 6.6; 12/7/49, 10.3.

13N/3E-17B1—Reference point—top of casing, elevation 34.1 feet, 260 feet south of Everglade Road, 0.7 mile east of George Washington Boulevard. 12/12/47, 6.7; 3/10/48, 8.1; 3/12/48, 8.1; 11/8/48, 12.2; 12/5/49, 12.0.

13N/3E-17D1—Reference point—top of casing, elevation 30 feet. South side of Everglade Road, 0.2 mile east of George Washington Boulevard. 12/18/47, 7.9; 3/11/48, 8.7. Well destroyed.

13N/3E-18A1—Reference point—top of casing, elevation 30 feet, 0.25 mile south of Everglade Road, 0.2 mile west of George Washington Boulevard. 12/18/47, 10.2; 3/11/48, 10.7; 11/4/48, 10.7. Well destroyed.

13N/3E-23B1—Reference point—top of concrete pit, elevation 34 feet, 0.1 mile east of Garden Highway, 0.15 mile north of Central Avenue. 11/19/47, 12.3; 3/25/48, 12.3; 11/4/48, 11.9; 3/8/49, 11.2; 12/7/49, 12.7.

13N/3E-23D1—Reference point—top of concrete, elevation 38.3 feet, 0.4 mile west of Garden Highway, 0.25 mile north of Central Avenue. 11/19/47, 14.8; 3/9/48, 16.7; 5/11/48, 13.0; 11/4/48, 16.0; 3/8/49, 14.6.

13N/3E-23F1—Reference point—hole in pump base, elevation 34 feet, 0.15 mile west of Garden Highway, 0.1 mile south of Central Avenue. 11/20/47, 12.8; 3/10/48, 15.1; 11/4/48, 13.7; 3/8/49, 11.3; 12/7/49, 13.1.

13N/3E-23L1—Reference point—hole in pump base, elevation 35 feet, 0.15 mile west of Garden Highway, 0.4 mile south of Central Avenue. 11/20/47, 13.3; 3/10/48, 16.0; 5/11/48, 11.0; 11/4/48, 13.7; 1/24/49, 13.6; 3/8/49, 12.7; 6/7/49, 16.3; 6/29/49, 17.2; 7/27/49, 16.9; 8/25/49, 17.8; 12/7/49, 14.6; 3/29/50, 12.2; 11/7/50, 14.1; 3/29/51, 9.4; 11/15/51, 11.6; 4/2/52, 6.0.

13N/3E-24C2—Reference point—bottom of pump base, elevation 39.6 feet, 0.25 mile north of Central Avenue, 0.8 mile east of Garden Highway. 11/20/47, 15.4; 3/9/48, 16.0; 11/4/48, 14.7; 3/8/49, 13.1; 3/29/50, 11.5; 11/7/50, 15.3; 3/29/51, 7.6; 11/16/51, 14.6; 4/2/52, 7.6.

13N/3E-24D1—Reference point—hole in concrete base, elevation 36.5 feet, 0.45 mile east of Garden Highway, 0.45 mile south of Wilson Road. 11/19/49, 12.2; 3/25/48, 11.9; 5/11/48, 9.1; 11/4/48, 11.9; 3/8/49, 10.6; 6/1/49, 12.0; 8/25/49, 15.4; 12/7/49, 13.1

13N/3E-24E1—Reference point—top of casing, elevation 35 feet, 0.2 mile south of Central Avenue, 0.6 mile east of Garden Highway. 11/20/47, 10.8; 3/9/48, 11.4; 11/5/48, 11.4.

13N/3E-24G1—Reference point—top of casing, elevation 39 feet, 100 feet south of Central Avenue, 1.05 miles east of Garden Highway. 11/20/47, 24.2; 3/9/48, 18.9; 11/4/48, 20.7; 1/24/49, 18.8; 3/8/49, 17.1; 12/7/49, 19.9.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

13N/3E-25N1—Reference point—top of casing, elevation 35 feet, 200 feet north of Oak Avenue, 0.7 mile east of Garden Highway. 11/20/47, 10.9; 3/10/48, 11.9; 11/4/48, 9.3; 1/24/49, 9.3; 3/8/49, 7.6; 12/7/49, 11.0.

13N/3E-26J1—Reference point—top of casing, elevation 35 feet, 300 feet south of Cypress Avenue, 0.4 mile east of Garden Highway. 11/20/47, 9.2; 3/10/48, 9.9.

13N/3E-35H1—Reference point—hole in casing, elevation 32 feet, 0.1 mile north of Laurel Avenue, 0.45 mile east of Garden Highway. 11/20/47, 9.7; 3/10/48, 8.0; 11/4/48, 8.8; 1/24/49, 9.0; 3/8/49, 7.0; 12/7/49, 10.4.

13N/3E-36N1—Reference point—top of 2" x 4" at top of west side of pit, elevation 33 feet, 0.3 mile south of Laurel Avenue, 0.55 mile east of Garden Highway. 12/5/47, 11.9; 3/10/48, 12.2; 5/11/48, 7.0; 12/11/48, 11.6; 3/16/49, 8.2; 12/6/49, 12.8; 3/29/50, 7.7; 11/3/50, 12.0; 4/3/51, 5.2; 11/16/51, 10.2; 4/4/52, 3.6.

13N/4E-1P1—Reference point—top of 14-inch casing, elevation 62 feet, 100 feet west of farm road, 1.1 miles south of Dairy Road. 11/28/47, 18.8.

13N/4E-1Q1—Reference point—bottom of slot inside of casing by air line, elevation 63.2 feet, 800 feet east of farm road, 1.1 miles south of Dairy Road. 11/28/47, 19.4; 2/11/48, 17.5; 2/21/48, 18.1; 3/29/48, 17.4; 5/5/48, 15.2; 6/3/48, 17.9; 7/2/48, 66.0 (operating); 11/12/48, 21.0; 3/24/49, 17.0; 11/28/49, 24.2.

13N/4E-2A1—Reference point—top of 12-inch casing, bottom of pit, elevation 52 feet, Ground elevation 66 feet, 300 feet south of Dairy Road, 2.2 miles southwest of U. S. Highway 99E. 11/28/47, 13.4; 3/2/48, 11.0; 11/12/48, 14.8; 3/25/49, 11.3; 11/23/49, 17.3; 3/28/50, 14.3; 11/8/50, 19.1; 4/4/51, 12.8; 11/30/51, 29.4.

13N/4E-2C1—Reference point—top of 14-inch casing, elevation 64 feet, West of Pleasant Grove Road (Forty Mile Road) about 1.5 miles southeast of Plumas School. 11/28/47, 28.0; 3/1/48, 26.2; 3/22/48, 28.3; 3/29/48, 26.4; 5/5/48, 24.5; 8/13/48, 78.8 (operating); 11/8/48, 29.4; 1/25/49, 27.7; 3/25/49, 26.1; 11/23/49, 31.8.

13N/4E-2K1—Reference point—lower left hole in pump base, elevation 66 feet, 100 feet southeast of Leach Road, 200 feet west of Pleasant Grove Road (Forty Mile Road). 11/29/47, 29.0; 3/1/48, 26.6; 4/8/48, 29.9; 3/25/49, 26.7; 11/23/49, 26.7; 3/28/50, 32.3; 11/6/50, 34.0; 4/3/51, 26.9; 11/30/51, 33.1; 4/1/52, 30.9.

13N/4E-3F1—Reference point—top of concrete pit, elevation 57 feet, West of Hoffman Road, 1.4 miles south of Plumas School. 11/8/48, 30.1.

13N/4E-3G1—Reference point—slot in side of casing, elevation 58 feet, East of Hoffman Road, 1.4 miles south of Plumas School. 11/28/47, 25.6; 11/8/48, 27.0; 11/25/49, 28.7; 3/28/50, 26.0; 11/6/50, 30.4; 4/4/51, 26.0; 12/5/51, 32.8; 4/1/52, 25.9.

13N/4E-4J1—Reference point—top of casing, bottom of pit, elevation 47 feet, ground elevation 52.0 feet, 250 feet west of farm road, 0.75 mile north of Leach Road. 11/29/47, 18.3; 3/1/48, 16.8; 11/8/48, 20.5; 3/25/49, 15.9; 11/26/49, 21.1.

13N/4E-4J2—Reference point—hole in side of casing, elevation 52 feet, 100 feet west of farm road, 0.75 mile north of Leach Road. 11/8/48, 26.1; 3/25/49, 21.1; 11/26/49, 26.0.

13N/4E-7E1—Reference point—hole in pump base, elevation 39 feet, 0.05 mile west of Feather River Boulevard, 2.9 miles south of Country Club Avenue. 11/17/47, 14.3; 3/9/48, 13.1; 5/5/48, 9.1; 5/31/48, 9.1; 7/2/48, 42.0 (operating); 8/1/48, 49.1 (operating); 9/2/48, 44.0 (operating); 9/30/48, 13.5; 11/10/48, 13.9; 1/21/49, 13.8; 3/22/49, 10.8; 6/1/49, 10.8; 6/29/49, 12.8; 7/28/49, 14.2; 8/26/49, 15.8; 12/2/49, 15.3; 3/29/50, 9.7; 11/6/50, 11.7; 3/30/51, 7.8; 11/16/51, 13.7; 4/1/52, 5.5.

13N/4E-9A1—Reference point—top of 14-inch casing, elevation 52 feet, West of farm road, 0.45 mile north of Leach Road. 11/29/47, 19.8; 3/1/48, 17.9; 11/8/48, 20.5; 3/25/49, 17.0; 11/26/49, 22.1; 3/28/50, 19.0; 11/6/50, 23.0; 4/3/51, 16.4; 12/6/51, 22.4; 4/1/52, 18.0.

13N/4E-9R1—Reference point—top of casing, elevation 50 feet, 0.30 mile south of Leach Road. 11/8/48, 21.4; 3/25/49, 17.2; 11/26/49, 24.1; 3/28/50, 18.7; 11/6/50; 25.4; 4/4/51, 14.8; 12/5/51, 23.0; 4/1/52, 14.9.

13N/4E-10D1—Reference point—top of 14-inch casing, elevation 54 feet, 0.25 mile east of farm road, 0.50 mile north of Leach Road. 11/29/47, 25.0; 3/1/48, 23.0; 11/8/48, 26.5; 3/25/49, 22.4; 11/26/49, 27.4; 4/1/52, 24.6.

13N/4E-10J1—Reference point—slot in side of casing, elevation 55 feet, 200 feet south of Leach Road. 11/8/48, 25.6; 3/25/49, 23.0; 11/26/49, 27.6; 3/28/50, 23.5; 11/6/50, 29.6; 4/3/51, 21.5; 4/1/52, 21.0.

13N/4E-11J1—Reference point—bottom of slot in top of casing, elevation 61.3 feet, 200 feet west of Pleasant Grove Road, 0.75 mile north of Four Corners. 12/2/47, 19.6; 2/11/48, 17.8; 2/21/48, 17.7; 3/8/48, 26.5; 3/22/48, 26.4; 3/29/48, 17.8; 5/5/48, 16.0; 6/3/48, 17.8; 9/30/48, 27.2; 11/15/48, 21.2; 1/26/49, 19.5; 3/31/49, 18.3; 12/2/49, 23.6; 3/29/50, 19.6; 11/8/50, 25.5; 4/3/51, 18.6; 11/20/51, 24.4; 4/4/52, 15.7.

13N/4E-12C2—Reference point—top of flange in bottom of pit, elevation 44 feet, Ground elevation 55 feet, 1,000 feet north of Wheatland-Rio Oso Road, 0.45 mile east of Pleasant Grove Road (Forty Mile Road). 11/25/47, 9.2; 2/11/48, 6.9; 2/21/48, 6.0; 3/29/48, 4.8; 11/12/48, 10.5; 3/24/49, 5.5; 6/6/49, 14.0; 7/1/49, 17.4; 8/1/49, 21.6; 8/31/49, 45.0 (operating); 11-26-49, 13.4.

13N/4E-12E1—Reference point—top of 14-inch casing, elevation 60 feet, 150 feet west of Wheatland-Rio Oso Road, 300 feet east of Pleasant Grove Road (Forty Mile Road). 11/29/47, 18.9.

13N/4E-12E2—Reference point—bottom of slot in top of 14-inch casing, elevation 60.8 feet, 100 feet west of Wheatland-Rio Oso Road, 400 feet east of Pleasant Grove Road (Forty Mile Road). 11/29/47, 18.5; 2/11/48, 16.2; 2/21/48, 16.0; 3/2/48, 16.6; 3/11/48, 16.6; 3/29/48, 14.9; 5/18/48, 13.2; 11/12/48, 19.7; 3/24/49, 15.2; 11/23/49, 24.5; 3/29/50, 16.6; 11/8/50, 23.0; 4/3/51, 14.0; 12/3/51, 24.2; 4/2/52, 10.8.

13N/4E-12G1—Reference point—hole in pump base, elevation 65 feet, North of Wheatland-Rio Oso Road, 0.85 mile east of Pleasant Grove Road (Forty Mile Road). 11/28/47, 22.1.

13N/4E-12H1—Reference point—hole in pump base, elevation 67.3 feet, 100 feet north of Wheatland-Rio Oso Road, 1.0 mile east of Pleasant Grove Road (Forty Mile Road). 11/28/47, 22.6; 2/11/48, 20.5; 2/21/48, 21.0; 3/29/48, 21.0; 11/12/48, 23.8; 3/24/49, 19.4; 11/26/49, 26.8.

13N/4E-12H2—Reference point—top of slot in pump base, elevation 67.2 feet, 100 feet north of Wheatland-Rio Oso Road, 0.90 mile east of Pleasant Grove Road (Forty Mile Road). 11/28/47, 22.2; 3/29/48, 19.8; 11/12/48, 23.4; 3/24/49, 19.0; 11/26/49, 26.6.

13N/4E-12H3—Reference point—top of 8-inch casing, elevation 68 feet, 200 feet south of Wheatland-Rio Oso Road, 1.0 mile east of Pleasant Grove Road (Forty Mile Road). 12/2/47, 24.2; 3/8/48, 25.4.

13N/4E-12K1—Reference point—groove in base plate, elevation 69.4 feet, 0.30 mile south of Wheatland-Rio Oso Road, 0.50 mile east of Pleasant Grove Road (Forty Mile Road). 12/2/47, 24.6; 3/8/48, 28.2; 3/29/48, 22.4; 11/15/48, 25.7; 3/31/49, 21.9; 12/2/49, 28.4.

13N/4E-12K2—Reference point—top ridge on base plate, elevation 70 feet, 1,000 feet south of Wheatland-Rio Oso Road, 0.75 mile east of Pleasant Grove Road (Forty Mile Road). 12/2/47, 24.4; 3/8/48, 29.6.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet meosured from reference point)

13N/4E-12L1—Reference point—pipe in base, elevation 65.6 feet, 1,100 feet south of Wheatland-Rio Oso Road, 0.25 mile east of Pleasant Grove Road (Forty Mile Road). 12/2/47, 23.2; 3/8/48, 30.9; 3/22/48, 32.7; 3/29/48, 21.6; 5/5/48, 19.2; 6/3/48, 21.2; 9/30/48, 30.7; 11/15/48, 24.8; 1/26/49, 23.0; 12/2/49, 27.6.

13N/4E-12L2—Reference point—slot in top of casing, elevation 65.1 feet, 800 feet south of Wheatland-Rio Oso Road, 0.30 mile east of Pleasant Grove Road (Forty Mile Road). 12/2/47, 21.6; 3/8/48, 28.3; 3/22/48, 29.0; 3/29/48, 19.9; 9/30/48, 29.3; 11/15/48, 23.4; 3/31/49, 22.8.

13N/4E-12Q1—Reference point—pipe in concrete base, elevation 70.5 feet, 0.30 mile north of Bear River Drive, 0.70 mile east of Pleasant Grove Road. 12/3/47, 26.0; 3/30/48, 24.4; 11/4/48, 27.9; 3/31/49, 23.5; 12/2/49, 30.2.

13N/4E-12R1—Reference point—hole in pump base, elevation 72.4 feet, 0.30 mile north of Bear River Drive, 0.90 mile east of Pleasant Grove Road. 12/3/47, 45.5; 3/30/48, 24.9; 11/4/48, 28.9; 1/26/49, 26.6; 3/31/49, 24.4; 12/2/49, 31.3.

13N/4E-13A1—Reference point—hole in pump base, elevation 71.6 feet, 1,200 feet north of Bear River Drive, 0.75 mile east of Pleasant Grove Road. 12/3/47, 26.5; 3/8/48, 31.6; 3/30/48, 24.9; 11/4/48, 28.3; 3/31/49, 24.0; 12/2/49, 30.8.

13N/4E-13B1—Reference point—hole in pump base, elevation 70 feet, 850 feet north of Bear River Drive, 0.60 mile east of Pleasant Grove Road. 11/4/48, 28.3.

13N/4E-13C1—Reference point—top of 14-inch casing, elevation 69.2 feet, 900 feet north of Bear River Drive, 0.40 mile east of Pleasant Grove Road. 12/3/47, 25.7; 11/4/48, 27.7; 3/31/49, 23.3; 12/2/49, 30.0.

13N/4E-13E1—Reference point—top of 14-inch casing, elevation 60.7 feet, 150 feet south of Bear River Drive, 700 feet east of Four Corners. 12/3/47, 19.5; 3/8/48, 24.2; 3/30/48, 18.1; 11/4/48, 21.6; 3/31/49, 17.0; 12/2/49, 23.6; 3/30/50, 19.8; 11/8/50, 25.4; 11/20/51, 23.1; 4/4/52, 16.7.

13N/4E-13F1—Reference point—bottom of pump base, elevation 62.9 feet, 150 feet south of Bear River Drive, 0.25 mile east of Four Corners. 12/2/47, 21.2; 3/10/48, 31.2; 11/4/48, 23.5; 3/31/49, 19.0; 12/2/49, 25.6.

13N/4E-13F2—Reference point—top of casing, elevation 65.5 feet, North side Bear River Drive, 0.30 mile east of Four Corners. 12/2/47, 23.2; 3/30/48, 21.8; 5/14/48, 19.5; 11/4/48, 25.5; 1/26/49, 23.0; 3/31/49, 21.0.

13N/4E-13F3—Reference point—top of 12-inch casing, elevation 66.9 feet, South side Bear River Drive, 0.50 mile east of Four Corners. 12/2/47, 23.6; 3/8/48, 28.2; 11/4/48, 25.5; 3/31/49, 21.2; 12/2/49, 27.9.

13N/4E-13G1—Reference point—top of 12-inch casing, elevation 67.8 feet, 200 feet south of Bear River Drive, 0.50 mile east of Four Corners. 12/2/47, 24.2; 3/8/48, 27.3; 11/4/48, 25.7; 3/31/49, 21.6; 12/2/49, 28.2.

13N/4E-13G2—Reference point—top of 14-inch casing, elevation 69.1 feet, South side Bear River Drive, 0.70 mile east of Four Corners. 12/2/47, 24.6; 3/10/48, 28.1; 3/30/48, 23.2; 11/4/48, 25.9; 3/31/49, 22.0; 12/2/49, 28.5; 3/30/50, 24.8; 11/8/50, 30.9; 4/3/51, 20.7; 11/20/51, 24.4; 4/4/52, 16.7.

13N/4E-13H1—Reference point—slot in concrete base, elevation 66 feet, 150 feet south of Bear River Drive, 0.95 mile east of Four Corners. 12/3/47, 22.4; 11/4/48, 24.4; 3/31/49, 21.7; 12/2/49, 27.1.

13N/4E-13K1—Reference point—top of twin holes in pump base, elevation 63 feet, 0.40 mile north of Gallagher Road, 0.50 mile east of Pleasant Grove Road. 12/5/47, 18.7.

13N/4E-13M1—Reference point—top of concrete foundation, elevation 60.8 feet, 700 feet east of Pleasant Grove Road, 0.30 mile north of Gallagher Road. 12/5/47, 19.6; 3/8/48, 25.7; 11/15/48, 21.6; 3/31/49, 17.7; 11/30/49, 25.1.

13N/4E-13M2—Reference point—top of casing, elevation 62.2 feet, 0.25 mile east of Pleasant Grove Road, 0.30 mile north of Gallagher Road. 12/5/47, 21.9; 3/8/48, 22.5; 3/31/48, 20.1; 11/15/48, 22.9; 4/1/49, 17.5; 11/30/49, 25.5.

13N/4E-13P1—Reference point—top of 14-inch casing, elevation 20.2 feet, 900 feet north of Gallagher Road, 0.40 mile east of Pleasant Grove Road. 12/5/47, 18.2; 3/8/48, 23.4; 11/5/48, 20.8; 4/1/49, 17.2; 11/30/49, 23.2.

13N/4E-13R1—Reference point—top of 14-inch casing, elevation 69.3 feet, 0.50 mile east of end of Gallagher Road, 1.00 mile east of Pleasant Grove Road. 12/8/47, 25.6; 3/10/48, 27.8; 3/31/48, 24.3; 11/5/48, 28.4; 4/1/49, 24.0; 11/30/49, 31.3; 3/30/50, 27.1; 11/9/50, 34.0; 4/4/51, 25.0; 11/21/51, 33.7.

13N/4E-14A1—Reference point—bottom of cutout in top of casing, elevation 59.28 feet, 900 feet north of Bear River Drive, 1,000 feet west of Pleasant Grove Road. 12/3/47, 19.1; 11/15/48, 20.4; 3/31/49, 16.7; 12/1/49, 22.9.

13N/4E-14D1—Reference point—bottom edge of pump base, elevation 55.0 feet, 900 feet east of Warren Road, 0.25 mile north of Bear River Drive. 12/3/47, 14.8; 2/10/48, 14.6; 3/31/48, 12.4; 11/15/48, 15.3; 3/31/49, 10.5; 12/1/49, 17.2.

13N/4E-14F1—Reference point—top of 12-inch casing, elevation 55.0 feet, 350 feet north of Bear River Drive, 0.30 mile east of Warren Road. 12/3/47, 17.7; 3/8/48, 20.0; 11/15/48, 18.6; 3/31/49, 14.2; 12/1/49, 20.8; 3/30/50, 15.9; 11/9/50, 22.2; 4/3/51, 13.0; 11/20/51, 19.2; 4/4/52, 6.0.

13N/4E-14F3—Reference point—top of casing, elevation 55.2 feet, 250 feet south of Bear River Drive, 0.40 mile east of Warren Road. 12/4/47, 17.4; 11/15/48, 18.9; 3/31/49, 14.8; 12/1/49, 21.3.

13N/4E-14J1—Reference point—hole in pump base, elevation 54 feet, 1,000 feet west of Pleasant Grove Road, 0.30 mile south of Bear River Drive. 12/4/47, 17.4; 11/15/48, 19.4; 3/31/49, 15.4; 12/1/49, 22.3.

13N/4E-14N1—Reference point—top of 14-inch casing in bottom of pit, elevation 48.5 feet, 400 feet east of Warren Road, 0.40 mile south of Bear River Drive. 12/4/47, 14.5; 3/31/48, 12.9; 11/15/48, 15.2; 3/31/49, 10.7; 12/1/49, 17.1.

13N/4E-14N2—Reference point—top of 14-inch casing, elevation 54.4 feet, 1,200 feet east of Warren Road, 0.35 mile south of Bear River Drive. 12/4/47, 21.0; 3/31/48, 19.5; 11/15/48, 21.8; 3/31/49, 17.2; 12/1/49, 23.9.

13N/4E-14Q1—Reference point—top of 14-inch casing, elevation 56 feet, 0.45 mile west of Pleasant Grove Road, 0.50 mile south of Bear River Drive. 12/4/47, 22.5; 11/15/48, 23.9; 3/31/49, 18.7; 12/1/49, 26.3.

13N/4E-14Q2—Reference point—top of 12-inch casing, elevation 59.1 feet, 0.25 mile west of Pleasant Grove Road, 0.25 mile north of Betz Road. 12/5/47, 23.2; 3/10/48, 33.3; 11/15/48, 24.6.

13N/4E-14R1—Reference point—hole in pump base, elevation 60.4 feet, West side Pleasant Grove Road, 1,000 ft. north of Gallagher Road. 12/5/47, 21.2; 3/8/48, 25.1; 3/31/48, 19.5; 5/8/48, 17.3; 11/5/48, 23.6; 11/15/48, 22.4; 1/26/49, 20.3; 3/31/49, 18.1; 11/30/49, 25.4.

13N/4E-14R2—Reference point—top of concrete pit, elevation 60.1 feet, West side Pleasant Grove Road, 1,100 feet north of Gallagher Road. 12/5/47, 21.8; 3/8/48, 21.5; 11/5/48, 23.6.

13N/4E-15A1—Reference point—top of pump base, elevation 54.7 feet, 350 feet west of Warren Road, 0.30 mile north of Bear River Drive. 12/3/47, 17.9; 3/8/48, 19.5; 3/31/48, 16.2; 11/15/48, 19.1; 3/31/49, 14.2; 12/1/49, 21.1.

13N/4E-15J2—Reference point—bottom edge of pump base, elevation 53.2 feet, South side Bear River Drive, 100 feet west of Warren Road. 12/4/47, 19.2; 3/10/48, 19.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Mode by Division of Water Resources
(Depths to woter in feet meosured from reference point)

13N 4E-15K1—Reference point—hole in pump base, elevation 51.8 feet, North side Bear River Drive, 1,200 feet northeast of Swanson Road. 12/4/47, 16.4; 3/30/48, 14.2; 5/5/48, 12.2; 6/3/48, 13.8; 7/2/48, 56.2; 11/15/48, 17.2; 1/26/49, 15.3; 3/31/49, 12.0; 5/25/49, 18.1; 6/29/49, 25.9; 8/26/49, 24.7; 12/1/49, 19.4.

13N 4E-15N1—Reference point—bottom of pump base, elevation 50.8 feet, North side Bear River Drive, 0.40 mile southwest of Swanson Road. 12/4/47, 19.2; 3/10/48, 18.2; 11/15/48, 19.0; 3/31/49, 12.5; 12/1/49, 21.3.

13N 4E-15N2—Reference point—hole in pump base, elevation 52.9 feet, 350 feet south of Bear River Drive, 0.30 mile southwest of Swanson Road. 12/4/47, 21.2; 3/10/48, 20.9; 11/15/48, 21.0; 3/31/49, 14.4; 12/1/49, 23.2.

13N 4E-15P1—Reference point—bottom of pump base, elevation 54.3 feet, 350 feet west of Swanson Road, 1,000 feet south of Bear River Drive. 12/4/47, 22.3; 3/10/48, 21.4; 11/15/48, 22.2; 3/31/49, 15.9; 12/1/49, 24.4.

13N 4E-15P2—Reference point—hole in pump base, elevation 51 feet, 200 feet north of junction of Swanson Road and Bear River Drive. 12/4/47, 17.0; 3/31/48, 14.2; 11/15/48, 17.0; 3/31/49, 11.1; 12/1/49, 18.8; 3/30/50, 11.6; 11/20/50, 19.1; 4/4/52, 5.9.

13N 4E-15R1—Reference point—bottom of slot in concrete base, elevation 54 feet, 100 feet west of Warren Road, 0.45 mile south of Bear River Drive. 12/4/47, 21.4; 3/8/48, 24.0; 11/15/48, 21.7; 3/31/49, 17.0; 12/1/49, 24.0.

13N 4E-16N1—Reference point—hole in pump base, elevation 43.7 feet, 600 feet west of Fourth Avenue, 0.75 mile north of Rio Oso Road. 12/6/47, 14.4; 3/30/48, 9.8; 5/5/48, 7.3; 5/31/48, 7.4; 11/16/48, 12.7; 4/1/49, 6.0; 5/25/49, 11.3; 6/2/49, 9.3; 7/1/49, 11.6; 8/1/49, 17.0; 8/31/49, 16.7; 11/30/49, 16.0; 3/30/50, 7.0; 11/9/50, 15.8; 4/3/51, 4.9; 11/20/51, 13.7; 4/4/52, 3.4.

13N 4E-17A1—Reference point—hole in base of pump, elevation 41 feet, 250 feet west of farm road, 1.25 miles north of Feather River Boulevard at Bear River Bridge. 11/21/47, 11.9; 3/10/48, 10.5; 12/8/49, 14.4.

13N 4E-17G2—Reference point—hole in base of pump, elevation 40 feet, 0.35 mile northeast of Feather River Boulevard at a point 0.60 mile northwest of Bear River Bridge. 11/21/47, 14.1; 3/10/48, 14.9; 11/5/48, 13.6; 3/15/49, 8.3; 12/7/49, 15.8.

13N 4E-17P1—Reference point—bottom of pump base, elevation 39 feet, 300 feet south of Feather River Boulevard, 0.60 mile northwest of Bear River Bridge. 11/20/47, 13.9; 3/10/48, 11.9; 5/8/48, 6.9; 11/5/48, 11.2; 1/24/49, 10.4; 3/15/49, 7.9; 6/1/49, 7.9; 7/29/49, 15.0; 8/26/49, 15.2; 12/8/49, 13.8; 3/29/50, 6.9; 11/6/50, 13.7; 3/30/51, 11.9; 11/16/51, 11.9.

13N 4E-17Q1—Reference point—top of floor board, elevation 42 feet, 800 feet east of Feather River Boulevard at a point 0.45 mile northwest of Bear River Bridge. 11/21/47, 13.1; 3/10/48, 11.9; 3/15/49, 7.2; 12/8/49, 14.9.

13N 4E-18F1—Reference point—hole in base of pump, elevation 35 feet, South side of curve in Feather River Boulevard, approximately 2.0 miles northwest of Bear River Bridge. 3/9/48, 13.0; 5/5/48, 9.0; 5/31/48, 9.0; 11/5/48, 11.5; 1/24/49, 13.0; 3/15/49, 11.3; 12/8/49, 15.9; 3/29/50, 10.6; 11/6/50, 15.1; 3/30/51, 7.5; 11/16/51, 13.8.

13N 4E-18L1—Reference point—top of tin casing, elevation 35 feet, 100 feet south of farm road, 1,200 feet southwest of Feather River Boulevard. 11/20/47, 11.8; 3/9/48, 13.3; 11/5/48, 14.7; 3/15/49, 11.1; 12/8/49, 15.8.

13N 4E-19Q1—Reference point—top of concrete under pump, elevation 35 feet, 0.25 mile northwest of Levee Road, 1.1 miles southwest of Feather River Boulevard at Bear River Bridge. 11/21/47, 13.7; 11/5/48, 15.7; 3/15/49, 9.9; 12/7/49, 17.0; 3/29/50, 10.1; 11/8/50, 15.6; 3/30/51, 10.2.

13N 4E-20B1—Reference point—top of casing, elevation 42 feet, Northeast of Feather River Boulevard just across Bear River Bridge. 11/21/47, 16.4; 3/10/48, 15.8; 11/5/48, 15.0.

13N 4E-20F1—Reference point—top of concrete under pump, elevation 39 feet, 900 feet west of Levee Road, 0.30 mile southwest of Feather River Boulevard at Bear River Bridge. 11/21/47, 12.3; 11/5/48, 12.2; 3/15/49, 7.0; 12/7/49, 13.7.

13N 4E-20G1—Reference point—base of pump, elevation 41 feet, 300 feet west of Levee Road, 700 feet southwest of Feather River Boulevard at Bear River Bridge. 11/21/47, 13.6; 11/5/48, 15.1; 3/15/49, 8.2; 12/7/49, 15.7.

13N 4E-20J1—Reference point—top of casing, elevation 41 feet, 400 feet south of Feather River Boulevard, 500 feet west of Sacramento Northern Railroad. 11/21/47, 12.9; 3/10/48, 11.9; 11/5/48, 11.8; 1/24/49, 10.4; 3/15/49, 6.6; 12/8/49, 14.3; 3/29/50, 6.9; 11/8/50, 14.4; 3/30/51, 3.8; 11/16/51, 12.2.

13N 4E-20N1—Reference point—top of casing, elevation 37 feet, North side of the west levee of Bear River, 0.99 mile south of Feather River Boulevard at Bear River Bridge. 11/21/47, 14.8; 11/5/48, 14.3; 3/15/49, 8.6; 12/7/49, 16.0.

13N 4E-20R2—Reference point—hole in pump base, elevation 41 feet, West of Sacramento Northern Railroad, 0.35 mile south of Rio Oso Road. 11/21/47, 15.9; 3/10/48, 14.9; 5/11/48, 11.4; 3/15/49, 11.0; 12/8/49, 16.3.

13N 4E-21A1—Reference point—bottom edge of pump base, elevation 50 feet, 560 feet south of west end of Bear River Drive. 12/4/47, 19.2; 3/10/48, 18.3; 3/31/48, 15.9; 11/15/48, 19.0; 1/26/49, 17.6; 3/31/49, 11.8; 12/1/49, 21.4; 3/30/50, 12.0; 11/9/50, 21.0; 4/3/51, 9.2; 11/20/51, 18.7; 4/4/52, 6.6.

13N 4E-21B1—Reference point—pipe elbow in casing, elevation 47.8 feet, 0.25 mile west of west end of Bear River Drive. 12/4/47, 16.7; 3/10/48, 19.0; 11/15/48, 16.6; 3/31/49, 9.8; 12/1/49, 18.8; 11/20/51, 16.3; 4/4/52, 5.9.

13N 4E-21C1—Reference point—bottom of flanged coupling, elevation 45.1 feet, 630 feet east of Fourth Avenue, 0.25 mile north of Rio Oso Road. 12/6/47, 17.0; 3/9/48, 15.3; 11/16/48, 15.9; 4/1/49, 8.9; 11/30/49, 18.4.

13N 4E-21D1—Reference point—top of flanged coupling, elevation 43 feet, West side of Fourth Avenue, 0.25 mile north of Rio Oso Road. 12/6/47, 15.0; 3/9/48, 12.8; 3/31/48, 11.7; 11/16/48, 13.5; 4/1/49, 7.9; 11/30/49, 16.4.

13N 4E-21E1—Reference point—top of 12-inch casing, elevation 42 feet, 250 feet north of Rio Oso Road, 800 feet west of Fourth Avenue. 12/6/47, 17.1; 3/11/48, 16.3.

13N 4E-21F1—Reference point—top of 14-inch casing, elevation 43 feet, 600 feet north of Rio Oso Road, 0.2 mile east of Fourth Avenue. 12/6/47, 17.4.

13N 4E-21H1—Reference point—hole in pump base, elevation 46.2 feet, 250 feet north of Rio Oso Road, 800 feet west of Pacific Avenue. 12/5/47, 17.1; 3/9/48, 15.4; 3/31/48, 14.6; 5/8/48, 11.5; 11/16/48, 16.9; 4/1/49, 10.0; 11/29/49, 18.8.

13N 4E-21L1—Reference point—top of 12-inch casing, elevation 42.5 feet, East side of Fourth Avenue, 250 feet south of Rio Oso Road. 12/8/47, 15.6; 3/9/48, 13.8; 11/15/48, 14.7; 4/1/49, 9.6; 11/30/49, 17.0.

13N 4E-21P1—Reference point—bottom of flanged coupling, elevation 36.1 feet, 250 feet east of Fourth Avenue, 300 feet north of Kempton Road. 12/8/47, 9.6; 3/9/48, 8.6.

13N 4E-21P2—Reference point—edge of pump base, elevation 41.7 feet, 600 feet north of Kempton Road, 0.25 mile east of Fourth Avenue. 12/8/47, 17.4; 3/9/48, 16.5; 3/31/48, 15.3; 11/16/48, 17.2; 4/1/49, 12.1; 11/30/49, 19.2; 3/30/50, 13.4; 11/9/50, 20.1; 1/3/51, 9.1; 11/21/51, 18.1; 4/4/52, 8.3.

13N 4E-21R1—Reference point—top of 8-inch casing, elevation 45 feet, 350 feet north of Kempton Road, 650 feet west of Pacific Avenue. 12/16/47, 20.7; 3/10/48, 19.9; 11/16/48, 21.2; 4/1/49, 17.0; 11/29/49, 23.2.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Divisian of Water Resaurces
(Depths to water in feet measured from reference paint)

13N/4E-22A1—Reference point—top of 16-inch casing, elevation 51 feet, 350 feet west of Warren Road, 700 feet north of Betz Road. 12/5/47, 22.6; 3/31/48, 21.1.

13N/4E-22E1—Reference point—top of 12-inch casing, bottom of pit, elevation 40.4 feet, 1,000 feet north of Rio Oso Road, 0.35 mile west of Swanson Road. 12/5/47, 10.4; 3/9/48, 8.8.

13N/4E-22F1—Reference point—hole in pump base, elevation 53.1 feet, 300 feet west of Swanson Road, 500 feet north of Rio Oso Road. 12/5/47, 22.2; 3/10/48, 21.6; 11/16/48, 22.1; 4/1/49, 16.9; 11/30/49, 24.4.

13N/4E-22G1—Reference point—top of 12-inch casing, elevation 55.1 feet, North side of Rio Oso Road, 700 feet east of Swanson Road. 12/5/47, 23.9; 3/9/48, 23.6; 11/16/48, 23.8; 4/1/49, 19.8; 11/30/49, 26.5; 3/30/50, 21.5; 11/9/50, 27.5; 4/4/51, 18.7; 11/20/51, 25.7; 4/3/52, 16.9.

13N/4E-23B1—Reference point—bottom of pump base, elevation 58.6 feet, South side of Gallagher Road, 0.30 mile west of Pleasant Grove Road. 12/5/47, 21.3; 3/10/48, 27.8; 3/31/48, 20.8; 11/15/48, 23.0; 3/31/49, 19.0; 11/30/49, 25.7.

13N/4E-23C1—Reference point—hole in pump base, elevation 55 feet, 0.25 mile north of Betz Road, 0.30 mile east of Warren Road. 12/5/47, 22.7; 3/8/48, 26.9; 3/31/48, 21.9; 11/15/48, 23.6; 3/31/49, 19.6; 11/30/49, 26.2.

13N/4E-23D1—Reference point—bottom of pump base, elevation 51 feet. East side of Warren Road, 1,000 feet north of Betz Road. 12/5/47, 23.4; 3/10/48, 27.6; 11/15/48, 23.8; 3/31/49, 19.5; 11/30/49, 26.4.

13N/4E-23Q1—Reference point—top of 14-inch casing, elevation 62.7 feet, 500 feet north of Kempton Road, 0.25 mile west of Pleasant Grove Road. 12/16/47, 26.2; 3/9/48, 26.2; 5/8/48, 22.9; 11/5/48, 27.3; 1/26/49, 25.4; 4/1/49, 24.0; 11/30/49, 30.0; 3/30/50, 26.9; 11/9/50, 33.1; 4/3/51, 26.5; 11/20/51, 31.4; 4/3/52, 26.8.

13N/4E-24D1—Reference point—top of 14-inch casing, elevation 61.8 feet, 800 feet south of Gallagher Road, 1,000 feet east of Pleasant Grove Road. 12/5/47, 21.0; 3/10/48, 25.2; 3/31/48, 19.8; 11/5/48, 23.8; 3/31/49, 19.4; 11/30/49, 26.1; 3/30/50, 22.4; 11/9/50, 28.5; 4/4/51, 20.6; 11/21/51, 26.4; 4/4/52, 18.0.

13N/4E-24Q1—Reference point—top of 12-inch casing, bottom of pit, elevation 53.8 feet, 100 feet north of Kempton Road, 0.75 mile east of Pleasant Grove Road. 12/8/47, 11.8.

13N/4E-26B1—Reference point—top of 14-inch casing, elevation 58 feet, 200 feet south of Kempton Road, 0.45 mile west of Pleasant Grove Road. 3/9/48, 25.3; 11/5/48, 25.6; 4/1/49, 21.3; 11/30/49, 27.4.

13N/4E-26H1—Reference point—hole in pump base, elevation 57 feet, 350 feet west of Pleasant Grove Road, 0.45 mile south of Kempton Road. 11/8/47, 24.2; 3/9/48, 24.6; 11/16/48, 26.4; 4/4/49, 22.0; 11/30/49, 28.5.

13N/4E-26R1—Reference point—top of 14-inch casing, elevation 59 feet, West side of Pleasant Grove Road, 0.85 mile south of Kempton Road. 12/8/47, 25.5; 3/8/48, 24.9; 3/31/48, 24.2; 11/16/48, 28.1; 1/26/49, 26.5; 4/4/49, 23.7; 5/25/49, 34.0; 6/29/49, 42.4; 7/29/49, 48.8; 8/26/49, 49.0; 11/30/49, 29.6; 3/30/50, 26.4; 11/9/50, 33.9; 11/21/51, 33.7; 4/3/52, 26.9.

13N/4E-27C1—Reference point—bottom of flanged coupling, bottom of pit, elevation 46 feet, 400 feet south of Kempton Road, 0.40 mile east of Pacific Avenue. 12/16/47, 18.0.

13N/4E-27N1—Reference point—hole in pump base, elevation 51 feet, 250 feet east of Pacific Avenue, 0.90 mile south of Kempton Road. 12/16/47, 24.0; 3/11/48, 25.2.

13N/4E-28D1—Reference point—top of 12-inch casing, bottom of pit, elevation 27.7 feet, 600 feet south of Kempton Road, 700 feet west of Fourth Avenue. 12/8/47, 2.7; 3/11/48, 1.3; 3/31/48, 0.4; 11/16/48, 2.4; 4/1/49, —2.8; 11/30/49, 3.3.

13N/4E-28F1—Reference point—access hole to casing in bottom of pit, elevation 32.7 feet, 100 feet east of Fourth Avenue, 0.25 mile south of Kempton Road. 12/8/47, 6.8; 4/1/49, 2.6.

13N/4E-28R1—Reference point—hole in base, elevation 46 feet, 250 feet west of Pacific Avenue, 0.80 mile south of Kempton Road. 12/16/47, 23.2; 3/10/48, 22.4; 11/16/48, 25.1; 4/5/49, 21.5; 11/29/49, 26.1; 11/21/51, 27.9; 4/3/52, 22.5.

13N/4E-29F1—Reference point—top of east concrete wall, elevation 36 feet, 400 feet west of junction of Mark Hopkins Avenue and Berry Road. 11/21/47, 14.7; 3/10/48, 13.1; 11/5/48, 14.3; 1/24/49, 12.5; 3/15/49, 9.5; 5/25/49, 10.5; 6/29/49, 14.5; 7/28/49, 18.3; 8/26/49, 18.4; 12/7/49, 15.7; 3/29/50, 9.5; 11/8/50, 16.4; 3/30/51, 6.2; 11/16/51, 14.8.

13N/4E-29G1—Reference point—top of casing, elevation 37 feet, 0.10 mile southeast of Berry Road, 0.20 mile northeast of Mark Hopkins Avenue. 11/21/47, 13.2; 3/10/48, 11.8; 5/11/48, 8.9; 11/5/48, 13.1; 3/15/49, 8.4; 12/8/49, 14.4.

13N/4E-29M2—Reference point—bottom 2" x 6" floor, elevation 34 feet, 150 feet northwest of Berry Road, 0.25 mile southwest of Mark Hopkins Avenue. 11/21/47, 15.4; 3/10/48, 13.1; 11/5/48, 14.5; 12/7/49, 16.0.

13N/4E-30R2—Reference point—top of casing, elevation 33 feet, 400 feet south of southwest end of Berry Road. 11/21/47, 15.1; 3/11/48, 13.8; 11/5/48, 15.1; 3/16/49, 13.6; 12/8/49, 16.0.

13N/4E-31J1—Reference point—top of casing, elevation 52 feet, 0.25 mile north of Cornelius Avenue, 0.70 mile west of Mark Hopkins Avenue. 12/8/47, 14.8; 3/11/48, 13.1; 5/11/48, 9.2; 12/14/48, 15.6; 3/28/49, 10.2; 12/7/49, 15.8.

13N/4E-32B1—Reference point—top of south concrete wall, elevation 34 feet, 100 feet north of Cramer Road, 150 feet west of Mark Hopkins Avenue. 12/9/47, 14.9; 3/11/48, 13.2; 12/15/48, 16.9; 3/16/49, 12.9; 12/7/49, 16.1.

13N/4E-32D1—Reference point—top of east concrete wall, elevation 34 feet, 200 feet north of Cramer Road, 0.50 mile west of Mark Hopkins Avenue. 12/9/47, 15.1; 3/11/48, 13.2; 12/15/48, 16.9; 3/16/49, 12.3; 12/7/49, 16.1.

13N/4E-32H1—Reference point—top of north concrete wall, elevation 40 feet, East side of Mark Hopkins Avenue, 0.55 mile north of Cornelius Avenue. 12/8/47, 13.6; 3/11/48, 12.8; 5/11/48, 11.1; 12/13/48, 13.9; 3/16/49, 20.3; 12/6/49, 18.0; 3/29/50, 14.6; 11/6/50, 21.0; 3/30/51, 13.5; 11/16/51, 20.8; 4/4/52, 13.4.

13N/4E-32L1—Reference point—top of south concrete wall, elevation 35 feet, 0.25 mile west of Mark Hopkins Avenue, 0.40 mile north of Cornelius Avenue. 12/8/47, 20.6; 3/11/48, 19.4; 12/14/48, 21.9; 3/28/49, 18.4; 12/7/49, 22.3.

13N/4E-33A2—Reference point—pipe in base, elevation 50 feet, 200 feet west of Pacific Avenue, 0.9 mile north of Cornelius Avenue. 12/16/47, 25.6; 3/10/48, 24.6; 3/31/48, 25.7; 11/16/48, 27.9; 1/26/49, 26.0; 4/5/49, 24.4; 11/29/49, 28.7; 3/30/50, 25.7; 11/9/50, 31.6; 4/3/51, 24.0; 11/21/51, 31.8; 4/3/52, 24.1.

13N/4E-33G1—Reference point—bottom of pump base, elevation 47 feet, 0.4 mile west of Pacific Avenue, 0.5 mile north of Cornelius Avenue. 12/16/47, 28.6; 3/10/48, 27.5; 3/31/48, 27.3; 5/11/48, 26.7; 11/16/48, 30.9; 4/5/49, 27.5; 11/29/49, 31.3.

13N/4E-33L1—Reference point—top of casing, elevation 45 feet, 0.3 mile north of Cornelius Avenue, 0.5 mile east of Electric Avenue. 3/29/49, 24.1.

13N/4E-33P1—Reference point—hole in pump base, elevation 45 feet, 0.5 mile east of Electric Avenue, 0.2 mile north of Cornelius Avenue. 3/11/48, 22.1; 12/14/48, 24.7; 3/29/49, 22.3; 12/7/49, 22.6; 3/27/50, 25.7; 11/6/50, 32.0; 4/2/51, 25.0; 11/16/51, 30.6; 4/3/52, 24.6.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

13N 4E-33R1—Reference point—top of concrete pit, elevation 46 feet, 200 feet west of Pacific Avenue, 600 feet north of Cornelius Avenue. 11 8 29, 21.5; 9 8 30, 20.6; 12 30 30, 20.9; 12 10 31, 21.6; 12 11 32, 20.9; 12 20 33, 21.3; 10 27 34, 21.3; 11 23 36, 23.5; 11 24 37, 25.6; 1 30 39, 19.8; 12 22 47, 24.2; 3 11 48, 22.5; 3 31 48, 22.6; 12 14 48, 26.1; 3 29 49, 23.6; 12 7 49, 26.1; 3 27 50, 24.2; 11 6 50, 29.7; 4 2 51, 23.5; 11 16 51, 23.3; 12 6 51, 31.1; 1 4 52, 24.3.

13N 4E-34L1—Reference point—top of casing, elevation 48 feet, 0.2 mile east of Pacific Avenue, 0.4 mile north of Cornelius Avenue. 12 16 47, 23.6; 3 10 48, 22.8; 3 31 48, 22.7; 10 16 48, 26.1; 4 5 49, 23.2; 11 29 49, 27.1; 3 30 50, 24.5; 11 9 50, 30.6; 4 3 51, 24.1; 11 21 51, 30.5; 4 3 52, 24.5.

13N 4E-35J1—Reference point—top of floor of pit, elevation 42 feet, 0.4 mile north of Cornelius Avenue, 0.02 mile west of Pleasant Grove Road. 12 8 47, 8.8; 3 31 48, 7.2; 11 16 48, 11.6; 4 4 49, 8.4; 11 30 49, 13.8; 3 30 50, 11.3; 11 9 50, 19.0.

13N 4E-35Q1—Reference point—top of casing, elevation 56.6 feet, 0.4 mile west of Pleasant Grove Road, 132 feet north of Cornelius Avenue. 3 11 48, 19.9; 12 13 48, 25.1; 3 29 49, 21.1; 12 7 49, 26.0; 11 19 51, 30.4.

13N 4E-36G1—Reference point—top of casing, elevation 58 feet, 528 feet north of Hicks Road, 0.6 mile east of Pleasant Grove Road. 12 16 47, 23.8; 3 9 48, 22.6; 11 16 48, 26.7; 4 4 49, 24.2; 11 30 49, 29.1.

13N 5E-3Q1—Reference point—top of casing at bottom of 10.6-foot pit, elevation 84 feet, 0.25 mile northeast of U. S. Highway 99E, 0.20 mile southeast of Bear River. 11 25 47, 4.4; 3 5 48, 5.5; 11 7 49, 6.0; 4 4 50, 4.9; 11 14 50, 5.7; 3 27 51, 2.6; 11 19 51, 6.3.

13N 5E-4J1—Reference point—top of pump base, elevation 83 feet, 0.2 mile southwest of U. S. Highway 99E at a point 0.45 mile northwest of Bear River bridge. 11 24 47, 14.8; 3 29 48, 12.7; 5 14 48, 11.9; 11 12 48, 15.6; 3 23 49, 12.9; 11 26 49, 17.3; 3 29 50, 14.1; 11 8 50, 17.5; 4 4 51, 12.5; 12 3 51, 16.6; 4 2 52, 11.3.

13N 5E-4J2—Reference point—top of casing, elevation 80 feet, 0.25 mile southwest of U. S. Highway 99E at a point 0.3 mile northwest of Yuba-Placer county line. 4 1 48, 9.2; 5 5 48, 7.9; 6 3 48, 8.5; 7 2 48, 64.0 (operating); 7 1 49, 60.7 (operating); 8 1 49, 65.8 (operating); 8 31 49, 28.8.

13N 5E-4L1—Reference point—hole in pump base, elevation 82.6 feet, 0.3 mile southwest of U. S. Highway 99E in Wheatland on south side of T. H. Richards' farm road. 11 24 47, 19.9; 3 4 48, 21.1; 11 12 48, 21.0; 3 24 49, 27.0; 11 26 49, 22.7.

13N 5E-4N1—Reference point—top of concrete base, elevation 79.9 feet, At T. H. Richards' ranch house, 0.8 mile southwest of Wheatland. 11 25 47, 17.7; 3 5 48, 21.6; 3 29 48, 15.4; 11 12 48, 18.7; 3 24 49, 14.9; 11 26 49, 20.4.

13N 5E-4R1—Reference point top of concrete crib, south of pump, elevation 84 feet, 0.35 mile southwest of U. S. Highway 99E at a point 0.2 mile northwest of Yuba-Placer county line. 11 24 47, 13.7; 5 14 48, 10.2; 11 12 48, 14.1; 1 26 49, 13.4; 3 23 49, 10.8; 11 26 49, 15.3.

13N 5E-5B1—Reference point—top of casing, elevation 69.9 feet, 0.4 mile northeast of Oakley Avenue, 0.45 mile northwest of Wheatland Avenue. 11 24 47, 15.2; 3 5 48, 14.1.

13N 5E-5C1—Reference point—hole in pump base, elevation 68.1 feet, 0.25 mile northeast of Oakley Avenue, 0.45 mile northwest of Wheatland Road. 11 22 47, 14.5; 3 5 48, 13.1; 3 29 48, 12.2; 5 14 48, 11.6; 11 11 48, 16.0; 1 26 49, 14.2; 3 23 49, 12.1; 11 28 49, 18.5; 3 29 50, 14.9; 11 8 50, 20.7; 4 1 51, 11.5; 11 29 51, 19.3; 1 2 52, 8.2.

13N 5E-5C2—Reference point—top of pump base, elevation 72.2 feet, 0.15 mile northeast of Oakley Avenue, 0.35 mile northwest of Wheatland Road. 11 20 47, 18.5; 3 5 48, 17.1.

13N 5E-5D1—Reference point—top of concrete pit, elevation 66.5 feet, 0.1 mile southwest of Oakley Avenue, 0.6 mile northwest of Wheatland Road. 11 20 47, 15.7; 3 5 48, 15.1.

13N 5E-5L1—Reference point—top of casing, elevation 80.6 feet, Southeast side of Wheatland Road, 0.15 mile southwest of Oakley Avenue. 11 20 47, 27.5; 3 8 48, 27.5; 11 11 48, 30.6; 3 24 49, 24.1; 11 26 49, 31.1.

13N 5E-5L2—Reference point—top of concrete curb around casing, elevation 68.1 feet, Southeast side of Wheatland Road, 0.15 mile southwest of Oakley Avenue. 11 20 47, 15.6; 3 8 48, 14.3; 11 11 48, 17.3; 3 24 49, 11.7.

13N 5E-5L3—Reference point—top of casing, elevation 78.1 feet, 300 feet southwest of Oakley Avenue, 0.1 mile northwest of Wheatland Road. 11 20 47, 24.3; 3 5 48, 23.2; 11 11 48, 25.9; 3 25 49, 21.0; 11 28 49, 28.6.

13N 5E-5N1—Reference point—top of concrete crib nearest pump, elevation 70.4 feet, 0.2 mile southeast of Wheatland Road, 0.45 mile southwest of Oakley Avenue. 11 21 47, 19.2; 3 29 48, 16.0; 11 12 48, 21.9; 3 24 49, 15.2; 11 26 49, 23.5.

13N 5E-5P1—Reference point—top of pump base, elevation 71.1 feet, 0.2 mile southwest of Oakley Avenue, 0.25 mile southeast of Wheatland Road. 11 20 47, 17.6; 3 8 48, 18.3; 3 24 49, 14.2; 11 26 49, 21.2.

13N 5E-5Q1—Reference point—top of casing, elevation 75 feet, Southwest side of Oakley Avenue, 0.3 mile southeast of Wheatland Road. 11 20 47, 23.4; 3 8 48, 21.1; 3 24 49, 18.0.

13N 5E-6E1—Reference point—hole in west side pump base, elevation 63.0 feet, 0.7 mile northwest of Wheatland Road, 1.05 miles southwest of Oakley Avenue. 11 21 47, 17.8; 2 21 48, 15.6; 11 12 48, 19.5; 1 26 49, 17.0; 3 24 49, 15.1; 11 23 49, 22.9; 3 20 50, 18.4; 11 8 50, 25.2; 4 3 51, 14.8; 11 30 51, 24.3; 4 2 52, 23.1.

13N 5E-6E2—Reference point—hole in pump base, elevation 63.3 feet, 0.9 mile northwest of Wheatland Road, 1.0 mile southwest of Oakley Avenue. 11 21 47, 19.4; 2 21 48, 16.7; 5 5 48, 13.7; 6 3 48, 15.1; 7 2 48, 21.4; 11 12 48, 21.0; 3 24 49, 16.5; 5 3 49, 21.2; 6 2 49, 22.0; 7 1 49, 51.6 (operating); 8 1 49, 30.1; 8 31 49, 28.8; 11 28 49, 24.3.

13N 5E-6J1—Reference point—top of casing, elevation 67.6 feet, 0.15 mile northwest of Wheatland Road, 0.55 mile southwest of Oakley Avenue. 11 21 47, 19.1; 11 12 48, 21.0; 3 24 49, 15.4; 11 26 49, 23.5.

13N 5E-6L1—Reference point—top of casing, elevation 61.9 feet, 0.5 mile northwest of Wheatland Road, 0.8 mile southwest of Oakley Avenue. 11 21 47, 20.1; 3 5 48, 20.1; 11 12 48, 21.7; 3 24 49, 16.6; 11 26 49, 24.8.

13N 5E-7B1—Reference point—notch in concrete casing, elevation 72.2 feet, Northwest side of Wheatland Road, 0.9 mile southwest of Oakley Avenue. 11 21 47, 24.5; 3 5 48, 26.1; 11 12 48, 25.7; 3 24 49, 20.5; 11 26 49, 28.8; 3 9 50, 23.4; 11 18 50, 30.0; 1 3 51, 19.3; 12 3 51, 29.3; 4 2 52, 16.5.

13N 5E-7C1—Reference point—top of casing, elevation 71.4 feet, Northwest side of Wheatland Road, 1.3 mile southwest of Oakley Avenue. 11 28 47, 24.3; 3 2 48, 25.9; 11 12 48, 25.4; 3 24 49, 20.9.

13N 5E-7C2—Reference point—hole in top of pump base, elevation 68.3 feet, Northwest side of Wheatland Road, 1.2 miles southwest of Oakley Avenue. 11 21 47, 21.5; 3 8 48, 25.1; 3 29 48, 18.6; 5 5 48, 16.3; 6 3 48, 17.5; 7 2 48, 33.0; 11 12 48, 22.7; 3 24 49, 18.1; 6 2 49, 29.8; 8 1 49, 48.1; 8 31 49, 36.3; 11 26 49, 25.7.

13N 5E-7E1—Reference point—slot in casing, elevation 69 feet, Northwest side of Wheatland Road, 1.5 miles southwest of Oakley Avenue. 11 28 47, 23.6; 3 2 48, 26.9; 11 12 48, 24.8; 3 24 49, 20.2; 11 23 49, 28.9.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Mode by Division of Water Resources
(Depths to water in feet measured from reference point)

13N/5E-7G1—Reference point—top of casing, elevation 80.5 feet. At Bear River north levee, 0.35 mile southeast of Wheatland Road, 1.1 miles southwest of Oakley Avenue. 11/21/47, 31.7; 3/5/48, 37.6; 3/29/48, 28.4; 5/14/48, 25.5; 11/12/48, 31.5; 1/26/49, 29.5; 3/24/49, 27.2; 11/23/49, 34.4.

13N/5E-7F1—Reference point—top of concrete base, elevation 77.3 feet. At Bear River north levee, 0.35 mile southeast of Wheatland Road, 1.3 miles southwest of Oakley Avenue. 11/21/47, 29.3; 3/8/48, 33.7; 11/12/48, 30.3; 3/24/49, 26.1; 11/23/49, 34.9; 3/29/50, 28.6; 11/6/50, 35.9; 4/3/51, 25.0; 12/3/51, 33.7; 4/2/52, 22.7.

13N/5E-7H1—Reference point—bottom of pump base, elevation 80.4 feet, 0.3 mile southeast of Wheatland Road, 0.9 mile southwest of Oakley Avenue. 11/21/47, 31.1; 3/5/48, 35.7; 11/12/48, 31.8; 3/24/49, 27.3; 11/23/49, 34.0

13N/5E-7K1—Reference point—hole in pump base, elevation 74.9 feet. West side of Huffaker Road, 0.55 mile north of Bear River Drive. 12/3/47, 26.4; 3/8/48, 29.4; 11/8/48, 27.9; 3/31/49, 23.2; 12/6/49, 30.3; 3/30/50, 26.0; 11/8/50, 33.0; 4/3/51, 21.7; 4/3/52, 18.7.

13N/5E-7L1—Reference point—edge of pump base, elevation 74.8 feet, 0.5 mile north of Bear River Drive on west side of Hudson Road extended. 12/3/47, 27.5; 3/30/48, 25.2; 11/4/48, 29.5; 3/30/49, 25.0; 12/2/49, 33.9.

13N/5E-7M1—Reference point—top of casing, elevation 73.4 feet. At Bear River north levee, 0.25 mile south of Wheatland Road, 1.1 miles east of Pleasant Grove Road. 12/24/47, 28.1; 3/8/48, 33.7; 3/29/48, 25.9; 11/15/48, 29.1; 3/31/49, 25.1; 12/2/49, 31.9.

13N/5E-8B1—Reference point—hole in pump base, elevation 76.7 feet, 0.1 mile southwest of Oakley Avenue, 0.5 mile southeast of Wheatland Road. 11/21/47, 20.6; 3/5/48, 21.3; 11/11/48, 23.3; 3/24/49, 17.3; 11/26/49, 24.2; 3/29/50, 20.1; 11/8/50, 24.5; 4/3/51, 16.6; 12/3/51, 22.2; 4/2/52, 13.2.

13N/5E-8G1—Reference point—hole in pump base, elevation 81.3 feet. At Bear River north levee, 0.1 mile southwest of Oakley Avenue, 11/21/37, 20.1; 3/5/48, 19.3; 11/11/48, 20.1; 3/24/49, 16.3. Well filled.

13N/5E-8H1—Reference point—hole in pump base, elevation 83.7 feet. At Bear River north levee, 0.1 mile northeast of Oakley Avenue. 11/25/47, 21.5; 3/5/48, 21.4; 3/29/48, 19.4; 11/12/48, 22.3; 3/24/49, 18.2; 11/26/49, 23.8.

13N/5E-8J1—Reference point—hole in pump base, elevation 84.4 feet, 0.7 mile north of Bear River Drive, 0.85 mile east of Brewer Road. 11/26/47, 26.6; 3/22/48, 25.5; 11/4/48, 28.5; 3/30/49, 24.0; 12/6/49, 30.3; 3/30/50, 17.9; 11/9/50, 31.0; 4/3/51, 24.0; 11/20/51, 29.8; 4/3/52, 14.6.

13N/5E-8L1—Reference point—hole in pump base, elevation 75 feet, 0.25 mile east of Brewer Road, 0.75 mile north of Bear River Drive. 11/26/47, 26.7; 3/22/48, 23.9; 11/4/48, 26.8; 3/30/49, 22.3; 12/6/49, 29.2.

13N/5E-8N1—Reference point—bottom of pump base by air line, elevation 76.4 feet, 0.15 mile east of Brewer Road, 0.5 mile north of Bear River Drive. 11/26/47, 25.0; 3/22/48, 23.0; 11/4/48, 25.8; 3/30/49, 21.8; 12/6/49, 28.0.

13N/5E-8P1—Reference point—top of casing, elevation 76.6 feet, 0.4 mile north of Bear River Drive, 0.5 mile east of Brewer Road. 11/26/47, 20.6; 3/22/48, 19.0; 3/30/48, 18.2; 11/4/48, 22.1; 3/30/49, 17.7; 12/6/49, 24.6.

13N/5E-8R1—Reference point—pipe in concrete base, elevation 75 feet, 0.5 mile north of Bear River Drive, 0.75 mile east of Brewer Road. 11/4/48, 25.1; 3/30/49, 20.4; 12/6/49, 27.1.

13N/5E-9C1—Reference point—slot in concrete base, elevation 76.8 feet, 0.1 mile north of Bear River north levee, 0.3 mile southeast of T. H. Richards' ranch house, 0.8 mile southwest of Wheatland. 11/25/47, 11.9; 3/5/48, 12.1; 3/29/48, 9.7; 11/12/48, 12.5; 3/24/49, 9.4; 11/26/49, 14.0.

13N/5E-9D1—Reference point—top of base under air line, elevation 82.3 feet. At Bear River north levee, 0.4 mile southeast of T. H. Richards' ranch house, 0.8 mile southwest of Wheatland. 11/25/47, 13.9; 3/5/48, 13.4; 3/29/48, 12.3; 11/12/48, 14.0; 3/24/49, 11.5; 11/26/49, 14.6; 3/29/50, 11.2; 11/8/50, 14.0; 4/3/51, 9.9; 12/3/51, 13.7; 4/2/52, 8.6.

13N/5E-9E1—Reference point—inside edge of tapered base, elevation 83.5 feet. At Bear River north levee, 0.45 mile south of T. H. Richards' ranch house, 0.8 mile southwest of Wheatland. 11/25/47, 18.1; 3/5/48, 17.6; 11/12/48, 18.2; 3/24/49, 15.2. Well destroyed.

13N/5E-9G1—Reference point—hole in pump base, elevation 85.1 feet, 0.3 mile west of Placer Road, 0.75 mile north of Bear River Drive. 11/26/47, 15.9; 11/4/48, 17.2; 3/30/49, 14.2; 12/6/49, 20.4.

13N/5E-9H1—Reference point—top of casing, elevation 86.4 feet, 1.0 mile north of Bear River Drive, 500 feet west of Placer Road extended. 11/26/47, 15.3; 11/4/48, 15.8; 3/30/49, 14.4; 11/7/49, 18.8; 12/6/49, 18.4; 11/9/50, 19.8. Well destroyed.

13N/5E-9H2—Reference point—hole in pump base, elevation 86.4 feet, 1.0 mile north of Bear River Drive, 600 feet west of Placer Road extended. 11/20/51, 20.1; 4/3/52, 13.5.

13N/5E-9P1—Reference point—hole in pump base, elevation 80.4 feet, 0.5 mile north of Bear River Drive, 0.7 mile west of Placer Road. 12/26/47, 17.6; 11/4/47, 19.5; 3/30/49, 15.6; 12/6/49, 21.0.

13N/5E-9R1—Reference point—hole in pump base, elevation 83.6 feet. West side of Placer Road, 0.5 mile north of Bear River Drive. 11/26/47, 15.7; 3/22/48, 14.5; 3/30/48, 13.8; 5/8/48, 12.9; 11/4/48, 17.2; 1/26/49, 16.7; 2/18/49, 16.3; 3/16/49, 15.7; 3/30/49, 14.8; 7/29/49, 50.5 (operating); 11/7/49, 19.9; 12/6/49, 19.6; 2/15/50, 17.6; 3/15/50, 17.2; 4/4/50, 16.7; 5/9/50, 18.1; 6/7/50, 20.0; 8/3/50, 21.9; 10/3/50, 22.2; 11/14/50, 20.3; 12/14/50, 16.5; 1/4/51, 15.2; 2/7/51, 13.2; 3/7/51, 12.8; 3/27/51, 12.6; 7/16/51, 23.7; 8/22/51, 24.9; 9/26/51, 19.5; 11/19/51, 19.6; 2/28/52, 13.5; 4/4/52, 12.0.

13N/5E-16D1—Reference point—hole in casing, elevation 78 feet. North side of Bear River Drive, 0.8 mile west of Placer Road. 11/26/47, 18.1; 3/22/48, 17.8; 3/30/48, 16.2; 5/8/48, 15.0; 11/4/48, 21.2; 1/26/49, 18.3; 3/30/49, 16.0; 6/29/49, 26.3; 7/27/49, 28.4; 8/26/49, 27.8; 12/6/49, 22.9; 3/30/50, 18.7; 11/9/50, 24.6; 4/3/51, 15.9; 11/20/51, 22.2; 4/3/52, 12.9.

13N/5E-16E1—Reference point—hole in pump base, elevation 75.9 feet, 0.1 mile south of Bear River Drive, 0.85 mile west of Placer Road. 11/26/47, 16.5; 3/22/48, 18.2; 11/4/48, 19.9; 3/30/49, 14.3; 12/6/49, 21.4.

13N/5E-17D1—Reference point—top of concrete base, elevation 71.2 feet, 0.15 mile east of Brewer Road, 0.2 mile north of Bear River Drive. 11/26/47, 18.3; 3/22/48, 19.7; 11/4/48, 22.3; 3/30/49, 18.9; 12/6/49, 25.1; 3/30/50, 22.2; 11/9/50, 27.2; 4/3/51, 18.9; 11/20/51, 25.6; 4/3/52, 15.6.

13N/5E-17J2—Reference point—hole in pump base, elevation 70 feet, 0.4 mile south of Bear River Drive, 1.0 mile west of Placer Road. 11/4/48, 19.3; 3/30/49, 13.4; 12/6/49, 21.1.

13N/5E-17R1—Reference point—hole in pump base, elevation 70 feet, 0.7 mile south of Bear River Drive, 0.8 mile east of Brewer Road. 11/4/48, 24.9; 3/30/49, 19.2; 12/6/49, 27.6; 3/30/50, 22.9; 11/9/50, 30.4; 4/4/51, 20.8; 11/20/51, 27.0; 4/3/52, 22.3.

13N/5E-18B1—Reference point—top of casing, elevation 70.8 feet, 1.5 miles east of Pleasant Grove Road, 0.25 mile north of Bear River Drive. 12/3/47, 23.3; 3/8/48, 27.4; 3/30/48, 21.1; 11/4/48, 25.1; 3/30/49, 20.6; 12/6/49, 28.0.

13N/5E-18B2—Reference point—hole in top of pump base, elevation 69.3 feet. North side of Bear River Drive, 0.3 mile west of Brewer Road. 12/17/47, 21.3; 3/22/48, 20.3; 3/30/48, 19.5; 5/14/48, 17.1; 11/4/48, 23.3; 1/26/49, 21.0; 3/30/49, 19.0; 11/30/49, 26.4.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Mode by Division of Water Resources
(Depths to water in feet measured from reference point)

13N 5E-18C1—Reference point—top of casing, elevation 69.6 feet, 0.25 mile north of Bear River Drive, 0.7 mile west of Brewer Road. 12/3/47, 22.5; 3/30/48, 20.3; 11/4/48, 24.0; 3/31/49, 19.8.

13N 5E-18F1—Reference point—top of casing, elevation 60.8 feet, South side of Bear River Drive, 0.6 mile west of Brewer Road. 12/3/47, 14.3; 3/8/48, 15.2; 3/30/48, 12.1; 5/14/48, 14.0; 11/4/48, 20.3; 3/31/49, 15.9; 5/25/49, 21.3; 8/3/49, 31.1; 12/6/49, 23.4.

13N 5E-18R1—Reference point—hole in casing, elevation 69 feet, West side of Brewer Road, 0.75 mile south of Bear River Drive. 12/17/47, 24.2; 3/22/48, 23.7; 3/30/48, 23.0; 5/8/48, 21.4; 11/5/48, 28.4; 3/30/49, 23.5; 11/30/49, 32.8; 3/30/50, 28.0; 11/20/51, 31.4; 4/3/52, 25.7.

13N 5E-19C1—Reference point—bottom of pump base, elevation 71.6 feet, 0.75 mile south of Bear River Drive, 1.2 miles east of Pleasant Grove Road. 12/8/47, 27.7; 3/10/48, 27.0; 3/31/48, 26.0; 5/8/48, 24.5; 11/5/48, 30.0; 1/26/49, 27.4; 4/1/49, 25.2.

13N 5E-19N1—Reference point—top of casing, elevation 68.3 feet, North side of Kempton Road, 1.1 miles east of Pleasant Grove Road. 12/8/47, 24.8; 3/9/48, 25.9; 3/31/48, 23.6; 5/8/48, 22.2; 11/5/48, 28.6; 1/26/49, 25.9; 4/1/49, 24.0; 5/25/49, 42.0; 6/29/49, 54.2; 7/27/49, 45.0; 8/26/49, 58.0; 11/30/49, 31.1; 3/30/50, 27.3; 11/9/50, 34.3; 4/3/51, 26.8; 4/3/52, 22.4.

13N 5E-19P1—Reference point—top of casing, elevation 70.0 feet, North side of Kempton Road, 1.4 miles east of Pleasant Grove Road. 12/8/47, 25.5; 3/9/48, 25.5; 3/31/48, 24.1; 5/8/48, 23.7; 11/5/48, 29.6; 1/26/49, 27.0; 4/1/49, 25.1; 11/30/49, 32.3.

13N 5E-19R1—Reference point—top of casing, elevation 72.5 feet, 100 feet north of Kempton Road, 0.05 mile west of Brewer Road. 12/17/47, 26.6; 3/9/48, 26.8; 11/5/48, 30.5; 4/1/49, 25.9; 11/30/49, 33.3; 3/30/50, 29.7; 11/9/50, 37.1; 4/3/51, 28.5; 11/20/51, 35.7; 4/3/52, 28.5.

13N 5E-28A1—Reference point—slot in concrete base, elevation 80 feet, South side of Kempton Road, 1.8 miles east of Brewer Road. 11/5/48, 28.2; 4/4/49, 22.4; 5/12/49, 25.1; 7/1/49, 29.5; 7/29/49, 31.4; 8/25/49, 32.8; 9/29/49, 31.1; 11/10/49, 29.4; 11/30/49, 28.7; 2/15/50, 26.3; 3/14/50, 25.9; 3/30/50, 25.3; 4/5/50, 25.2; 5/8/50, 27.5; 6/7/50, 31.5; 7/7/50, 34.2; 8/1/50, 36.5; 9/6/50, 38.0; 10/3/50, 34.0; 11/9/50, 31.5; 11/14/50, 31.2; 1/4/51, 25.8; 2/7/51, 26.0; 3/27/51, 24.3; 5/9/51, 24.8; 11/15/51, 31.3; 11/20/51, 31.1; 2/28/52, 25.4; 3/31/52, 24.0; 4/3/52, 24.0.

13N 5E-28C1—Reference point—top of casing, elevation 76 feet, South side of Kempton Road, 1.3 miles east of Brewer Road. 12/17/47, 22.0; 3/9/48, 21.4; 11/5/48, 29.5; 4/4/49, 24.4; 11/10/49, 32.7; 11/30/49, 31.7; 3/30/50, 27.7; 11/9/50, 34.9; 3/27/51, 27.2; 11/20/51, 33.8; 4/3/52, 26.4.

13N 5E-23N1—Reference point—top of casing, elevation 80.7 feet, North side of Waltz Road, 1.25 miles east of Brewer Road. 11/5/48, 29.8; 1/26/49, 26.6; 4/1/49, 25.0; 11/10/49, 33.8; 3/15/50, 28.7; 3/30/50, 28.2; 4/5/50, 28.1; 9/5/50, 43.9; 10/3/50, 39.0; 11/10/50, 35.7; 11/14/50, 35.3; 12/14/50, 32.6; 1/4/51, 32.2; 3/23/51, 28.7; 11/15/51, 36.8; 11/21/51, 36.3; 3/31/52, 29.7; 4/3/52, 29.1.

13N 5E-23R1—Reference point—top of casing, elevation 84.7 feet, 0.1 mile north of Waltz Road, 2.0 miles east of Brewer Road. 11/5/48, 27.1; 4/4/49, 22.0; 9/29/49, 30.3; 11/9/49, 28.1; 2/15/50, 25.2; 3/15/50, 24.7; 4/5/50, 24.1; 5/9/50, 25.1; 6/7/50, 28.0; 7/7/50, 30.2; 8/1/50, 32.2; 9/5/50, 35.4; 10/3/50, 31.2; 11/14/50, 30.0; 12/14/50, 27.7; 1/4/51, 27.2; 3/23/51, 24.8; 5/9/51, 25.7; 6/5/51, 33.1; 7/16/51, 38.0; 8/22/51, 40.6; 9/26/51, 36.8; 11/15/51, 32.9; 2/28/52, 27.3; 3/31/52, 26.3.

13N 5E-29Q1—Reference point—top of casing, elevation 75.8 feet, North side of Waltz Road, 0.6 mile east of Brewer Road. 4/5/50, 28.5.

13N 5E-30A1—Reference point—top of casing, elevation 68 feet, Southwest of corner of Kempton and Brewer Roads. 4/1/49, 27.2.

13N 5E-30C1—Reference point—top of casing, elevation 70.3 feet, South side of Kempton Road, 0.6 mile west of Brewer Road. 12/8/47, 25.9; 3/9/48, 26.3; 3/31/48, 24.5; 11/5/48, 29.9; 4/1/49, 25.3; 11/30/49, 32.6.

13N 5E-30J1—Reference point—hole in pump base, elevation 69 feet, West side of Brewer Road, 0.3 mile north of Waltz Road. 3/22/49, 25.8.

13N 5E-30R1—Reference point—top of casing, elevation 70 feet, Northwest corner of Brewer and Waltz Roads. 11/5/48, 29.5; 4/4/49, 24.8; 11/9/49, 33.2; 11/30/49, 33.4; 2/15/50, 29.5; 3/14/50, 29.0; 3/30/50, 28.3; 4/5/50, 28.2; 11/10/50, 36.1; 11/15/51, 34.7; 11/21/51, 34.7; 3/31/52, 28.7; 4/3/52, 28.5.

13N 5E-31G1—Reference point—top of casing, elevation 69 feet, North side of Hicks Road, 0.35 mile west of Brewer Road. 12/16/47, 22.6; 3/9/48, 21.7; 3/31/48, 21.1; 11/5/48, 27.3; 1/26/49, 24.3; 4/4/49, 22.3; 11/10/49, 30.9; 11/30/49, 30.4; 2/16/50, 27.5; 3/14/50, 26.8; 3/30/50, 26.1; 11/3/50, 33.5; 11/10/50, 33.5; 4/3/52, 26.6.

13N 5E-32C1—Reference point—top of casing, elevation 74 feet, South side of Waltz Road, 0.35 mile east of Brewer Road. 2/25/49, 29.6; 4/1/49, 25.6; 5/12/49, 30.1; 6/27/49, 36.2; 7/29/49, 39.8; 8/25/49, 41.4; 9/29/49, 37.1; 11/9/49, 33.8; 2/15/50, 30.2; 3/15/50, 29.5; 4/5/50, 29.0; 5/9/50, 30.5; 6/7/50, 35.7; 7/7/50, 40.3; 8/1/50, 43.2; 9/5/50, 45.3; 10/3/50, 40.6; 11/14/50, 37.1; 12/14/50, 34.8; 1/4/51, 34.4; 3/23/51, 27.9; 5/9/51, 33.1; 6/5/51, 36.7; 7/11/51, 39.5; 8/22/51, 42.2; 9/26/51, 38.9; 11/15/51, 35.8; 2/28/52, 31.1; 3/31/52, 29.9.

13N 5E-33L1—Reference point—top of casing, elevation 80.1 feet, 0.35 mile north of Cornelius Avenue, 1.3 miles east of Brewer Road. 12/22/48, 27.5; 3/18/49, 25.3; 11/10/49, 34.3; 4/6/50, 28.2; 5/8/50, 28.9; 11/13/50, 35.0; 3/27/51, 29.1; 11/15/51, 37.8; 4/7/52, 30.6.

13N 5E-33P1—Reference point—top of casing, elevation 79.3 feet, 100 feet north of Cornelius Avenue, 1.3 miles east of Brewer Road. 12/22/48, 26.0; 3/18/49, 24.2; 11/10/49, 32.2; 4/6/50, 27.3; 11/13/50, 34.5; 3/27/51, 28.9; 11/15/51, 37.0; 4/7/52, 30.3.

14N 2E-2D2—Reference point—top of casing, elevation 39 feet, 0.15 mile south of Bogue Road, 0.6 mile east of Schlag Road. 12/15/47, 5.3; 3/8/48, 6.4; 11/12/48, 5.2; 3/21/49, 1.8; 11/29/49, 5.4; 3/24/50, 4.3; 11/2/50, 3.9; 3/28/51, 3.5; 11/16/51, 4.2; 4/1/52, 4.0.

14N 2E-10F1—Reference point—top of casing, elevation 35 feet, West side of Schlag Road, 0.55 mile north of Oswald Road. 11/27/29, 9.8; 10/6/30, 9.0; 12/12/31, 9.0; 11/30/32, 9.6; 11/10/34, 9.6; 11/28/36, 9.6; 1/25/39, 10.1; 1/13/41, 5.0.

14N 2E-10L1—Reference point—top of casing, elevation 37 feet, West side of Schlag Road, 0.5 mile north of Oswald Road. 12/20/33, 12.2; 11/10/34, 12.7; 11/11/36, 12.6; 11/24/37, 12.8.

14N 2E-10R1—Reference point—top of casing, elevation 30 feet, North side of Oswald Road, 0.45 mile east of Schlag Road. 11/6/47, 8.9; 12/15/48, 10.5; 12/9/49, 10.6; 11/10/50, 9.4; 12/8/51, 3.4.

14N 2E-12H1—Reference point—top of pipe in base, elevation 41 feet, 150 feet west of Township Road, 0.6 mile north of Oswald Road. 12/15/47, 9.5; 3/9/48, 10.6; 11/12/48, 9.7; 3/21/49, 8.2; 11/29/49, 10.6.

14N 2E-13A1—Reference point—top of casing, elevation 42.1 feet, 0.05 mile south of Oswald Road, 0.1 mile west of Township Road. 12/15/47, 8.9; 3/8/48, 10.3; 11/12/48, 6.1; 3/21/49, 7.0; 11/29/49, 8.4.

14N 2E-13C1—Reference point—top of casing, elevation 39 feet, 100 feet south of Oswald Road, 0.7 mile west of Township Road. 12/15/47, 5.5; 3/8/48, 6.6; 11/12/48, 4.7; 3/21/49, 3.1; 11/29/49, 6.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet meosured from reference point)

14N/2E-13R1—Reference point—top of casing, elevation 37 feet, 0.1 mile west of Township Road, 0.4 mile south of Pierce Road. 12/15/47, 10.9; 3/8/48, 11.7; 10/8/48, 8.0; 11/12/48, 9.5; 1/18/49, 11.0; 3/21/49, 8.5; 6/6/49, 10.4; 6/30/49, 6.7; 7/27/49, 5.4; 8/25/49, 5.5; 11/29/49, 11.1; 3/24/50, 10.9; 11/2/50, 10.2; 3/28/51, 9.0; 11/16/51, 11.2; 4/1/52, 6.5.

14N/2E-14E1—Reference point—top of casing, elevation 34 feet, 0.4 mile south of Oswald Road, 0.4 mile west of Boulton Road. 12/15/47, 5.5; 3/8/48, 6.6; 11/12/48, 4.7; 3/21/49, 3.1; 11/29/49, 6.0.

14N/2E-14J1—Reference point—top of stone casing, elevation 36 feet, 0.1 mile south of Pierce Road, 0.3 mile east of Boulton Road. 12/15/47, 4.7; 3/8/48, 6.0; 10/8/48, 2.2; 11/12/48, 3.9.

14N/2E-26R1—Reference point—top of casing, elevation 33 feet, 0.2 mile north of O'Banion Road, 1.1 miles west of Township Road. 12/11/47, 7.4; 3/10/48, 7.6; 11/8/48, 6.4; 3/24/49, 3.9; 12/2/49, 7.7.

14N/3E-1H1—Reference point—top of casing, elevation 54 feet, 0.20 mile west of Feather River Boulevard, 1.70 miles north of Ella Avenue. 11/12/47, 21.2; 3/5/48, 20.0; 5/8/48, 15.8; 10/7/48, 23.8; 11/11/48, 22.3; 1/27/49, 20.9; 3/22/49, 17.6; 6/1/49, 25.2; 7/3/49, 25.5; 8/26/49, 25.5; 12/1/49, 23.5; 3/28/50, 17.2; 11/21/51, 22.7; 4/5/52, 10.8.

14N/3E-1R1—Reference point—top of casing, elevation 53 feet, 0.20 mile west of Feather River Boulevard, 1.20 miles north of Ella Avenue. 11/12/47, 20.5; 3/5/48, 20.2; 11/11/48, 20.1; 3/22/49, 17.9; 12/1/49, 23.5.

14N/3E-2G1—Reference point—hole in base of pump, elevation 49 feet, 0.36 mile north of Stewart Road, 0.45 mile east of Garden Highway. 11/11/47, 32.3; 3/24/48, 24.0; 10/6/48, 27.7; 11/15/48, 24.4; 3/17/49, 21.4; 11/30/49, 29.8.

14N/3E-2Q1—Reference point—hole in base of pump, elevation 53.9 feet, 0.07 mile south of Stewart Road, 0.10 mile east of Garden Highway. 11/10/47, 26.8; 3/4/48, 33.9; 11/15/48, 28.8; 3/17/49, 21.7; 11/30/49, 23.2; 3/27/50, 21.4; 11/3/50, 26.7; 3/29/51, 17.9; 11/20/51, 27.2.

14N/3E-3A1—Reference point—hole in side of pump, elevation 50 feet, 0.19 mile south of Bogue Road, 0.25 mile east of Highway 24. 11/10/47, 36.1; 3/23/48, 35.5; 10/6/48, 36.3; 11/15/48, 31.0; 3/7/49, 29.3; 11/30/49, 35.0; 3/27/50, 30.5; 11/3/50, 33.5; 3/28/51, 27.2; 11/16/51, 32.2.

14N/3E-3C2—Reference point—hole in base of pump, elevation 53.1 feet, 0.05 mile south of Bogue Road, 0.11 mile west of State Highway 24. 3/12/48, 43.8; 10/6/48, 35.6; 11/11/48, 33.9; 1/18/49, 32.8; 3/7/49, 32.1; 6/1/49, 37.6; 6/28/49, 45.0; 7/27/49, 47.5; 8/25/49, 42.3; 12/1/49, 35.4.

14N/3E-3C3—Reference point—bottom of pump base, elevation 53.1 feet, 0.27 mile south of Bogue Road, 0.06 mile west of State Highway 24. 3/29/48, 36.4; 11/15/48, 33.9; 3/7/49, 32.7; 11/30/49, 35.0.

14N/3E-3F1—Reference point—top of casing, elevation 51.3 feet, 0.2 mile west of State Highway 24, 0.45 mile south of Bogue Road. 11/18/47, 31.6; 3/23/48, 39.2; 10/6/48, 34.0; 11/11/48, 32.8; 3/17/49, 30.9; 11/30/49, 34.4.

14N/3E-3G1—Reference point—hole in pump base, elevation 52 feet, 0.17 mile east of State Highway 24, 0.54 mile south of Bogue Road. 3/4/48, 37.5; 11/16/48, 32.8; 3/17/49, 29.7; 11/30/49, 32.9.

14N/3E-3N1—Reference point—top of casing, elevation 55.4 feet, 0.09 mile south of Stewart Road, 0.40 mile west of State Highway 24. 11/10/47, 38.7; 3/4/48, 41.5; 11/15/48, 39.7; 3/17/49, 37.1; 11/30/49, 43.7.

14N/3E-3N2—Reference point—hole in base of pump, elevation 48 feet, South side of Stewart Road, 0.30 mile west of State Highway 24. 3/12/48, 40.4; 11/15/48, 34.7.

14N/3E-3P1—Reference point—top of pit, elevation 50 feet, 0.10 mile north of Reed Road, 0.17 mile west of State Highway 24. 11/26/29, 28.3; 9/27/30, 32.4; 12/12/31, 33.8; 12/1/32, 32.4; 12/15/33, 33.4; 11/10/34, 34.1; 11/25/36, 28.4; 11/24/37, 26.2; 1/26/39, 20.4; 1/13/41, 24.0; 11/6/47, 33.8; 12/15/48, 34.2; 12/9/49, 36.0; 11/10/50, 39.1.

14N/3E-3R2—Reference point—slot in base, elevation 51.3 feet, 0.19 mile south of Stewart Road, 0.35 mile east of Garden Highway. 11/10/47, 31.1; 11/15/48, 28.4; 3/17/49, 25.2; 11/30/49, 30.7.

14N/3E-4E3—Reference point—top of casing, elevation 47 feet, 0.05 mile south of Star Road, 0.20 mile east of Grove Avenue. 12/16/47, 30.6; 3/24/48, 31.7; 11/12/48, 33.3; 3/18/49, 30.0; 11/29/49, 35.8.

14N/3E-4G1—Reference point—hole in pump base, elevation 50.1 feet, 0.20 mile east of Walton Avenue, 0.48 mile south of Bogue Road. 11/18/47, 33.8; 3/12/48, 35.4; 10/6/48, 37.0; 11/11/48, 35.1; 3/18/49, 33.1; 11/30/49, 37.1.

14N/3E-4Q1—Reference point—hole in base of pump, elevation 47 feet, 0.10 mile north of Reed Road, 0.04 mile east of Walton Avenue. 11/10/47, 32.9; 3/4/48, 34.0; 3/12/48, 36.7; 3/29/48, 32.3; 11/15/48, 33.9; 3/18/49, 31.2; 11/29/49, 35.6; 3/27/50, 33.2; 11/3/50, 38.5; 3/28/51, 32.9; 11/16/51, 36.2.

14N/3E-5A2—Reference point—top of concrete pit, elevation 49 feet, West side of Grove Avenue, 0.15 mile south of Bogue Road. 12/16/47, 29.9; 3/9/48, 32.7; 10/7/48, 34.8; 11/12/48, 32.5; 3/18/49, 29.0; 11/29/49, 34.0.

14N/3E-5C1—Reference point—hole in base of pump, elevation 50 feet, 0.07 mile south of Bogue Road, 0.50 mile east of George Washington Boulevard. 12/16/48, 30.4; 3/9/48, 28.8; 10/7/48, 31.2; 11/12/48, 29.0; 3/18/49, 26.1; 6/1/49, 32.8; 7/27/49, 41.8; 8/25/49, 39.0; 11/29/49, 30.2; 3/27/50, 27.1; 11/3/50, 33.5; 3/28/51, 23.6; 4/1/52, 23.8.

14N/3E-5D1—Reference point—invert of pipe in base, elevation 48.1 feet, South side of Bogue Road, 0.15 mile east of George Washington Boulevard. 12/20/47, 23.4; 3/5/48, 25.3; 10/4/48, 26.6; 11/18/48, 24.8; 3/29/49, 22.0.

14N/3E-5K1—Reference point—hole in base of pump, elevation 46 feet, 0.14 mile north of Stewart Road, 0.47 mile west of Grove Avenue. 3/9/48, 27.3; 3/30/48, 28.4; 11/12/48, 31.0; 12/9/49, 31.7.

14N/3E-6G1—Reference point—slot in concrete base, elevation 45 feet, 0.45 mile west of George Washington Boulevard, 0.38 mile south of Bogue Road. 12/16/47, 13.9; 3/9/48, 14.7; 11/12/48, 14.6; 12/9/49, 15.0.

14N/3E-6M1—Reference point—hole in base of pump, elevation 40 feet, 0.50 mile north of Reed Road, 0.06 mile east of Township Road. 12/15/47, 10.8; 3/24/48, 13.2; 10/8/48, 7.3; 11/12/48, 9.3; 1/18/49, 10.9; 3/21/49, 9.2; 6/6/49, 6.1; 6/28/49, 6.7; 7/27/49, 6.6; 8/25/49, 6.0; 11/29/49, 10.1; 3/24/50, 9.9; 11/2/50, 10.0; 3/28/51, 8.7; 11/16/51, 9.2; 4/1/52, 7.9.

14N/3E-7A1—Reference point—hole in base of pump, elevation 45 feet, 0.12 mile south of Reed Road, 0.25 mile west of George Washington Boulevard. 12/17/47, 19.5; 3/9/48, 20.2; 11/12/48, 20.6; 3/21/49, 18.6; 11/29/49, 21.3.

14N/3E-7M1—Reference point—top of casing under pump, elevation 42 feet, 0.10 mile east of Township Road, 0.52 mile north of Oswald Avenue. 12/15/47, 11.2; 3/9/48, 12.3; 11/12/48, 11.8; 3/21/49, 10.2; 11/29/49, 11.2; 3/24/50, 10.8; 11/2/50, 11.8; 3/28/51, 9.0; 11/16/51, 11.1; 4/2/52, 10.1.

14N/3E-8B1—Reference point—hole in base of pump, elevation 45 feet, South side of Reed Road, 0.52 mile west of Walton Avenue. 12/17/47, 26.3; 3/9/48, 25.6; 11/12/48, 30.2; 3/21/49, 25.0; 11/29/49, 31.1; 3/27/50, 26.1; 11/3/50, 35.3; 3/28/51, 24.3; 11/16/51, 31.6; 4/2/52, 27.7.

14N/3E-8D1—Reference point—hole in base of pump, elevation 46.6 feet, South side of Reed Road, 0.15 mile east of George Washington Boulevard. 12/17/47, 23.2; 3/9/48, 23.5; 3/21/49, 21.6.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

14N 3E-8J1—Reference point—hole in base of pump, elevation 45 feet, 0.03 mile west of Grove Avenue, 0.45 mile north of Oswald Avenue, 12/16/47, 27.8; 3/4/48, 29.0; 11/12/48, 30.8; 3/18/49, 27.3; 11/29/49, 33.1; 3/27/50, 29.4; 11/3/50, 36.2; 3/28/51, 29.1; 11/19/51, 33.8; 4/2/52, 23.8.

14N 3E-8K1—Reference point—hole in base of pump, elevation 45 feet, 0.40 mile west of Grove Avenue, 0.35 mile north of Oswald Road, 12/16/47, 26.9; 3/24/48, 28.3; 11/12/48, 30.9; 3/18/49, 26.8; 11/29/49, 32.1.

14N 3E-8M3—Reference point—top of casing, elevation 45 feet, 0.20 mile east of George Washington Boulevard, 0.50 mile north of Oswald Road, 12/17/47, 22.7; 3/9/48, 21.1; 10/7/48, 28.0; 11/12/48, 25.6; 1/18/49, 23.1; 3/21/49, 21.8; 6/1/49, 25.0; 6/30/49, 26.3; 7/27/49, 34.5; 8/25/49, 31.5; 11/29/49, 26.7.

14N 3E-8N1—Reference point—top of casing, elevation 44.8 feet, North side of Oswald Avenue, 0.15 mile east of George Washington Boulevard, 12/16/47, 21.5; 3/9/48, 16.4; 3/12/48, 21.8; 11/12/48, 23.8; 3/21/49, 20.7; 11/29/49, 21.9; 3/24/50, 21.4; 11/2/50, 29.3; 3/28/51, 18.9; 11/19/51, 25.5; 4/2/52, 13.5.

14N 3E-9A2—Reference point—top of concrete pit, south edge, elevation 40 feet, 0.1 mile south of Reed Road, 0.35 mile east of Walton Avenue, 11/19/47, 32.0; 3/4/48, 32.3; 5/12/48, 31.1; 11/15/48, 32.1; 11/18/49, 32.1; 3/18/49, 31.0; 11/30/49, 35.2.

14N 3E-9D1—Reference point—hole in base of pump, elevation 46 feet, 0.10 mile south of Reed Road, 0.45 mile west of Walton Road, 12/16/47, 31.4; 3/9/48, 33.8.

14N 3E-9K1—Reference point—top of casing, elevation 45 feet, South side of Barry Road, 0.25 mile east of Walton Avenue, 11/8/47, 33.2; 3/4/48, 34.9; 3/12/48, 34.1; 3/29/48, 32.5; 10/6/48, 35.6; 11/15/48, 34.3; 3/17/49, 32.0; 11/30/49, 35.8.

14N 3E-9Q1—Reference point—hole in base of pump, elevation 42 feet, North side of Oswald Road, 0.25 mile east of Walton Avenue, 3/12/48, 29.0; 11/15/48, 23.4; 3/17/49, 21.3.

14N 3E-10B1—Reference point—top of casing, elevation 50 feet, 0.17 mile east of State Highway 24, 0.33 mile north of Barry Road, 11/19/47, 29.4; 10/6/48, 31.3; 11/30/49, 31.2; 11/3/50, 33.5; 11/20/51, 31.7.

14N 3E-10B2—Reference point—top of casing, elevation 49 feet, 0.32 mile south of Stewart Road, 0.18 mile east of State Highway 24, 11/19/47, 29.4; 3/4/48, 32.0; 10/6/48, 31.3; 11/15/48, 31.5; 3/7/49, 26.3; 11/30/49, 31.2; 3/27/50, 28.4; 11/3/50, 33.5; 3/29/51, 24.8; 11/20/51, 31.7.

14N 3E-10F1—Reference point—top of casing at bottom of pit, elevation 27 feet, 0.70 mile west of State Highway 24, 0.80 mile north of Barry Road, 11/18/47, 35.1; 3/4/48, 34.1; 3/12/48, 33.9; 11/15/48, 34.8; 3/17/49, 31.7; 11/29/49, 36.6.

14N 3E-10N1—Reference point—top of concrete base, elevation 18.6 feet, 0.08 mile north of Oswald Avenue, 0.36 mile west of State Highway 24, 11/8/47, 30.1; 3/12/48, 32.1; 3/29/48, 29.1; 5/12/48, 27.0; 10/6/48, 32.2; 11/15/48, 31.3; 1/18/49, 29.4; 3/17/49, 28.5; 11/30/49, 32.2; 3/29/50, 30.0; 11/3/50, 33.9; 3/29/51, 28.6; 11/20/51, 32.3.

14N 3E-11D2—Reference point—top of casing, elevation 49 feet, 0.10 mile north of Barry Road, 0.63 mile east of State Highway 24, 11/19/47, 27.3; 3/4/48, 30.6; 3/29/48, 31.3; 5/12/48, 23.4; 10/6/48, 34.1; 11/16/48, 27.7; 11/18/49, 25.8; 3/17/49, 24.4; 6/1/49, 31.6; 6/28/49, 39.2; 8/3/49, 38.9; 8/25/49, 31.8; 11/30/49, 29.1.

14N 3E-11F2—Reference point—hole in base of pump, elevation 51.7 feet, 0.17 mile north of Barry Road, 0.95 mile east of State Highway 24, 11/10/47, 27.1; 3/23/48, 27.8; 11/16/48, 21.2; 3/17/49, 20.7; 11/30/49, 26.1; 3/27/50, 19.6; 11/3/50, 26.1; 3/29/51, 16.0; 11/20/51, 25.0.

14N 3E-12F1—Reference point—top of casing, elevation 52 feet, 0.65 mile north of Ella Road, 0.50 mile east of Feather River Boulevard, 3/28/50, 17.0; 11/6/50, 23.6; 3/30/51, 18.4; 4/5/52, 20.6.

14N 3E-12M1—Reference point—hole in base of pump, elevation 50 feet, 0.22 mile north of Ella Avenue, 0.84 mile west of Feather River Boulevard, 11/12/47, 20.4; 3/6/48, 20.5; 11/15/48, 20.2; 3/22/49, 16.8; 12/1/49, 22.1; 3/28/50, 17.6; 11/6/50, 72.1; 11/21/51, 20.8; 4/5/52, 9.5.

14N 3E-12Q1—Reference point—hole in base of pump, elevation 53.6 feet, 0.23 mile north of Ella Avenue, 0.29 mile west of Feather River Boulevard, 11/11/49, 21.7; 3/5/48, 23.0; 5/8/48, 19.5.

14N 3E-13B1—Reference point—top of casing, elevation 50.9 feet, 0.17 mile south of Ella Avenue, 0.44 mile west of Feather River Boulevard, 11/12/47, 20.7; 3/5/48, 22.8; 11/11/48, 20.2; 3/2/49, 18.0; 12/1/49, 22.1; 3/28/50, 21.7; 11/6/50, 21.8; 3/30/51, 13.0; 11/20/51, 21.8; 4/5/52, 12.1.

14N 3E-13N1—Reference point—hole in base of pump, elevation 48.3 feet, 0.11 mile north of Plumas Road, 0.81 mile west of Feather River Boulevard, 3/6/48, 24.1; 5/8/48, 16.0; 11/11/48, 19.8; 1/27/49, 18.4; 3/21/49, 16.9; 12/1/49, 21.1; 3/29/50, 17.4; 11/6/50, 20.9; 4/5/52, 10.0.

14N 3E-14E1—Reference point—hole in base of pump, elevation 47 feet, 0.20 mile west of Garden Highway, 0.75 mile north of Messick Road, 11/18/47, 25.3; 3/23/48, 22.1; 11/15/48, 22.2; 3/17/49, 19.6; 11/29/49, 22.4.

14N 3E-14E2—Reference point—top of casing, elevation 47 feet, 0.11 mile west of Garden Highway, 0.75 mile north of Messick Road, 11/10/47, 20.6; 3/5/48, 23.7; 5/12/48, 13.9; 10/6/48, 21.6; 11/15/48, 20.2; 1/27/49, 19.2; 3/17/49, 17.1; 6/1/49, 19.5; 6/30/49, 26.7; 7/27/49, 28.0; 8/25/49, 25.7; 11/29/49, 23.3; 3/29/50, 16.4; 11/3/50, 23.3; 3/29/51, 12.7; 11/20/51, 20.8.

14N 3E-14N1—Reference point—hole in base of pump, elevation 46 feet, 0.27 mile north of Messick Road, 0.13 mile east of Garden Highway, 11/18/47, 19.1; 3/5/48, 27.7; 11/15/48, 19.4; 3/17/49, 16.6; 11/29/49, 21.6.

14N 3E-14R1—Reference point—hole in base of pump, elevation 49.4 feet, 1.07 miles west of Feather River Boulevard, 0.67 mile north of Broadway, 11/11/47, 24.3; 3/6/48, 25.8; 11/11/48, 20.9; 3/21/49, 17.9; 12/1/49, 22.1; 3/29/50, 17.9; 11/6/50, 22.3; 3/30/51, 13.4; 11/20/51, 21.1; 4/5/52, 10.9.

14N 3E-15A2—Reference point—slot in base of pump, elevation 47 feet, 0.57 mile south of Barry Road, 0.41 mile east of State Highway 24, 11/19/47, 27.6; 3/23/48, 27.8; 11/15/48, 29.7; 3/17/49, 24.8; 11/29/49, 28.8.

14N 3E-15B1—Reference point—top of casing, elevation 47 feet, 0.18 mile south of Oswald Avenue, 0.04 mile east of State Highway 24, 11/8/47, 39.0; 3/5/48, 33.8; 3/12/48, 32.5; 11/15/48, 28.5; 3/17/49, 35.1; 11/29/49, 33.2.

14N 3E-15B2—Reference point—top of casing, elevation 48 feet, 1.0 mile north of Messick Road, 0.17 mile east of State Highway 24, 11/18/47, 26.9.

14N 3E-15E1—Reference point—hole in base of pump, elevation 17.2 feet, 0.48 mile south of Oswald Road, 0.43 mile west of State Highway 24, 3/23/48, 27.9; 10/6/48, 29.0; 11/15/48, 27.0; 3/17/49, 25.9; 11/30/49, 29.4.

14N 3E-15P1—Reference point—top of casing, elevation 45 feet, 0.38 mile north of Messick Road, 0.02 mile west of State Highway 24, 3/23/48, 29.2; 11/15/48, 17.2; 3/17/49, 25.9; 11/29/49, 28.5.

14N 3E-16C1—Reference point—hole in base of pump, elevation 48.9 feet, 0.10 mile west of Walton Avenue, 0.22 mile south of Oswald Road, 12/16/47, 32.3; 3/20/48, 30.6; 3/26/48, 29.9; 3/30/48, 29.9; 5/12/48, 28.1; 11/15/48, 31.8; 3/18/49, 29.6; 11/29/49, 34.7.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

14N/3E-16E1—Reference point—top of casing, elevation 47.7 feet, 0.25 mile east of Carlson Road, 0.40 mile south of Oswald Road. 12/16/47, 27.1; 3/20/48, 29.0; 10/7/48, 30.2; 11/15/48, 28.9; 3/18/49, 26.8; 11/29/49; 35.8; 3/27/50, 28.6; 11/3/50, 32.6; 3/29/51, 30.2; 11/19/51, 30.6; 4/2/52, 22.2.

14N/3E-16J1—Reference point—top of casing, elevation 46.4 feet, 0.77 mile west of State Highway 24, 0.64 mile south of Oswald Avenue. 11/7/47, 28.4; 3/5/48, 25.2; 3/12/48, 25.3; 10/6/48, 28.2; 11/15/48, 26.8; 1/27/49, 26.1; 3/17/49, 25.4; 3/29/50, 26.6; 11/3/50, 24.2; 3/29/51, 25.1.

14N/3E-17B1—Reference point—top of "I" beam pump support, elevation 44 feet, 0.35 mile west of Carlson Road, 0.06 mile south of Oswald Road. 12/16/47, 31.9; 3/9/48, 24.2; 3/12/48, 24.7; 11/12/48, 26.9; 3/18/49, 24.0; 11/29/49, 29.0.

14N/3E-17Q1—Reference point—top of casing under pump, elevation 42.5 feet, 0.30 mile west of Carlson Road, 0.25 mile north of Best Road. 12/16/47, 22.7; 3/8/48, 23.5; 3/12/48, 23.2; 10/7/48, 26.3; 11/15/48, 24.9; 1/27/49, 23.9; 3/18/49, 23.1; 11/29/49, 29.7.

14N/3E-17R1—Reference point—top of casing, elevation 45.9 feet, West side of Carlson Road, 0.23 mile north of Best Road. 3/30/48, 24.5; 11/15/48, 27.3; 3/18/49, 25.8.

14N/3E-18D1—Reference point—top of casing, elevation 43 feet, Southeast corner of Oswald Avenue and Township Road. 11/26/29, 9.3; 10/6/30, 7.2; 12/12/31, 11.0; 11/30/32, 10.3; 12/20/33, 12.5; 11/10/34, 10.1; 11/28/36, 8.7; 11/24/37, 8.6; 1/25/39, 8.5; 1/13/41, 1.3; 11/6/47, 6.9; 12/15/48, 7.9; 12/9/49, 7.9; 11/10/50, 7.7; 12/8/51, 5.8.

14N/3E-18F1—Reference point—top of casing, elevation 40 feet, 0.41 mile south of Oswald Avenue, 0.23 mile east of Township Road. 12/15/47, 11.3; 3/8/48, 6.1; 10/8/48, 5.1; 11/12/48, 5.1; 3/2/49, 5.0; 11/29/49, 5.8; 3/27/50, 5.2; 11/2/50, 6.7; 3/28/51, 4.8; 11/16/51, 6.7; 4/2/52, 5.0.

14N/3E-18H3—Reference point—top of concrete pit, elevation 41 feet, West side George Washington Boulevard, 0.44 mile south of Oswald Avenue. 12/16/47, 19.6; 3/8/48, 18.2; 10/7/48, 20.9; 11/12/48, 20.1; 3/21/49, 18.0; 11/29/49, 20.6.

14N/3E-18R1—Reference point—top of casing, elevation 40 feet, 0.10 mile north of Best Road, 0.26 mile west of George Washington Boulevard. 12/15/47, 16.9; 3/8/48, 17.1; 11/12/48, 18.5; 3/21/49, 16.8; 11/29/49, 19.6.

14N/3E-19L1—Reference point—hole in pump base, elevation 37 feet, 0.50 mile west of George Washington Boulevard, 0.69 mile south of Best Boad. 12/5/47, 10.9; 3/8/48, 11.6; 10/8/48, 15.8; 11/12/48, 13.8; 3/18/49, 12.7; 11/29/49, 14.9; 3/27/50, 13.1; 11/2/50, 15.8; 3/28/51, 10.6; 11/16/51, 14.5; 4/2/52, 6.0.

14N/3E-19P1—Reference point—top of pipe in base, elevation 38 feet, 0.50 mile west of George Washington Boulevard, 0.83 mile north of Best Road. 12/11/47, 13.2; 3/24/48, 14.0; 11/8/48, 13.7; 3/24/49, 12.2; 12/2/49, 14.6.

14N/3E-20A2—Reference point—hole in casing, elevation 44.5 feet, 0.10 mile south of Best Road, east side of George Washington Boulevard. 12/16/47, 22.7; 3/8/48, 21.6; 11/15/48, 25.3; 3/18/49, 24.0; 11/29/49, 26.9; 3/27/50, 25.4; 11/3/50, 32.6; 3/28/51, 25.2; 11/19/51, 26.4; 4/2/52, 18.4.

14N/3E-20E1—Reference point—top of casing, elevation 40 feet, 0.27 mile south of Best Road, 0.20 mile east of George Washington Boulevard. 12/16/47, 17.9; 3/8/48, 20.0; 3/29/48, 18.0; 11/12/48, 20.1; 3/18/49, 18.3; 11/29/49, 21.7.

14N/3E-20F1—Reference point—top of casing, elevation 40 feet, 0.49 mile east of George Washington Boulevard, 0.51 mile north of Hutchinson Road. 12/16/47, 20.8; 3/8/48, 23.7; 3/12/48, 23.6; 10/7/48, 24.0; 11/15/48, 23.1; 3/18/49, 21.4; 11/29/49, 24.8; 3/27/50, 22.6; 11/2/50, 26.4; 3/28/51, 20.6; 11/19/51, 24.2; 4/2/52, 15.7.

14N/3E-20Q1—Reference point—top of concrete pit, elevation 42 feet, 0.54 mile west of George Washington Boulevard, 0.14 mile north of Hutchinson Road. 12/13/47, 20.1; 3/10/48, 21.3; 3/12/48, 21.5; 11/8/48, 24.9; 3/23/49, 20.5; 12/5/49, 24.0; 3/24/50, 21.5; 11/7/50, 26.7; 3/28/51, 21.8; 11/15/51, 22.7; 4/3/52, 14.8.

14N/3E-21M1—Reference point—top of casing, elevation 44.3 feet, 0.46 mile north of Hutchinson Road, west side of Carlson Road. 12/16/47, 21.8; 3/8/48, 23.0; 3/20/48, 23.4; 3/26/48, 22.2; 3/30/48, 21.7; 10/7/48, 24.2; 11/15/48, 24.0; 3/18/49, 23.2; 11/29/49, 25.7.

14N/3E-21Q1—Reference point—hole in pump base, elevation 42 feet, North side of Hutchinson Road, 0.48 mile west of State Highway 24. 11/15/47, 21.9; 3/8/48, 23.9; 3/12/48, 27.4; 3/26/48, 22.0; 3/29/48, 21.9; 5/12/48, 21.2; 11/9/48, 25.0; 1/18/49, 24.0; 3/23/49, 22.8; 6/1/49, 21.8; 6/28/49, 30.4; 8/3/49, 20.1; 8/25/49, 28.6; 12/6/49, 26.0.

14N/3E-22B2—Reference point—bottom of pump base, elevation 48.3 feet, North side of Messick Road, 0.50 mile west of Garden Highway. 11/7/47, 25.9; 3/5/48, 26.1; 3/12/48, 26.6; 3/29/48, 25.2; 10/6/48, 28.5; 11/15/48, 25.8; 3/17/49, 24.4; 11/30/49, 27.6; 3/29/50, 25.2; 11/3/50, 28.0; 3/29/51, 22.3; 11/20/51, 26.3.

14N/3E-22E2—Reference point—bottom of pump base, elevation 47.8 feet, South of Messick Road, 0.1 mile east of State Highway 24. 11/7/47, 26.6; 3/5/48, 26.2; 3/12/48, 27.8; 11/15/48, 25.3; 3/17/49, 23.8; 11/29/49, 27.5.

14N/3E-22H1—Reference point—top of casing, elevation 47.2 feet, 0.03 mile west of Garden Highway, 0.16 mile south of Messick Road. 3/5/48, 22.1; 10/6/48, 19.8; 11/15/48, 20.7.

14N/3E-22R1—Reference point—hole in concrete base, elevation 45.2 feet, West side Garden Highway, 0.15 mile north of Hutchinson Road. 11/15/47, 20.9; 3/8/48, 26.4; 3/29/48, 19.0; 5/12/48, 16.5; 11/10/48, 20.7; 1/24/49, 19.9; 3/23/49, 17.9; 12/6/49, 22.4.

14N/3E-23D2—Reference point—top of concrete base, elevation 48.1 feet, 0.2 mile east of Garden Highway, 0.03 mile south of Messick Road. 11/7/47, 20.6; 3/23/48, 21.1; 10/6/48, 23.3; 11/15/48, 22.2; 3/17/49, 20.9; 11/29/49, 23.0; 3/29/50, 18.8; 11/3/50, 22.9; 3/29/51, 16.3; 11/20/51, 22.3.

14N/3E-24B1—Reference point—hole in pump base, elevation 50.8 feet, 0.01 mile south of Plumas Road, 0.26 mile west of Feather River Boulevard. 11/11/47, 23.1; 3/6/48, 22.6; 5/8/48, 20.7; 10/7/48, 24.2; 11/11/48, 22.0; 3/21/49, 19.9; 6/1/49, 24.6; 7/3/49, 31.0; 7/28/49, 28.8; 8/26/49, 30.0; 12/1/49, 23.4; 3/29/50, 22.2; 11/6/50, 24.5; 3/30/51, 14.4; 11/20/51, 23.9; 4/5/52, 14.6.

14N/3E-24G1—Reference point—top of casing at pit bottom, elevation 39.4 feet, 0.10 mile north of Broadway, 0.31 mile east of Feather River Boulevard. 11/11/47, 14.2; 3/6/48, 12.1, 11/11/48, 12.0; 3/21/49, 9.4; 12/1/49, 13.4.

14N/3E-25B2—Reference point—hole in side of pump, elevation 47 feet, South of Anderson Road, 0.31 mile west of Feather River Boulevard. 11/17/47, 22.5; 3/8/48, 19.7; 5/8/48, 17.3; 11/10/48, 20.1; 1/24/49, 18.9; 3/23/49, 17.6; 12/2/49, 21.3.

14N/3E-25C1—Reference point—top of casing, elevation 49.5 feet, 0.15 mile south of Anderson Road, 0.71 mile west of Feather River Boulevard. 11/17/47, 22.3; 3/8/48, 19.8; 11/10/48, 22.0; 3/23/49, 19.8; 12/2/49, 22.7; 3/29/50, 18.6; 11/6/50, 22.6; 3/30/51, 15.9; 11/6/51, 21.5; 4/1/52, 15.4.

14N/3E-25K2—Reference point—top of casing, elevation 46.1 feet, 0.01 mile south of Country Club Road, 0.26 mile west of Feather River Boulevard. 11/17/47, 17.8; 3/8/48, 18.5; 3/23/49, 15.6; 12/2/49, 19.1.

14N/3E-26M2—Reference point—hole in base of pump, elevation 44 feet, 0.32 mile north of O'Banion Road, 0.22 mile east of Garden Highway. 11/14/47, 21.0; 3/8/48, 23.4; 5/6/48, 14.4; 6/1/48, 14.7; 7/3/48, 52.4 (operating); 11/10/48, 20.9; 3/23/49, 16.8; 12/6/49, 22.4.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

14N/3E-27D1—Reference point—top of casing, elevation 42 feet. East side of State Highway 24, 0.10 mile south of Hutchinson Road. 11/15/47, 21.7; 3/8/48, 22.0; 3/12/48, 28.4; 5/12/48, 20.8; 11/9/48, 24.2; 3/23/49, 21.8; 12/6/49, 25.4; 3/29/50, 23.2; 11/7/50, 26.1; 3/29/51, 19.9; 11/15/51, 26.4; 4/3/52, 13.5.

14N/3E-27J1—Reference point—hole in base of pump, elevation 43 feet. West side of Garden Highway, 0.36 mile north of O'Banion Road. 11/14/47, 21.4; 3/8/48, 30.7; 5/5/48, 15.0; 11/10/48, 20.6; 3/23/49, 17.1; 6/1/49, 21.5; 8/30/49, 26.6; 12/6/49, 22.1; 3/29/50, 17.6; 11/7/50, 22.3; 3/29/51, 13.8; 11/15/51, 21.1; 4/3/52, 9.0.

14N/3E-27M2—Reference point—hole in base of pump, elevation 41 feet, 0.06 mile east of State Highway 24, 0.33 mile north of O'Banion Road. 11/15/47, 22.3; 3/8/48, 24.1; 11/9/48, 23.1; 3/23/49, 20.6; 12/6/49, 24.8.

14N/3E-28G2—Reference point—top of casing, elevation 41 feet, 0.28 mile west of State Highway 24, 0.45 mile south of Hutchinson Road. 1/16/48, 21.4.

14N/3E-28M1—Reference point—top of wooden platform under pump, elevation 43.6 feet, 0.31 mile north of O'Banion Road, 0.15 mile east of Carlson Road. 12/13/47, 21.6; 3/9/48, 25.4; 3/12/48, 25.6; 11/8/48, 25.6; 3/24/49, 22.3; 12/5/49, 26.6.

14N/3E-28R1—Reference point—top of casing, elevation 40 feet, 0.16 mile west of State Highway 24, 0.16 mile north of O'Banion Road. 11/14/47, 21.3; 3/24/48, 21.9; 11/9/48, 23.8; 3/23/49, 20.4; 12/6/49, 30.3; 3/29/50, 22.5; 11/2/50, 26.7; 3/29/51, 19.5.

14N/3E-29A1—Reference point—hole in base of pump, elevation 43.5 feet, 0.16 mile west of Carlson Road, 0.24 mile south of Hutchinson Road. 12/13/47, 22.6; 3/10/48, 24.0; 3/12/48, 24.6; 11/8/48, 25.1; 3/24/49, 22.2; 12/5/49, 26.3.

14N/3E-29L1—Reference point—top of casing, elevation 41 feet, 0.48 mile east of George Washington Boulevard, 0.27 mile north of O'Banion Road. 12/13/47, 20.0; 3/9/48, 20.0; 11/8/48, 21.3; 3/24/49, 18.9; 5/31/49, 28.1; 6/30/49, 31.3; 8/1/49, 32.0; 12/5/49, 22.4.

14N/3E-29R1—Reference point—hole in pump base, elevation 43.5 feet. West side of Carlson Road, 0.19 mile north of O'Banion Road. 5/21/48, 22.1; 11/8/48, 25.6; 3/24/49, 22.5; 12/5/49, 26.4; 3/29/50, 23.5; 11/7/50, 28.0; 3/29/51, 21.6; 11/15/51, 26.9; 4/3/52, 16.0.

14N/3E-30E1—Reference point—top of casing, elevation 36 feet, 0.22 mile east of Township Road, 0.40 mile south of Hutchinson Road. 12/11/47, 12.1; 3/10/48, 8.6; 3/12/48, 8.5; 11/8/48, 8.3; 3/24/49, 6.4; 12/2/49, 9.1.

14N/3E-30H1—Reference point—top of casing, elevation 38 feet, 0.28 mile south of Hutchinson Road, 0.03 mile west of George Washington Boulevard. 12/11/47, 14.9; 3/10/48, 14.6; 3/12/48, 14.5; 11/8/48, 16.1; 3/24/49, 14.0; 12/2/49, 17.5.

14N/3E-30M1—Reference point—top of concrete pit (west wall), elevation 37 feet, 0.38 mile north of O'Banion Road, 0.03 mile east of Township Road. 12/11/47, 8.5; 3/10/48, 9.6; 3/12/48, 9.6; 11/8/48, 9.3; 3/24/49, 6.0; 12/2/49, 9.0.

14N/3E-31B1—Reference point—top of casing, elevation 38 feet, 0.06 mile south of O'Banion Road, 0.36 mile west of George Washington Boulevard. 12/11/47, 12.6; 3/10/48, 13.1; 3/12/48, 13.1; 3/29/48, 12.9; 11/8/48, 12.2; 1/24/49, 13.1; 3/24/49, 11.4; 12/2/49, 13.4; 3/29/50, 12.0; 11/7/50, 15.3; 3/29/51, 10.7; 11/15/51, 14.3; 4/3/52, 7.7.

14N/3E-31L1—Reference point—top of casing, elevation 35 feet, 0.24 mile east of Township Road, 0.66 mile south of O'Banion Road. 12/11/47, 12.3; 3/10/48, 7.9; 3/12/48, 7.9; 11/8/48, 9.5; 3/25/49, 8.7.

14N/3E-31R1—Reference point—top of casing, elevation 36 feet, 0.12 mile west of George Washington Boulevard, 0.78 mile south of O'Banion Road. 12/12/47, 15.9; 3/10/48, 16.3; 3/12/48, 16.1; 11/8/48, 14.2; 3/24/49, 13.5; 12/5/49, 16.3.

14N/3E-32D1—Reference point—hole in base of pump, elevation 40 feet, 0.11 mile south of O'Banion Road, 0.09 mile east of George Washington Boulevard. 12/2/47, 16.7; 3/10/48, 17.5; 3/12/48, 17.4; 5/12/48, 16.2; 11/8/48, 16.7; 3/24/49, 14.8; 6/30/49, 20.8; 8/25/49, 19.2; 12/5/49, 17.9.

14N/3E-33D3—Reference point—hole in base of pump, elevation 40 feet, 0.18 mile south of O'Banion Road, 0.03 mile west of Burch Road. 12/12/47, 26.1; 3/9/48, 21.2; 3/12/48, 20.8; 3/29/48, 19.7; 5/29/48, 18.2; 11/8/48, 12.7; 1/19/49, 20.6; 3/24/49, 19.0; 6/1/49, 21.7; 6/28/49, 44.2; 7/27/49, 28.4; 8/25/49, 23.6.

14N/3E-33M2—Reference point—top of 2" x 4" plank over earth pit, elevation 27.8, 0.67 mile south of O'Banion Road, 0.15 mile west of Burch Road. 12/12/47, 15.8; 3/24/48, 16.9.

14N/3E-34C1—Reference point—top of casing, elevation 39 feet, 0.21 mile east of State Highway 24, south side of O'Banion Road. 11/14/47, 20.4; 3/8/48, 24.2; 3/29/48, 21.4; 5/12/48, 19.4; 11/9/48, 23.5; 1/19/49, 21.7; 3/23/49, 20.6; 12/6/49, 25.3.

14N/3E-34L1—Reference point—hole in side of pump, elevation 40 feet, 0.43 mile east of State Highway 24, 0.51 mile south of O'Banion Road. 11/14/47, 26.9; 3/8/48, 24.5; 11/10/48, 28.4; 3/25/49, 22.7; 12/6/49, 21.7.

14N/3E-35Q1—Reference point—hole in side of pump, elevation 43 feet, 0.35 mile east of Garden Highway, 0.57 mile north of Tudor Road. 11/14/47, 21.2; 3/8/48, 17.2; 11/10/48, 17.3; 3/23/49, 11.4; 12/6/49, 18.9.

14N/3E-36C1—Reference point—top of casing, elevation 50 feet, 0.51 mile south of Country Club Road, 0.72 mile east of Feather River Boulevard. 11/17/47, 17.7; 3/9/48, 16.7; 5/8/48, 9.2; 11/10/48, 18.2; 1/24/49, 17.6; 3/23/49, 11.8; 12/2/49, 18.6; 3/29/50, 10.7; 11/6/50, 18.0; 3/30/51, 11.0; 11/16/51, 16.2; 4/1/52, 6.4.

14N/4E-2F1—Reference point—top of casing outside shed, elevation 67.8 feet, 0.1 mile west of Virginia Road, 0.3 mile south of junction of Earle and Spenceville Roads. 12/4/47, 20.8; 3/18/48, 19.6; 11/22/48, 23.4; 3/21/49, 22.3.

14N/4E-2K1—Reference point—top of casing under pump, elevation 65.9 feet, 200 feet east of Virginia Road, 0.7 mile south of Spenceville Road. 12/4/47, 17.2; 5/18/48, 16.7; 11/22/48, 21.0; 11/23/49, 26.8.

14N/4E-2R1—Reference point—top of casing under pump, elevation 68.9 feet, 250 feet north of Earle Road, 0.2 mile east of junction of Virginia Road and Spenceville Roads. 12/3/47, 21.5; 3/18/48, 21.3; 11/19/48, 25.9; 3/21/49, 24.2; 11/23/49, 32.3.

14N/4E-4A1—Reference point—hole in side of pump, elevation 65 feet, 0.9 mile north of Hale Road, 1.0 mile east of U. S. Highway 99E. 12/1/47, 29.1; 3/18/48, 27.4; 11/19/48, 31.3; 3/23/49, 29.2; 11/23/49, 35.0; 3/27/50, 32.3; 11/3/50, 36.2; 4/5/51, 30.8; 11/21/51, 37.2; 4/4/52, 32.1.

14N/4E-4C1—Reference point—vertical hole in side of pump, elevation 63 feet, 0.6 mile east of U. S. Highway 99E, 0.9 mile north of Hale Road. 11/19/48, 28.4; 3/23/49, 26.1; 11/23/49, 31.6.

14N/4E-4M1—Reference point—top of hole in pump base, elevation 60 feet, 0.2 mile west of U. S. Highway 99E, 0.7 mile north of McGowan Road. 12/1/47, 21.3; 3/17/48, 19.9; 11/19/48, 23.9; 3/21/49, 21.7; 12/7/49, 26.7; 3/27/50, 24.5; 11/3/50, 28.5; 4/5/51, 24.6; 11/21/51, 33.7; 4/2/52, 26.2.

14N/4E-5A1—Reference point—top of casing under pump, elevation 60 feet, 0.05 mile west of U. S. Highway 99E, 1.3 miles north of McGowan Road. 12/1/47, 23.2; 3/17/48, 21.4.

14N/4E-5C1—Reference point—top tin, casing under pump, elevation 58 feet, 1.3 miles north of McGowan Road, 0.5 mile west of U. S. Highway 99E. 12/1/47, 22.8; 3/15/48, 22.1.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet meosured from reference point)

14N/4E-5J1—Reference point—top of casing under pump, elevation 62 feet, 0.3 mile west of U. S. Highway 99E, 0.8 mile north of McGowan Road. 12/1/47, 20.8; 3/15/48, 19.7.

14N/4E-5L1—Reference point—top of casing, elevation 60 feet, 0.4 mile west of U. S. Highway 99E, 1.9 miles north of McGowan Road. 12/1/47, 22.1; 3/15/48, 21.5; 11/19/48, 24.1; 3/21/49, 23.0; 12/7/49, 26.5; 4/3/52, 23.8.

14N/4E-7A1—Reference point—top of casing, 2.5 feet above ground, elevation 55 feet, 0.15 mile west of Arboga Road, 0.80 mile north of Ella Road. 11/12/47, 22.3; 3/15/48, 20.9; 5/14/48, 22.0; 10/17/48, 27.2; 11/11/48, 23.0; 3/21/49, 21.0; 12/1/49, 24.6; 3/29/50, 22.7; 11/6/50, 26.2; 3/30/51, 20.7; 11/20/51, 25.4; 4/5/52, 20.6.

14N/4E-7A2—Reference point, top of casing, elevation 58 feet, 264 feet west of Arboga Road, 0.81 mile north of Ella Road. 3/5/48, 21.5; 5/14/48, 21.6; 3/21/49, 19.5; 12/1/49, 25.0; 3/29/50, 21.2; 11/6/50, 27.9.

14N/4E-7D1—Reference point—top of casing at bottom of 9-foot pit, elevation 52 feet, 500 feet east of Feather River Boulevard, 0.85 mile north of Ella Road. 11/12/47, 12.3; 3/5/48, 11.0; 10/7/48, 13.8; 11/11/48, 11.5; 3/22/49, 10.5; 12/1/49, 15.2.

14N/4E-7F1—Reference point—top of discharge flange, elevation 53 feet, 0.4 mile east of Feather River Boulevard, 0.7 mile north of Ella Avenue. 11/12/47, 16.1; 3/5/48, 19.0; 11/11/48, 19.7; 3/22/49, 17.4; 12/1/49, 20.5.

14N/4E-8C1—Reference point—top of casing, concrete box, elevation 57 feet, 0.9 mile west of U. S. Highway 99E, 0.4 mile north of McGowan Road. 12/1/47, 28.2.

14N/4E-9B1—Reference point—top of casing, elevation 62 feet, 200 feet west of U. S. Highway 99E, 0.3 mile north of McGowan Road 12/2/47, 28.6; 3/17/48, 27.3; 11/19/48, 30.6; 3/21/49, 28.5; 11/23/49, 33.9.

14N/4E-9F1—Reference point—hole in pump base, elevation 60 feet, 50 feet north of McGowan Road, 0.7 mile west of U. S. Highway 99E. 11/19/48, 28.2; 1/25/49, 27.0; 3/18/49, 25.5; 11/23/49, 31.5; 3/28/50, 28.2; 11/3/50, 33.3; 4/5/51, 28.1.

14N/4E-9L1—Reference point—top of casing under pump, elevation 61 feet, 0.3 mile south of McGowan Road, 0.8 mile west of U. S. Highway 99E. 12/2/47, 23.7; 3/17/48, 21.4.

14N/4E-9Q1—Reference point—top of casing, elevation 52 feet, 0.7 mile west of U. S. Highway 99E, 0.3 mile south of McGowan Road. 12/2/47, 20.9; 3/17/48, 10.4; 11/19/48, 13.5; 3/18/49, 10.0; 11/23/49, 16.9; 4/2/52, 9.5.

14N/4E-10H2—Reference point—top of concrete pit, north edge, elevation 63 feet, 1.1 miles east of U. S. Highway 99E, 0.6 mile north of Ostrom Road. 12/3/47, 23.9; 3/18/48, 23.5; 11/19/48, 27.6; 3/21/49, 25.1; 11/23/49, 32.5; 3/22/50, 28.2; 11/3/50, 33.8; 4/5/51, 28.4; 11/23/51, 24.2; 4/4/52, 17.2.

14N/4E-10L1—Reference point—top of casing under pump, elevation 60 feet, 0.1 mile east of U. S. Highway 99E, 0.4 mile north of Slaughter House Road. 12/3/47, 16.9; 3/17/48, 15.4.

14N/4E-10M1—Reference point—top of casing 2 feet above ground line, elevation 58 feet, 0.2 mile west of U. S. Highway 99E, 0.4 mile north of Slaughter House Road. 11/19/48, 16.4.

14N/4E-10R1—Reference point—top of casing under pump, elevation 62 feet, 50 feet north of Ostrom Road, 0.5 mile east of U. S. Highway 99E. 12/3/47, 23.7; 3/18/48, 22.3; 11/19/48, 27.7; 11/23/49, 31.3.

14N/4E-11C1—Reference point—top of casing, elevation 68.6 feet, 2.0 miles east of U. S. Highway 99E, 0.7 mile south of Virginia Road. 11/18/48, 24.7.

14N/4E-11C2—Reference point—top of casing, elevation 68 feet, 1.9 miles east of U. S. Highway 99E, 0.7 mile south of Virginia Road. 11/18/48, 26.1; 3/21/49, 24.2; 11/23/49, 31.6.

14N/4E-11H1—Reference point—top of casing, elevation 72 feet, 1.0 mile west of Bradshaw Road, 0.6 mile north of Ostrom Road. 11/18/48, 29.4; 3/21/49, 27.7; 11/24/49, 35.9; 3/27/50, 33.2; 11/2/50, 38.6; 4/5/51, 34.6; 11/23/51, 40.6; 4/4/52, 37.2.

14N/4E-11J1—Reference point—top of casing, elevation 69.8 feet, 0.4 mile north of Ostrom Road, 1.1 miles west of Bradshaw Road. 11/18/48, 30.1; 3/21/49, 28.3; 11/23/49, 36.4.

14N/4E-11Q1—Reference point—top of casing, elevation 71 feet, 50 feet north of Ostrom Road, 1.5 miles west of Bradshaw Road. 11/18/48, 30.0; 11/23/49, 34.8.

14N/4E-12A1—Reference point—hole in pump base, elevation 75 feet, 100 feet west of Bradshaw Road, 1.0 mile north of Ostrom Road. 11/18/48, 31.4; 1/18/48, 28.8; 3/29/49, 28.1; 11/23/49, 36.6; 3/30/50, 33.6; 11/2/50, 40.5; 4/5/51, 43.2; 4/4/52, 37.1.

14N/4E-12B1—Reference point—hole in pump base, elevation 72 feet, 0.4 mile west of Bradshaw Road, 1.0 mile north of Ostrom Road. 11/18/48, 29.0; 4/5/51, 34.7.

14N/4E-12E1—Reference point—top of casing, elevation 70 feet, 0.7 mile north of Ostrom Road, 100 feet east of Virginia Road. 10/7/48, 29.55; 11/18/48, 28.9; 1/18/49, 28.0; 3/21/49, 27.15; 11/23/49, 35.4.

14N/4E-12R1—Reference point—top of casing, elevation 78 feet, 100 feet northwest of the intersection of Bradshaw and Ostrom Roads. 10/7/48, 35.0; 11/18/48, 33.0; 3/18/49, 30.8; 11/23/49, 39.8; 3/22/50, 36.7; 11/2/50, 44.2; 4/5/51, 39.0; 11/23/51, 47.4; 4/3/52, 40.8.

14N/4E-13A1—Reference point—top of casing, elevation 79.4 feet, 50 feet west of Bradshaw Road, 0.2 mile south of Ostrom Road. 3/24/48, 29.8; 10/7/48, 37.4; 11/18/48, 35.1; 1/18/48, 33.8; 3/18/49, 32.8; 11/23/49, 41.8; 3/27/50, 38.4.

14N/4E-13B1—Reference point—top of casing, elevation 75.5 feet, 0.3 mile west of Bradshaw Road, 100 feet south of Ostrom Road. 11/18/46, 31.6.

14N/4E-13C1—Reference point—top of casing, elevation 73.5 feet, 100 feet south of Ostrom Road, 0.6 mile west of Bradshaw Road. 10/7/48, 30.6; 11/18/48, 29.0; 1/18/49, 28.0; 3/18/49, 27.0; 11/23/49, 34.9; 3/27/50, 32.0; 11/2/50, 38.4; 4/5/51, 33.4; 11/23/51, 39.8; 4/3/52, 35.1.

14N/4E-13Q1—Reference point—top of casing under pump, elevation 71 feet, 0.9 mile south of Ostrom Road, 0.5 mile east of Virginia Road. 12/3/47, 30.4; 3/18/48, 29.1; 10/7/48, 34.7; 11/18/48, 33.6; 3/18/49, 31.6; 11/23/49, 39.0; 3/27/50, 36.7; 11/3/50, 41.8; 4/5/51, 37.9.

14N/4E-13R1—Reference point—top of casing, elevation 80 feet, 50 feet west of Bradshaw Road, 1 mile south of Ostrom Road. 11/18/48, 39.1; 3/18/49, 36.5; 11/24/49, 57.7.

14N/4E-14C1—Reference point—top of casing, elevation 70 feet, 20 feet south of Ostrom Road, 0.8 mile east of U. S. Highway 99E. 10/7/48, 30.7; 11/18/48, 29.0; 1/18/49, 28.0; 3/18/49, 29.1; 11/24/49, 33.9; 3/27/50, 31.5; 11/2/50, 36.2; 4/5/51, 31.6; 11/23/51, 38.4; 4/4/52, 33.6.

14N/4E-14J1—Reference point—top of casing, elevation 62 feet, 200 feet west of Virginia Road, 0.5 mile south of Ostrom Road. 12/3/47, 23.8; 3/18/48, 22.6; 10/7/48, 27.5; 11/18/48, 27.0; 3/18/49, 25.4.

14N/4E-14R1—Reference point—top of casing, elevation 70 feet, 260 feet west of Virginia Road, 0.4 mile north of U. S. Highway 99E. 3/18/49, 30.4.

14N/4E-15C1—Reference point—hole in pump base, elevation 64.6 feet, 200 feet south of Slaughter House Road, 0.4 mile west of U. S. Highway 99E. 12/2/47, 23.9; 3/17/48, 22.6; 10/7/48, 30.5; 11/19/48, 25.9; 3/18/49, 23.3; 11/23/49, 29.6; 3/28/50, 26.5; 11/3/50, 31.0; 4/5/51, 26.0; 11/21/51, 33.1; 4/2/52, 28.9.

14N/4E-15C2—Reference point—top of casing under pump, elevation 65 feet, 500 feet south of Slaughter House Road, 0.3 mile west of U. S. Highway 99E. 12/2/47, 23.1; 3/17/48, 20.8.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

14N 4E-15C3—Reference point—top of casing, 1 foot below ground, elevation 62.7 feet, 250 feet north of Slaughter House Road, 0.2 mile west of U. S. Highway 99E. 11/22/29, 16.4; 9/18/30, 15.9; 12/11/31, 16.4; 12/10/32, 15.7; 12/21/33, 11.0; 11/23/34, 10.7; 11/22/37, 15.8; 11/27/39, 12.1; 12/21/40, 15.3; 11/7/47, 23.2; 12/16/48, 24.3; 12/7/49, 28.2; 11/10/50, 29.7; 12/5/51, 31.3.

14N 4E-15C4—Reference point—top of 1-inch pipe to jet, elevation 65.2 feet, 0.1 mile north of Slaughter House Road, 0.3 mile west of U. S. Highway 99E. 11/19/48, 26.6; 3/18/49, 24.1; 11/23/49, 30.3.

14N 4E-15D1—Reference point—top of casing, elevation 55.9 feet, 200 feet southwest of Slaughter House Road, 0.7 mile due west of U. S. Highway 99E. 12/2/47, 15.8; 3/17/48, 14.1; 11/19/48, 17.5.

14N 4E-15L1—Reference point—top of casing under pump, elevation 66 feet, 0.8 mile west of U. S. Highway 99E, 0.4 mile south of Slaughter House Road. 12/2/47, 25.6; 3/17/48, 24.4; 10/7/48, 29.5; 11/19/48, 27.6; 1/25/49, 26.6; 3/18/49, 25.2; 5/25/49, 33.1; 6/29/49, 34.5; 7/29/49, 35.5; 11/23/49, 31.4; 3/28/50, 28.4; 11/3/50, 32.8; 4/5/51, 28.2; 11/21/51, 37.0; 4/2/52, 29.0.

14N 4E-16M1—Reference point—top of casing, elevation 55 feet, 1.3 miles south of McGowan Road, 0.4 mile east of Western Pacific Railroad tracks. 12/3/47, 22.5; 3/18/48, 20.3; 11/19/48, 20.9; 3/13/49, 18.4.

14N 4E-17C1—Reference point—top of casing under pump, elevation 55 feet, 0.5 mile south of McGowan Road, 100 feet west of Western Pacific Railroad. 12/2/47, 23.9; 3/18/48, 20.6; 11/19/48, 23.6; 3/18/49, 21.1; 11/22/49, 25.3; 3/28/50, 22.8; 11/3/50, 26.7; 4/5/51, 20.8.

14N 4E-17D1—Reference point—hole in side of casing, elevation 54 feet, 0.5 mile south of McGowan Road, 0.3 mile west of Western Pacific Railroad. 3/18/49, 21.0; 3/28/50, 22.5.

14N 4E-17D2—Reference point—top of casing under pump, elevation 54 feet, 0.5 mile south of McGowan Road, 0.3 mile west of Western Pacific Railroad. 12/1/47, 22.3.

14N 4E-17P1—Reference point—top of casing under pump, elevation 58.7 feet, 500 feet west of Western Pacific Railroad, 1.4 miles south of McGowan Road. 12/3/47, 23.2; 3/18/48, 21.8; 5/14/48, 23.2; 11/19/48, 24.4; 3/18/49, 21.9; 11/23/49, 25.8; 3/28/50, 23.0; 11/31/50, 26.6; 4/5/51, 20.9; 4/3/52, 23.2.

14N 4E-18C1—Reference point—hole in top of casing, elevation 53.1 feet, 200 feet south of Ella Road, 0.4 mile east of Feather River Boulevard. 11/11/47, 20.9; 3/5/48, 19.7; 10/7/48, 27.5; 11/11/48, 19.5; 1/27/49, 18.7; 3/21/49, 17.8; 12/1/49, 20.4; 3/28/50, 19.1; 11/6/50, 23.5; 3/30/51, 15.1; 11/20/51, 23.3; 4/5/52, 15.7.

14N 4E-18H1—Reference point—bottom of pump, elevation 54.1 feet, 400 feet west of Arboga Road, 0.5 mile south of Ella Road. 11/11/47, 21.2; 3/5/48, 19.8; 10/7/48, 24.9; 11/11/48, 21.0; 3/21/49, 19.6; 12/1/49, 21.6.

14N 4E-18J1—Reference point—top of suction flange, elevation 45.6 feet, 400 feet west of Arboga Road, 0.6 mile south of Ella Road. 11/11/47, 17.6; 3/5/48, 14.2; 11/11/48, 16.3; 3/21/49, 14.8; 12/1/49, 22.0.

14N 4E-19E1—Reference point—top of casing, 4 feet below ground in pit, elevation 52 feet, 0.2 mile east of Feather River Boulevard, 0.1 mile north of Broadway. 11/8/29, 8.0; 9/26/30, 8.7; 12/11/31, 8.6; 12/31/32, 8.6; 12/21/33, 8.9; 11/20/34, 9.1; 11/27/36, 9.1; 11/21/37, 11.1; 1/30/39, 6.6; 12/21/40, 8.1.

14N 4E-19L1—Reference point—top of casing, 0.6 foot above ground, elevation 18 feet, 0.1 mile east of Feather River Boulevard, 0.1 mile south of Broadway. 11/7/47, 20.6; 12/16/48, 20.7; 12/9/49, 21.8; 11/10/50, 23.6; 12/5/51, 21.2.

14N 4E-19P1—Reference point—top of casing, top of concrete floor, elevation 50.1 feet, 0.3 mile south of Broadway, 0.5 mile east of Feather River Boulevard. 11/17/47, 33.6; 3/9/48, 18.4; 11/10/48, 19.7; 3/23/49, 17.5; 12/2/49, 21.4; 3/29/50, 18.9; 11/6/50, 22.3; 3/30/51, 18.7; 11/16/51, 22.1; 4/1/52, 9.5.

14N 4E-20D1—Reference point—top of casing under pump, elevation 53 feet, 200 feet north of Broadway, 0.6 mile west of Arboga Road. 12/3/47, 24.9; 3/18/48, 23.3.

14N 4E-20E1—Reference point—pump base hole, elevation 54.3 feet, 150 feet north of Broadway, 1.0 mile east of Feather River Boulevard. 11/11/48, 20.9; 3/21/49, 18.2.

14N 4E-20M1—Reference point—bottom of pump mount, blocked up from concrete, elevation 52.2 feet, 50 feet south of Broadway, 0.95 mile east of Feather River Boulevard. 11/11/47, 22.4; 3/6/48, 20.0; 10/7/48, 22.8; 11/11/48, 21.5; 1/24/29, 20.6; 3/21/49, 19.7; 12/1/49, 23.0; 3/29/50, 20.9; 11/6/50, 23.1; 11/20/51, 23.3; 4/5/52, 17.4.

14N 4E-20M2—Reference point—hole in side of pump, elevation 52.8 feet, 400 feet south of Broadway, 1.0 mile east of Feather River Boulevard. 11/11/47, 18.7; 3/6/48, 20.0; 10/7/48, 21.7; 11/11/48, 19.5; 3/2/49, 16.9; 12/1/49, 21.2; 3/29/50, 18.5; 11/6/50, 22.1; 3/30/51, 18.0; 11/20/51, 21.7; 4/5/52, 16.1.

14N 4E-22F1—Reference point—hole in top of pump base, elevation 60 feet, 100 feet west of Forty Mile Road, 1.35 miles south of Slaughter House Road. 12/1/47, 22.6; 3/1/48, 21.3; 3/31/48, 20.8; 10/7/48, 25.6; 11/8/48, 24.0; 1/25/49, 23.0; 3/18/49, 21.5; 11/23/49, 27.7.

14N 4E-22F2—Reference point—hole in base of pump, elevation 58.4 feet, 200 feet west of Forty Mile Road, 1.2 miles south of Slaughter House Road. 12/2/47, 18.7; 3/17/48, 17.4.

14N 4E-22F3—Reference point—access pipe in concrete base, elevation 61.9 feet, 150 feet west of Forty Mile Road, 1.3 miles south of Slaughter House Road. 12/2/47, 23.6; 3/17/48, 22.2; 11/19/48, 24.9; 3/18/49, 21.9; 11/23/49, 27.0; 3/28/50, 25.6; 11/2/50, 30.1; 4/5/51, 28.9; 11/21/51, 32.4; 4/2/52, 25.5.

14N 4E-22M1—Reference point—top of casing, elevation 61.8 feet, 0.4 mile west of Forty Mile Road, 1.25 miles north of Plumas School. 12/1/47, 21.7; 3/1/48, 20.5; 10/7/48, 25.1; 11/8/48, 23.5; 3/25/49, 20.5; 11/23/49, 26.4; 3/28/50, 23.1; 11/3/50, 28.1; 12/3/51, 28.1; 4/1/52, 23.9.

14N 4E-22P1—Reference point—top of concrete curb around open pit well, elevation 64.9 feet, 50 feet west of Forty Mile Road, 1.2 miles north of Plumas School. 11/21/47, 26.9.

14N 4E-23A1—Reference point—top of casing, elevation 60 feet, 300 feet southwest of U. S. Highway 99E, 1.5 miles southeast of Slaughter House Road. 12/3/47, 31.7; 3/18/48, 30.2; 11/18/48, 33.8; 3/18/49, 32.2; 11/23/49, 38.2; 3/29/50, 36.5; 11/3/50, 40.4; 11/21/51, 43.4; 4/2/52, 41.0.

14N 4E-23B1—Reference point—top of casing, elevation 70 feet, 0.07 mile southwest of U. S. Highway 99E, 0.38 mile northwest of Virginia Road. 12/3/47, 30.7; 3/18/48, 29.5.

14N 4E-23G1—Reference point—top of pump base, elevation 70 feet, 0.70 mile west of U. S. Highway 99E, at a point 2.02 miles southeast of Slaughter House Road. 12/1/47, 30.9; 10/7/48, 33.2; 11/8/48, 32.9; 3/29/49, 30.9; 11/25/49, 37.2.

14N 4E-23Q1—Reference point—top of casing, elevation 72 feet, 1.98 miles south of Slaughter House Road, 1.05 miles east of Forty Mile Road. 11/21/47, 32.6; 3/3/48, 29.2.

14N 4E-23R1—Reference point—top of casing, elevation 67 feet, 1.98 miles south of Slaughter House Road, 1.48 miles east of Forty Mile Road. 11/21/47, 30.5; 3/31/47, 29.7; 11/11/48, 33.0; 3/29/49, 30.6; 11/25/49, 36.1.

14N 4E-24B1—Reference point—top of pump base, elevation 75 feet, 0.80 mile east of Virginia Road, 1 mile south of Ostrom Road. 3/18/49, 28.3.

14N 4E-24H1—Reference point—top of pump base, elevation 85 feet, 1.3 miles south of Ostrom Road, 0.14 mile west of Bradshaw Road. 11/18/48, 36.9; 3/18/49, 34.0; 11/23/49, 42.9; 3/27/50, 39.8; 11/2/50, 45.8; 4/5/51, 41.3; 11/30/51, 51.7; 4/3/52, 43.7.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

14N/4E-24M1—Reference point—top of casing, elevation 70 feet, 0.05 mile southwest of U. S. Highway 99E, 0.38 mile southeast of Virginia Road. 11/21/47, 22.5; 3/2/48, 28.7; 11/11/48, 31.1; 3/23/49, 28.3; 11/25/49, 34.5.

14N/4E-24P1—Reference point—top of pump base, elevation 70 feet. West side of U. S. Highway 99E, 0.68 mile southeast of Virginia Road. 11/21/47, 32.7; 3/2/48, 30.5; 11/9/48, 33.7; 1/25/49, 31.9; 3/23/49, 30.5; 5/25/49, 40.3; 7/1/49, 44.8; 11/25/49, 38.5; 3/28/50, 35.1; 11/3/50, 40.6; 4/4/51, 35.8; 12/6/51, 39.6; 4/2/52, 41.9.

14N/4E-25R1—Reference point—top of casing, elevation 74 feet, 0.53 mile northwest of Dairy Road, 0.67 mile southwest of U. S. Highway 99E. 12/2/47, 29.4; 3/2/48, 27.6; 10/7/48, 32.8; 11/11/48, 31.2; 3/29/49, 28.0; 11/23/49, 34.7.

14N/4E-26A1—Reference point—hole in base of pump, elevation 65 feet, 1.03 miles southeast of Virginia Road, 0.98 mile west of U. S. Highway 99E. 11/11/48, 33.2; 3/29/49, 30.2.

14N/4E-26C1—Reference point—top of casing, elevation 66 feet, 1.45 mile north of Levee Road, 0.95 mile east of Forty Mile Road. 12/1/47, 18.2; 3/3/48, 16.7; 11/11/48, 19.7; 3/29/49, 17.5; 11/25/49, 22.4; 3/29/50, 20.9; 11/8/50, 24.8; 4/4/51, 20.8; 5/5/51, 23.5; 4/2/52, 23.0.

14N/4E-27D1—Reference point—top of casing, elevation 60 feet, 1.20 miles north of Levee Road, 0.40 mile west of Forty Mile Road. 11/21/47, 24.8.

14N/4E-27L1—Reference point—pipe in base, elevation 64.1 feet, 2.60 miles south of Slaughter House Road, west side of Forty Mile Road. 12/1/47, 24.8; 3/1/48, 23.4; 3/29/48, 23.5; 10/7/48, 30.0; 11/8/48, 28.1; 1/25/49, 26.7; 3/25/49, 25.6; 11/23/49, 29.6; 3/28/50, 28.0; 11/3/50, 32.5; 11/30/51, 23.0; 4/1/52, 28.5.

14N/4E-27R1—Reference point—top of casing, elevation 60 feet, 2.85 miles south of Slaughter House Road, 0.52 mile east of Forty Mile Road. 12/2/47, 30.3; 3/1/48, 28.7; 11/8/48, 31.7; 3/25/49, 28.8; 11/23/49, 33.6.

14N/4E-28N1—Reference point—top of casing, elevation 49 feet, 2.05 miles south of Slaughter House Road, 1.50 miles west of Forty Mile Road. 11/8/29, 10.5; 9/26/30, 10.4; 12/11/31, 11.0; 12/5/32, 11.1; 12/21/33, 11.2; 11/20/34, 11.5; 11/27/36, 11.9; 11/24/37, 12.0; 11/30/39, 9.2; 12/21/40, 10.9; 11/7/47, 13.1; 12/16/48, 13.8; 12/9/49, 15.9; 11/10/50, 15.0; 12/5/51, 15.9.

14N/4E-28R1—Reference point—pipe in base of pump, elevation 60.2 feet, 0.55 mile north of Levee Road, 0.68 mile west of Forty Mile Road. 12/2/47, 25.2; 3/1/48, 24.1; 11/8/48, 25.6; 3/25/49, 23.6; 11/23/49, 27.4; 3/28/50, 25.6; 11/3/50, 29.1; 4/4/51, 21.7; 11/30/51, 34.1; 4/1/52, 24.6.

14N/4E-30E1—Reference point—hole in base of pump, elevation 48.6 feet, 0.11 mile east of Feather River Boulevard, 0.25 mile south of Anderson Road. 11/17/47, 23.5; 3/9/48, 19.3; 11/10/48, 20.3; 3/23/49, 18.1; 12/2/49, 21.8.

14N/4E-30F1—Reference point—top of casing, elevation 45 feet, 0.15 mile north of Country Club Road, 0.46 mile east of Feather River Boulevard. 11/17/47, 16.9; 3/9/48, 16.9; 11/10/48, 17.9.

14N/4E-30K1—Reference point—top of casing, elevation 45.0 feet, South side of Country Club Boulevard, 0.51 mile east of Feather River Boulevard. 11/17/47, 14.5; 3/8/48, 14.5; 5/8/48, 12.0; 11/10/48, 15.4; 1/29/49, 14.4; 3/23/49, 12.1; 6/1/49, 22.6; 6/29/49, 24.0; 7/28/49, 25.7; 8/26/49, 30.1; 3/29/50, 13.5; 11/6/50, 17.2; 3/30/51, 12.2; 11/16/51, 16.8; 4/1/52, 12.2.

14N/4E-31E1—Reference point—top of casing, elevation 38.5 feet, 0.06 mile east of Feather River Boulevard, 0.80 mile south of Country Club Road. 11/10/48, 11.9; 3/22/49, 8.9; 12/2/49, 11.8.

14N/4E-32L1—Reference point—top of casing, elevation 45 feet, 1.0 mile south of Country Club Avenue, 1.24 miles east of Feather River Boulevard. 11/17/47, 18.0; 3/9/48, 18.2; 11/10/48, 17.3; 3/29/49, 15.4; 12/2/49, 19.3.

14N/4E-33K1—Reference point—top of casing, elevation 51 feet, 1.50 mile west of Forty Mile Road, 0.55 mile north of Levee Road. 12/1/47, 19.7; 11/8/48, 20.6; 3/25/49, 18.0.

14N/4E-33M1—Reference point—top of casing, elevation 51 feet, 3.73 miles south of Slaughter House Road, 0.21 mile east of Western Pacific Railroad. 11/17/47, 14.3; 3/9/48, 13.1; 5/5/48, 9.1; 5/31/48, 9.1; 11/10/48, 13.9; 1/24/49, 13.8; 3/22/49, 10.8; 6/1/49, 10.8; 6/29/49, 12.8; 7/28/49, 14.2; 8/26/49, 15.8; 12/2/49, 15.3; 3/29/50, 9.7; 11/6/50, 14.7; 11/16/51, 13.7; 4/1/52, 5.5.

14N/4E-34C1—Reference point—top of concrete pit, elevation 63.4 feet, 3.05 miles south of Slaughter House Road, 0.05 mile west of Forty Mile Road. 12/1/47, 27.8; 3/1/48, 26.5; 5/5/48, 25.1; 6/3/48, 26.8; 6/24/48, 32.2 (operating); 7/8/48, 29.2 (operating).

14N/4E-35N1—Reference point—slot in base, elevation 62 feet. West side of Forty Mile Road, 0.60 mile northwest of Dairy Road. 11/28/47, 25.7; 3/1/48, 24.4; 3/21/48, 24.2; 3/29/48, 23.8; 5/5/48, 22.5; 5/13/48, 61.5 (operating); 11/8/48, 27.5; 1/26/49, 25.6; 3/25/49, 24.0; 11/23/49, 30.3; 3/28/50, 27.3; 11/6/50, 32.1; 4/4/51, 26.3; 11/30/51, 33.1; 4/1/52, 27.4.

14N/4E-36G1—Reference point—top of casing, elevation 70 feet, 0.20 mile northwest of U. S. Highway 99E. 12/2/47, 30.5; 3/2/48, 28.5; 3/29/48, 28.0; 10/7/48, 33.6; 11/11/48, 32.4; 1/25/49, 31.8; 3/25/49, 29.0; 11/23/49, 36.7; 3/28/50, 32.6; 11/8/50, 37.6; 4/4/51, 30.8; 12/3/51, 41.0.

14N/5E-5A1—Reference point—top of casing, elevation 90.2 feet, 400 feet south of Spenceville Road, 1.0 mile west of South Beale Road. 12/5/49, 39.1; 11/2/50, 46.9; 4/5/51, 41.9; 4/4/52, 41.5.

14N/5E-6B1—Reference point—top of 12-inch casing, elevation 78.5 feet, 150 feet south of Spenceville Road, 2.25 miles west of South Beale Road. 11/28/48, 26.0; 1/18/49, 25.2; 3/21/49, 24.9; 11/24/49, 32.4; 3/27/40, 30.3; 11/2/50, 37.6; 4/5/51, 32.8; 11/30/51, 37.6; 4/4/52, 34.6.

14N/5E-6D1—Reference point—top of 8-inch casing, elevation 76.4 feet, 600 feet south of Spenceville Road, 1.75 miles east of Virginia Road. 12/24/47, 22.4; 3/24/48, 22.3; 3/21/49, 23.7; 11/24/49, 33.7.

14N/5E-6D2—Reference point—top of 6-inch casing, elevation 73.6 feet, 800 feet south of Spenceville Road, 1.75 miles east of Virginia Road. 11/18/48, 23.9.

14N/5E-8A1—Reference point—top of 16-inch casing, elevation 90 feet, 0.40 mile northwest of South Beale Road at a point 0.70 mile northeast of Ostrom Road. 11/18/48, 24.7.

14N/5E-8D1—Reference point—top of casing, elevation 82 feet, 1.0 mile north of Ostrom Road, 1.0 mile east of Bradshaw Road. 3/18/49, 31.2.

14N/5E-8R1—Reference point—top of 14-inch casing, elevation 89.6 feet, 0.15 mile northeast of intersection of Ostrom Road and South Beale Road. 11/18/48, 30.5; 3/18/49, 30.1; 11/23/49, 39.7; 4/5/52, 39.2.

14N/5E-15D1—Reference point—top of casing, elevation 111 feet, 500 feet east of Ostrom Road, 0.25 mile south of Ostrom Road. 12/9/49, 42.3; 11/2/50, 46.4; 12/8/51, 47.3.

14N/5E-16C1—Reference point—top of brick casing, elevation 99 feet, 100 feet south of Ostrom Road, 100 feet west of Jasper Lane. 11/22/29, 26.3; 9/8/30, 25.5; 12/11/31, 27.5; 12/10/32, 26.7; 12/21/33, 27.6; 11/20/34, 27.8; 11/23/36, 26.4; 11/22/37, 25.6; 1/27/39, 25.5; 1/13/41, 30.0; 11/7/47, 30.0; 12/23/47, 29.7; 3/24/48, 30.0; 10/7/48, 31.2; 11/18/48, 31.2; 12/16/48, 31.9; 1/18/49, 31.7; 3/18/49, 31.2.

14N/5E-16C2—Reference point—top of casing, elevation 100 feet, 40 feet west of Jasper Lane, 40 feet south of Ostrom Road. 12/5/51, 41.9.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

14N 5E-17B1—Reference point—top of 12-inch casing, elevation 85.7 feet, 100 feet south of Ostrom Road, 0.30 mile west of South Beale Road. 12/23/47, 28.0; 3/24/48, 24.7; 10/7/48, 31.3; 11/18/48, 30.7; 3/18/49, 29.8; 11/23/49, 40.7; 4/3/52, 40.1.

14N 5E-17B2—Reference point—top of 16-inch casing, elevation 90.4 feet, Northwest side of South Beale Road, 1,000 feet southwest of Ostrom Road intersection. 11/19/48, 34.6; 3/18/49, 33.4; 11/23/49, 42.6.

14N 5E-17D1—Reference point—top of 12 inch casing, elevation 86.8 feet, 600 feet south of Ostrom Road, 0.80 mile west of South Beale Road. 11/18/48, 37.1; 1/18/49, 36.0; 3/18/49, 35.2; 11/23/49, 48.3.

14N 5E-18A1—Reference point—top of casing, elevation 87.0 feet, 750 feet south of Ostrom Road, 0.80 mile west of South Beale Road. 12/23/47, 33.7; 3/24/48, 32.9; 10/7/48, 39.0; 11/18/48, 37.5; 1/18/49, 36.4; 3/18/49, 35.6; 11/23/49, 45.1; 3/27/50, 41.8; 11/2/50, 50.1; 4/5/51, 44.4; 11/23/51, 50.5; 1/3/52, 45.8.

14N 5E-18B1—Reference point—top of 12-inch casing, elevation 78.1 feet, South side of Ostrom Road, 0.35 mile east of Bradshaw Road. 12/23/47, 25.7; 3/2/48, 28.5; 10/7/48, 33.5; 11/18/48, 31.7; 3/18/49, 28.0; 5/25/49, 36.6; 6/29/49, 40.4; 8/1/49, 42.7; 8/30/49, 51.2; 11/23/49, 39.7.

14N 5E-21R1—Reference point—top of casing, elevation 93 feet, 200 feet northeast of Jasper Lane at a point 1.9 miles south of Ostrom Road. 11/25/47, 21.5.

14N 5E-26P1—Reference point—top of concrete crib, elevation 119.7 feet, 0.25 mile southeast of Wheatland-Spenceville Road at a point 0.85 mile northeast of Jasper Lane. 11/25/47, 28.5; 3/6/48, 28.2; 11/9/48, 28.8; 3/23/49, 27.5; 12/9/49, 31.0; 3/29/50, 29.9; 11/8/50, 33.7; 4/5/51, 29.9.

14N 5E-27K1—Reference point—top of concrete crib, elevation 84.7 feet, 0.25 mile northeast of Jasper Lane at a point 0.85 mile northwest of Wheatland-Spenceville Road. 11/25/47, 12.0; 3/6/48, 11.8; 11/9/48, 13.2; 3/23/49, 11.3; 6/29/49, 12.7; 7/28/49, 13.3; 8/30/49, 13.9; 11/28/49, 16.8.

14N 5E-27L1—Reference point—top of 14 inch casing at bottom of pit, elevation 81.2 feet, 900 feet northeast of Jasper Lane at a point 1.1 miles northwest of Wheatland-Spenceville Road. 27L2 replaces 27L1 after 4/4/51. 11/25/47, 6.7; 3/6/48, 6.3; 11/9/48, 7.9; 3/23/49, 6.0; 11/28/49, 9.1; 3/29/50, 7.1; 11/8/50, 12.2; 4/4/51, 5.4.

14N 5E-27L2—Reference point—top of casing, elevation 92 feet, 900 feet northeast of Jasper Lane at a point 1.1 miles northwest of Wheatland-Spenceville Road. 11/21/51, 32.2; 4/2/52, 27.5.

14N 5E-28M1—Reference point—top of casing pit, elevation 86.5 feet, 1.0 mile southwest of Jasper Lane at a point 1.15 miles northwest of Wheatland-Spenceville Road. 11/26/47, 25.7; 3/6/48, 24.6; 11/9/48, 26.9; 3/29/49, 24.5; 11/28/49, 30.4; 3/29/50, 27.7; 11/28/49, 30.4; 3/29/50, 27.7; 11/8/50, 34.0; 1/1/51, 29.0; 11/21/51, 31.2; 4/2/52, 28.2.

14N 5E-30J1—Reference point—top of 11-inch casing, elevation 81.8 feet, 0.30 mile northeast of U. S. Highway 99E at a point 1.8 miles northwest of Wheatland Road. 11/25/47, 38.8; 11/9/48, 32.8; 3/29/49, 29.1; 12/8/49, 36.0.

14N 5E-30Q1—Reference point—top of 16-inch casing, elevation 76.6 feet, 100 feet southwest of Oakley Lane, 0.10 miles northwest of Dairy Road. 11/24/47, 30.4; 3/5/48, 28.6; 3/29/48, 27.9; 5/8/48, 27.0; 11/11/48, 32.5; 1/25/49, 31.0; 3/23/49, 29.5; 11/23/49, 35.9; 3/28/50, 35.7; 11/8/50; 39.5; 4/4/51, 34.5; 12/6/51, 39.0; 1/2/52, 36.1.

14N 5E-31B1—Reference point—hole in casing, elevation 76.8 feet, 150 feet northwest of Dairy Road, 500 feet southwest of Oakley Lane. 11/22/47, 28.1; 3/5/48, 27.1; 11/11/48, 30.2; 3/25/49, 26.8; 11/25/49, 33.6.

14N 5E-31J1—Reference point—top of 8-inch casing at bottom of pit, elevation 59.8 feet, 100 feet southwest of Oakley Lane, 0.45 mile southeast of Dairy Road. 11/22/47, 11.2; 3/5/48, 9.5; 11/11/48, 13.1; 3/25/49, 9.3; 11/28/49, 16.1.

14N 5E-32F1—Reference point—top of 14-inch casing, elevation 71.0 feet, Southwest of U. S. Highway 99E, 0.35 mile southeast of Dairy Road. 11/22/47, 17.1; 3/5/48, 16.6; 3/29/48, 15.6; 11/11/48, 19.4; 1/26/49, 18.0; 3/24/49, 16.0; 11/23/49, 22.5.

14N 5E-32M1—Reference point—top of 12-inch casing, elevation 67.2 feet, 0.25 mile northeast of Oakley Lane, 0.60 mile southeast of Dairy Road. 11/22/47, 14.7; 3/5/48, 13.6; 11/11/48, 16.2; 3/23/49, 12.5; 11/28/49, 19.7.

14N 5E-32N1—Reference point—top of casing at bottom of pit, elevation 63.2 feet, Southwest side of Oakley Lane, 0.70 miles southeast of Dairy Road. 11/20/47, 11.7; 3/5/48, 10.7; 11/11/48, 13.3; 3/25/49, 9.3; 11/23/49, 17.2; 3/29/50, 12.7; 11/8/50, 18.5; 4/4/51, 9.9; 12/3/51, 17.6; 4/2/52, 8.5.

14N 5E-32R1—Reference point—top of concrete base, elevation 73.8 feet, 400 feet southwest of U. S. Highway 99E at a point 0.55 mile northwest of Wheatland Road. 12/24/47, 16.9; 3/5/48, 15.7; 11/11/48, 17.5; 3/30/49, 15.0; 5/3/49, 16.9; 6/2/49, 19.8; 7/2/49, 21.1; 8/31/49, 24.0; 11/28/49, 20.3.

14N 5E-32R2—Reference point—top of 14-inch casing, elevation 74.8 feet, 100 feet southwest of U. S. Highway 99E, 0.55 mile northwest of Wheatland Road. 11/24/47, 17.3; 3/5/48, 16.2; 11/11/48, 18.5; 3/30/49, 15.2; 6/2/49, 24.9; 7/2/49, 27.6; 8/31/49, 28.0; 11/24/49, 21.1; 3/29/50, 18.0; 11/8/50, 23.1; 4/4/51, 15.1; 11/21/51, 23.2; 4/2/52, 13.0.

14N 5E-33K1—Reference point—bottom of slot in casing, elevation 78.3 feet, 0.40 mile northwest of Wheatland-Spenceville Road at a point 0.45 mile northeast of U. S. Highway 99E. 11/25/47, 14.0; 3/6/48, 13.3; 11/9/48, 15.5; 3/23/49, 11.4; 11/28/49, 17.6; 3/29/50, 13.9; 11/8/50, 19.5; 11/21/51, 19.5; 4/2/52, 10.4.

14N 5E-33M1—Reference point—top of casing at bottom of pit, elevation 65.8 feet, 0.15 mile northeast of U. S. Highway 99E at a point 0.55 mile northwest of Wheatland Road. 11/25/47, 6.0; 3/6/48, 5.6; 12/6/48, 6.8.

14N 5E-33Q1—Reference point—top of concrete well curb, elevation 86 feet, Northwest of the northeast corner of town of Wheatland, 1,000 feet north of school house east side. 11/22/29, 22.2; 9/18/30, 23.6; 12/11/31, 23.3; 12/10/32, 22.4; 12/21/33, 22.7; 11/20/34, 23.5; 11/23/36, 23.4; 11/22/37, 22.0; 1/27/39, 20.8; 1/2/40, 20.4; 11/7/47, 27.0; 12/16/48, 26.3; 12/9/49, 29.0; 11/8/50, 31.3; 12/5/51, 28.8.

14N 5E-34F1—Reference point—top of casing, elevation 90.2 feet, 500 feet northwest of Wheatland-Spenceville Road, 0.25 mile southwest of Jasper Lane. 11/25/47, 19.0; 3/6/48, 18.1; 11/9/48, 20.2; 3/23/49, 17.4; 11/28/49, 22.5.

14N 5E-34H1—Reference point—base of pump, elevation 99.7 feet, 600 feet southeast of Wheatland-Spenceville Road, 1,000 feet northeast of Jasper Lane. 11/25/47, 20.6; 3/6/48, 20.4; 11/9/48, 21.2; 3/23/49, 19.8; 11/28/49, 23.4.

15N 1E-12A1—Reference point—hole in pump base, elevation 150 feet, 1.05 miles north of South Butte Road, 2.1 miles west of Irwin Avenue. 12/2/48, 83.0 (operating).

15N 1E-12H1—Reference point—hole in pump base, elevation 80 feet, 0.75 mile north of South Butte Road, 2.1 miles west of Irwin Avenue. 12/2/48, 13.2.

15N 1E-3A1—Reference point—hole in pump base, elevation 57 feet, 0.1 mile north of South Butte Road, 2.1 miles west of Irwin Avenue. 12/22/49, 25.1; 3/4/48, 21.8; 3/29/49, 19.4; 11/15/49, 24.0; 3/23/50, 13.3; 11/2/50, 27.2; 4/3/52, 27.1.

15N 1E-13B1—Reference point—hole in cement pipe base, elevation 55 feet, 0.15 mile north of South Butte Road, 2.3 miles west of Irwin Avenue. 12/2/48, 31.8; 11/2/50, 33.2; 3/26/51, 63.8 (operating).

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Divisian of Water Resources
(Depths to woter in feet meosured from reference point)

15N/1E-14F1—Reference point—bottom of 2" x 4" board under pump, elevation 54 feet. South side of South Butte Road, 0.3 mile east of Sutter Bypass east levee. 12/22/47, 18.5; 3/4/48, 18.3; 5/4/48, 15.5; 6/2/48, 15.8; 7/3/48, 16.6; 8/3/48, 17.7; 9/1/48, 17.9; 12/2/48, 18.9; 12/8/49, 19.0; 3/23/50, 10.9; 11/2/50, 19.6.

15N/1E-14F2—Reference point—top of concrete pit, elevation 47 feet, 0.05 mile south of South Butte Road, 0.2 mile east of Sutter Bypass east levee. 11/27/29, 16.8; 10/6/30, 15.0; 12/16/31, 14.8; 12/8/32, 15.0; 12/15/33, 15.1; 11/2/34, 14.8; 11/23/34, 14.3; 11/27/36, 14.4; 11/15/37, 15.6; 1/25/39, 14.8; 1/11/41, 10.7; 11/4/47, 15.4; 12/13/48, 15.7; 12/8/49, 16.1; 11/10/50, 16.8; 12/7/51, 14.3.

15N/2E-1A1—Reference point—top of concrete pit, elevation 58.0 feet, 100 feet south of Nuestro Road, 0.15 mile west of Township Road. 12/19/47, 11.9; 3/3/48, 12.7; 12/1/48, 12.5; 1/20/49, 12.2; 3/16/49, 12.2; 6/28/49, 10.2; 7/27/49, 9.4; 11/11/49, 13.2; 3/23/50, 13.2; 11/6/50, 13.5; 4/3/51, 9.7; 11/14/51, 12.1; 4/3/52, 6.5.

15N/2E-1C1—Reference point—top of casing, elevation 58.2 feet, 0.1 mile south of Nuestro Road, 0.65 mile west of Township Road. 12/19/47, 10.3; 12/2/48, 11.7; 11/11/49, 11.5.

15N/2E-1H1—Reference point—top of concrete pit, elevation 57.7 feet, 150 feet west of Township Road, 0.35 mile south of Nuestro Road. 12/22/47, 13.3; 3/3/48, 13.6; 12/1/48, 14.0; 3/16/49, 13.7; 11/11/49, 14.6.

15N/2E-2C1—Reference point—top of wooden platform under pump, elevation 60.4 feet, 50 feet west of East Butte Road, 0.15 mile north of Nuestro Road. 12/19/47, 11.8; 3/3/48, 11.8; 12/2/48, 9.5; 3/16/49, 8.0; 11/10/49, 6.5; 3/22/50, 9.4; 11/2/50, 6.8; 4/4/51, 8.6; 11/14/51, 8.1; 4/3/52, 6.3.

15N/2E-2H1—Reference point—top of casing, elevation 57.6 feet, 0.3 mile south of Nuestro Road, 1.1 miles west of Township Road. 12/19/47, 10.4; 3/3/48, 11.3; 12/2/48, 10.0; 3/16/49, 9.0; 11/11/49, 9.2; 3/23/50, 10.1; 11/2/50, 9.1; 4/4/51, 9.7; 11/14/51, 9.0; 4/3/52, 7.9.

15N/2E-3K1—Reference point—top of casing, elevation 57 feet, 0.1 mile east of Mallott Road, 0.8 mile north of Butte House Road. 12/22/47, 10.7; 3/4/48, 11.8; 12/2/48, 10.0; 11/16/49, 9.5.

15N/2E-4Q1—Reference point—top of casing, elevation 86 feet, 0.15 mile east of Acacia Avenue, 0.3 mile north of Butte House Road. 12/22/47, 35.7; 3/4/48, 36.2; 12/2/48, 35.6; 3/29/49, 36.0; 11/16/49, 36.6.

15N/2E-4R1—Reference point—base of pump, elevation 74 feet, 0.3 mile east of Acacia Avenue, 0.35 mile north of Butte House Road. 12/22/47, 34.2; 12/2/48, 35.0; 11/16/49, 37.0; 3/23/50, 36.0; 11/2/50, 38.0; 4/5/51, 34.0; 11/15/51, 37.0; 4/3/52, 31.0.

15N/2E-8J1—Reference point—hole in pump base, elevation 75 feet, 0.2 mile west of Irwin Avenue, 0.45 mile north of South Butte Road. 5/4/48, 33.6; 12/2/48, 34.7; 12/8/49, 34.8; 3/23/50, 34.2; 11/15/51, 35.8; 4/3/52, 34.7.

15N/2E-8Q1—Reference point—hole in pump base, elevation 62 feet, 250 feet north of South Butte Road, 0.25 mile west of Irwin Avenue. 12/22/47, 29.4; 12/2/48, 29.3; 3/29/49, 27.8; 11/15/49, 29.6; 3/23/50, 27.7; 11/2/50, 30.6; 4/5/51, 30.6; 11/15/51, 30.3; 4/3/52, 24.5.

15N/2E-10F1—Reference point—top of casing, elevation 56 feet, 0.1 mile south of Butte House Road, 0.2 mile west of Mallott Road. 12/22/47, 21.2; 3/5/48, 19.1; 3/29/49, 20.0; 11/16/49, 20.5; 3/23/50, 21.4; 11/2/50, 20.5; 3/26/51, 20.1; 11/15/51, 20.1; 4/2/52, 15.5.

15N/2E-11C1—Reference point—top of casing, elevation 53.6 feet, 200 feet north of Butte House Road, 0.15 mile west of East Butte Road. 12/22/47, 9.0; 3/3/48, 10.6; 12/2/48, 7.7; 3/16/49, 9.1; 11/10/49, 7.4; 3/23/50, 8.2; 11/2/50, 7.6; 4/4/51, 9.1; 11/14/51, 6.9; 4/3/52, 7.2.

15N/2E-11N1—Reference point—top of casing, elevation 50 feet, 50 feet west of Humphrey Road, 0.55 mile south of Butte House Road. 12/22/47, 9.9; 3/5/48, 10.8; 9/27/48, 5.1; 11/17/48, 8.9; 3/28/49, 9.1.

15N/2E-12A1—Reference point—top of casing, elevation 55.8 feet, 100 feet southwest of intersection of Township and Pease Roads. 12/21/47, 5.8; 3/3/48, 16.8; 12/1/48, 15.0; 3/16/49, 13.6; 11/11/49, 14.8.

15N/2E-12K1—Reference point—base of pump, elevation 53.8 feet, 100 feet north of Butte House Road, 0.45 mile west of Township Road. 12/22/47, 13.2; 3/3/48, 12.4; 12/2/48, 11.9; 1/20/49, 13.3; 3/17/49, 11.5; 11/10/49, 11.3; 3/23/50, 11.1; 11/1/50, 11.3; 4/4/51, 9.2; 11/14/51, 10.0; 4/3/52, 5.2.

15N/2E-12R1—Reference point—top of casing, elevation 52 feet, 0.1 mile west of Township Road, 0.3 mile south of Butte House Road. 12/19/47, 6.2; 3/24/48, 7.2; 11/18/48, 7.0; 3/28/49, 6.0; 11/23/49, 6.4.

15N/2E-13E1—Reference point—top of wooden planks under pump, elevation 50 feet, 0.3 mile south of Fortuna Road, 0.9 mile west of Township Road. 12/22/47, 7.8; 3/5/48, 9.5; 11/18/48, 11.3; 3/28/49, 7.5; 11/23/49, 9.4.

15N/2E-13J2—Reference point—top of casing at bottom of pit, elevation 46 feet, 250 feet west of Township Road, 0.4 mile north of State Highway 20. 12/19/47, 8.1; 3/5/48, 9.1; 9/27/48, 9.3; 11/18/48, 9.0; 3/28/49, 8.1; 5/26/49, 8.0; 6/28/49, 10.7; 7/27/49, 11.3; 8/26/49, 10.5; 11/23/49, 9.8; 3/23/50, 8.0; 3/27/51, 6.8; 11/14/51, 7.9; 4/1/52, 4.4.

15N/2E-14A1—Reference point—top of brick casing, elevation 51.7 feet, 200 feet south of Fortuna Road, 1 mile west of Township Road. 12/22/47, 10.8; 3/3/48, 10.2; 12/2/48, 10.1; 3/16/49, 9.2; 11/11/49, 9.3; 3/23/50, 9.7; 11/2/50, 9.6; 4/4/51, 7.4; 11/14/51, 7.9; 4/3/52, 5.8.

15N/2E-15C1—Reference point—top of casing at bottom of pit, elevation 39 feet, 200 feet south of South Butte Road, 0.85 mile east of Acacia Road. 12/23/47, 4.0; 3/4/48, 4.5; 12/2/48, 3.3; 12/8/49, 2.4.

15N/2E-15D1—Reference point—top of casing in pit, elevation 44 feet, South side of South Butte Road, 0.5 mile east of Acacia Avenue. 12/23/47, 5.4; 3/4/48, 6.2; 12/2/48, 6.2; 3/29/49, 6.1; 11/16/49, 4.4; 3/23/50, 4.7; 11/2/50, 4.1; 4/1/51, 4.3; 11/15/51, 3.6; 4/2/52, 1.1.

15N/2E-15R1—Reference point—top of casing, elevation 48 feet, 150 feet west of Humphrey Road, 0.1 mile north of State Highway 20. 12/22/47, 9.3; 3/5/48, 10.4; 9/27/48, 3.8; 11/17/48, 5.9; 3/28/49, 4.5; 11/23/49, 5.7; 3/24/50, 5.5; 10/31/50, 4.7; 3/26/51, 3.1; 11/15/51, 4.1; 4/1/52, 2.6.

15N/2E-16E1—Reference point—slot in casing, elevation 56 feet, 200 feet west of Third Avenue, 0.25 mile south of South Butte Road. 12/22/47, 21.4; 3/4/48, 22.2; 12/2/48, 21.15; 3/29/49, 20.7; 11/16/49, 20.0.

15N/2E-17E1—Reference point—slot in casing, elevation 46 feet, 0.3 mile south of South Butte Road, 0.7 mile west of Irwin Avenue. 12/22/47, 14.1; 3/4/48, 14.1; 12/2/48, 14.2; 3/29/49, 12.1; 11/15/49, 14.9; 3/23/50, 12.9; 11/2/50, 15.8; 3/26/51, 35.2 (operating); 11/15/51, 21.0; 4/3/52, 8.9.

15N/2E-21C1—Reference point—top of casing in pit, elevation 38 feet, South west corner of Acacia Road and State Highway 20. 12/22/47, 1.6; 3/4/48, 2.6; 12/2/48, 1.8; 3/29/49, 0.8; 11/16/49, 0.3; 3/24/50, 0.5; 11/2/50, —0.7; 3/26/51, —1.0; 11/15/51, 0.0; 4/2/52, —2.7.

15N/2E-22B1—Reference point—top of casing, elevation 46 feet, 0.2 mile south of State Highway 20, 0.3 mile west of Humphrey Road. 12/23/47, 10.2; 3/4/48, 11.2; 12/2/48, 9.5; 3/24/49, 4.9; 11/16/49, 8.9; 3/23/50, 9.5; 11/2/50, 9.1; 3/26/51, 8.5; 11/15/51, 8.3; 4/2/52, 6.8.

15N/2E-22R1—Reference point—top of casing, elevation 45 feet, 200 feet north of Franklin Road, 0.15 mile west of Humphrey Road. 12/22/47, 8.9; 3/5/48, 9.5; 9/27/48, 6.0; 11/17/48, 8.0; 3/28/49, 4.1.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N 2E-23B1—Reference point—top of casing, elevation 45 feet, 100 feet south of State Highway 20, 0.75 mile east of Humphrey Road. 12/22/47, 6.8; 3/5/48, 7.8; 11/17/48, 6.2; 3/28/49, 5.9; 11/23/49, 6.4; 3/24/50, 6.7; 10/31/50, 7.1; 3/26/51, 5.0; 11/15/51, 5.2; 4/1/52, 2.8.

15N 2E-24B1—Reference point—hole in pump base, elevation 51 feet, 300 feet south of State Highway 20, 0.3 mile west of Township Road. 12/22/47, 13.7; 3/5/48, 14.4; 9/27/48, 12.4; 11/17/48, 13.5; 3/28/49, 13.5; 11/23/49, 8.1; 3/24/50, 13.8; 10/31/50, 14.6; 3/27/51, 11.0; 11/11/51, 12.9; 4/1/52, 7.0.

15N 2E-24N1—Reference point—top of concrete foundation, elevation 47 feet, 0.1 mile north of Franklin Road, 0.8 mile west of Township Road. 11/27/29, 14.0; 10/6/30, 13.0; 12/15/31, 14.0; 11/30/32, 13.0; 12/14/33, 13.9; 11/10/34, 13.6; 11/28/36, 11.2; 11/24/37, 10.9; 1/25/39, 10.3; 1/11/41, 5.6; 11/4/47, 9.4; 12/14/48, 10.9; 12/8/49, 10.4; 11/10/50, 10.4; 12/7/51, 6.6.

15N 2E-25A1—Reference point—top of concrete pit, elevation 48 feet, 0.05 mile south of Franklin Road, 0.2 mile west of Township Road. 12/22/47, 13.4; 3/5/48, 14.6; 11/17/48, 13.5; 3/28/49, 12.2; 11/23/49, 13.5; 3/24/50, 13.1; 10/31/50, 13.4; 3/27/51, 10.7; 11/14/51, 12.0; 4/1/52, 6.9.

15N 2E-25N1—Reference point—top of casing, elevation 49 feet, 0.1 mile north of Lincoln Road, 0.85 mile west of Township Road. 12/22/47, 11.8; 3/5/48, 13.0; 11/17/48, 11.1; 3/28/49, 10.6; 11/23/49, 10.8.

15N 2E-26B1—Reference point—top of concrete pipe casing, elevation 46 feet, 50 feet south of Franklin Road, 0.6 mile east of Humphrey Road. 12/22/47, 7.3; 3/5/48, 8.2; 9/27/48, 3.0; 11/17/48, 6.0; 3/28/49, 5.5; 11/23/49, 6.4; 3/24/50, 6.9; 10/31/50, 5.6; 3/27/51, 5.3; 11/15/51, 5.2; 4/1/52, 4.1.

15N 2E-26E1—Reference point—top of wooden box casing, elevation 42 feet, 250 feet east of Humphrey Road, 0.45 mile south of Franklin Road. 12/22/47, 9.8; 3/5/48, 9.8; 11/17/48, 8.2; 3/28/49, 6.6; 11/23/49, 7.0; 3/24/50, 8.1; well destroyed.

15N 2E-28D1—Reference point—top of casing, elevation 41 feet, 500 feet south of Franklin Road, 0.1 mile west of Wadsworth Canal west levee. 12/22/47, 7.1; 3/4/48, 8.2; 12/2/48, 7.0; 3/29/49, 5.5; 11/16/49, 5.9; 3/23/50, 7.7.

15N 2E-28D2—Reference point—top of casing in pit, elevation 38 feet, 500 feet south of Franklin Road, 0.2 mile west of Wadsworth Canal west levee. 11/2/50, 2.5; 3/26/51, 11.6 (operating); 11/15/51, 2.4; 4/3/52, —0.8.

15N 2E-34D1—Reference point—top of casing, elevation 41 feet, Southeast of intersection of Lincoln and Clements roads. 12/22/47, 7.5; 3/4/48, 8.1; 12/2/48, 7.0; 11/15/49, 5.1.

15N 2E-35B1—Reference point—top of casing in pit, elevation 35 feet, 0.1 mile south of Lincoln Road, 1.4 miles west of Township Road. 12/22/47, 1.6; 3/5/48, 2.6; 10/4/48, 0.5; 11/17/48, 1.5; 3/28/49, —0.6.

15N 2E-35D1—Reference point—hole in pump base, elevation 42 feet, 0.1 mile south of Lincoln Road, 1.8 miles west of Township Road. 12/23/47, 8.7; 3/6/48, 9.5; 11/17/48, 8.1; 3/28/49, 6.2; 11/23/49, 8.3; 3/24/50, 6.8; 11/1/50, 7.2; 3/27/51, 6.8; 11/11/51, 6.2; 4/1/52, 1.7.

15N 2E-35Q1—Reference point—top of casing, elevation 41.6 feet, 0.1 mile north of Bogue Road, 1.3 miles west of Township Road. 12/22/47, 5.0; 3/5/48, 6.1; 10/4/48, 4.7; 11/17/48, 4.4; 3/29/49, 3.0; 11/25/49, 4.1; 3/24/50, 4.1; 11/1/50, 3.3; 3/27/51, 2.9; 11/14/51, 2.5.

15N 2E-36A1—Reference point—top of casing, elevation 46 feet, 100 feet south of Lincoln Road, 0.1 mile west of Township Road. 12/22/47, 12.3; 3/5/48, 13.3; 10/4/48, 10.6; 11/12/48, 11.6; 3/28/49, 11.6; 6/28/49, 6.7; 7/27/49, 7.4; 8/25/49, 7.9; 11/23/49, 11.2; 3/24/50, 11.3; 11/1/50, 10.9; 3/27/51, 9.4; 11/11/51, 10.2; 4/2/52, 6.3.

15N 2E-36H1—Reference point—top of plank in pit, elevation 40 feet, 0.15 mile west of Township Road, 0.45 mile south of Lincoln Road. 12/22/47, 6.3; 3/5/47, 7.5; 11/17/48, 4.1; 3/29/49, 5.0.

15N 2E-36P1—Reference point—top of casing, elevation 43.7 feet, 0.15 mile north of Bogue Road, 0.65 mile west of Township Road. 12/22/47, 7.6; 3/5/48, 8.9; 11/17/48, 6.0; 3/29/49, 3.6; 11/25/49, 5.8; 3/24/50, 6.8.

15N 3E-1C1—Reference point—top of 16-inch casing, elevation 63 feet, 0.3 mile east of State Highway 24, 1.0 mile south of Ellis Road. 11/6/47, 14.5; 3/17/48, 14.0; 11/30/48, 14.9; 1/26/49, 14.2; 3/17/49, 13.0; 11/17/49, 15.7; 3/21/50, 13.1; 11/6/50, 15.9; 3/29/51, 9.9; 11/27/51, 14.6; 4/6/52, 7.5.

15N 3E-1D1—Reference point—hole in pump base, elevation 64 feet, 0.1 mile east of State Highway 24, 0.75 mile south of Ellis Road. 11/6/47, 19.5; 3/20/48, 16.1; 11/30/48, 17.0; 3/17/49, 15.0; 11/16/49, 18.8.

15N 3E-2A1—Reference point—top of 16-inch casing, elevation 64 feet, 0.3 mile west of State Highway 24, 0.85 mile south of Ellis Road. 11/6/47, 25.1; 3/20/48, 18.9; 11/30/48, 21.6; 11/16/49, 22.3; 3/31/50, 16.3; 11/6/50, 22.1.

15N 3E-2A2—Reference point—top of 14-inch casing, elevation 63 feet, 0.25 mile west of State Highway 24, 1.05 miles south of Ellis Road. 11/6/47, 20.4; 11/30/48, 14.7; 3/17/49, 16.9; 11/17/49, 19.0.

15N 3E-2A3—Reference point—hole in base of pump, elevation 65 feet, 0.05 mile west of State Highway 24, 0.5 mile south of Ellis Road. 11/6/47, 18.4; 3/20/48, 18.2; 12/2/48, 17.7; 3/17/49, 15.5; 11/16/49, 19.8.

15N 3E-2B2—Reference point—hole in base of pump, elevation 64 feet, 0.35 mile west of State Highway 24, 0.75 mile south of Ellis Road. 11/6/47, 21.2; 11/30/48, 17.2; 3/17/49, 16.2; 11/16/49, 22.0; 3/29/51, 12.9.

15N 3E-2C1—Reference point—hole in base of pump, elevation 65 feet, 0.85 mile west of State Highway 24, 0.9 mile south of Ellis Road. 11/6/47, 24.5; 3/20/48, 23.5; 11/30/48, 23.3; 3/17/49, 20.4; 11/17/49, 25.3; 3/21/50, 19.2; 11/6/50, 24.3; 3/29/51, 15.1; 11/16/51, 23.5; 4/6/52, 10.2.

15N 3E-2H1—Reference point—bottom of pump base, elevation 63 feet, 0.3 mile west of State Highway 24, 1.25 miles south of Ellis Road. 11/6/47, 20.6; 3/17/48, 19.0; 5/7/48, 17.3; 11/30/48, 19.6; 3/17/49, 17.8; 11/17/49, 21.3.

15N 3E-2J1—Reference point—top of 16-inch casing, elevation 63 feet, 0.1 mile west of State Highway 24, 1.6 miles south of Ellis Road. 11/6/47, 17.8; 3/17/48, 16.8; 5/7/48, 14.8; 11/30/48, 17.4; 1/26/49, 16.7; 3/17/49, 15.5; 11/17/49, 18.4.

15N 3E-3D2—Reference point—top of casing, elevation 63.7 feet, 250 feet south of Eager Road, 0.1 mile west of U.S. Highway 99E. 11/4/47, 25.8.

15N 3E-3G1—Reference point—hole in base of pump, elevation 62 feet, 0.2 mile south of Rednall Road, 0.3 mile east of U.S. Highway 99E. 11/5/47, 28.6; 3/17/48, 28.1; 5/12/48, 23.6; 11/29/48, 28.5; 3/17/49, 25.7; 11/14/49, 30.6; 3/22/50, 24.9; 11/6/50, 29.6; 4/3/51, 21.2; 11/14/51, 27.7; 4/3/52, 19.1.

15N 3E-4C1—Reference point—top of casing, elevation 60.9 feet, 0.20 mile south of Eager Road, 0.65 mile west of Onstott Road. 12/19/47, 23.2; 3/2/48, 27.5; 12/1/48, 22.7; 3/17/49, 21.2; 11/11/49, 25.8; 4/3/51, 18.4.

15N 3E-4C2—Reference point—hole in pump base, elevation 61.5 feet, 0.25 mile south of Eager Road, 0.50 mile west of Onstott Road. 5/4/48, 22.9; 6/3/48, 22.0; 9/1/48, 30.3; 9/30/48, 27.2; 11/29/48, 23.7; 1/20/49, 23.2; 3/17/49, 22.5; 11/11/49, 27.1; 3/22/50, 23.7; 11/1/50, 27.5; 11/14/51, 23.7; 4/3/52, 11.9.

15N 3E-4H1—Reference point—top of concrete base, bottom of pit, elevation 47.2 feet, 0.1 mile west of Onstott Road, 0.6 mile south of Eager Road. 11/4/47, 17.9; 11/20/48, 15.5; 3/17/49, 12.4; 11/14/49, 16.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N/3E-4J1—Reference point—top of casing, bottom of pit, elevation 47.7 feet, 0.15 mile west of Onstott Road, 0.85 mile south of Eager Road. 11/4/47, 17.6; 11/29/48, 16.0; 3/17/49, 13.0; 11/14/49, 18.4; 11/14/50, 23.0.

15N/3E-4N1—Reference point—top of casing, elevation 59.4 feet, 0.1 mile north of Pease Road, 0.5 mile east of Terra Buena Road. 12/21/47, 27.1; 3/24/48, 27.1; 12/1/48, 27.6; 3/16/49, 26.5; 5/26/49, 27.0; 6/30/49, 34.0; 11/11/49, 29.6; 3/23/50, 25.9; 11/6/50, 30.7; 4/4/51, 22.6; 11/14/51, 26.8.

15N/3E-5B2—Reference point—hole in base of pump, elevation 62.5 feet, 0.15 mile south and 150 feet east of a point on Eager Road at intersection of Larkin Road. 12/19/47, 21.8; 3/2/48, 22.1; 12/1/48, 20.7; 1/20/49, 20.2; 3/17/49, 19.5; 11/11/49, 23.0.

15N/3E-5D2—Reference point—hole in base of pump, elevation 59.8 feet, 50 feet south of Nuestro Road, 0.4 mile west of Terra Buena Road. 12/19/47, 18.7; 3/24/48, 20.6; 12/1/48, 18.0; 3/16/49, 17.3; 11/11/49, 19.9; 3/23/50, 15.1; 11/6/50, 22.0; 4/3/51, 12.3; 11/14/51, 18.2; 4/3/52, 7.4.

15N/3E-5G1—Reference point—hole in base of pump, elevation 59.5 feet, 0.25 mile east of Terra Buena Road, 0.5 mile north of Pease Road. 12/19/47, 18.9; 3/3/48, 24.2; 12/1/48, 23.0; 3/16/49, 22.0; 11/11/49, 24.7.

15N/3E-6B1—Reference point—top of 2" x 6" bridge over concrete pit, elevation 59.8 feet, 200 feet east of Broadway, 0.15 mile west of Nuestro Road. 12/19/47, 16.8; 3/24/48, 17.4; 12/1/48, 16.1; 3/16/49, 13.7; 11/11/49, 18.2.

15N/3E-6C1—Reference point—top of 2" x 6" bridge over concrete pit, elevation 58.8 feet, 400 feet north of Nuestro Road, 0.2 mile east of Township Road. 12/19/47, 14.2; 3/3/48, 14.3; 12/1/48, 14.9; 3/16/49, 12.2; 5/26/49, 13.8; 6/28/49, 15.4; 7/27/49, 17.3; 8/25/49, 16.5; 11/11/49, 16.3.

15N/3E-6Q1—Reference point—slot in concrete base, elevation 56.4 feet, 0.2 mile north of Pease Road, 0.4 mile east of Township Road. 12/21/47, 17.8; 3/3/48, 17.6; 12/1/48, 18.2; 3/16/49, 17.0; 11/11/49, 18.7; 3/23/50, 21.9; 11/1/50, 20.8; 4/4/51, 12.9; 11/14/51, 17.4; 4/3/52, 7.5.

15N/3E-7H2—Reference point—top of casing, elevation 57.0 feet, 0.5 mile north of Butte House Road, 0.55 mile west of Terra Buena Road. 12/21/47, 23.9; 3/24/48, 23.6; 12/1/48, 24.8; 3/16/49, 22.5; 11/11/49, 26.1.

15N/3E-7P1—Reference point—hole in base of pump, elevation 55.4 feet, 500 feet south of Butte House Road, 0.35 mile east of Township Road. 12/21/47, 19.8; 3/3/48, 20.8; 12/1/48, 21.0; 3/16/49, 19.5; 11/10/49, 22.1.

15N/3E-7Q1—Reference point—hole in base of pump, elevation 56 feet, 150 feet south of Butte House Road, 0.45 mile east of Township Road. 12/19/47, 20.7; 3/24/48, 20.9; 11/18/48, 22.1; 3/28/49, 19.8; 11/23/49, 22.9; 3/23/50, 19.8; 10/31/50, 24.4; 3/27/51, 17.9; 11/14/51, 21.2; 4/1/52, 9.8.

15N/3E-7R1—Reference point—top of discharge pipe, elevation 55.8 feet, 0.1 mile north of Butte House Road, 0.7 mile west of Terra Buena Road. 12/21/47, 23.8; 3/3/48, 22.5; 12/1/48, 24.8; 3/16/49, 22.5; 11/11/49, 26.2; 3/23/50, 19.6; 11/1/50, 23.3; 4/4/51, 19.4; 11/14/51, 24.1; 4/3/52, 12.2.

15N/3E-8C1—Reference point—bottom of pump base, elevation 57.5 feet, 50 feet south of Pease Road, 0.15 mile west of Terra Buena Road. 12/22/47, 23.9; 3/3/48, 24.7; 12/1/48, 24.2; 1/20/49, 23.0; 3/16/49, 22.2; 11/11/49, 25.0; 3/23/50, 21.5; 11/1/50, 28.0; 4/4/51, 17.4; 11/14/51, 23.6; 4/3/52, 11.2.

15N/3E-8J4—Reference point—top of casing, elevation 56.8 feet, 200 feet west of Elmer Avenue, 0.7 mile north of Butte House Road. 12/22/47, 27.9; 3/3/48, 26.9; 3/16/49, 26.0; 11/11/49, 30.7.

15N/3E-9A1—Reference point—top of concrete floor, elevation 59.8 feet, 300 feet south of Pease Road, 0.1 mile west of Onstott Road. 11/4/47, 37.9; 5/12/48, 27.1; 6/1/48, 26.5; 6/30/48, 48.8 operating; 8/2/48, 45.0; 9/30/48, 33.2; 10/21/48, 31.8; 11/30/48, 29.3; 1/20/49, 27.4; 3/17/49, 26.4; 11/14/49, 31.3; 3/22/50, 22.2; 11/1/50, 31.0; 4/4/51, 24.1; 11/14/51, 27.3; 4/3/52, 19.7.

15N/3E-9C1—Reference point—top of casing, elevation 58.1 feet, 0.1 mile south of Pease Road, 0.55 mile west of Onstott Road. 11/4/47, 40.6; 3/17/48, 27.6; 11/29/48, 27.4; 3/17/49, 25.5; 11/14/49, 29.5.

15N/3E-9G1—Reference point—top of pneumatic gage hole, elevation 61.0 feet, 50 feet east of Stabler Lane, 0.45 mile south of Pease Road. 11/4/47, 32.8; 3/17/48, 34.2; 11/29/48, 32.5; 3/17/49, 29.4; 11/14/49, 34.8.

15N/3E-9N1—Reference point—bottom of pump base, elevation 57.6 feet, 100 feet east of Blevin Road, 0.55 mile north of Butte House Road. 12/22/47, 29.8; 3/3/48, 31.6; 12/1/48, 31.0; 3/16/49, 28.0; 11/11/49, 33.3.

15N/3E-9P3—Reference point—top of 12-inch casing, elevation 55 feet, 0.30 mile east of Blevin Road, 0.60 mile north of Butte House Road. 11/18/47, 27.7; 11/18/48, 28.2; 3/23/49, 26.6.

15N/3E-9R2—Reference point—bottom of pump base, elevation 200 feet, West of Onstott Road, 1.4 miles north of Butte House Road. 11/18/47, 35.0; 3/17/48, 35.5; 11/19/48, 36.4; 3/23/49, 32.0; 11/22/49, 37.9; 3/23/50, 34.0; 11/13/51, 34.4; 4/1/52, 32.6.

15N/3E-10G1—Reference point—hole in pump base, elevation 60 feet, 0.05 mile west of U. S. Highway 99E, 0.50 mile south of Pease Road. 11/19/47, 30.2; 3/17/48, 28.3; 11/19/48, 34.6; 3/23/49, 26.6; 11/22/49, 33.4; 3/23/50, 24.3; 11/30/50, 30.8; 3/27/51, 20.9; 11/14/51, 36.1; 4/1/52, 20.3.

15N/3E-11B1—Reference point—top of concrete base, elevation 60 feet, 0.80 mile west of State Highway 24, 2.50 miles south of Ellis Road. 11/7/49, 21.5; 3/7/48, 21.1; 5/19/48, 18.1; 11/30/48, 21.6; 3/17/49, 19.2; 11/17/49, 23.1; 3/21/50, 19.2; 11/6/50, 23.0; 3/29/51, 16.5; 11/16/51, 22.3; 4/6/52, 12.1.

15N/3E-11H1—Reference point—top of casing, elevation 61 feet, 0.45 mile west of State Highway 24, 2.70 miles south of Ellis Road. 11/6/47, 18.5; 3/17/48, 16.8; 11/30/48, 17.8; 3/17/49, 15.6; 11/17/49, 18.2.

15N/3E-11H2—Reference point—top of casing, elevation 61 feet, 0.40 mile west of State Highway 24, 2.70 miles south of Ellis Road. 11/6/47, 16.9; 3/17/48, 16.4; 11/30/48, 16.7; 3/17/49, 13.5; 11/17/49, 17.7.

15N/3E-14M1—Reference point—top of casing, elevation 57 feet, 0.35 mile east of U. S. Highway 99E at a point 0.70 mile north of State Highway 20. 11/19/47, 24.2; 3/17/48, 22.2. Well destroyed.

15N/3E-15B2—Reference point—hole in pump base, elevation 59 feet, 0.05 mile west of U. S. Highway 99E, 1.0 mile north of State Highway 20. 11/19/47, 31.4; 3/17/48, 30.2; 5/12/48, 26.7; 9/27/48, 31.1; 11/19/48, 33.6; 3/23/49, 28.8; 11/22/49, 32.9; 3/23/50, 28.4; 10/30/50, 32.0; 3/27/51, 30.8; 4/1/52, 24.1.

15N/3E-15E2—Reference point—base of pump, elevation 58.6 feet, 400 feet east of Onstott Road, 0.30 mile north of Butte House Road. 11/18/47, 35.3; 3/4/48, 34.8; 3/15/48, 34.8; 11/19/48, 41.8; 3/23/49, 32.7; 11/22/49, 39.3; 3/23/50, 34.6; 11/30/50, 38.7; 3/27/51, 33.9; 3/13/51, 36.1; 4/1/52, 29.7.

15N/3E-16C1—Reference point—hole in pump base, elevation 56 feet, 0.25 mile east of Blevin Road, 0.50 mile north of Butte House Road. 11/19/47, 33.6; 3/17/48, 33.6; 5/13/48, 30.8; 11/19/48, 39.0; 3/23/49, 32.2; 11/29/49, 36.4; 11/3/50, 36.6.

15N/3E-16L1—Reference point—concrete rim of pit, elevation 56 feet, 300 feet east of Tharp Road, 0.1 mile south of Butte House Road. 11/18/47, 34.8; 3/15/48, 34.8; 11/18/48, 37.9; 3/23/49, 32.0; 11/23/49, 36.1; 3/23/50, 33.6; 10/31/50, 38.2; 3/27/51, 31.4; 11/14/51, 35.2; 4/1/52, 24.5.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N 3E-16R2—Reference point—top of casing, elevation 57.1 feet, 300 feet east of Blevin Road, 0.35 mile north of Butte House Road. 12/19/47, 31.0; 3/24/48, 32.9; 9/27/48, 34.5; 11/18/48, 31.7; 3/28/49, 28.9; 11/23/49, 32.7; 3/23/50, 29.7; 11/23/49, 32.7; 3/23/50, 29.7; 10/30/50, 35.2; 3/27/51, 27.2; 11/11/51, 31.9; 4/1/52, 24.8.

15N 3E-17C1—Reference point—top of casing at bottom of pit, elevation 16.8 feet, 200 feet east of Hooper Road, 0.05 mile north of Butte House Road. 12/19/47, 17.5; 3/6/48, 16.0; 9/27/48, 20.9; 11/18/48, 19.0; 3/28/49, 16.0; 11/23/49, 19.3; 3/23/50, 24.8; 10/30/50, 20.7; 3/27/51, 13.5.

15N 3E-17P2—Reference point—top of flanged coupling at bottom of pit, elevation 41.0 feet, 0.05 mile north of State Highway 20, 0.25 mile east of Hooper Road. 12/19/47, 15.1; 3/6/48, 14.6; 9/27/48, 19.6; 11/18/48, 16.9; 3/28/49, 12.8. Well destroyed.

15N 3E-18R1—Reference point—top of casing, elevation 53 feet, 0.1 mile north of State Highway 20, 0.1 mile west of George Washington Boulevard. 12/19/47, 23.3; 3/6/48, 22.8; 11/18/48, 25.6; 3/28/49, 21.9; 11/23/49, 26.2; 10/31/50, 28.2; 3/27/51, 19.7; 11/11/51, 25.3; 4/1/52, 12.7.

15N 3E-19B1—Reference point—2" x 4" on top of concrete pit, elevation 57.3 feet, 0.21 mile south of State Highway 20, 0.54 mile east of Township Road. 12/21/47, 29.2; 3/3/48, 27.6; 12/1/48, 30.0; 1/20/49, 28.7; 3/16/49, 27.0; 11/11/49, 32.3; 3/23/50, 27.5; 11/1/50, 22.4; 4/4/51, 25.6; 11/14/51, 30.6.

15N 3E-20E1—Reference point—top of casing, elevation 37.5 feet, 0.48 mile west of El Margarita Road, 0.53 mile south of State Highway 20. 12/19/47, 9.6; 3/6/48, 9.5; 9/27/48, 13.8; 11/18/48, 11.7; 3/28/49, 8.4; 11/25/49, 11.3.

15N 3E-20G1—Reference point—hole in base of pump, elevation 52 feet, 0.25 mile east of El Margarita Road, 0.50 mile south of State Highway 20. 12/19/47, 30.8; 3/6/48, 31.0; 3/28/49, 28.7; 11/25/49, 29.1; 10/31/50, 36.6; 11/14/51; 39.4; 4/1/52, 23.6.

15N 3E-20R1—Reference point—top of casing, elevation 53.4 feet, 0.20 mile west of Harding Road, 0.05 mile north of Franklin Road. 12/19/47, 29.9; 3/24/48, 30.8; 11/18/48, 33.2; 3/28/49, 28.0; 5/26/49, 33.5; 6/28/49, 35.4; 7/27/49, 38.4; 8/25/49, 38.7; 11/25/49, 33.4; 3/27/50, 30.1; 10/31/50, 35.3; 3/27/51, 28.9; 11/14/51, 36.6; 1/1/52, 25.3.

15N 3E-21C1—Reference point—hole in concrete base, elevation 54 feet, 0.40 mile east of Harding Road, 0.12 mile south of State Highway 20. 3/17/48, 32.8; 11/18/48, 32.5; 3/23/49, 29.2; 11/25/49, 31.4.

15N 3E-21D1—Reference point—hole in concrete base, elevation 55.6 feet, 0.05 mile south of State Highway 20, 0.24 mile east Harding Road. 12/19/47, 30.8; 3/24/48, 31.2; 5/12/48, 31.1; 9/22/48, 37.1; 11/18/48, 32.8; 3/28/49, 28.8; 5/26/49, 37.8; 6/30/49, 45.0; 8/25/49, 41.8; 11/25/49, 31.1.

15N 3E-21F1—Reference point—hole in concrete base, elevation 55 feet, 0.28 mile east of Harding Road, 0.38 mile south of State Highway 20. 11/17/47, 34.3; 3/17/48, 34.8; 11/18/48, 39.3; 3/23/49, 31.5; 11/25/49, 38.9; 10/31/50, 39.0; 3/27/51, 32.5; 11/11/51, 37.3; 4/1/52, 28.4.

15N 3E-21L2—Reference point—top of casing, elevation 55.0 feet, 0.04 mile west of Walton Road, 0.61 mile south of State Highway 20. 12/19/47, 32.2; 3/24/48, 32.7; 11/18/48, 31.5; 3/28/49, 30.3; 11/25/49, 35.9.

15N 3E-21P2—Reference point—slot in casing, elevation 51.3 feet, 0.18 mile north of Franklin Road, 0.48 mile east of Harding Road. 11/18/47, 33.3; 3/15/48, 34.8; 11/18/48, 34.8; 3/23/49, 31.0; 11/25/49, 35.4.

15N 3E-21Q1—Reference point—top of pit, elevation 53 feet, North side of Franklin Road, 0.25 mile east of Walton Road. 1/4/41, 24.5; 11/4/47, 33.6; 12/15/48, 33.5; 12/8/49, 36.1; 11/17/50, 38.4; 12/7/51, 35.8.

15N 3E-21R1—Reference point—top of casing, elevation 53.3 feet, 0.1 mile west of Onstott Road, 0.13 mile north of Franklin Road. 11/17/47, 31.1; 3/17/48, 31.4; 3/29/48, 30.4; 5/12/48, 30.7; 9/27/48, 35.1; 11/18/48, 32.7; 3/23/49, 29.5; 11/25/49, 35.1; 3/27/50, 31.4; 10/31/50, 36.2; 3/27/51, 30.7; 11/13/51, 34.5; 1/1/52, 26.7.

15N 3E-22D1—Reference point—hole in base of pump, elevation 54.8 feet, 0.05 mile east of Onstott Road, 0.17 mile south of State Highway 20. 11/17/47, 31.2; 3/17/48, 31.5; 9/27/48, 34.2; 11/19/48, 32.2; 3/23/49, 29.2; 11/25/49, 34.7.

15N 3E-24N1—Reference point—top of casing, elevation 48.6 feet, 0.38 mile southwest of Western Pacific Railroad crossing of Yuba River, 0.50 mile west of U. S. Highway 99E. 11/14/47, 10.0; 3/19/48, 8.6; 11/23/48, 11.0; 3/24/49, 6.8; 11/22/49, 13.8; 3/28/50, 24.0; 11/20/51, 31.3; 4/2/52, 12.6.

15N 3E-24N2—Reference point—top of casing, elevation 70.9 feet, 0.35 mile southwest of Western Pacific Railroad crossing of Yuba River, 0.50 mile north of U. S. Highway 99E. 11/14/47, 31.5; 3/19/48, 29.9; 11/23/48, 31.7.

15N 3E-24Q1—Reference point—pipe in base, elevation 64.8 feet, 0.04 mile south of Riverside Boulevard, 0.04 mile west of Western Pacific Railroad. 11/12/47, 27.2; 3/19/48, 27.4; 11/22/48, 31.4; 3/24/49, 24.8; 12/13/49, 31.0.

15N 3E-25C1—Reference point—top of casing, elevation 53.4 feet, 0.15 mile west of Riverside Boulevard, 0.55 mile south of Western Pacific Railroad crossing on Yuba River. 11/14/47, 14.6; 3/19/48, 13.2; 3/30/48, 12.5; 11/23/48, 15.0; 3/24/49, 11.2; 11/22/49, 15.1.

15N 3E-25F1—Reference point—top of casing, elevation 61.0 feet, 0.85 mile south of Western Pacific Railroad crossing on Yuba River, 0.27 mile west of Riverside Boulevard. 11/12/47, 24.4; 3/19/48, 23.3; 11/23/48, 25.1; 3/24/49, 21.6; 11/22/49, 26.5; 3/28/50, 20.8; 11/9/50, 25.6; 3/28/51, 15.1; 11/20/51, 24.0; 4/3/52, 15.3.

15N 3E-25H1—Reference point—base of pump, elevation 59.9 feet, South side of Walnut Avenue, 0.15 mile southwest of Garden Avenue. 11/12/47, 22.3; 3/19/48, 22.5; 10/4/48, 24.2; 11/22/48, 23.2; 3/24/49, 19.5; 11/18/49, 23.8.

15N 3E-25H2—Reference point—hole in base of pump, elevation 57.1 feet, West side of Garden Avenue, 0.15 mile south of Walnut Avenue. 11/14/47, 19.3; 11/22/48, 20.8; 3/24/49, 18.0; 11/18/49, 21.5.

15N 3E-25K1—Reference point—hole in base of pump, elevation 61.5 feet, 0.11 mile east of Riverside Boulevard, 0.86 mile north of Feather River Boulevard. 11/12/47, 24.8; 3/19/48, 23.1; 11/23/48, 24.8.

15N 3E-25K2—Reference point—top of casing, elevation 48.0 feet, 0.15 mile east of Riverside Boulevard, 0.82 mile north of Feather River Boulevard. 11/12/47, 10.9; 3/19/48, 9.3; 3/30/48, 8.7; 10/4/48, 21.2; 11/22/48, 19.5; 3/24/49, 16.7; 11/22/49, 21.0.

15N 3E-26M1—Reference point—top of casing, elevation 52 feet, 0.31 mile north of Lincoln Road, 0.24 mile east of Garden Highway. 11/14/47, 23.8; 3/17/48, 23.6; 3/2/48, 20.8; 10/4/48, 26.8; 11/19/48, 24.7; 3/23/49, 21.8; 6/29/49, 29.8; 7/31/49, 32.8; 8/25/49, 31.4; 11/28/49, 25.9; 3/27/50, 21.1; 11/1/50, 26.1; 3/27/51, 23.2; 11/13/51, 28.0; 4/1/52, 17.0.

15N 3E-27C1—Reference point—hole in base of pump, elevation 53 feet, 0.10 mile west of Clark Avenue, 0.14 mile south of Franklin Road. 11/17/47, 29.7; 3/17/48, 29.9; 11/19/48, 31.6; 3/23/49, 30.5.

15N 3E-28B3—Reference point—top of pit, elevation 53 feet, 0.25 mile east of Walton Road, south side of Franklin Road. 11/27/29, 23.8; 9/27/30, 27.8; 12/15/31, 28.8; 12/1/32, 28.4; 12/14/33, 30.5; 11/10/34, 31.3; 11/25/36, 21.5; 11/24/37, 23.6; 1/26/39, 18.3.

15N 3E-28C1—Reference point—top of casing, elevation 54.2 feet, 0.18 mile west of Walton Road, 0.07 mile south of Franklin Road. 12/19/47, 33.1; 3/24/48, 33.4; 5/12/48, 31.3; 9/27/48, 36.4; 11/18/48, 36.6; 3/28/49, 31.5; 11/25/49, 37.1.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N/3E-28G1—Reference point—top of casing, elevation 54.3 feet. 0.09 mile east of Walton Road, 0.37 mile south of Franklin Road. 11/17/47, 33.7; 3/15/48, 33.5; 11/18/48, 36.4; 3/23/49, 32.0; 11/25/49, 36.6; 3/27/50, 34.3; 10/31/50, 39.6; 3/27/51, 33.2; 11/13/51, 37.4; 4/1/52, 28.5.

15N/3E-28Q1—Reference point—base of pump, elevation 52.9 feet, 0.10 mile north of Lincoln Road, 0.18 mile east of Walton Road. 11/17/47, 32.0; 3/15/48, 32.0; 3/29/48, 31.4; 10/4/48, 35.2; 11/18/48, 34.8; 3/23/49, 31.0; 11/28/49, 36.6.

15N/3E-29D1—Reference point—bottom of flange coupling in pit, elevation 40.2 feet, west side of Butte Avenue, 0.14 mile south of Franklin Road. 12/19/47, 13.3; 3/5/48, 14.2; 11/18/48, 17.9; 3/28/49, 13.0; 12/13/49, 17.3; 3/27/50, 14.9; 11/1/50, 19.7; 3/27/51, 11.1; 11/14/51, 19.0; 4/1/52, 16.7.

15N/3E-29N1—Reference point—top of casing, in pit, elevation 36.9 feet, 0.14 mile north of Lincoln Road, 0.13 mile east of George Washington Boulevard. 12/19/47, 10.4; 3/5/48, 10.6; 11/18/48, 12.0; 3/28/49, 9.1; 11/23/49, 14.3; 3/27/50, 9.6; 11/1/50, 14.9; 3/27/51, 7.6; 11/14/51, 15.3; 4/1/52, 14.0.

15N/3E-29R2—Reference point—top of pump base, elevation 51.9 feet, 0.57 mile west of Walton Avenue, 0.03 mile north of Lincoln Road. 12/19/47, 31.6; 3/24/48, 31.1; 10/4/48, 34.7; 11/18/48, 33.2; 11/25/49, 34.8.

15N/3E-30Q1—Reference point—top of discharge pipe, elevation 47 feet. North side Lincoln Road, 0.40 mile west of George Washington Boulevard. 12/22/47, 20.3; 3/5/48, 20.5; 10/4/48, 21.6; 11/17/48, 20.7; 3/28/49, 18.9; 11/23/49, 21.3.

15N/3E-32N1—Reference point—top of casing, elevation 48.4 feet, 0.05 mile north of Bogue Road, 0.20 mile east of George Washington Boulevard. 12/20/47, 23.7; 3/5/48, 27.9; 11/17/48, 25.4; 3/29/49, 23.5; 11/25/49, 24.3; 3/27/50, 22.9; 11/1/50, 30.5; 3/27/51, 20.4; 11/14/51, 27.6; 4/1/52, 15.8.

15N/3E-33D1—Reference point—hole in base of pump, elevation 51 feet, 0.08 mile south of Lincoln Road, 0.32 mile west of Walton Road. 5/4/48, 30.0; 6/1/48, 29.4; 11/18/48, 34.7; 3/29/49, 29.5; 11/25/49, 35.0; 3/27/50, 32.3; 11/1/50, 37.7; 3/27/51, 31.3; 11/14/51, 35.5; 4/1/52, 29.0.

15N/3E-33F1—Reference point—hole in base of pump, elevation 52.0 feet, 0.10 mile west of Walton Road, 0.27 mile south of Lincoln Road. 12/20/47, 29.7; 3/5/48, 34.5; 5/4/48, 28.3; 5/12/48, 29.2; 6/1/48, 28.2; 11/18/48, 35.0; 3/29/49, 31.8; 11/25/49, 33.7; 3/27/50, 30.5; 11/1/50, 36.0; 3/27/51, 29.9; 11/14/51, 36.3; 4/1/52, 26.0.

15N/3E-33K1—Reference point—hole in base of pump, elevation 52.1 feet. East side of Walton Road, 0.54 mile south of Lincoln Road. 3/12/48, 36.1; 5/6/48, 31.3; 6/1/48, 30.9; 11/11/48, 36.5.

15N/3E-33K2—Reference point—hole in base of pump, elevation 49 feet, 0.20 mile east of Walton Road, 0.73 mile south of Lincoln Road. 11/17/47, 35.6; 3/15/48, 35.6; 11/25/49, 35.9.

15N/3E-33N2—Reference point—hole in base of pump, elevation 48.4 feet, 0.32 mile west of Walton Road, 0.06 mile north of Bogue Road. 12/20/47, 27.9; 3/5/48, 33.8; 11/18/48, 30.0; 3/29/49, 26.7; 11/25/49, 31.4; 3/27/50, 20.6; 11/1/50, 34.4; 11/14/51, 32.9; 4/1/52, 23.8.

16N/3E-33P1—Reference point—top of concrete pit, elevation 50.5 feet. West side of Walton Road, 0.15 mile north of Bogue Road. 11/10/47, 30.3; 3/23/48, 32.7; 11/11/48, 32.1; 1/18/49, 29.8; 3/7/49, 29.0; 11/29/49, 33.2; 3/27/50, 30.6; 11/3/50, 35.7; 11/16/51, 33.3.

15N/3E-33C2—Reference point—hole in base of pump, elevation 48.6 feet, 0.20 mile north of Bogue Road, 0.10 mile east of Walton Avenue. 3/16/48, 34.0; 11/11/48, 31.6; 3/7/49, 29.1; 12/1/49, 33.4.

15N/3E-34L1—Reference point—top of casing, elevation 50 feet, 0.52 mile south of Lincoln Road, 0.96 mile east of Walton Road. 11/14/47, 31.3; 3/15/48, 33.9; 5/5/48, 29.2; 6/1/48, 29.2; 7/3/48, 57.0 (operating); 8/3/48, 48.1; 9/30/48, 37.8; 10/4/48, 41.5; 11/19/48, 37.7; 3/23/49, 31.0; 5/31/49, 33.7; 8/31/49, 38.6; 11/28/49, 36.8; 3/27/50, 31.5; 11/1/50, 35.7; 3/28/51, 30.3; 11/13/51, 33.9; 4/1/52, 32.0.

15N/3E-34N1—Reference point—top of casing, elevation 39.5 feet, 0.05 mile west of Phillips Road, 0.15 mile north of Bogue Road. 3/12/48, 21.2; 11/11/48, 37.0; 3/7/49, 34.2; 12/1/49, 36.5.

15N/3E-35E1—Reference point—top of casing, elevation 50 feet, 0.37 mile east of Garden Highway, 0.44 mile south of Lincoln Road. 11/14/47, 22.1; 3/17/48, 21.2; 11/23/48, 22.5; 3/23/49, 20.5; 11/28/49, 21.1; 3/27/50, 20.8.

15N/4E-3A1—Reference point—top of casing, elevation 95.0 feet 0.31 mile east of Hallwood Road, south side of Walnut Road. 11/25/47, 16.6; 3/3/48, 19.8; 4/1/48, 19.1; 11/29/48, 17.0; 3/22/49, 18.8; 11/18/49, 17.7.

15N/4E-3B1—Reference point—top of casing, elevation 95.4 feet, 0.47 mile south of Walnut Road, 0.03 mile west of Hallwood Road. 11/25/47, 23.5; 3/3/48, 26.2; 11/29/48, 24.0; 1/27/49, 25.2; 3/22/49, 23.9; 11/16/49, 23.7.

15N/4E-3D1—Reference point—top of casing, elevation 93.4 feet, 0.45 mile west of Hallwood Road, 0.01 mile south of Walnut Road. 11/25/47, 18.8; 3/3/48, 21.9; 4/1/48, 21.8; 11/29/48, 20.0; 1/27/49, 22.2; 3/22/49, 20.1; 11/18/49, 19.4.

15N/4E-3D2—Reference point—top of casing, elevation 90 feet, 0.56 mile west of Hallwood Road, southeast of curve in Walnut Road. 11/29/48, 22.2; 3/23/49, 22.0.

15N/4E-4A1—Reference point—top of casing, elevation 90.4 feet, South side of Walnut Road, 0.85 mile along Walnut Road from intersection with State Highway 20. 11/25/47, 19.9; 3/3/48, 20.9; 11/29/48, 19.8; 3/22/49, 19.0; 11/18/49, 19.2.

15N/4E-4C1—Reference point—top of casing, elevation 88.7 feet, 0.05 mile south of Walnut Road, 0.41 mile along Walnut Road from intersection with State Highway 20. 11/25/47, 19.4; 3/3/48, 21.1; 4/1/48, 20.4; 11/29/48, 20.4; 3/22/49, 18.8; 11/18/49, 20.0.

15N/4E-4D1—Reference point—hole in pump base, elevation 85 feet, 0.03 mile southeast of intersection of State Highway 20 and Walnut Road. 11/29/48, 26.1; 1/27/49, 26.0; 3/22/49, 23.2; 12/9/49, 27.1.

15N/4E-4E1—Reference point—top of 10-inch casing inside shed, elevation 87.5 feet, 0.17 mile east of State Highway 20, 0.38 mile south along State Highway 20 from intersection of Walnut Road. 11/25/47, 21.9; 3/2/48, 22.8; 4/1/48, 22.4; 11/26/48, 22.8; 1/27/49, 23.2; 3/22/49, 21.0; 11/18/49, 22.5; 3/23/50, 21.5; 10/31/50, 22.2; 3/30/51, 20.5; 11/14/51, 22.3.

15N/4E-4H1—Reference point—top of tin casing at suction line, elevation 85 feet, 0.9 mile east of State Highway 20, 0.5 mile south of Walnut Road. 11/28/47, 20.2; 3/2/48, 20.8; 4/1/48, 21.7; 3/22/49, 20.5; 11/18/49, 20.8.

15N/4E-4N1—Reference point—top of casing, elevation 85.6 feet, 0.55 mile east of State Highway 20, 0.82 mile south of intersection of State Highway 20 and Walnut Road. 11/25/47, 24.3; 3/2/48, 24.3; 4/1/48, 23.5; 11/26/48, 24.6; 3/22/49, 22.6; 12/9/49, 25.2.

15N/4E-4N2—Reference point—top of casing, elevation 85.3 feet, 0.61 mile east of State Highway 20, 0.91 mile south along State Highway 20 from intersection with Walnut Road. 11/25/47, 23.9; 3/2/48, 23.9; 3/22/49, 22.0.

15N/4E-4P1—Reference point—top of casing, elevation 86.5 feet, 0.72 mile east of State Highway 20, 0.73 mile south along State Highway 20 from intersection with Walnut Road. 11/25/47, 70.4; 3/2/48, 25.6.

15N/4E-4R1—Reference point—hole in side of pump, elevation 85.7 feet, 0.81 mile northwest of Dantoni Packing Shed on Dantoni Road, southeast of Yuba River. 11/24/47, 26.3; 3/4/48, 25.0; 3/31/48, 27.3; 10/4/48, 25.4; 11/24/48, 25.4; 1/17/49, 25.2; 3/16/49, 24.0; 5/24/49, 26.3; 6/29/49, 28.7; 7/28/49, 27.8; 8/26/49, 27.9; 11/21/49, 26.2; 3/23/50, 24.1; 10/31/50, 26.5; 4/2/51, 21.4; 11/21/51, 25.6; 4/5/52, 20.4.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N/4E-5D1—Reference point—top of tin casing, elevation 65 feet, 0.17 mile northwest of Kimball Lane at curve, 1.0 mile along Kimball Lane from intersection with Nigger Jack Slough Road. 11/26/47, 7.2; 3/1/48, 8.8; 11/30/48, 8.2; 3/23/49, 8.5; 12/9/49, 8.5.

15N/4E-6C1—Reference point—top of suction pipe flange, elevation 65 feet, 0.10 mile north of intersection of Kimball Lane and Nigger Jack Slough Road on west side of Nigger Jack Slough Road. 11/7/47, 8.3; 12/2/48, 6.0; 3/18/49, 4.5; 11/17/49, 5.1.

15N/4E-7J1—Reference point—top of casing, elevation 68 feet. North side of State Highway 20, 1.65 miles along State Highway 20 from Yuba Street. 11/19/47, 15.9; 3/19/48, 15.9; 11/21/48, 16.3; 3/28/48, 15.0; 11/17/49, 16.0; 3/28/50, 15.8; 11/2/50, 15.7; 3/28/51, 10.5; 11/16/51, 16.2; 4/2/52, 10.2.

15N/4E-7M1—Reference point—hole in base of pump, elevation 61 feet, 0.80 mile north of 15th Street, west side of Nigger Jack Slough Road. 11/19/47, 19.4; 3/19/48, 18.8; 10/5/48, 19.1; 11/22/48, 19.7; 3/28/49, 17.5; 11/17/49, 19.8; 3/28/50, 16.9.

15N/4E-8D1—Reference point—top of casing outside milk house, elevation 65 feet, 0.46 mile east of Nigger Jack Slough Road, 0.25 mile northwest of State Highway 20. 11/25/47, 15.4; 3/2/48, 16.1; 11/30/48, 15.9; 3/22/49, 14.7; 11/21/49, 15.1; 3/23/50, 14.3; 10/31/50, 15.0; 3/30/51, 14.7; 11/14/51, 15.8; 4/5/52, 12.6.

15N/4E-8M1—Reference point—top of casing, elevation 74 feet, 0.20 mile east of State Highway 20, 1.68 miles from intersection with Yuba Street. 11/25/47, 23.1; 3/2/48, 22.7; 11/26/48, 23.1; 3/22/49, 22.2; 12/9/49, 24.7.

15N/4E-8R1—Reference point—base of pump, elevation 80.3 feet, 1.58 miles north of intersection of Dantoni and Hammond Roads on south bank of Yuba River. 11/19/47, 26.7; 3/2/48, 26.7; 3/31/48, 25.7; 5/5/48, 23.3; 6/1/48, 23.2; 10/4/48, 26.8; 11/21/48, 26.9; 3/16/49, 25.4; 11/21/49, 27.7; 3/23/50, 25.0; 10/31/50, 27.7; 4/2/51, 22.2; 11/21/51, 26.9; 4/5/52, 23.4.

15N/4E-9G1—Reference point—top of casing, elevation 84.6 feet, 0.70 mile northwest of Dantoni Road, 0.10 mile southwest along road from Dantoni Packing Shed. 11/24/47, 29.6; 3/3/48, 24.9; 3/4/48, 25.1; 10/4/48, 25.9; 11/24/48, 25.5; 1/17/49, 24.9; 3/16/49, 23.7; 11/21/49, 26.0; 3/23/50, 23.2; 10/31/50, 25.9; 4/2/51, 21.1; 11/21/51, 25.0; 4/5/52, 20.3.

15N/4E-9R1—Reference point—hole in side of pump, elevation 77.2 feet, 0.23 mile northwest of Dantoni Road, 0.40 mile southwest along road from Dantoni Packing Shed. 11/24/47, 19.2; 3/1/48, 20.9; 3/3/48, 21.0; 11/24/48, 20.1; 3/16/49, 20.2; 11/21/49, 21.1.

15N/4E-10F1—Reference point—hole in base of pump, elevation 80.5 feet, 0.23 mile northwest of Dantoni Road, 0.20 mile northeast along road from Dantoni Packing Shed. 11/24/47, 21.5; 3/1/48, 19.8; 3/31/48, 25.7; 10/4/48, 20.9; 11/24/48, 20.6; 3/16/49, 19.7; 11/21/49, 21.5.

15N/4E-10L2—Reference point—pipe in concrete base, elevation 87.8 feet, 0.12 mile southeast from Dantoni Road, opposite Dantoni Packing Shed. 11/21/47, 26.2; 3/3/48, 31.0; 3/4/48, 26.9; 5/6/48, 25.0; 10/8/48, 27.4; 11/21/48, 27.3; 1/17/49, 26.8; 3/16/49, 26.1; 3/24/49, 31.0; 6/29/49, 29.5; 7/28/49, 30.3; 8/30/49, 30.5; 11/21/49, 28.6.

15N/4E-10N1—Reference point—hole in casing, elevation 84.1 feet, 0.16 mile southeast of Dantoni Road, 0.30 mile southwest along road from Dantoni Packing Shed. 11/24/47, 28.6; 3/1/48, 26.0; 3/31/48, 26.6; 5/6/48, 24.2; 10/4/48, 26.2; 11/24/48, 26.5; 3/16/49, 25.8; 11/21/49, 28.0; 12/7/49, 27.8; 3/23/50, 26.6; 10/31/50, 28.2; 4/2/51, 20.7; 11/21/51, 26.9; 4/5/52, 23.0.

15N/4E-11C1—Reference point—top of casing, elevation 90 feet, 1.60 miles north of Hammonton Road at a point 0.55 mile southwest along Hammonton Road from Brophy Road. 5/13/48, 25.0; 6/1/48, 24.7; 10/1/48, 27.5; 11/23/48, 27.5; 1/17/49, 26.9; 3/16/49, 26.5; 11/21/49, 28.8; 3/23/50, 25.4; 3/30/51, 18.8; 11/1/51, 27.1; 4/4/52, 18.4.

15N/4E-11G1—Reference point—hole in pump base, elevation 85 feet, 1.17 miles north of Hammonton Road at a point 0.35 mile southwest along Hammonton Road from Brophy Road. 5/13/48, 25.3; 6/1/48, 24.9; 9/1/48, 29.5; 10/1/48, 26.2; 11/23/48, 26.1, 1/17/49, 26.1; 3/16/49, 25.4; 4/12/49, 24.1; 5/24/49, 28.5; 6/29/49, 29.4; 7/28/49, 28.5; 8/26/49, 28.4; 11/21/49, 23.6; well destroyed.

15N/4E-11K1—Reference point—hole in top of pump base, elevation 83 feet, 0.29 mile west of Brophy Road, 0.90 mile north of Brophy School. 5/13/48, 18.1; 10/1/48, 20.1; 11/23/48, 19.4; 3/16/49, 18.4.

15N/4E-12P1—Reference point—hole in pump base, elevation 82.3 feet, 0.57 mile north of Brophy School, 0.29 mile east of Brophy Road. 11/24/47, 24.3; 3/1/48, 25.9; 3/31/48, 23.8; 11/23/48, 27.5; 11/21/49, 26.7; 12/5/49, 26.6; 3/24/50, 22.4; 11/2/50, 27.6; 4/4/52, 19.4.

15N/4E-13B1—Reference point—top of casing, elevation 84 feet, South side of Hammonton Road, 0.4 mile northeast from intersection with Brophy Road. 12/24/47, 22.9; 3/23/48, 22.6; 11/23/48, 25.7; 3/21/49, 22.1; 12/5/49, 26.2; 3/23/50, 22.7; 11/2/50, 27.7; 4/2/51, 18.7; 11/21/51, 26.4; 4/4/52, 20.4.

15N/4E-14B1—Reference point—top of casing, elevation 80.5 feet, 0.21 mile north of Hammonton Road, 0.20 mile southwest from intersection with Brophy Road. 11/26/47, 16.1; 3/1/48, 16.4; 3/31/48, 16.4; 11/24/48, 17.8; 3/17/49, 16.3; 11/22/49, 16.4; 3/30/51, 4.6; 11/20/51, 17.0; 4/4/52, 4.7.

15N/4E-14N1—Reference point—hole in pump base, elevation 79 feet, 0.11 mile south of Hammonton Road, 0.85 mile southwest from intersection with Brophy Road. 5/6/48, 24.0; 6/3/48, 26.7; 3/17/49, 25.7; 11/21/49, 30.3.

15N/4E-14N2—Reference point—top of casing, elevation 78.8 feet, North side of Hammonton Road, 0.87 mile southwest from intersection with Brophy Road. 11/26/47, 22.7; 5/6/48, 21.8; 10/1/48, 26.4; 10/8/48, 25.8; 11/24/48, 24.9; 1/17/49, 23.9; 3/16/49, 23.3; 5/24/49, 31.3; 6/29/49, 33.5; 7/28/49, 35.3; 8/26/49, 30.8; 11/22/49, 27.7; 3/23/50, 24.3; 11/10/50, 28.7; 3/30/51, 18.5; 11/20/51, 27.9; 4/4/52, 20.3.

15N/4E-14P1—Reference point—hole in pump base, elevation 82 feet, 0.52 mile west of Brophy Road, 0.23 mile south of Hammonton Road. 5/6/48, 25.2; 6/3/48, 28.7; 3/17/49, 26.9; 8/2/49, 40.6; 11/21/49, 30.7.

15N/4E-15A1—Reference point—pipe in concrete base, elevation 78.5 feet, 1.02 miles west of Brophy Road, 0.86 mile north of Hammonton Road. 11/26/47, 18.3; 3/2/48, 17.1; 3/31/48, 18.5; 10/8/48, 20.2; 11/24/48, 19.6; 1/7/49, 19.0; 3/16/49, 18.4; 11/21/49, 21.0; 3/23/50, 19.1; 11/10/50, 22.0; 4/2/51, 11.1; 11/21/51, 20.3; 4/4/52, 12.2.

15N/4E-15L1—Reference point—top of concrete pit, elevation 81.5 feet, 0.15 mile east of Griffith Avenue, 0.66 mile north of Hammonton Road. 11/26/47, 27.0; 3/2/48, 29.8.

15N/4E-16A1—Reference point—hole in side of pump base, elevation 79.5 feet, North side of Dantoni Road, 0.73 mile along road from Dantoni Packing Shed. 11/7/47, 22.5; 3/2/48, 23.2; 3/31/48, 22.7; 10/4/48, 23.7; 10/8/48, 23.7; 11/24/48, 23.7; 1/17/49, 23.2; 3/16/49, 23.0; 11/21/49, 25.1.

15N/4E-16K1—Reference point—base of pump, elevation 81.0 feet, 0.03 mile west of Dantoni Road, 1.43 miles along road from intersection with Hammonton Road. 11/22/47, 26.8; 3/2/48, 28.2; 3/31/48, 27.9; 10/4/48, 30.0; 10/8/48, 29.9; 11/24/48, 29.2; 3/16/49, 28.4; 11/22/49, 31.2; 11/10/50, 30.5; 4/2/51, 21.5; 11/21/51, 29.5; 4/5/52, 22.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N/4E-16N2—Reference point—hole in pump base, elevation 74.5 feet, 0.28 mile northwest of Dantoni Road, 0.76 mile along road from intersection with Hammonton Road. 11/19/47, 23.9; 3/2/48, 23.3; 3/31/48, 23.1; 5/6/48, 22.3; 6/1/48, 21.8; 10/4/48, 24.5; 11/24/48, 24.2; 3/16/49, 23.6.

15N/4E-16P1—Reference point—base of pump, elevation 76.9 feet, 0.23 mile west of Dantoni Road, 1.31 miles along road from intersection with Hammonton Road. 11/5/47, 24.7; 3/2/48, 24.1; 5/13/48, 24.2; 6/1/48, 22.3; 10/4/48, 25.8; 10/8/48, 25.7; 11/24/48, 24.7; 3/16/49, 24.4; 11/21/49, 28.2.

15N/4E-17M1—Reference point—top of casing, elevation 74.2 feet, 0.76 mile measured perpendicular north of Simpson Lane at a point 0.82 mile from 7th St. Bridge. 11/11/47, 26.4; 3/19/48, 25.8; 3/30/48, 25.5; 11/5/48, 27.0; 11/22/48, 32.8; 3/24/49, 25.2; 11/17/49, 27.3; 3/28/50, 24.7; 11/2/50, 28.2; 3/28/51, 17.9; 11/16/51, 25.8; 4/2/52, 15.9.

15N/4E-17N1—Reference point—top of casing, elevation 74.5 feet, 0.35 mile measured perpendicular north of Simpson Lane at a point 1.27 miles from intersection with Yuba Street. 11/11/47, 26.0; 3/19/48, 25.4; 3/30/48, 25.3; 11/22/48, 26.6; 3/24/49, 25.2; 11/17/49, 27.6.

15N/4E-18G1—Reference point—top of casing, elevation 71 feet, 0.13 mile east of State Highway 20 at a point 0.90 mile from intersection with Yuba Street. 11/19/47, 27.7; 3/19/48, 26.2; 11/21/48, 28.5; 3/28/49, 24.5; 11/17/49, 28.1; 11/2/50, 26.2; 3/28/51, 22.3; 11/16/51, 28.1; 4/2/52, 21.6.

15N/4E-18Q1—Reference point—base of pump at edge, elevation 68.7 feet, 0.36 mile measured perpendicular north of Simpson Lane at a point 0.75 mile from intersection with Yuba Street. 11/12/47, 23.7; 3/18/48, 22.5; 11/22/48, 24.3; 3/24/49, 22.0; 11/17/49, 25.5; 11/16/51, 27.7.

15N/4E-19H1—Reference point—surface of concrete block, elevation 67.0 feet, 0.13 mile measured perpendicular south of Simpson Lane at a point 1.04 miles from intersection with Yuba Street. 11/11/47, 23.5; 3/19/48, 22.6; 10/5/48, 29.0; 11/22/48, 26.5; 3/24/49, 20.7; 11/17/49, 25.0; 11/2/50, 25.3; 3/28/51, 13.7.

15N/4E-19J1—Reference point—hole in pump base, elevation 71.8 feet, 0.43 mile south of Simpson Lane at a point 1.12 miles from intersection with Yuba Street. 11/11/47, 27.4; 3/19/48, 27.3; 3/24/49, 26.8; 11/18/49, 30.0; 3/28/50, 27.5; 11/3/50, 30.3; 3/28/51, 18.5; 11/16/51, 26.5; 4/2/52, 17.6.

15N/4E-19N1—Reference point—top of casing, elevation 59.9 feet. South bank of Levee Road, 0.35 mile east of U. S. Highway 99E bridge over Yuba River. 11/10/47, 20.0; 3/17/48, 19.0; 3/24/49, 17.0; 11/18/49, 21.4.

15N/4E-19P1—Reference point—top of casing, elevation 64.0 feet, 0.04 mile south of levee between Avondale and Southern Pacific Railroad. 11/11/47, 22.7; 3/17/48, 22.6; 3/30/48, 21.1; 11/22/48, 33.7; 3/24/49, 21.0; 12/13/49, 25.2.

15N/4E-20F1—Reference point—hole in pump base, elevation 72.5 feet, 0.20 mile due west from intersection of Hammonton and Dantoni Roads. 11/11/47, 25.7; 3/17/48, 26.0; 5/3/48, 24.7; 6/2/48, 25.4; 11/22/48, 26.2; 3/24/49, 26.5; 11/17/49, 29.6; 3/28/50, 27.3; 11/16/51, 25.1; 4/2/52, 23.6.

15N/4E-20L1—Reference point—top of casing, elevation 66 feet, 0.41 mile north of Hammonton Road at a point 0.55 mile along Hammonton Road from intersection with U. S. Highway 99E. 11/11/47, 14.3; 3/17/48, 15.0; 11/22/48, 13.3; 11/18/49, 22.4; 11/3/50, 22.7; 3/28/51, 12.6.

15N/4E-20N1—Reference point—top of casing, elevation 57.8 feet, 0.40 mile north of Hammonton Road at a point 0.41 mile along Hammonton Road from intersection with U. S. Highway 99E. 11/11/47, 13.6; 3/17/48, 13.9; 10/4/48, 24.4; 11/22/48, 19.3; 3/24/49, 13.5; 11/18/49, 16.1; 3/28/50, 14.3.

15N/4E-20N2—Reference point—top of casing, 8.5 feet below top of concrete pit, elevation 53.4 feet, 0.22 mile north of Hammonton Road at a point 0.45 mile along Hammonton Road from intersection with U. S. Highway 99E. 11/11/47, 12.6; 3/17/48, 12.9; 3/24/49, 6.0; 11/18/49, 8.6.

15N/4E-20N3—Reference point—top of casing, elevation 58.9 feet, 0.31 mile north of Hammonton Road at a point 0.50 mile along Hammonton Road from intersection with U. S. Highway 99E. 4/8/47, 14.7; 3/17/48, 15.3; 3/30/48, 14.5; 11/12/48, 22.2; 3/24/49, 15.9; 11/18/49, 17.3.

15N/4E-20P1—Reference point—top of concrete pit, east wall, elevation 67.5 feet, 0.14 mile due west of intersection of Hammonton and Linda Roads. 12/10/47, 22.5; 3/1/48, 22.5; 11/22/48, 23.3; 3/17/49, 22.9; 11/22/49, 24.6; 3/24/50, 23.2; 11/2/50, 25.7; 11/15/51, 20.7.

15N/4E-20R1—Reference point—top of casing, elevation 67.4 feet. North side of Linda Road, 0.41 mile east of Hammonton Road. 12/12/47, 22.2; 3/1/48, 21.3; 11/22/48, 23.6; 11/22/49, 25.2.

15N/4E-21F1—Reference point—base of wooden block supporting pump, south side, elevation 70.4, 0.10 mile north of Hammonton Road, 0.68 mile west of Griffith Avenue. 11/26/47, 23.6; 3/1/48, 23.6; 10/8/48, 25.7; 11/24/48, 24.8; 3/16/49, 23.5; 6/29/49, 29.2; 8/26/49, 31.0; 11/21/49, 28.8; 3/23/50, 25.3; 11/2/50, 30.0; 3/30/51, 19.1; 11/20/51, 30.8; 4/5/52, 21.9.

15N/4E-21R2—Reference point—hole in pump base, elevation 75.1 feet. West side of Griffith Avenue, 0.05 mile north of North Beale Road. 11/26/47, 27.1; 10/8/48, 29.4; 11/22/48, 29.2; 3/17/49, 27.8; 11/21/49, 32.3; 3/24/50, 29.9; 11/3/50, 34.3; 3/30/51, 26.3; 11/21/51, 33.7; 4/3/52, 26.9.

15N/4E-22B1—Reference point—top of casing, elevation 73.6 feet. North side of Hammonton Road, 0.75 mile along road from intersection with Griffith Avenue. 11/26/47, 20.6; 3/1/48, 20.1; 3/31/48, 20.0; 5/6/48, 19.6; 10/1/48, 23.3; 10/8/48, 23.1; 11/24/48, 22.4; 1/17/49, 21.9; 3/16/49, 21.3; 5/24/49, 24.9; 7/1/49, 31.1; 8/3/49, 28.9; 8/26/49, 28.1; 11/21/49, 25.3; 3/23/50, 22.7; 11/2/50, 27.2; 3/30/51, 15.2; 11/20/51, 24.9; 4/4/52, 27.1.

15N/4E-22K1—Reference point—top of casing, elevation 86.9 feet, 0.40 mile north of North Beale Road, 0.76 mile east of Griffith Road. 12/10/47, 27.7; 3/1/48, 34.7; 10/8/48, 36.6; 11/22/48, 36.9; 3/17/49, 36.5; 11/22/49, 40.0.

15N/4E-22L1—Reference point—top of casing, elevation 74 feet, 0.39 mile east of Griffith Road, 0.26 mile north of North Beale Road. 11/22/29, 25.7; 9/16/30, 25.3; 12/14/31, 27.3; 12/9/32, 27.6.

15N/4E-22P1—Reference point—top of concrete foundation, elevation 72 feet, 0.32 mile east of Griffith Road, 0.15 mile north of North Beale Road. 11/5/47, 23.6; 12/10/48, 26.3; 12/9/49, 29.5; 11/10/50, 31.5; 12/5/51, 30.7.

15N/4E-22P2—Reference point—top of brick lining of well, elevation 73 feet, 0.31 mile east of Griffith Road, 0.15 mile north of North Beale Road. 12/14/33, 29.6; 11/20/34, 30.4; 11/28/36, 27.9; 11/22/37, 27.6; 1/27/39, 25.1; 1/9/41, 22.0.

15N/4E-23A1—Reference point—crack between wood blocks, southeast corner, elevation 84.2 feet. West side of Brophy Road, 0.96 mile north of North Beale Road. 11/26/47, 24.5; 3/1/48, 24.1; 3/31/48, 24.0; 5/6/48, 23.4; 6/3/48, 38.0; 10/1/48, 28.1; 10/8/48, 27.5; 11/23/48, 26.5; 1/17/49, 25.7; 3/16/49, 25.3; 6/1/49, 34.6; 7/3/49, 39.5 (operating); 8/2/49, 39.5 (operating); 11/22/49, 31.0; 3/23/50, 26.7; 11/2/50, 31.2; 3/30/51, 23.8; 11/21/51, 30.8; 4/4/52, 25.1.

15N/4E-23P1—Reference point—top of casing, elevation 77.2 feet, 0.04 mile north of North Beale Road, 0.65 mile east of Brophy Road. 12/10/47, 27.1; 3/1/48, 27.6; 3/31/48, 24.9; 10/8/48, 27.3; 11/22/48, 27.4; 3/17/49, 27.0; 11/22/49, 30.3; 11/2/50, 32.5.

15N/4E-23R1—Reference point—top of wooden platform under pitcher pump, elevation 79.1 feet, 0.05 mile northwest of intersection of North Beale and Brophy Roads. 12/10/47, 24.2; 3/1/48, 24.2.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

15N 4E-24C1—Reference point—top of casing, elevation 83 feet, 0.19 mile east of Brophy Road, 0.99 mile north of North Beale Road. 5-5-48, 25.1; 6-3-48, 28.6; 11-23-48, 28.1; 1-17-49, 27.4; 3-16-49, 27.0; 7-3-49, 16.0 (operating); 8-2-49, 52.0 (operating); 12-5-49, 30.8; 3-24-50, 29.1; 11-2-50, 33.3; 4-2-51, 28.3; 11-21-51, 38.1; 4-4-52, 35.9.

15N 4E-25L1—Reference point—hole in pump base, elevation 78 feet, 0.49 mile east of Brophy Road, 0.51 mile south of North Beale Road. 10-6-49, 30.0; 11-23-48, 29.5; 3-21-49, 28.6; 12-5-49, 33.7; 3-27-50, 32.1; 11-2-50, 37.2; 4-4-51, 34.5; 11-21-51, 40.0; 4-5-52, 36.7.

15N 4E-26J1—Reference point—hole in base of pump, elevation 76 feet, 0.70 mile south of North Beale Road due south of Brophy Road. 11-23-48, 28.8; 3-17-49, 28.5; 11-23-49, 31.9; 12-5-49, 32.6.

15N 4E-27E2—Reference point—top of concrete north wall, elevation 71.0 feet, 0.23 mile east of Griffith Road, 0.40 mile south of North Beale Road. 12/10-47, 23.1; 3/1/48, 22.3; 3-31-48, 22.4; 10-8-48, 25.5; 11-22-48, 25.4; 3-17-49, 24.5; 11-22-49, 28.5; 4-4-52, 25.3.

15N 4E-28D1—Reference point—hole in pump base, elevation 77.7 feet, 0.04 mile south of North Beale Road, 0.17 mile east of intersection of North Beale and Linda Roads. 11/26/47, 32.3; 3-1-48, 31.5; 11-22-48, 34.1; 3/26-49, 32.5; 11/21-49, 36.9; 3-24-50, 34.3; 11-2/50, 38.9; 3/30/51, 37.5 (operating); 11-21-51, 39.1; 4-3/52, 31.5.

15N 4E-29E1—Reference point—top of casing, elevation 61 feet, 0.23 mile northeast of U. S. Highway 99E, 0.20 mile southeast of Hammonton Road. 12-10-47, 20.9; 3/1/48, 20.6.

15N 4E-29F2—Reference point—top of 4" x 4" bridge over pit, elevation 64 feet, 0.26 mile south of North Beale Road, 0.62 mile west of intersection of North Beale and Linda Roads. 12/10/47, 22.4; 3/1/48, 20.9.

15N 4E-29P1—Reference point—top of 4" x 6" mud sill of shed, elevation 63.6 feet, 0.03 mile north of Earle Road, 0.04 mile east of Southern Pacific Railroad. 12/10/47, 21.5; 3/1/48, 22.7; 10-8-48, 25.0; 11-22-48, 24.2.

15N 4E-30B2—Reference point—hole in base of pump, elevation 62.7 feet, Northeast side of Avondale Avenue, 0.05 mile northwest of North Beale Road. 11/10-47, 21.3; 3/17/48, 20.3; 10-4-48, 23.7; 11-22-48, 22.2; 3-24-49, 19.0; 12/13/49, 23.4; 3-28-50, 20.5; 11-2-50, 24.6.

15N 4E-30D1—Reference point—base of pump, north side, elevation 59.1 feet, 0.03 mile south of U. S. Highway 99E at first turn south of Rancho Motel. 11-10-47, 20.4; 3-17/48, 20.5; 3-30-48, 18.8; 5-5-48, 16.0; 6-2-48, 16.6; 7-1-48, 39.2 (operating); 11-22-48, 21.6; 3-24-49, 18.0; 5-24/49, 20.8; 6-29-49, 24.3; 8-26-49, 25.1; 11-22-49, 24.8; 3-28/50, 17.0; 11-2-50, 22.3; 3-28-51, 10.2; 10-20-51, 21.8.

15N 4E-30E2—Reference point—base of pump, elevation 56.8 feet, Southwest side of Garden Avenue, 0.38 mile southeast of Walnut Avenue. 11-12-47, 18.9; 3-19-48, 17.8; 10-4-48, 22.1; 11-22-48, 21.0; 3-21-49, 16.8; 11-18-49, 21.2.

15N E-30L1—Reference point—top of pump base, elevation 56.0 feet, 0.04 mile southwest of Garden Avenue, 0.25 mile northwest of Feather River Boulevard. 11-11-47, 18.2; 3-19-48, 16.8; 11-22-18, 18.8; 3-21-49, 16.0; 11-18-49, 21.2.

15N 4E-30L2—Reference point—hole in pump base, elevation 56.5 feet, 0.03 mile northwest of Feather River Boulevard, 0.08 mile southwest of Garden Avenue. 11-12-47, 18.2; 3-19-48, 17.3; 3-30-48, 17.0; 3-24-49, 16.7; 12-13-49, 20.7; 3-28-50, 7.0; 11-2-50, 21.7; 3-28-51, 10.2; 11/20-51, 18.2; 4-1-52, 9.8.

15N 4E-31K1—Reference point—hole in pump base, elevation 63.1 feet, 0.56 mile south of Earle Road, 0.33 mile west of Arboga Road. 12-10-47, 21.8; 3-2-48, 21.4; 3-30-48, 20.9; 11-22-48, 23.1; 3-17-49, 21.6; 11-23-49, 22.7.

15N 4E-31Q1—Reference point—hole in side of pump, elevation 57 feet, 0.34 mile west of Arboga Road, 2.20 miles north of Ella Road. 11-12-47, 23.0; 3/5/48, 21.4.

15N 4E-32D1—Reference point—hole in pump base, elevation 61.6 feet, 0.10 mile west of intersection of U. S. Highway 99E and Earle Road, 0.03 mile south of Earle Road. 12-10/47, 31.2; 3/2/48, 22.7; 3/30-48, 22.3; 11/22/48, 24.5; 3/18/49, 23.1; 11/23-49, 26.1; 11-2/50, 28.5.

15N 4E-32D2—Reference point—top of casing, elevation 62 feet, South side Pasado Avenue 0.13 mile west of U. S. Highway 99E. 3/19/48, 22.4; 11/22/48, 27.6; 3/28/50, 27.1.

15N 4E-32F1—Reference point—top of wood frame in concrete floor under pump, elevation 62.2 feet, 0.18 mile west of U. S. Highway 99E at a point 0.53 mile south of intersection with Earle Road. 12/10/47, 21.8; 3/2/48, 22.2; 3/30-48, 20.8; 5-14/48, 20.9; 11/22/48, 23.7; 11/23/49, 25.1.

15N 4E-32L1—Reference point—top of concrete under pump, elevation 64 feet, 0.06 mile east of Olivehurst Avenue at a point 0.03 mile from intersection with U. S. Highway 99E. 12/1/47, 30.7; 3/17/48, 22.8.

15N 4E-32M1—Reference point—top of casing, elevation 60 feet, 0.40 mile due west of intersection of Olivehurst Avenue and U. S. Highway 99E. 12/1/47, 22.1; 3/17/48, 22.3; 11/19/48, 24.4; 3/21-49, 23.5.

15N 4E-33D1—Reference point—top of casing, elevation 70.5 feet, 0.10 mile south of Earle Road, 0.80 mile east of intersection with U. S. Highway 99E. 12/10/47, 28.2; 3/1/48, 26.7; 11/22/49, 33.1.

15N 4E-33D2—Reference point—top of concrete pit, north wall, elevation 70.2 feet, 0.10 mile south of Earle Road, 0.85 mile west of Griffith Avenue. 12/10/47, 28.1; 3/2/48, 26.6; 3/31/48, 26.6; 10-8/48, 31.6; 11/22/48, 30.5; 3/17/49, 28.2; 11-22/49, 33.8; 3/24/50, 30.8; 4-4/52, 31.8.

15N 4E-33H1—Reference point—top of casing, elevation 64.0 feet, 0.05 mile west of Griffith Avenue, 0.46 mile south of Earle Road. 12/4/47, 26.8; 3/18/48, 25.5; 11-19/48, 29.3; 3/23/49, 27.5; 11-23/49, 32.6; 3/27/50, 30.3; 11-2/50, 34.9; 7/5/51, 29.5; 11/30/51, 34.9; 4/4/52, 30.3.

15N 4E-33R1—Reference point—top of casing, elevation 65 feet, 1.51 miles north of McGowan Road, 1 mile due east of U. S. Highway 99E. 12-1/47, 26.8; 3/8/48, 29.6; 11/19/48, 33.9; 3/23-49, 31.6; 11-23/49, 38.0.

15N 4E-34D1—Reference point—top of wooden floor of pump house, elevation 69.4 feet, South side of Earle Road, 0.10 mile east of Griffith Avenue. 12/10/47, 22.7; 10-8/48, 26.5; 11/22/48, 25.6; 3/17/49, 24.8; 11/22-49, 29.0; 3/30/51, 26.8; 11-21-51, 31.2; 4/4/52, 26.1.

15N 4E-35E1—Reference point—top of 6" x 6" sill, south wall, elevation 68.7 feet, 0.15 mile east of curve in Earle Road, 1.32 miles south of North Beale Road. 12/10-47, 23.4; 3/1/48, 13.8; 3-31-48, 13.6; 10-8/48, 26.1; 11-22-48, 26.5; 3/17-49, 26.1; 11/22/49, 30.2; 3-24-50, 29.8; 11-2-50, 32.4; 3/30-51, 30.4; 11-21-51, 35.2; 4-4-52, 32.6.

15N 4E-35Q1—Reference point—top of casing, elevation 72.2 feet, North side of Spenceville Road, 0.26 mile east of intersection with Earle Road. 12-4/47, 21.8; 3/18/48, 21.6; 11-18-48, 25.3; 3/23/49, 23.9.

15N 5E-19C1—Reference point—top of brick curb, elevation 86 feet, 1.20 miles south of Hammonton Road at a point 1.50 miles from intersection of Brophy Road. 11-22-29, 24.3; 9-6-30, 24.1; 12-14-31, 26.2; 12-9/32, 25.7; 12-11/33, 25.9; 11-20/34, 26.6; 11/28-36, 25.4; 1-9-41, 3.0; 11-6-47, 24.6; 12-10-48, 24.6; 12-7-49, 27.3; 11/10/50, 26.9.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Mode by Division of Woter Resources
(Depths to water in feet meosured from reference point)

15N/5E-19L1—Reference point—top of concrete crib, elevation 86 feet, 1.77 miles south of Hammonton Road at a point 1.40 miles from intersection of Brophy Road. 11/22/29, 25.8; 9/26/30, 25.5; 12/14/31, 26.5; 12/9/32, 26.7; 12/14/33, 27.4; 11/20/34, 27.6; 11/28/36, 26.2; 11/23/37, 27.1; 1/9/41, 3.0; 11/6/47, 30.9; 12/10/48, 33.4; 12/7/49, 37.0; 11/10/50, 39.6; 12/5/51, 69.7.

15N/5E-31R1—Reference point—top of casing, elevation 79.2 feet. North side of Spenceville Road, 2.43 miles east of intersection with Virginia Road. 12/24/47, 22.1; 3/24/48, 22.0; 11/18/48, 26.7; 1/18/48, 24.9; 3/21/49, 24.2; 12/5/49, 32.2; 3/27/50, 30.3; 11/2/50, 38.4; 4/2/51, 33.2; 4/4/52, 36.5.

15N/5E-32J1—Reference point—top of casing, elevation 91 feet, 0.26 mile north of Spenceville Road, 3.43 miles east of intersection with Virginia Road. 12/24/47, 33.9; 3/24/48, 33.7; 11/18/48, 36.0; 3/21/49, 36.1; 12/5/49, 43.5; 3/27/50, 42.1; 11/2/50, 50.6; 4/2/51, 45.6; 11/21/51, 48.6.

16N/2E-1B1—Reference point—top of casing, elevation 76.2 feet, 350 feet south of Pennington Road, 0.3 mile west of Township Road. 12/22/47, 10.1; 3/1/48, 10.4; 12/8/48, 9.6; 3/29/49, 8.0; 11/8/49, 9.4; 3/21/50, 8.8; 11/2/50, 9.7 3/27/51, 8.6; 11/13/51, 9.2; 4/2/52, 8.1.

16N/2E-1J1—Reference point—hole in pump flange, elevation 72.1 feet, 0.2 mile west of Township Road, 0.5 mile south of Pennington Road. 12/23/47, 7.2; 3/1/48, 7.4; 12/18/48, 6.9; 1/20/49, 6.5; 3/21/49, 4.0; 11/9/49, 6.6.

16N/2E-2A1—Reference point—top of concrete floor, elevation 74.2 feet, 300 feet south of Pennington Road, 0.15 mile west of Schroeder Road. 12/22/47, 8.1; 3/1/48, 8.6; 12/8/48, 7.7; 3/20/49, 6.1; 11/8/49, 6.1; 3/21/50, 7.3; 11/2/50, 6.9; 3/23/51, 7.2; 11/13/51, 7.3; 4/2/52, 6.6.

16N/2E-2J1—Reference point—top of casing, elevation 73.6 feet, 300 feet west of Schroeder Road, 0.75 mile south of Pennington Road. 12/23/47, 8.8; 3/1/48, 9.2; 12/8/48, 8.7; 3/21/49, 5.7; 11/9/49, 6.1.

16N/2E-3K1—Reference point—top of casing, elevation 71.0 feet, 0.50 mile south of Pennington Road, 0.50 mile west of Krehe Road. 11/26/29, 8.4; 10/21/30, 8.7; 12/16/31, 8.1; 12/9/32, 8.4; 12/13/33, 7.0; 11/21/34, 7.8; 11/27/36, 7.5; 12/1/37, 7.1; 1/25/39, 6.8; 1/10/41, 3.5; 11/4/47, 2.7; 12/14/48, 6.2; 11/8/49, 5.6; 11/10/50, 6.7; 11/26/51, 6.1.

16N/2E-4B1—Reference point—top of casing, elevation 73.7 feet, 0.30 mile south of Pennington Road, 1.27 miles west of Krehe Road. 12/22/47, 9.9; 3/2/48, 10.1; 12/3/48, 10.0; 3/30/49, 8.2; 11/15/49, 8.6.

16N/2E-5B1—Reference point—bottom of flange above discharge pipe, elevation 74.8 feet, 0.15 mile south of Pennington Road, 2.3 miles west of Krehe Road. 12/22/41, 6.8; 3/2/48, 6.7; 12/3/48, 9.2; 3/30/49, 10.0; 11/16/49, 8.0.

16N/2E-5L1—Reference point—top of casing, elevation 87.8 feet, 0.55 mile south-southeast of 90 degree turn in Pennington Road, 2.5 miles west of Krehe Road. 12/22/47, 12.8; 3/2/48, 12.8; 12/3/48, 13.6; 3/30/49, 12.0; 11/15/49, 14.0; 3/24/50, 12.8; 11/2/50, 16.1; 3/27/51, 12.9.

16N/2E-12J1—Reference point—top of casing, elevation 71.8 feet, 0.25 mile west of Township Road, 0.15 mile north of Paseo Avenue. 12/23/47, 8.5; 3/1/48, 8.6; 12/8/48, 8.4; 3/21/49, 4.0; 11/9/49, 8.0; 3/22/50, 7.3; 11/3/50, 8.0; 4/3/51, 7.1; 11/14/51, 7.8; 4/2/52, 7.0.

16N/2E-13G2—Reference point—top of casing, elevation 64.6 feet, 0.3 mile west of Township Road, 0.7 mile north of Clark Road. 12/23/47, 7.0; 3/1/48, 3.6; 12/8/48, 3.2; 3/21/49, —1.5; 11/10/49, 5.8; 3/22/50, 7.4.

16N/2E-24D1—Reference point—top of casing, elevation 66.4 feet, 100 feet south of Clark Road, 0.8 mile west of Township Road. 12/23/47, 8.9; 3/1/48, 8.0; 12/8/48, 7.7; 1/20/49, 8.5; 3/21/49, 6.1; 11/10/49, 4.5; 3/22/50, 8.2; 11/3/50, 8.1; 4/3/51, 36.2 (operating); 11/14/51, 8.2; 4/2/52, 6.6.

16N/2E-25P1—Reference point—top of casing, elevation 62.1 feet, 100 feet north of Sanders Road, 1.0 mile west of Broadway. 12/19/47, 9.7; 3/3/48, 10.5; 12/2/48, 9.2; 1/20/49, 10.0; 3/16/49, 8.8; 11/10/49, 7.7; 3/22/50, 9.2; 11/6/50, 8.2; 4/4/51, 8.6; 11/14/51, 8.3; 4/3/52, 6.9.

16N/2E-26K1—Reference point—top of casing, elevation 66.4 feet, 500 feet east of East Butte Road, 0.25 mile north of Sanders Road. 12/19/47, 14.7; 3/3/48, 14.5; 12/2/48, 13.5; 3/16/49, 13.3; 11/10/49, 10.8; 3/22/50, 11.9; 11/2/50, 12.8; 4/4/51, 11.9; 11/14/51, 12.4; 4/3/52, 9.2.

16N/2E-35B1—Reference point—top of casing, elevation 64 feet, 800 feet east of East Butte Road, 0.25 mile south of Sanders Road. 11/26/29, 12.0; 10/21/30, 11.5; 12/16/31, 13.0; 12/8/32, 12.1; 11/21/34, 12.2; 11/24/36, 12.7; 12/1/37, 11.0; 1/25/39, 12.0; 1/11/41, 6.7; 11/4/47, 1.0; 12/14/48, 12.1; 11/11/49, 10.3; 11/10/50, 11.1; 11/26/51, 11.6.

16N/2E-35C2—Reference point—top of casing (10 feet above ground), elevation 65 feet, 300 feet west of East Butte Road, 0.1 mile south of Sanders Road. 12/13/33, 16.3; 11/21/34, 16.9; 12/1/37, 14.5; 1/25/39, 16.2; 1/11/41, 9.8.

16N/3E-1E1—Reference point—top of casing at bottom of pit, ground elevation 80 feet, 0.1 mile east of State Highway 24, 0.6 mile north of Ramirez Road. 11/3/47, 12.5; 3/23/48, 9.4; 12/6/48, 11.2; 3/21/49, 9.4; 11/15/49, 13.4.

16N/3E-1E2—Reference point—base of pump, elevation 80 feet, 0.20 mile east of State Highway 24, 0.6 mile north of Ramirez Road. 11/3/47, 22.3; 3/23/48, 19.2; 12/6/48, 20.6; 3/21/49, 19.0; 11/15/49, 23.1; 3/21/50, 17.0; 11/7/50, 24.5; 3/29/51, 15.2; 11/15/51, 21.7; 4/6/52, 10.7.

16N/3E-1M1—Reference point—top of casing, elevation 78 feet, 500 feet east of State Highway 24, 0.3 mile north of Ramirez Road. 11/4/47, 21.2; 3/23/48, 18.5.

16N/3E-1P2—Reference point—base of pump, elevation 78 feet, 300 feet north of Ramirez Road, 0.60 mile east of State Highway 24. 11/4/47, 18.4; 3/23/48, 15.1; 12/2/48, 15.8; 3/21/49, 15.0; 11/15/49, 18.2; 3/2/50, 19.7; 3/29/51, 11.6; 11/15/51, 17.7; 4/6/52, 5.6.

16N/3E-2C1—Reference point—top of casing, elevation 80 feet, 0.60 mile west of State Highway 24, 0.70 mile north of Ramirez Road. 11/3/47, 21.6; 3/23/48, 18.0; 12/6/48, 20.5; 3/21/49, 18.5; 11/15/49, 22.6; 3/21/50, 16.2; 11/7/50, 22.4; 3/29/51, 14.0; 11/15/51, 21.0; 4/6/52, 10.3.

16N/3E-2J1—Reference point—top of casing, elevation 79 feet, 0.17 mile west of State Highway 24, 0.32 mile north of Ramirez Road. 6/1/48, 16.5; 6/30/48, 20.0; 7/21/48, 34.9; 9/1/48, 21.2; 9/30/48, 20.6; 12/3/48, 17.9; 3/21/49, 16.1.

16N/3E-4L1—Reference point—top of casing, elevation 75 feet, 30 feet west of Sheldon Road, 0.25 mile south of Archer Road. 11/10/47, 10.4; 3/20/48, 13.4; 12/3/48, 10.9; 3/8/49, 13.0; 11/9/49, 9.2.

16N/3E-4M1—Reference point—top of casing, elevation 79.2 feet, 50 feet east of Sinnard Road, 0.15 mile south of Archer Road. 12/23/47, 11.3; 3/1/48, 11.9; 12/3/48, 10.7; 3/21/49, 9.4; 11/9/49, 9.9.

16N/3E-4N1—Reference point—top of casing, elevation 76.9 feet, 100 feet south of Coleman Avenue, 0.05 mile west of Sinnard Road. 12/23/47, 9.9; 3/1/48, 10.8; 12/3/48, 9.2.

16N/3E-5A1—Reference point—top of casing, elevation 78.6 feet, 400 feet south of Pennington Road, 0.4 mile east of Larkin Road. 12/23/47, 10.7; 3/1/48, 11.0; 12/8/48, 10.5; 3/30/49, 9.0; 11/8/49, 10.1; 3/22/50, 8.1; 11/2/50, 11.1; 3/27/51, 8.3; 11/14/51, 10.6; 4/2/52, 7.5.

16N/3E-5P1—Reference point—hole in pump base, elevation 74.0 feet, 0.15 mile west of Larkin Road, 1.0 mile north of Paseo Road. 5/4/48, 8.9; 6/2/48, 8.7; 6/30/48, 49.9 (operating); 12/4/48, 11.5; 3/21/49, 5.4; 4/3/51, 7.7.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

16N 3E-6A1—Reference point—top of casing, elevation 77.9 feet. South side of Pennington Road, 0.8 mile east of Township Road. 12/22/47, 12.1; 3/1/48, 11.4; 5/13/48, 10.0; 12/8/48, 12.3; 1/21/49, 11.4; 3/30/49, 8.0; 11/8/49, 12.6; 3/22/50, 8.6; 11/2/50, 13.6; 3/27/51, 7.5; 11/13/51, 12.8; 4/2/52, 5.2.

16N 3E-7D2—Reference point—top of casing, elevation 73.5 feet, 0.1 mile east of Township Road, 0.65 mile north of Paseo Avenue. 12/23/47, 10.1; 3/1/48, 9.8; 12/8/48, 9.5; 3/21/49, 3.6; 11/9/49, 9.2; 3/22/50, 8.0; 11/3/50, 10.0; 4/3/51, 7.4; 11/14/51, 8.7; 4/2/52, 7.0.

16N 3E-8C1—Reference point—top of curb, elevation 74.1 feet, 0.2 mile west of Larkin Road, 0.75 mile north of Paseo Avenue. 12/23/47, 8.9; 3/1/48, 9.1; 12/4/48, 9.1; 3/21/49, 5.4; 11/9/49, 6.9; 3/22/50, 5.5; 11/3/50, 9.9; 4/3/51, 6.3; 11/14/51, 8.9; 4/2/52, 2.9.

16N 3E-8P1—Reference point—top of casing, elevation 72.0 feet, 200 feet north of Paseo Avenue, 0.15 mile west of Larkin Road. 12/23/47, 8.8; 3/1/48, 9.0; 12/4/48, 8.7; 3/21/49, 5.5; 11/9/49, 7.3.

16N 3E-8R1—Reference point—top of casing, elevation 71 feet, 160 feet north of Paseo Avenue, 400 feet east of U. S. Highway 99E. 1/10/41, 3.1; 11/5/47, 7.6; 12/5/47, 9.2; 12/13/48, 9.3; 11/9/49, 7.1; 3/22/50, 8.7; 11/10/50, 9.4; 4/2/51, 7.2; 11/26/51, 7.8.

16N 3E-8R2—Reference point—top of casing, elevation 71 feet, 100 feet north of Paseo Avenue, 300 feet east of U. S. Highway 99E. 1/23/29, 8.8; 9/27/30, 8.3; 12/16/31, 9.3; 12/9/32, 9.3; 12/13/33, 8.9; 11/21/34, 7.3; 1/24/36, 8.4; 12/1/37, 7.3; 1/26/39, 10.3.

16N 3E-9A1—Reference point—top of casing, elevation 72 feet, 1,500 feet north of Bishop Road, 100 feet east of Levee. 11/10/47, 14.9; 3/20/48, 17.1; 12/3/48, 16.0; 3/8/49, 17.4; 11/9/49, 13.7; 3/22/50, 10.0; 11/3/50, 13.8; 4/2/51, 11.0; 11/14/51, 14.5; 4/3/52, 11.7.

16N 3E-9M1—Reference point—top of casing, elevation 71 feet, 400 feet east of Simard Road, 0.3 mile north of Paseo Avenue. 3/20/48, 11.5; 12/3/48, 10.8; 3/8/49, 11.3; 11/9/49, 8.7; 3/22/50, 9.1; 11/3/50, 9.0; 4/2/51, 7.3; 11/14/51, 8.8; 4/3/52, 5.9.

16N 3E-9Q1—Reference point—top of casing, elevation 75 feet, 60 feet west of Kent Avenue, 150 feet north of Paseo Avenue. 11/10/47, 16.1; 3/20/48, 19.1; 5/13/48, 13.1; 12/3/48, 18.6; 3/8/49, 18.2; 11/8/49, 17.2.

16N 3E-11C1—Reference point—base of pump, elevation 79 feet, 0.50 mile west of State Highway 24 on Ramirez Road extension. 11/4/47, 21.2; 3/23/48, 18.9; 5/7/48, 16.6; 12/3/48, 19.9; 1/26/49, 19.4; 3/21/49, 19.0; 11/15/49, 22.1; 3/21/50, 18.1; 11/7/50, 22.6; 3/29/51, 14.4; 11/15/51, 20.8; 4/6/52, 10.6.

16N 3E-11E1—Reference point—top of casing, elevation 78 feet, 0.75 mile west of State Highway 24, 0.45 mile south of Ramirez Road. 11/5/47, 21.2; 3/23/48, 18.3; 12/3/48, 20.7; 3/21/49, 17.6; 11/15/49, 21.6.

16N 3E-11F1—Reference point—top of casing, elevation 77 feet, 0.50 mile west of State Highway 24, 0.35 mile south of Ramirez Road. 11/5/47, 20.6; 3/23/48, 18.6; 12/3/48, 19.1; 3/21/49, 17.0; 11/15/49, 21.1.

16N 3E-11F2—Reference point—base of pump, elevation 76 feet, 0.50 mile west of State Highway 24, 0.30 mile south of Ramirez Road. 11/5/47, 19.8; 3/23/48, 17.5; 12/3/48, 19.2; 3/21/49, 15.2; 11/15/49, 20.3.

16N 3E-11K1—Reference point—base of pump, elevation 76 feet, 0.20 mile west of State Highway 24, 0.70 mile south of Ramirez Road. 11/5/47, 19.8; 3/23/48, 20.6; 12/3/48, 18.0; 3/18/49, 16.5; 11/15/49, 19.4.

16N 3E-11L1—Reference point—top of casing, elevation 76 feet, 0.40 mile west of State Highway 24, 0.7 mile south of Ramirez Road. 11/5/47, 18.0; 3/23/48, 16.2; 12/3/48, 16.4; 3/18/49, 14.6; 11/15/49, 17.8.

16N 3E-11Q1—Reference point—top of casing, elevation 75 feet, 750 feet west of State Highway 24, 0.9 mile south of Ramirez Road. 11/5/47, 10.1; 12/3/48, 9.5; 3/18/49, 7.0; 11/15/49, 10.0.

16N 3E-12B1—Reference point—top of casing, elevation 79 feet, 20 feet south of Ramirez Road, 0.70 mile east of State Highway 24. 11/4/47, 16.4; 3/23/48, 14.5; 5/7/48, 13.1; 12/2/48, 14.5; 1/25/49, 14.2; 3/21/49, 13.0; 11/15/49, 16.7.

16N 3E-12B2—Reference point—top of casing, elevation 79 feet, 750 feet south of Ramirez Road, 0.75 mile east of State Highway 24. 11/4/47, 9.4; 3/23/48, 7.4; 12/2/48, 7.2; 3/21/49, 5.6; 11/15/49, 8.6.

16N/3E-12E1—Reference point—top of casing at bottom of pit, elevation 76 feet, 0.3 mile east of State Highway 24, 0.6 mile south of Ramirez Road. 11/5/47, 10.2; 3/23/48, 7.6; 12/6/48, 9.5; 3/18/49, 7.5; 11/15/49, 10.3; 3/21/50, 15.3; 11/7/50, 20.6*; 3/29/51, 11.9; 11/15/51, 18.2*; 4/6/52, 6.4*.

16N/3E-12L2—Reference point—top of casing, elevation 76 feet, 0.6 mile east of State Highway 24, 0.6 mile south of Ramirez Road. 11/7/47, 11.3; 3/23/48, 9.2; 12/6/48, 5.4; 3/18/49, 8.0; 11/15/49, 10.1.

16N/3E-13G1—Reference point—top of casing, elevation 72 feet, 2,600 feet north of Magnon Way, 4,300 feet east of State Highway 24. 11/7/47, 14.6; 3/25/48, 13.8; 12/10/48, 13.7; 11/16/49, 14.7; 3/21/50, 13.6; 11/7/50, 18.1; 3/29/51, 9.1; 4/6/52, 5.5.

16N/3E-14B1—Reference point—top of casing, elevation 75 feet, 500 feet west of State Highway 24, 1.2 miles south of Ramirez Road. 11/5/47, 9.2; 3/23/48, 8.1; 5/7/48, 5.8; 12/3/48, 7.8; 3/18/49, 6.1; 11/15/49, 9.3; 3/21/50, 10.0; 11/7/50, 10.3; 3/29/51, 1.7; 11/15/51, 7.9; 4/6/52, 3.7.

16N/3E-14C1—Reference point—top of casing, elevation 74 feet, 1.2 miles south of Ramirez Road, 0.4 mile west of State Highway 24. 11/5/47, 9.75; 3/25/48, 9.1; 12/3/48, 6.8; 3/18/48, 6.8; 11/15/49, 9.9.

16N/3E-14D1—Reference point—top of casing, elevation 72 feet, 1.2 miles south of Ramirez Road, 0.5 mile west of State Highway 24. 11/5/47, 9.9; 3/23/48, 10.7; 5/7/48, 5.8; 12/3/48, 8.9; 1/26/49, 7.9; 3/18/49, 7.0; 11/15/49, 10.2; 3/21/50, 13.9; 11/7/50, 11.2; 3/29/51, 9.4; 11/15/51, 15.8.

16N/3E-14J1—Reference point—hole in front of base of pump, elevation 71 feet, 600 feet north of Magnolia Way, 950 feet east of State Highway 24. 11/8/47, 16.1; 3/25/48, 14.8; 12/3/48, 15.3; 3/18/49, 13.1; 11/16/49, 16.5.

16N/3E-14L1—Reference point—top of casing at bottom of 12-foot pit, elevation 59 feet, 0.5 mile west of State Highway 24, 1.5 miles south of Ramirez Road. 11/8/47, 6.7; 3/25/48, 5.1; 12/3/48, 5.3; 3/18/49, 5.1; 11/16/49, 7.3; 3/21/50, 3.2; 11/7/50, 7.8; 3/29/51, 12.0*; 11/15/51, 18.8*; 4/6/52, 6.0.

16N/3E-16M1—Reference point—top of concrete block, elevation 70 feet, 900 feet south of Cutting Avenue, 300 feet east of U. S. Highway 99E. 11/10/47, 7.65; 3/20/48, 11.7; 12/3/48, 8.9.

16N/3E-17C1—Reference point—top of flange under pump, elevation 72.4 feet, 400 feet east of Larkin Road, 0.8 mile north of Clark Road. 12/23/47, 8.7; 3/1/48, 8.8; 12/4/48, 7.7, 3/21/49, 6.5; 11/9/49, 7.8; 3/22/50, 7.6; 11/3/50, 8.9; 4/3/51, 7.5; 11/14/51, 8.2; 4/2/52, 6.9.

16N/3E-17Q1—Reference point—top of concrete pit, elevation 70.5 feet, 0.2 mile east of Larkin Road, 500 feet north of Clark Road. 12/23/47, 9.3; 3/2/48, 10.1; 5/4/48, 8.0; 6/1/48, 7.0; 12/1/48, 9.4; 1/20/49, 9.8; 3/21/49, 7.5; 5/26/49, 7.0; 6/30/49, 5.6; 7/31/49, 6.2; 8/31/49, 6.5; 11/10/49, 8.7; 3/22/50, 8.9; 11/3/50, 8.8; 4/3/51, 6.8; 11/14/51, 7.9; 4/3/52, 5.4.

* Top of pit.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

16N/3E-18C1—Reference point—top of casing, elevation 68.3 feet, 100 feet south of Pasco Avenue, 100 feet west of Broadway. 12/23/47, 6.4; 3/1/48, 6.3; 12/4/48, 8.3; 1/20/49, 6.2; 3/21/49, 4.1.

16N/3E-19C1—Reference point—top of casing, elevation 66.8 feet, 250 feet west of Broadway, 0.1 mile south of Clark Road. 12/23/47, 7.1; 3/2/48, 7.2; 12/4/48, 6.8; 3/21/49, 4.7; 11/10/49, 5.5; 3/22/50, 8.6; 11/3/50, 6.3; 4/3/51, 6.4; 11/14/51, 6.7; 4/2/52, 5.7.

16N/3E-20E1—Reference point—slot in concrete base, elevation 69.8 feet, 200 feet west of Marden Avenue, 0.2 mile south of Clark Road. 12/23/47, 10.4; 3/24/48, 11.3; 12/4/48, 10.2; 3/21/49, 8.1; 5/26/49, 7.5; 6/28/49, 7.8; 7/27/49, 9.3; 8/25/49, 8.7; 11/10/49, 9.7; 3/22/50, 10.0; 11/3/50, 9.3; 4/3/51, 9.6; 11/14/51, 10.3; 4/2/52, 9.2.

16N/3E-21D1—Reference point—hole in base of pump, elevation 70 feet, 200 feet south of Clark Road, 0.6 mile east of Larkin Road. 12/23/47, 10.7; 3/2/48, 11.4; 12/3/48, 10.3; 11/8/49, 10.3; 3/22/50, 9.6; 11/3/50, 10.3; 4/3/51, 6.4; 11/4/51, 9.2; 4/3/52, 4.0.

16N/3E-21J1—Reference point—top of casing, elevation 68.0 feet, 0.4 mile east of U. S. Highway 99E, 0.3 mile north of Encinal Road. 11/10/47, 17.9; 3/20/48, 16.4; 5/13/48, 13.3; 12/3/48, 17.5; 1/21/49, 17.0; 3/8/49, 16.8; 11/10/49, 18.6; 3/22/50, 17.2; 4/3/51, 10.5; 11/14/51, 16.5; 4/3/52, 5.2.

16N/3E-21P2—Reference point—top of casing, elevation 65.9 feet, West side of Southern Pacific Railroad Right of Way, 0.1 mile north of Encinal Road. 12/23/47, 14.5; 3/2/48, 15.3; 12/3/48, 14.1; 3/21/49, 13.0; 11/10/49, 15.3.

16N/3E-23C1—Reference point—top of casing, elevation 71 feet, 0.25 mile west of State Highway 24 at a point 0.4 mile south of Magnolia Way intersection. 11/8/47, 17.2; 3/25/48, 15.9; 5/19/48, 13.9; 12/2/48, 15.9; 1/26/49, 15.5; 3/8/49, 13.0.

16N/3E-23J1—Reference point—top of casing, elevation 70 feet, 0.1 mile east of State Highway 24, 0.3 mile north of Woodruff Lane. 11/8/47, 14.3; 3/25/48, 13.1; 5/19/48, 11.9; 12/2/48, 14.6; 3/18/49, 13.0; 11/16/49, 15.1.

16N/3E-23R3—Reference point—center of pump shaft, elevation 70 feet, 200 feet north of Woodruff Lane, 0.3 mile east of State Highway 24. 11/8/47, 14.0; 3/25/48, 13.0; 12/2/48, 13.0; 3/18/49, 11.5; 11/16/49, 13.9.

16N/3E-24A1—Reference point—top of casing, elevation 70 feet, 0.2 mile south of Magnolia Way extended 1.1 miles east of State Highway 24. 11/7/47, 13.8; 3/25/48, 13.5; 12/2/48, 13.7; 1/26/49, 14.4; 3/18/49, 11.1; 11/16/49, 14.5; 3/21/50, 12.1; 11/6/50, 15.8; 3/29/51, 9.4; 11/15/51, 15.1; 4/6/52, 6.0.

16N/3E-24C1—Reference point—top of casing, elevation 70 feet, 0.4 mile south of Magnolia Way, 0.75 mile east of State Highway 24. 11/7/47, 12.3; 3/25/48, 11.7; 12/10/48, 12.1; 3/18/49, 9.8; 11/16/49, 13.2.

16N/3E-24Q1—Reference point—top of casing in pit, elevation 66 feet, North of Woodruff Lane, 1.05 miles east of State Highway 24. 11/7/47, 4.2; 3/25/48, 4.2; 5/19/48, 2.9; 11/30/48, 4.6; 11/16/49, 11.8; 3/21/50, 8.8; 11/6/50, 12.8; 3/29/51, 6.9; 11/15/51, 17.3; 9/6/52, 5.0.

16N/3E-24R2—Reference point—hole in pump base, elevation 69 feet, 0.1 mile north of Woodruff Lane, 0.1 mile east of State Highway 24. 6/2/48, 11.8; 7/1/48, 15.2; 7/21/48, 15.5; 8/1/48, 18.1; 9/2/48, 17.3.

16N/3E-26F1—Reference point—hole in pump base, elevation 69 feet, 0.45 mile west of State Highway 24, at a point 0.3 mile south of Woodruff Lane intersection. 11/15/47, 18.0; 5/3/48, 12.3; 6/1/48, 13.2; 11/30/48, 18.2; 12/13/48, 18.1; 1/26/49, 15.5; 3/18/49, 14.1; 12/9/49, 18.7; 3/21/50, 14.0; 11/6/50, 17.8; 11/10/50, 18.6; 3/29/51, 10.1; 11/15/51, 17.4; 12/7/51, 14.7; 4/6/52, 5.9.

16N/3E-26F2—Reference point—top of concrete pit, elevation 68 feet, 0.5 mile west of State Highway 24, at a point 0.3 mile south of Woodruff Lane intersection. 11/26/29, 15.9; 9/25/30, 15.6; 12/16/31, 16.7; 12/6/32, 16.8; 12/14/33, 16.5; 11/23/34, 16.9; 11/24/36, 15.8; well destroyed.

16N/3E-26G1—Reference point—hole in pump base, elevation 68 feet, 0.25 mile west of State Highway 24 at a point 0.3 mile south of Woodruff Lane intersection. 5/7/48, 12.2; 6/30/48, 52.6 (operating); 11/30/48, 13.6.

16N/3E-26G2—Reference point—top of casing, elevation 68 feet, 0.15 mile west of State Highway 24, at a point 0.3 mile south of Woodruff Lane intersection. 12/1/37, 11.0; 1/27/39, 9.4; 1/10/41, 6.5.

16N/3E-27E1—Reference point—top of casing, elevation 66 feet, 0.1 mile north of Morse Road, 0.4 mile east of U. S. Highway 99E. 3/17/48, 21.9; 11/29/48, 23.7; 3/17/49, 20.0; 5/26/49, 20.5; 6/28/49, 24.5; 7/27/49, 25.1; 8/25/49, 26.2; 11/14/49, 25.2.

16N/3E-28C1—Reference point—top of concrete pit, elevation 65 feet, 0.05 mile south of Encinal Road, 0.1 mile west of U. S. Highway 99E. 3/17/48, 14.2; 11/29/48, 14.6; 3/17/49, 13.7; 11/14/49, 15.5.

16N/3E-28E1—Reference point—top of casing, elevation 65 feet, 0.25 mile south of Encinal Avenue, 0.35 mile west of U. S. Highway 99E. 11/4/47, 17.5.

16N/3E-28N1—Reference point—top of casing, elevation 64.6 feet, 200 feet north of Sanders Road, 0.6 mile east of Larkin Road. 12/19/47, 17.2; 11/29/48, 17.5; 3/17/49, 15.8; 11/10/49, 18.6; 3/22/50, 15.9; 11/3/50, 18.9; 4/3/51, 11.2; 11/14/51, 16.6; 4/3/52, 7.6.

16N/3E-29B1—Reference point—top of concrete pit, elevation 66.8 feet, South side of Encinal Road, 0.2 mile east of Larkin Road. 12/23/47, 12.8; 3/2/48, 13.6; 5/13/48, 11.5; 12/4/48, 13.0; 1/19/49, 13.0.

16N/3E-29N1—Reference point—top of concrete pit, elevation 65.8 feet, 0.25 mile west of Sacramento Northern Railroad tracks, 0.25 mile north of Sanders Road. 12/19/47, 15.3; 3/2/48, 15.2; 12/1/48, 14.3; 3/16/49, 14.0; 1/10/49, 14.7; 3/22/50, 13.2; 11/3/50, 14.5; 4/3/51, 9.6; 11/14/51, 12.4; 4/3/52, 7.3.

16N/3E-29R1—Reference point—hole in pump base, elevation 62 feet, 150 feet north of Sanders Road, 0.4 mile east of Larkin Road. 5/4/48, 17.3; 6/1/48, 16.1; 11/29/48, 19.6.

16N/3E-30A2—Reference point—top of casing, elevation 68.8 feet, 0.1 mile south of Encinal Road, 0.35 mile east of Broadway. 12/23/47, 12.1; 3/2/48, 12.8; 12/4/48, 11.9; 3/21/49, 11.4; 11/10/49, 11.0.

16N/3E-30F1—Reference point—top of pit wall, elevation 64.3 feet, 0.1 mile west of Broadway, 0.45 mile south of Encinal Road. 12/23/47, 11.1; 3/2/48, 11.6; 12/4/48, 10.8; 1/19/49, 10.7; 3/21/49, 9.0; 11/10/49, 10.5; 3/22/50, 10.1; 11/3/50, 10.7; 4/3/51, 9.2; 11/14/51, 10.8; 4/3/52, 6.7.

16N/3E-30L1—Reference point—top of casing next to pump, elevation 62.5 feet, 0.4 mile north of Sanders Road, 400 feet west of Broadway. 12/19/47, 8.9; 3/2/48, 9.5; 12/1/48, 8.7; 3/16/49, 8.8; 11/10/49, 7.8.

16N/3E-30R1—Reference point—top of casing next to pump, elevation 62.5 feet, 500 feet north of Sanders Road, 0.5 mile west of Sacramento Northern Railroad. 12/19/47, 12.9; 3/2/48, 12.6.

16N/3E-31D1—Reference point—top of casing under pump, elevation 60.4 feet, 500 feet south of Sanders Road, 0.2 mile west of Broadway Road. 12/19/47, 9.1; 3/3/48, 9.7; 3/16/49, 9.5.

16N/3E-31K2—Reference point—top of tin cover under pump, elevation 63.2 feet, 0.2 mile east of Broadway Road, 0.5 mile south of Sanders Road. 12/19/47, 13.7; 3/3/48, 14.1; 12/1/48, 17.3; 3/16/49, 16.4; 11/11/49, 18.3; 3/22/50, 15.2; 11/6/50, 19.3; 4/3/51, 12.1; 11/14/51, 16.6; 4/3/52, 17.0.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

16N 3E-32A2—Reference point—pump base hole, elevation 64.9 feet, 200 feet south of Sanders Road, 0.6 mile east of Sacramento Northern Railroad. 1/6/48, 19.5; 3/2/48, 19.7; 11/29/48, 21.0; 3/17/49, 17.0; 11/10/49, 19.8.

16N 3E-32B2—Reference point—top of 2" x 14" bridge over earth pit, elevation 64.4 feet, 200 feet south of Sanders Road, 0.3 mile east of Sacramento Northern Railroad. 12/19/47, 15.9; 3/2/48, 17.25; 12/1/48, 16.2; 3/17/49, 15.0; 11/10/49, 17.7.

16N 3E-32C2—Reference point—top of casing under pump, elevation 64.4 feet, 0.2 mile south of Sanders Road, 200 feet west of Sacramento Northern Railroad. 12/19/47, 18.1; 3/2/48, 18.7; 12/1/48, 16.9; 3/17/49, 16.1; 11/11/49, 18.5; 3/22/50, 15.9; 11/3/50, 18.2; 4/3/51, 11.3; 11/14/51, 16.1; 4/3/52, 6.4.

16N 3E-32G2—Reference point—hole in pump base, elevation 62.8 feet, 0.5 mile south of Sanders Road, 0.3 mile east of Sacramento Northern Railroad. 12/19/47, 18.9; 3/2/48, 20.2; 12/1/48, 16.9; 3/17/49, 16.8; 11/11/49, 19.8.

16N 3E-33D1—Reference point—top of concrete base, elevation 61.2 feet, 100 feet south of Sanders Road at a point 0.55 mile west of U. S. Highway 99E. 11/4/47, 17.2; 11/29/48, 19.2; 1/20/49, 17.2; 3/17/49, 16.8; 5/26/49, 17.1; 6/28/49, 19.3; 7/27/49, 26.15; 8/25/49, 25.9; 11/14/49, 20.0.

16N 3E-33E1—Reference point—top of concrete base under pump, elevation 64.1 feet, 0.3 mile south of Sanders Road at a point 0.8 mile west of U. S. Highway 99E. 11/4/47, 17.6; 3/17/48, 21.3; 5/13/48, 15.6; 11/29/48, 17.3; 11/14/49, 18.7; 3/22/50, 16.0; 11/6/50, 19.1; 4/3/51, 11.6; 4/3/52, 7.6.

16N 3E-33J2—Reference point—edge of pump base, elevation 66 feet, 150 feet west of U. S. Highway 99E at a point 0.45 mile north of Eager Road. 5/12/48, 20.3; 11/29/48, 27.0; 1/20/49, 23.0; 3/17/49, 22.0; 11/14/49, 27.3; 3/22/50, 22.0; 11/6/50, 25.4; 4/3/51, 17.2.

16N 3E-33P1—Reference point—hole beneath pump base, elevation 61.9 feet, 250 feet north of Eager Road at a point 0.6 mile west of U. S. Highway 99E. 1/9/48, 22.9; 11/22/48, 22.6; 3/17/49, 22.5; 11/14/49, 25.5.

16N 3E-35G1—Reference point—top of volute plug, elevation 67 feet, 400 feet north of Ellis Road at a point 0.5 mile west of State Highway 24. 11/6/47, 17.1; 1/26/49, 14.7; 3/18/49, 18.0; 11/16/49, 22.3.

16N 3E-35J1—Reference point—top of casing, elevation 70 feet, 100 feet south of Ellis Road at a point 0.2 mile west of State Highway 24. 11/6/47, 18.7; 3/29/48, 17.7; 11/30/48, 19.0; 3/17/49, 17.0; 11/16/49, 20.2.

16N 3E-35L1—Reference point—top of air gage hole, elevation 65 feet, 0.2 mile south of Ellis Road at a point 0.7 mile west of State Highway 24. 11/6/47, 20.2; 3/20/48, 20.1; 11/30/48, 20.9; 3/17/49, 20.1; 11/16/49, 22.9; 3/21/50, 17.4; 11/6/50, 22.9; 3/29/51, 19.5; 11/15/51, 23.5; 4/6/52, 10.1.

16N 3E-36G1—Reference point—top of concrete base under pump, elevation 64 feet, 300 feet north of Bills Road at a point 0.5 mile east of State Highway 24. 11/5/47, 11.7; 3/29/48, 11.4; 5/7/48, 10.0; 11/30/48, 12.2; 3/18/49, 9.6; 11/16/49, 12.1; 3/21/50, 11.1; 11/6/50, 12.7; 3/29/51, 6.7; 11/15/51, 11.8; 4/6/52, 4.6.

16N 4E-4L1—Reference point—top of concrete cribbing, elevation 96 feet, 0.15 mile west of La Porte Road, 0.30 mile north of Ramirez Road. 11/19/47, 22.4; 3/15/48, 22.8; 12/1/48, 23.1; 3/23/49, 24.0; 3/22/50, 24.9; 10/31/50, 26.7; 3/28/51, 23.5.

16N 4E-4N1—Reference point—top of casing, elevation 94 feet, 10.0 feet north of Ramirez Road, 0.05 mile east of Loma Rica Road. 3/15/48, 10.8.

16N 4E-5G1—Reference point—top of concrete cribbing, elevation 91 feet, 0.15 mile north of Ramirez Road, 0.5 mile west of Loma Rica Road. 11/19/47, 19.4; 3/15/48, 19.4; 12/1/48, 20.9; 3/23/49, 18.0; 12/9/49, 22.5; 3/22/50, 20.6; 10/31/50, 24.9; 3/28/51, 19.2; 11/14/51, 23.4; 4/6/52, 23.4.

16N 4E-6H1—Reference point—base of pump, elevation 85 feet, 0.50 mile north of Ramirez Road, 1.0 mile west of Loma Rica Road. 11/4/47, 17.8; 11/18/47, 17.2; 3/15/48, 17.6; 3/23/48, 17.4; 12/1/48, 18.1; 12/2/48, 19.0; 1/26/49, 17.1; 3/21/49, 16.2; 11/15/49, 20.7; 3/22/50, 17.6; 3/29/51, 16.7.

16N 4E-6J1—Reference point—top of casing, elevation 86 feet, 0.25 mile north of Ramirez Road, 1.0 mile west of Loma Rica Road. 11/4/47, 19.4; 11/19/47, 19.2; 3/15/48, 19.2; 3/23/48, 19.2; 12/1/48, 19.4; 12/2/48, 20.0; 3/21/49, 18.1; 11/15/49, 22.6; 3/21/50, 20.0; 3/22/50, 20.0; 11/7/50, 23.8; 11/15/51, 22.7; 4/6/52, 16.5.

16N 4E-6N1—Reference point—top of casing, elevation 80 feet, 30 feet north of Ramirez Road, 1.1 miles east of State Highway 24. 11/4/47, 16.9; 3/23/48, 15.5; well destroyed.

16N 4E-7B1—Reference point—top of casing, elevation 82 feet, 200 feet south of Ramirez Road, 1.5 miles west of Loma Rica Road. 11/4/47, 16.6; 3/23/48, 15.5; 12/2/48, 17.0; 3/21/49, 16.1; 11/15/49, 18.6.

16N 4E-8A1—Reference point—hole in pump base, elevation 91 feet, 150 feet south of Ramirez Road, 0.15 mile west of Loma Rica Road. 11/19/47, 18.8; 3/15/48, 20.0; 5/7/48, 17.5; 3/23/49, 17.8; 6/7/49, 40.5; 7/3/49, 37.3; 8/2/49, 37.6; 11/15/49, 22.0; 3/22/50, 19.8; 10/31/51, 18.9; 11/14/51, 23.0; 11/27/51, 22.6; 4/6/52, 18.0.

16N 4E-8A2—Reference point—top of casing, elevation 94 feet. South side of Ramirez Road, 0.15 mile west of Loma Rica Road. 11/26/29, 18.4; 9/25/30, 17.6; 12/14/31, 19.5; 12/6/32, 19.2; 12/14/33, 19.6; 11/23/34, 19.8; 11/24/36, 18.1; 11/23/37, 17.8; 11/27/39, 15.7; 1/9/41, 16.8; 11/5/47, 18.1; 12/13/48, 21.0; 12/9/49, 22.1; 11/10/50, 23.6.

16N 4E-9J1—Reference point—top of casing, elevation 95 feet, 200 feet west of Bangor Road, 0.6 mile south of Ramirez Road. 11/19/47, 23.2; 3/15/48, 23.4; 12/1/48, 24.0; 3/23/49, 21.8; 11/15/49, 26.6.

16N 4E-10E1—Reference point—top of casing at bottom of pit, elevation 80 feet, 400 feet east of Bangor Road, 0.35 mile south of Ramirez Road. 3/15/48, 2.4; 12/1/48, 3.4; 3/23/49, 2.6.

16N 4E-16A1—Reference point—hole in 4" x 4" board support, elevation 90 feet, 0.1 mile east of Bangor Road, 1.1 mile south of Ramirez Road. 11/19/47, 19.8; 3/15/48, 20.5; 5/7/48, 19.6; 12/1/48, 20.0; 3/23/49, 20.0; 11/17/49, 23.6; 3/23/50, 21.9; 10/31/50, 25.3; 3/28/51, 21.4; 11/14/51, 24.7; 4/6/52, 20.6.

16N 4E-16E1—Reference point—hole in pump base, elevation 81 feet, 100 feet east of Loma Rica Road, 1.25 miles south of Ramirez Road. 11/19/47, 13.0; 3/15/48, 9.3; 12/1/48, 13.6; 3/23/49, 11.8; 11/17/49, 16.5; 3/23/50, 14.5; 3/28/51, 13.1; 11/14/51, 14.6; 4/6/52, 10.8.

16N 4E-21M1—Reference point—top of casing, elevation 75 feet, 0.1 mile east of Loma Rica Road, 0.15 mile south of Bangor Road. 11/19/47, 5.6; 3/15/48, 6.5; 12/1/48, 6.2; 3/23/49, 4.0.

16N 4E-25M1—Reference point—top of concrete floor at bottom of pit, elevation 89 feet, 0.1 mile south of State Highway 20, 1.50 miles east of Loma Rica Road. 11/26/47, 2.8; 3/3/48, 5.0.

16N 4E-26F1—Reference point—top of casing, elevation 91 feet, 0.20 mile north of State Highway 20, 0.85 mile east of Loma Rica Road. 11/26/47, 16.5; 3/3/48, 17.4; 11/29/48, 16.9; 3/23/49, 17.2; 11/18/49, 17.8.

16N 4E-27F1—Reference point—bottom of 90° elbow on suction pipe, elevation 93.6 feet, 600 feet north of Woodruff Lane, 0.20 mile west of Loma Rica Road. 11/26/47, 7.3; 11/18/49, 8.4.

16N 4E-27M1—Reference point—top of casing, elevation 89 feet, 150 feet south of Woodruff Lane, 0.2 mile west of State Highway 20. 12/6/32, 6.4; 12/14/33, 6.9; 11/23/34, 6.9; 11/28/36, 5.6; 11/23/37, 11.6 (operating); 1/9/41, 2.7.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

16N/4E-27N1—Reference point—top of casing, elevation 89.9 feet, 500 feet north of State Highway 20, 0.30 mile south of Woodruff Lane. 11/27/29, 10.9; 9/25/30, 8.3; 12/14/31, 11.3; 1/9/41, 4.8; 11/5/47, 7.5; 11/26/47, 4.9; 3/3/48, 13.7; 11/29/48, 11.2; 12/13/48, 12.0; 3/23/49, 11.0; 11/18/49, 10.2; 12/9/49, 11.7; 3/23/50, 12.5; 10/31/50, 8.8; 3/30/51, 10.7; 11/14/51, 10.5; 11/27/51, 11.8; 4/6/52, 8.2.

16N/4E-28B1—Reference point—top of casing, elevation 89.4 feet, 0.25 mile north of Woodruff Lane, 0.60 mile east of Kimball Lane. 11/26/47, 13.3; 3/3/48, 16.1; 11/29/48, 13.7; 3/23/49, 12.2; 11/18/49, 12.8.

16N/4E-28E1—Reference point—top of 90° elbow, elevation 80.9 feet, 0.20 mile north of Woodruff Lane, 0.15 mile east of Kimball Lane. 11/26/47, 9.7; 3/3/48, 10.8; 11/29/48, 10.2; 3/23/49, 7.0; 11/18/49, 9.5; 3/23/50, 10.0; 10/31/50, 8.2; 3/30/51, 9.7; 11/14/51, 9.1; 4/6/52, 7.9.

16N/4E-29B1—Reference point—top of casing, elevation 78.1 feet, 500 feet west of Mathews Lane, 0.35 mile north of Woodruff Lane. 11/26/47, 8.7; 3/3/48, 9.6; 5/7/48, 8.1; 11/29/48, 9.3; 3/23/49, 7.2; 11/17/49, 9.5; 10/31/50, 9.0.

16N/4E-33B1—Reference point—top of casing, elevation 83 feet, 200 feet north of West Hallwood Road, 0.6 mile west of State Highway 20. 11/26/47, 7.7; 3/3/48, 10.6; 11/30/48, 8.5; 3/23/49, 13.0; 11/15/49, 7.9.

16N/4E-33J1—Reference point—top of casing, elevation 88.7 feet, 200 feet east of State Highway 20, 0.45 mile south of West Hallwood Road. 11/26/47, 11.8; 3/3/48, 14.9; 3/23/49, 13.0; 11/18/49, 11.8.

16N/4E-33K1—Reference point—top of casing, elevation 84.0 feet, 200 feet northwest of State Highway 20, 0.70 mile south of West Hallwood Road. 11/26/47, 9.2; 3/8/48, 12.1; 11/30/48, 10.5; 3/23/49, 9.7; 11/18/49, 9.7.

16N/4E-33N1—Reference point—top of casing cap, elevation 80.1 feet, 200 feet northwest of State Highway 20, 1.3 miles south of West Hallwood Road. 11/26/47, 8.3; 3/4/48, 11.5; 11/30/48, 10.6; 3/23/49, 9.2; 11/18/49, 10.0; 3/23/50, 10.2; 10/31/50, 9.3; 3/30/51, 9.1; 11/14/51, 10.0; 4/5/52, 7.4.

16N/4E-34B1—Reference point—top of casing, elevation 96.8 feet, 100 feet north of West Hallwood Road, 200 feet east of levee. 11/25/47, 14.4; 3/3/48, 20.5; 11/29/48, 19.5; 3/22/49, 15.8; 11/18/49, 14.6.

16N/4E-34D1—Reference point—top of casing, elevation 91.9 feet, 600 feet west of State Highway 20, 0.20 mile north of West Hallwood Road. 11/26/47, 12.7; 3/3/48, 16.1; 11/30/48, 13.8; 3/23/49, 13.5; 11/18/49, 13.0.

16N/4E-34L1—Reference point—top of casing 2.5 feet above ground, elevation 98.5 feet, 0.4 mile north of Walnut Road, 200 feet west of Hallwood Road. 10/25/47, 17.5; 3/3/48, 21.7; 11/29/48, 18.7; 3/22/49, 19.9; 11/18/49, 18.3.

16N/4E-34Q1—Reference point—top of casing under pump, elevation 95.3 feet, 400 feet north of Walnut Road, 400 feet east of Hallwood Road. 11/25/47, 16.7; 3/3/48, 21.1; 11/29/48, 17.7; 3/22/49, 19.3; 11/18/49, 16.7; 3/23/50, 19.7; 10/31/50, 16.6; 3/30/51, 17.6; 11/14/51, 17.1; 4/6/52, 15.1.

16N/4E-35M1—Reference point—top of casing under pump, elevation 101.1 feet, 0.6 mile east of Hallwood Road, 0.5 mile north of Walnut Road. 11/25/47, 15.3; 3/3/48, 17.9; 4/1/48, 18.1; 3/23/49, 16.8; 11/18/49, 16.6.

17N/1E-25J1—Reference point—hole in base of pump, elevation 77 feet, 100 feet south of North Butte Road, 0.4 mile west of 90° turn (NW.) in North Butte Road. 3/25/48, 18.9; 12/3/48, 19.7; 3/30/49, 16.7; 11/15/49, 22.0; 3/24/50, 16.6; 11/2/50, 21.6; 3/27/51, 21.2; 11/13/51, 23.8.

17N/2E-22R1—Reference point—top of casing, elevation 79.5 feet, 0.07 mile northwest of intersection of Krehe and Lucerne Roads. 12/22/47, 7.7; 3/2/48, 8.3; 11/15/49, 7.4.

17N/2E-24N1—Reference point—top of casing, elevation 81.1 feet, 100 feet north of Lucerne Road, 0.95 mile west of Township Road. 12/22/47, 7.4; 3/1/48, 8.2; 12/8/48, 8.0; 1/21/49, 7.5; 3/30/49, 4.5; 11/8/49, 6.5.

17N/2E-29M1—Reference point—hole in pump base, elevation 79.6 feet, 0.1 mile east of Crane Road, 0.3 mile north of Bigelow Road. 12/22/47, 14.6; 12/3/48, 16.1; 3/30/49, 12.6; 11/15/49, 16.1; 3/24/50, 13.5; 3/27/51, 12.6.

17N/2E-29Q1—Reference point—top of casing, elevation 77.9 feet, 0.1 mile, east-northeast of 90° turn in Bigelow Road, at a point 0.5 mile east of Crane Road. 12/23/47, 13.9; 3/2/48, 15.1; 12/3/48, 15.5; 3/30/49, 12.0; 11/15/49, 14.3.

17N/2E-30N1—Reference point—top of casing, elevation 83 feet, 0.15 mile south of Pennington Road at a point 0.1 mile west of Pennington School. 3/25/48, 22.9; 12/3/48, 24.1; 3/30/49, 21.3; 11/15/49, 25.2.

17N/2E-31A1—Reference point—top of casing, elevation 85 feet, 100 feet north of Pennington Road at a point 0.1 mile west of Bigelow and Pennington Roads intersection. 3/25/48, 23.5; 12/3/48, 24.7; 3/30/49, 22.8; 11/15/49, 25.5; 3/24/50, 23.0; 11/2/50, 26.7; 3/27/51, 21.8; 11/13/51, 28.3; 4/2/52, 20.2.

17N/2E-33J1—Reference point—top of casing, elevation 71.3 feet, 0.35 mile north of Pennington Road, 1.05 miles west of Krehe Road. 12/23/47, 6.4; 3/2/48, 6.5; 12/13/48, 6.2; 3/30/49, 4.0; 11/15/49, 3.7.

17N/2E-34A1—Reference point—top of casing, elevation 74.6 feet, East side of Krehe Road, 0.9 mile north of Pennington Road. 12/22/47, 6.8; 3/1/48, 7.2; 12/8/48, 6.8; 1/21/49, 6.6; 3/30/49, 5.0; 11/8/49, 4.2; 3/21/50, 6.7; 11/2/50, 4.9; 3/27/51, 12.7 (operating); 11/13/51, 6.2; 4/2/52, 5.8.

17N/2E-34Q1—Reference point—top of outer casing, elevation 71.8 feet, North side of Pennington Road, 0.5 mile west of Krehe Road. 12/22/47, 6.4; 3/2/48, 7.1; 12/3/48, 7.0; 3/30/49, 5.0; 11/15/49, 5.7; 3/24/50, 5.5; 11/2/50, 5.5; 3/27/51, 6.6; 11/13/51, 6.1; 4/2/52, 5.4.

17N/2E-35A1—Reference point—top of casing, elevation 75.2 feet, 50 feet west of Schroeder Road, 0.95 mile north of Pennington Road. 12/22/47, 4.7; 3/1/48, 5.7; 12/8/48, 5.5; 3/30/49, 4.0; 5/26/49, 3.8; 6/28/49, 4.2; 7/27/49, 3.4; 8/25/49, 3.5; 11/8/49, 4.4; 3/21/50, 6.0; 11/2/50, 5.9; 3/27/51, 5.0; 11/13/51, 6.2; 4/2/52, 5.5.

17N/2E-36H1—Reference point—top of casing, elevation 76 feet, 300 feet west of Township Road, 0.6 mile north of Pennington Road. 3/26/48, 7.0; 12/8/48, 7.9.

17N/3E-22R1—Reference point—top of casing, elevation 86 feet, 0.25 mile north of Laurel Road at a point 0.48 mile west of intersection with Thame Road. 10/29/47, 23.3; 3/22/48, 26.0; 12/10/48, 21.9; 3/8/49, 21.2; 11/14/49, 23.3; 3/21/50, 22.2; 11/7/50, 23.4; 3/28/51, 16.8; 11/15/51, 22.1; 4/6/52, 13.6.

17N/3E-23P1—Reference point—hole in concrete base, elevation 87 feet, 0.37 mile north of Laurel Road, due north of intersection with Thame Road. 10/29/47, 22.7; 12/10/48, 20.5; 3/8/49, 20.0; 11/14/49, 22.9.

17N/3E-25G1—Reference point—hole in base of pump, elevation 85 feet, 2.57 miles north of Ramirez Road, 0.53 mile east of State Highway 24. 10/29/47, 22.9; 3/22/48, 19.1; 12/10/48, 19.4; 3/8/49, 18.8; 11/14/49, 21.6; 3/21/50, 18.1; 11/7/50, 21.7; 3/28/51, 46.0 (operating); 11/15/51, 23.4; 4/6/52, 9.3.

17N/3E-25M1—Reference point—hole in base of pump, elevation 80 feet, 2.27 miles north of Ramirez Road, 0.15 mile east of State Highway 24. 10/29/47, 22.6; 3/22/48, 19.8; 12/10/48, 20.8.

17N/3E-25N1—Reference point—hole in base of pump, elevation 84 feet, 1.97 miles north of Ramirez Road, 0.24 mile east of State Highway 24. 3/22/48, 20.7; 12/10/48, 19.3; 3/8/49, 18.0; 11/14/49, 21.8.

TABLE 1—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Division of Water Resources
(Depths to water in feet measured from reference point)

17N/3E-25Q1—Reference point—hole in base of pump, elevation 84 feet, 2.27 miles north of Ramirez Road, 0.75 mile east of State Highway 24. 10/31/47, 18.7; 3/22/48, 18.7; 12/10/48, 17.7; 3/8/49, 15.3; 11/14/49, 20.2.

17N/3E-26A2—Reference point—hole in base of pump, elevation 85 feet, 0.04 mile south of Laurel Road, 0.10 mile west of State Highway 24. 10/28/47, 22.8; 3/28/48, 21.9; 12/10/48, 21.1; 1/26/49, 20.5; 3/8/49, 20.1; 11/14/49, 23.7; 3/21/50, 21.1; 11/7/50, 22.8; 3/28/51, 14.6; 11/15/51, 27.6; 4/6/52, 11.1.

17N/3E-26B1—Reference point—flange of suction line, elevation 87 feet, 0.07 mile north of Laurel Road, 0.28 mile west of State Highway 24. 10/29/47, 15.5; 3/22/48, 11.9; 5/7/48, 9.7; 12/10/48, 13.5; 3/8/49, 12.5; 11/14/49, 15.5.

17N/3E-26H1—Reference point—hole in base of pump, elevation 85 feet, 0.25 mile south of Laurel Road, 0.22 mile west of State Highway 24. 10/29/47, 24.1; 12/10/48, 22.6; 11/14/49, 23.7.

17N/3E-26R1—Reference point—hole in base of pump, elevation 84 feet, 0.10 mile west of State Highway 24, 0.65 mile south of Laurel Road. 10/29/47, 20.0; 3/22/48, 20.8; 12/10/48, 18.8; 3/8/49, 18.0; 11/14/49, 21.0.

17N/3E-28P1—Reference point—top of flange on suction pipe, elevation 82 feet, 0.18 mile east of Cooley Road, 1.10 miles north of intersection of Meteer Road. 10/31/47, 5.8; 3/20/48, 7.4; 5/30/48, 4.7; 12/8/48, 4.9; 3/8/49, 7.0; 11/8/49, 5.5; 3/22/50, 5.1; 11/3/50, 7.0; 3/27/51, 3.1; 11/14/51, 6.5; 4/3/52, 2.2.

17N/3E-29C1—Reference point—top of casing, elevation 82.4 feet, 0.21 mile west of Larkin Road, 0.04 mile north of Riviera Road. 12/22/47, 8.9; 3/1/48, 9.4; 12/8/48, 9.7; 3/30/49, 5.9; 11/8/49, 8.2; 3/21/50, 6.3; 11/2/50, 8.8; 3/27/51, 5.8; 11/13/51, 8.8; 4/2/52, 4.5.

17N/3E-29H1—Reference point—top of casing, elevation 77.7 feet, South side Riviera Road, 0.52 mile east of Larkin Road. 12/23/47, 5.0; 3/1/48, 5.6; 5/12/48, 3.5; 11/8/49, 4.7.

17N/3E-30F1—Reference point—top of casing, elevation 80.6 feet, South side Riviera Road, 0.35 mile east of Township Road. 11/26/29, 4.7; 9/27/30, 3.3; 12/16/31, 6.2; 12/9/32, 5.4; 12/13/33, 5.6; 11/21/34, 5.4; 11/23/37, 3.7; 1/26/39, 6.4; 1/10/49, 3.1; 11/4/47, 7.8; 12/5/47, 8.0; 12/22/47, 8.2; 3/1/48, 8.5; 12/8/48, 8.6; 12/13/48, 9.3; 11/8/49, 7.6; 3/30/49, 5.4; 3/21/50, 3.5.

17N/3E-30G1—Reference point—top of casing, elevation 81 feet, South Side of Riviera Road, 0.23 mile west of U. S. Highway 99E. 11/10/50, 8.6; 11/26/51, 8.7.

17N/3E-30N1—Reference point—top of pumphouse floor, elevation 73.0 feet, 0.08 mile east of Township Road, 1.25 miles north of Pennington Road. 12/22/47, 4.1; 3/1/48, 4.4; 5/13/48, 3.1; 12/8/48, 4.0; 1/21/49, 4.0; 3/30/49, 1.5; 5/26/49, 7.0; 6/28/49, 7.0; 7/27/49, 7.5; 8/25/49, 8.5; 11/8/49, 3.7; 3/21/50, 6.5; 11/2/50, 8.9; 3/27/51, 6.6; 11/13/51, 8.4; 4/2/52, 1.0.

17N/3E-31A2—Reference point—hole in base of pump, elevation 82 feet, 1.01 miles west of Township Road, 0.85 mile north of Pennington Road. 12/8/48, 10.0; 3/30/49, 6.6.

17N/3E-31M1—Reference point—top of casing, elevation 75 feet, 0.24 mile east of Township Road, 0.32 mile north of Pennington Road. 3/26/48, 7.1; 12/8/48, 9.1.

17N/3E-32B1—Reference point—top of casing, elevation 81.5 feet, 0.09 mile east of Larkin Road, 1 mile south of Riviera Road. 12/23/47, 12.2; 3/1/48, 12.4; 12/8/48, 11.7; 3/30/49, 8.1; 1/8/49, 13.3; 3/22/50, 7.8; 3/27/51, 6.5; 11/13/51, 9.8; 4/2/52, 4.7.

17N/3E-33Q1—Reference point—top of casing, elevation 80 feet, North side of Pennington Road, 0.50 mile east of Meteer Road. 11/10/47, 12.2; 3/20/48, 16.7; 12/3/48, 13.1; 3/8/49, 16.6; 11/9/49, 10.7; 3/22/50, 14.0; 11/3/50, 11.4; 4/2/51, 11.3; 11/14/51, 12.4; 4/3/52, 8.8.

17N/3E-35H1—Reference point—top of casing, elevation 82 feet, 0.05 mile west of State Highway 24, 1.57 miles north of Ramirez Road. 10/29/47, 21.5; 3/22/48, 19.0; 10/10/48, 19.7; 3/8/49, 19.0; 11/15/49, 22.2.

17N/3E-35H2—Reference point—hole in base of pump, elevation 82 feet, 1.67 miles north of Ramirez Road, west side of State Highway 24. 10/29/47, 23.4; 3/22/48, 21.0; 5/7/48, 17.2; 12/10/48, 19.9; 3/8/49, 19.0; 11/15/49, 22.3; 3/21/50, 18.2; 11/7/50, 22.9; 3/28/51, 14.2; 11/15/51, 22.3; 4/6/52, 10.1.

17N/3E-36B1—Reference point—top of casing, elevation 84 feet, 0.70 mile east of State Highway 24, 1.87 miles north of Ramirez Road. 10/31/47, 17.9; 3/22/48, 17.6; 12/10/48, 17.0; 3/8/49, 15.5; 11/14/49, 19.6.

17N/3E-36B2—Reference point—hole in base of pump, elevation 84 feet, 0.55 mile east of State Highway 24, 1.9 miles north of Ramirez Road. 10/31/47, 23.7; 3/22/48, 17.3; 5/7/48, 17.0; 12/10/48, 17.6; 1/26/49, 17.1; 3/8/49, 16.3; 11/14/49, 19.9; 3/21/50, 16.6; 11/7/50, 20.2; 3/28/51, 12.3; 11/15/51, 18.6; 4/6/52, 7.4.

17N/3E-36E1—Reference point—slot in base, elevation 83 feet, 0.2 mile east of State Highway 24, 1.55 miles north of Ramirez Road. 10/31/47, 20.3; 3/22/48, 18.4; 3/8/49, 17.7; 11/15/49, 20.8.

17N/4E-22H1—Reference point—top of casing, elevation 116 feet, 0.2 mile east of La Porte Road bridge across Middle Honcut Creek. 2/25/48, 16.1; 3/15/48, 15.3; 11/17/49, 18.3; 3/28/51, 12.1; 11/14/51, 18.6; 4/6/52, 10.2.

17N/4E-27E1—Reference point—top of concrete pit cribbing, elevation 105 feet, 0.30 mile west of La Porte Road bridge across South Honcut Creek. 11/19/47, 29.9; 3/15/48, 33.2; 11/30/48, 30.0; 3/23/49, 24.2.

17N/4E-27F1—Reference point—top of casing, elevation 106 feet, West side La Porte Road, south bank of South Honcut Creek. 11/18/47, 24.8; 3/30/48, 24.2; 5/12/48, 24.2; 11/30/48, 24.9; 3/23/49, 23.1; 11/17/49, 28.0; 3/22/50, 24.9; 10/3/50, 30.2; 3/28/51, 24.1; 11/14/51, 30.3; 4/6/52, 23.8.

17N/4E-29L1—Reference point—hole in pump base, elevation 80 feet, 1.02 miles west of Southern Pacific Railroad tracks, 0.30 mile south of South Honcut Creek. 12/1/48, 21.2; 3/23/49, 19.5; 11/17/49, 26.1; 3/22/50, 22.3; 10/31/50, 30.0; 3/28/51, 21.6; 11/27/51, 14.6; 4/6/52, 5.0.

17N/4E-33D1—Reference point—top of casing, elevation 96 feet, West side Southern Pacific Railroad tracks, 1.08 miles north along tracks from intersection with Ramirez Road. 11/18/47, 24.1; 3/15/48, 24.8; 12/1/48, 25.2; 3/23/49, 27.6; 11/17/49, 27.6; 3/22/50, 27.0; 10/31/50, 28.0; 3/28/51, 25.1; 11/14/51, 28.1; 4/6/52, 24.3.

17N/4E-35C1—Reference point—hole in pump base, elevation 122 feet, South side Iowa City Road, 1.20 miles east of La Porte Road. 3/15/48, 26.7; 11/17/49, 28.5; 3/28/51, 28.5; 11/14/51, 33.1; 4/6/52, 30.1.

TABLE 2

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by S. T. Harding
(Depths to water in feet meosured from reference point)

13N/2E-1 (Harding 43)—Reference point—top of pump house floor, elevation 35 feet, 1,800 feet north of east quarter corner of section. 9/20/31, 16.5; 12/2/32, 15.7.

13N/3E-2 (Harding 139)—Reference point—top of casing, elevation 43 feet, 30 feet north of east and west center line, 1,700 feet east of Garden Highway. 10/16/31, 22.7; 11/29/32, 18.0.

13N/3E-3 (Harding 76)—Reference point—top of casing, elevation 40 feet, 200 feet south and 1,400 feet east of center of section. 10/13/31, 21.3; 11/29/32, 19.2.

13N/3E-4 (Harding 141A)—Reference point—top of casing, elevation 39 feet, 800 feet south and 50 feet west of northeast corner of section. 10/9/31, 22.1; 12/2/32, 20.0.

13N/3E-4 (Harding 70)—Reference point—top of casing, elevation 40 feet, 20 feet west of Sawtelle Avenue at southeast corner of section. 10/8/31, 23.0; 12/2/32, 20.0.

13N/3E-5 (Harding 140)—Reference point—top of pit, elevation 36 feet, 550 feet south and 200 feet west of north quarter corner of section. 10/9/31, 23.0; 12/2/32, 20.7.

13N/3E-5 (Harding 141)—Reference point—top of casing, elevation 34 feet, 200 feet west and 300 feet north of east quarter corner of section. 10/9/31, 20.5; 12/2/32, 18.0.

13N/3E-7 (Harding 73)—Reference point—top of casing, elevation 33 feet, 1,300 feet east of west quarter corner of section. 10/8/31, 12.0; 12/2/32, 13.0.

13N/3E-9 (Harding 72)—Reference point—top of wall of pit, elevation 35 feet, 500 feet south of north quarter corner of section. 10/8/31, 18.5; 12/2/32, 13.1.

13N/3E-10 (Harding 69)—Reference point—top of wall of wooden pit, elevation 38 feet, 500 feet north and 500 feet south of northeast corner of section. 10/8/31, 17.0; 12/2/32, 17.1.

13N/3E-11 (Harding 75)—Reference point—top of wall of pit, elevation 40 feet, 2,000 feet south and 600 feet west of northeast corner of section. 10/8/31, 17.5; 12/7/32, 15.6.

13N/3E-13 (Harding 74)—Reference point—top of wall of pit, elevation 38 feet, 100 feet east and 1,000 feet north of southwest corner of section. 10/8/31, 16.8; 12/7/32, 17.1.

13N/3E-14 (Harding 64)—Reference point—top of wall of pit, elevation 35 feet, 500 feet north of intersection of Wilson Road and Garden Highway. 10/6/31, 15.5; 12/2/32, 15.2.

13N/3E-15 (Harding 63)—Reference point—top of casing, elevation 35 feet, West side of Southern Pacific Railroad, ¼ mile north of Wilson Road. 10/6/31, 15.0; 12/2/32, 13.8.

13N/3E-16 (Harding 62)—Reference point—top of casing, elevation 36 feet, 500 feet north of southeast corner of section. 10/6/31, 17.0; 12/2/32, 16.4.

13N/3E-16 (Harding 71)—Reference point—top of casing, elevation 31 feet, 1,300 feet east and 2,700 feet south of northwest corner of section. 10/8/31, 12.0; 12/2/32, 11.3.

13N/3E-23 (Harding 60)—Reference point—top of concrete pit wall, elevation 35 feet, 100 feet east of Garden Highway, 2,200 feet south of north quarter corner of section. 10/6/31, 15.5; 12/2/32, 12.5.

13N/3E-23 (Harding 61)—Reference point—top of casing, elevation 36 feet, 500 feet east and 200 feet south of northwest corner of section. 10/6/31, 16.4; 12/2/32, 15.2.

14N/2E-4 (Harding 51)—Reference point—top of casing, elevation 37 feet, 300 feet west and 200 feet south of northeast corner of section. 9/26/31, 8.3; 11/30/32, 6.6.

14N/2E-36 (Harding 47)—Reference point—top of casing, elevation 34 feet, 500 feet south of north quarter corner of section. 9/23/31, 12.0; 12/2/32, 11.6.

14N/2E-36 (Harding 42)—Reference point—top of casing, elevation 35 feet. At east quarter corner of section. 9/20/31, 14.0; 12/2/32, 13.2.

14N/3E-1 (Harding 99)—Reference point—top of casing, elevation 53 feet, 200 feet west of Feather River Boulevard and 1.5 miles south of Alicia Station. 10/16/31, 12.0; 12/5/32, 12.3.

14N/3E-2 (Harding 54)—Reference point—top of casing below ground, elevation 48 feet, 5,200 feet east of Southern Pacific Railroad and 1,500 feet north of latitude 39° 05′. 9/26/31, 21.3; 11/29/32, 18.5.

14N/3E-2 (Harding 79)—Reference point—top of casing, elevation 48 feet, 1,400 feet east and 700 feet south of northwest corner of section. 10/13/31, 19.5; 11/29/32, 16.0.

14N/3E-3 (Harding 66)—Reference point—top of casing, elevation 51 feet, 700 feet west of Southern Pacific Railroad, 1,700 feet south of north line of section. 10/7/31, 35.3; 12/1/32, 33.0.

14N/3E-4 (Harding 57)—Reference point—top of concrete pit, elevation 51 feet, 1,150 feet east and 800 feet south of north quarter corner of section. 9/28/31, 36.3; 11/30/32, 35.3.

14N/3E-4 (Harding 56)—Reference point—top of concrete pit, elevation 48 feet, 600 feet east and 360 feet south of west quarter corner of section. 9/27/31, 33.9; 11/30/32, 32.0.

14N/3E-8 (Harding 118)—Reference point—top of casing, elevation 44 feet, 1,500 feet north and 200 feet east of southwest corner of section. 9/28/31, 25.1; 11/30/32, 23.6.

14N/3E-9 (Harding 123)—Reference point—top of pit, elevation 46 feet, 300 feet east and 200 feet north of south quarter corner of section. 9/30/31, 32.5; 11/30/32, 31.0.

14N/3E-10 (Harding 116)—Reference point—top of pit, elevation 50 feet, 300 feet north of east and west center line, 550 feet west of Southern Pacific Railroad. 10/1/31, 36.0; 12/1/32, 32.6.

14N/3E-10 (Harding 115)—Reference point—top of casing, elevation 52 feet, 700 feet south and 200 feet west of northeast corner of section. 10/1/31, 33.8; 11/29/32, 29.0.

14N/3E-11 (Harding 55)—Reference point—top of casing, elevation 53 feet, 4,400 feet east of Southern Pacific Railroad, 100 feet south of latitude 39° 05′. 9/5/31, 30.1; 10/17/31, 29.0.

14N/3E-13 (Harding 100)—Reference point—top of wall of pit, elevation 50 feet, West of Feather River Boulevard, 500 feet north of Pearson Station. 10/16/31, 10.0; 12/5/32, 10.1.

14N/3E-15 (Harding 67)—Reference point—top of concrete pit, elevation 47 feet, 800 feet east and 150 feet south of northwest corner of section. 10/7/31, 32.7; 12/1/32, 29.2.

14N/3E-15 (Harding 124)—Reference point—top of concrete pit, elevation 48 feet, 1,600 feet south of north line and 200 feet east of Southern Pacific Railroad. 10/8/31, 30.8; 12/1/32, 25.2.

14N/3E-15 (Harding 122)—Reference point—top of concrete pit, elevation 45 feet, 2,150 feet north and 600 feet east of southwest corner of section. 10/17/31, 29.4; 12/1/32, 24.0.

14N/3E-16 (Harding 58)—Reference point—bottom of 6 x 6 strut across top of pit, elevation 45 feet, 750 feet north and 40 feet west of southwest corner of section. 9/29/31, 25.8; 11/30/32, 25.6.

14N/3E-16 (Harding 120)—Reference point—top of concrete pit, elevation 45 feet, 1,350 feet east and 200 feet north of south quarter corner of section. 10/17/31, 27.7; 12/1/32, 25.4.

14N/3E-17 (Harding 119)—Reference point—top of casing, elevation 42 feet, 1,500 feet north and 100 feet east of southwest corner of section. 10/3/31, 21.5; 11/30/32, 20.0.

14N/3E-18 (Harding 45)—Reference point—top of wall of concrete pit, elevation 39 feet, 1,100 feet east and 2,000 feet south of northwest corner of section. 9/21/31, 14.5; 11/30/32, 14.4.

14N/3E-19 (Harding 46)—Reference point—top of pit wall, elevation 38 feet, 1,800 feet east and 900 feet south of northwest corner of section. 9/21/31, 16.0; 11/30/32, 15.0.

14N/3E-20 (Harding 123A)—Reference point—top of casing, elevation 42 feet, 2,000 feet north and 130 feet west of southeast corner of section. 10/3/31, 29.7; 12/1/32, 26.4.

TABLE 2—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by S. T. Harding
(Depths to water in feet measured from reference point)

14N/3E-22 (Harding 68)—Reference point—top of concrete pit, elevation 45 feet, 1,100 feet south of north line of section and 350 feet west of Garden Highway. 10/8/31, 23.4; 11/29/32, 19.7.

14N/3E-23 (Harding 107)—Reference point—top of pit wall, elevation 50 feet. West end of Country Club Road on center line of section. 10/16/31, 20.5; 12/9/32, 19.7.

14N/3E-23 (Harding 129)—Reference point—top of casing, elevation 46 feet, 100 feet east of Garden Highway and 1,650 feet north of latitude 39° 32' 30". 10/13/31, 25.2.

14N/3E-27 (Harding 131)—Reference point—top of casing, elevation 42 feet, 700 feet east of Southern Pacific Railroad and 300 feet north of south line of section. 10/16/31, 25.0; 11/29/32, 21.7.

14N/3E-27 (Harding 130)—Reference point—top of casing, elevation 44 feet, 2,000 feet south of latitude 39° 32' 30" and 400 feet west of Garden Highway. 10/13/31, 25.2; 11/29/32, 21.2.

14N/3E-28 (Harding 128)—Reference point—top of concrete pit, elevation 40 feet, 500 feet east and 1,600 feet north of southwest corner of section. 10/12/31, 29.8; 12/1/32, 27.0.

14N/3E-28 (Harding 127)—Reference point—top of casing, elevation 42 feet, 150 feet west and 25 feet south of northwest corner of section. 10/12/31, 30.3; 12/1/32, 27.4.

14N/3E-29 (Harding 126)—Reference point—top of planks across top of pit, elevation 41 feet, 1,200 feet west and 1,600 feet south of northeast corner of section. 10/10/31, 29.0; 12/1/32, 26.7.

14N/3E-29 (Harding 125)—Reference point—top of concrete casing, elevation 42 feet, 750 feet north and 300 feet west of south quarter corner of section. 9/5/31, 29.2; 10/9/31, 28.3; 12/2/32, 25.5.

14N/3E-30 (Harding 77)—Reference point—top of casing, elevation 39 feet, 1,500 feet south and 250 feet west of northeast corner of section. 10/13/31, 23.1; 12/2/32, 20.7.

14N/3E-31 (Harding 44)—Reference point—top of concrete pit, elevation 37 feet, 1,000 feet west and 200 feet south of northeast corner of section. 9/20/31, 21.5; 12/2/32, 16.5.

14N/3E-32 (Harding 133)—Reference point—top of casing, elevation 36 feet, 2,000 feet north and 200 feet east of southwest corner of section. 10/14/31, 23.3; 12/2/32, 20.7.

14N/3E-32 (Harding 132)—Reference point—top of casing, elevation 37 feet, 250 feet south and 150 feet west of center of section. 10/14/31, 25.0; 11/29/32, 21.0.

14N/3E-33 (Harding 134)—Reference point—top of tile at hand pump, elevation 43 feet, 200 feet south and 1,410 feet east of northwest corner of section. 10/14/31, 27.6; 12/1/32, 24.8.

14N/3E-34 (Harding 135)—Reference point—top of pit, elevation 41 feet, 300 feet east and 40 feet south of northwest corner of section. 10/14/31, 27.8; 12/1/32, 24.9.

14N/3E-35 (Harding 138)—Reference point—top of wood pit, elevation 42 feet, 100 feet west of levee, 500 feet north of south line of section. 10/16/31, 18.3; 11/29/32, 17.5.

14N/3E-35 (Harding 137)—Reference point—top of casing, elevation 43 feet, 100 feet east of Garden Highway, 100 feet north of south line of section. 10/16/31, 25.4; 11/29/32, 22.1.

14N/3E-35 (Harding 136)—Reference point—top of wooden pit, elevation 42 feet, 200 feet east of Garden Highway, 1,100 feet north of south line of section. 10/16/31, 24.8; 11/29/32, 22.0.

14N/4E-8 (Harding 101)—Reference point—top of pit wall, elevation 56 feet, 700 feet west and 700 feet south of west quarter corner of section. 10/16/31, 12.0; 12/3/32, 12.8.

14N/4E-8 (Harding 103)—Reference point—top of casing, elevation 63 feet, 200 feet southeast of northwest corner of section. 10/16/31, 18.0; 12/3/32, 18.8.

14N/4E-19 (Harding 104)—Reference point—top of casing, elevation 49 feet. Immediately north of center of section. 10/16/31, 14.0; 12/3/32, 13.5.

14N/4E-31 (Harding 98)—Reference point—top of casing, elevation 59 feet, 50 feet east of bend in River Road, ½ mile above Alicia. 10/16/31, 18.0; 12/3/32, 17.0.

15N/2E-1 (Harding 18)—Reference point—top of casing, elevation 56 feet, 1,000 feet south and 180 feet west of northeast corner of section. 9/7/31, 11.8; 10/17/31, 11.3; 12/8/32, 10.2.

15N/2E-12 (Harding 17)—Reference point—top of casing in pit, elevation 51 feet, 1,600 feet south and 400 feet west of northeast corner of section. 9/7/31, 8.1; 10/17/31, 9.3; 12/8/32, 10.1.

15N/2E-12 (Harding 114)—Reference point—top of casing, elevation 54 feet, 200 feet south of Butte House Road on north side of east and west center line of section. 10/1/31, 8.5; 12/8/32, 11.9.

15N/2E-13 (Harding 35)—Reference point—top of highest horizontal flange on suction, elevation 51 feet, 1,800 feet west and 200 feet north of east quarter corner of section. 9/18/31, 14.5; 12/8/32, 14.6.

15N/2E-13 (Harding 113)—Reference point—top of casing, elevation 50 feet, 1,000 feet east and 500 feet north of west quarter corner of section. 10/1/31, 8.0; 12/8/32, 9.7.

15N/2E-26 (Harding 111)—Reference point—top of casing, elevation 44 feet, 2,000 feet west and 50 feet south of northeast corner of section. 10/1/31, 7.0; 11/30/32, 7.7.

15N/2E-28 (Harding 112)—Reference point—top of casing, elevation 43 feet, 500 feet west of east quarter corner of section. 10/1/31, 9.0; 11/30/32, 7.9.

15N/2E-35 (Harding 53)—Reference point—top of casing, elevation 38 feet, 0.25 mile west and 300 feet north of southeast corner of section. 9/26/31, 5.0; 11/30/32, 5.4.

15N/3E-1 (Harding 87)—Reference point—top of casing, elevation 64 feet. East side of State Highway 24, 0.5 mile north of Walnut Avenue. 10/15/31, 14.5; 12/5/32, 13.8.

15N/3E-1 (Harding 85)—Reference point—top of casing, elevation 66 feet, 200 feet north of Walnut Avenue, 0.25 mile west of State Highway 24. 10/15/31, 19.5; 12/5/32, 15.8.

15N/3E-1 (Harding 84)—Reference point—top of walls of pit, elevation 61 feet, 700 feet east of State Highway 24 and 1 mile north of railroad crossing. 10/15/31, 6.0.

15N/3E-1 (Harding 84A)—Reference point—top of casing, elevation 61 feet, 300 feet east of State Highway 24 and 1 mile north of railroad crossing. 12/5/32, 5.0.

15N/3E-2 (Harding 86)—Reference point—top of casing, elevation 68 feet, 500 feet north of west end of Walnut Avenue. 10/15/31, 25.5; 12/5/32, 24.1.

15N/3E-2 (Harding 109)—Reference point—top of casing, elevation 62 feet. West end of first road to left on State Highway 24 after crossing bridge ¼ mile north of cemetery. 10/20/31, 21.5; 12/5/32, 21.0.

15N/3E-2 (Harding 108)—Reference point—top of wall of pit, elevation 61 feet, 0.60 mile west of State Highway 24, on first left road after crossing bridge, ¼ mile north of cemetery. 10/20/31, 19.0; 12/5/32, 18.3.

15N/3E-3 (Harding 4)—Reference point—top of casing, elevation 61 feet, 250 feet south and 240 feet east of northwest corner of section. 8/31/31, 22.7; 10/17/31, 23.4.

15N/3E-4 (Harding 15)—Reference point—top of concrete pit, elevation 60 feet, 1,900 feet north and 900 feet west of southeast corner of section. 9/4/31, 25.5; 10/17/31, 25.5; 12/7/32, 23.7.

15N/3E-5 (Harding 14)—Reference point—2 inches above top of concrete pit, elevation 59 feet. On east line 1,800 feet north of southeast corner of section. 9/3/31, 24.5; 10/17/31, 24.5; 12/7/32, 22.8.

TABLE 2—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by S. T. Harding
(Depths to water in feet measured from reference point)

15N/3E-6 (Harding 16)—Reference point— top of casing, elevation 60 feet, 1,320 feet west and 1,200 feet north of southeast corner of section. 9/7/31, 18.2; 12/8/32, 17.1.

15N/3E-9 (Harding 22)—Reference point—top of concrete pit, elevation 58 feet, 1,000 feet south and 500 feet east of west quarter corner of section. 9/10/31, 28.1; 10/17/31, 27.9; 12/8/32, 25.7.

15N/3E-10 (Harding 19)—Reference point—top of concrete pit, elevation 63 feet. Near north quarter of section. 9/8/31, 30.7; 10/17/31, 30.5; 12/7/32, 28.0.

15N/3E-11 (Harding 82)—Reference point—top of casing, elevation 57 feet. Under Southern Pacific Railroad trestle 2 miles north of Yuba City. 10/20/31, 16.5; 12/6/32, 16.3.

15N/3E-13 (Harding 110)—Reference point—top of casing, elevation 62 feet, 50 feet east of road which runs north and south behind Marysville High School and 0.4 mile south of north end of road. 10/20/31, 12.0; 12/5/32, 12.6.

15N/3E-14 (Harding 83)—Reference point—top of wall of pit, elevation 56 feet, 400 feet east and 200 feet south of west quarter corner of section. 10/13/31, 21.5.

15N/3E-15 (Harding 21)—Reference point—top of concrete pit, elevation 60 feet, 500 feet west of highway and 100 feet south of north line of section. 9/8/31, 29.3; 10/17/31, 29.1; 12/7/32, 27.2.

15N/3E-16 (Harding 23)—Reference point—top of concrete pit, elevation 58 feet, 750 feet south and 850 feet west of northeast corner of section. 9/10/31, 30.2; 10/17/31, 29.7; 12/7/32, 27.7.

15N/3E-17 (Harding 29)—Reference point—top of concrete pit, elevation 56 feet, 1,100 feet east of Live Oak drain, south of Sacramento Northern Railroad. 9/19/31, 25.0; 12/8/32, 22.5.

15N/3E-19 (Harding 37)—Reference point—floor of pit, 8 feet deep, elevation 50 feet, 660 feet east and 500 feet south of northwest corner of section. 9/18/31, 16.0; 10/17/31, 17.5; 11/28/32, 16.9.

15N/3E-19 (Harding 36)—Reference point—top of concrete pit wall, elevation 50 feet, 1,320 feet north and 300 feet east of southwest corner of section. 9/18/31, 18.0; 12/1/32, 17.0.

15N/3E-20 (Harding 20)—Reference point—top of concrete pit, elevation 57 feet, 850 feet west and 40 feet south of northeast corner of section. 9/8/31, 31.4; 10/17/31, 31.0; 12/1/32, 28.6.

15N/3E-20 (Harding 28)—Reference point—floor of pump house or top of pit, elevation 56 feet, 220 feet east and 250 feet north of south quarter corner of section. 9/18/31, 32.1.

15N/3E-21 (Harding 24)—Reference point—top of casing, elevation 55 feet, 1,100 feet west and 400 feet south of northeast corner of section. 9/10/31, 28.1; 10/17/31, 28.5.

15N/3E-23 (Harding 27)—Reference point—top of casing, elevation 57 feet. In Yuba City, back of blacksmith shop, 150 feet south of Sutter Hotel. 9/17/31, 22.2; 11/29/32, 21.1.

15N/3E-26 (Harding 48)—Reference point—top of concrete pit, elevation 54 feet, 3,800 feet east and 700 feet south of northwest corner of section. 9/—/31, 26.5; 11/29/32, 26.0.

15N/3E-26 (Harding 80)—Reference point—top of casing, elevation 50 feet, 2,000 feet east of northwest corner of section. 10/13/31, 20.5.

15N/3E-26 (Harding 81)—Reference point—top of casing, elevation 55 feet, 100 feet west of toe of levee, 3,500 feet south of Yuba City south limit. 10/13/31, 23.5; 11/29/32, 25.5.

15N/3E-27 (Harding 25)—Reference point—top of casing, elevation 55 feet, 500 feet west and 300 feet south of north quarter corner of section. 8/17/31, 30.2; 12/1/32, 28.5.

15N/3E-27 (Harding 49)—Reference point—top of concrete pit, elevation 51 feet, 1,000 feet west and 1,300 feet north of south quarter corner of section. 9/1/31, 32.2; 11/30/32, 32.4.

15N/3E-28 (Harding 26)—Reference point—top of wood pit, elevation 53 feet. South side of highway, 1,100 feet west of northeast corner of section. 4/—/13, 17.0; 9/17/31, 31.4; 12/1/32, 28.4.

15N/3E-29 (Harding 31)—Reference point—top of concrete pit, elevation 50 feet, 150 feet north and 50 feet west of southeast corner of section. 9/22/31, 32.4; 11/30/32, 29.4.

15N/3E-29 (Harding 30)—Reference point—top of concrete pit, elevation 49 feet, 660 feet east and 660 feet north of southwest corner of section. 9/20/31, 25.2; 11/30/32, 22.6.

15N/3E-30 (Harding 39)—Reference point—top of frame of wooden pit, elevation 52 feet, 1,320 feet south of north quarter corner on east bank of Live Oak drain. 9/19/31, 22.5.

15N/3E-31 (Harding 40)—Reference point—top of wall of concrete pit, elevation 45 feet, 1,800 feet east and 200 feet north of southwest corner of section. 9/19/31, 17.5; 11/30/32, 17.3.

15N/3E-31 (Harding 38)—Reference point—top of wall of concrete pit, elevation 47 feet, 200 feet west and 200 feet south of northeast corner of section. 9/19/31, 22.0; 11/30/32, 21.8.

15N/3E-32 (Harding 32)—Reference point—top of concrete pit, elevation 50 feet, 600 feet east and 500 feet north of south quarter corner of section. 9/22/31, 32.7; 12/1/32, 29.1.

15N/3E-33 (Harding 33)—Reference point—top of concrete pit, elevation 50 feet, 1,150 feet east and 250 feet south of northwest corner of section. 9/23/31, 33.3; 11/30/32, 30.6.

15N/3E-34 (Harding 50)—Reference point—top of concrete pit, elevation 52 feet, 1,600 feet north and 400 feet east of south quarter corner of section. 9/—/31, 34.6; 12/1/32, 32.7.

15N/4E-32 (Harding 102)—Reference point—top of wall of pit, elevation 61 feet, 50 feet east of west line of section, 500 feet south of railroad crossing. 10/16/31, 17.0; 12/3/32, 18.0.

16N/3E-2 (Harding 95)—Reference point—top of casing, elevation 80 feet, 100 feet north of Ramirez Road, 0.50 mile east of State Highway 24. 10/15/31, 17.5.

16N/3E-11 (Harding 96)—Reference point—top of casing, elevation 76 feet. At west end of road running west from State Highway 24, 0.8 mile north of Magnolia Avenue. 10/15/31, 19.5; 12/6/32, 17.9.

16N/3E-14 (Harding 97)—Reference point—top of wall of pit, elevation 75 feet, 500 feet west of State Highway 24, 400 feet south of La Finca Lane. 10/15/31, 15.0; 12/6/32, 14.9.

16N/3E-19 (Harding 12)—Reference point—top of casing, elevation 67 feet, 1,260 feet east and 200 feet north of north quarter of section. 9/2/31, 10.1; 12/7/32, 10.1.

*16N/3E-21 (Harding 10)—Reference point—top of wood pit, west side, elevation 68 feet. Near southeast corner of section, 0.5 mile east of Southern Pacific Railroad. 9/2/31, 23.8; 10/17/31, 22.9; 12/7/32, 20.8.

16N/3E-24 (Harding 90)—Reference point—top of casing, elevation 70 feet. North of Woodruff Road, 1 mile east of State Highway 24. 10/15/31, 10.0; 12/6/32, 11.5.

16N/3E-27 (Harding 78)—Reference point—top of casing, elevation 69 feet, 500 feet north of east and west center line of section at toe of levee. 10/13/31, 25.0; 12/7/32, 22.4.

16N/3E-28 (Harding 8)—Reference point—top of concrete pit, west side, elevation 64 feet, 1,300 feet west of U. S. Highway 99E, 250 feet north of south line of section. 9/2/31, 21.8; 10/17/31, 20.6; 12/7/32, 19.1.

16N/3E-28 (Harding 9)—Reference point—top of casing, elevation 66 feet, 1,000 feet south of north line of section and 300 feet east of Southern Pacific Railroad. 9/2/31, 19.0; 10/17/31, 19.2; 12/7/32, 17.7.

16N/3E-29 (Harding 2)—Reference point—top of concrete pit, elevation 66 feet, 100 feet west and 120 feet south of northeast quarter of northwest quarter of section. 8/13/31, 13.5; 10/17/31, 13.2; 12/7/32, 12.6.

TABLE 2—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Meosurements Made by S. T. Hording
(Depths to water in feet meosured from reference point)

16N 3E-29 (Harding 1)—Reference point—top of casing, elevation 65 feet, 1,880 feet north and 660 feet west of east quarter corner of section. 8/31/31, 15.5; 10/17/31, 14.8; 12/7/32, 13.7.

16N 3E-29 (Harding 6)—Reference point—top of casing, elevation 65 feet, 750 feet east and 1,100 feet north of south quarter corner of section. 8/31/31, 18.4; 10/17/31, 18.0; 12/7/32, 16.3.

16N 3E-29 (Harding 91)—Reference point—top of casing, elevation 71 feet. At cross roads at east end of Woodruff Road. 10/15/31, 6.5; 12/6/32, 6.0.

16N 3E-30 (Harding 11)—Reference point—top of casing, elevation 66 feet, 1,750 feet east and 500 feet north of southwest corner of section. 9/2/31, 10.1; 12/7/32, 12.0.

16N 3E-31 (Harding 34)—Reference point—top of timber frame, elevation 61 feet, 1,300 feet east and 300 feet north of south quarter corner of section. 9/17/31, 18.0; 10/17/31, 20.0; 12/7/32, 17.8.

16N 3E-32 (Harding 13)—Reference point—top of concrete pit, elevation 64 feet, 1,350 feet south and 300 feet east of north quarter corner of section. 9/2/31, 19.1; 10/17/31, 18.6; 12/7/32, 17.5.

16N 3E-32 (Harding 3)—Reference point—top of wood pit, west side, elevation 60 feet, 600 feet north and 300 feet east of south quarter corner of section. 8/31/31, 19.3; 10/17/31, 18.9; 12/7/32, 17.0.

16N 3E-33 (Harding 5)—Reference point—top of casing, elevation 64 feet, 3,300 feet west of U. S. Highway 99E, 200 feet south of north line of section. 8/31/31, 24.9; 10/17/31, 19.1; 12/7/32, 17.5.

16N 3E-33 (Harding 7)—Reference point—top of concrete base, elevation 60 feet, 1,100 feet east and 400 feet north of southwest corner of section. 9/1/31, 20.6; 12/7/32, 18.8.

16N 3E-35 (Harding 89)—Reference point—top of wall of pit, elevation 66 feet, 1,000 feet west of angle in Oroville Highway, 0.5 mile north of Ellis Road. 10/15/31, 18.0; 12/6/32, 16.4.

16N 3E-35 (Harding 88)—Reference point—top of wall of pit, elevation 65 feet, 0.75 mile north of Walnut Avenue, 0.50 mile west of Oroville Highway. 10/15/31, 20.0; 12/6/32, 19.1.

16N 3E-36 (Harding 92)—Reference point—top of wall of pit, elevation 65 feet, 600 feet south of Ellis Road, 500 feet west of Western Pacific Railroad. 10/15/31, 7.5; 12/5/32, 8.5.

TABLE 3

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Sutter County Farm Advisor
(Depths to water in feet and/or inches measured from reference point)

13N/3E-2C1—Reference point—air gage. 1/19/32, 18.2; 2/24/32, 17.5; 3/2/32, 17.9; 4/18/32, 19.0; 5/23/32, 17.1; 6/15/32, 20.4; 7/18/32, 23.0; 9/8/32, 19.8; 10/25/32, 19.0; 11/15/32, 19.3; 12/23/32, 19.0; 2/3/33, 18.5; 3/3/33, 18.6; 4/11/33, 21.4; 5/2/33, 19.8; 6/28/33, 24.2; 8/1/33, 35.0; 9/14/33, 32.0; 10/17/33, 31.0; 3/22/34, 27.0; 9/18/34, 31.5; 11/9/34, 30.0; 12/27/34, 29.3; 1/22/35, 27.8; 3/22/35, 26.3; 4/19/35, 23.7; 5/27/35, 22.7; 7/2/35, 57.8 (operating); 10/31/35, 28.4; 12/26/35, 27.6; 1/3/36, 26.0; 2/25/36, 22.0; 4/11/36, 23.0; 6/15/36, 29.0; 7/24/36, 33.0; 8/20/36, 28.0; 9/24/36, 27.8; 10/27/36, 27.8; 12/28/36, 27.0; 2/9/37, 26.0; 4/5/37, 20.0; 5/13/37, 20.0.

13N/3E-5E2—Reference point—top of pit. 5/16/31, 20′ 8″; 7/11/31, 24′ ¾″; 8/31/31, 21′ 7½″; 9/23/31, 21′ 7″; 10/16/31, 21′ ½″; 11/17/31, 20′ 7″; 12/17/31, 19′ 11″; 1/19/32, 18′ 11″; 2/24/32, 18′ 3¾″; 3/22/32, 17′ 11½″; 4/19/32, 18′ 5½″; 5/23/32, 19′ 6″; 6/23/32, 19′ 2″; 9/13/32, 19′ 11½″; 10/18/32, 19′ 10″; 11/30/32, 19′ 7″; 12/27/32, 19′ 6″; 2/6/33, 19′ 2″; 3/5/33, 18′ 10½″; 4/10/33, 19′ ¾″; 5/17/33, 20′ 5½″; 8/1/33, 22′ 4¾″; 9/14/33, 21′ 5¾″; 3/16/34, 19′ 5½″; 11/9/34, 20′ 7″; 12/11/34, 20′ 0″; 2/15/35, 17′ 7″; 3/22/35, 18.0; 4/19/35, 17.5; 5/24/35, 17.6; 7/2/35, 24.8 (operating); 8/21/35, 18.7; 9/25/35, 18.5; 10/31/35, 18.5; 12/26/35, 18.1; 1/24/36, 17.7; 2/25/36, 16.6; 4/14/36, 15.2; 4/22/36, 16.7; 8/18/36, 16.9; 9/28/36, 16.9; 10/21/36, 16.4; 12/28/36, 15.8; 2/9/37, 15.3.

13N/3E-24G1—Reference point—air gage. 5/6/31, 19.9; 7/15/31, 22.2; 8/28/31, 19.9; 9/22/31, 21.1; 10/14/31, 19.9; 11/17/31, 19.9; 12/17/31, 19.7; 1/2/32, 17.2; 1/19/32, 16.5; 2/25/32, 15.8; 3/2/32, 17.6; 4/26/32, 15.1; 6/22/32, 16.9; 7/18/32, 19.9; 9/8/32, 18.8; 10/18/32, 18.1; 11/15/32, 18.8; 12/22/32, 18.1; 2/3/33, 17.6; 3/3/33, 17.4; 4/11/33, 21.1; 5/2/33, 17.6; 6/28/33, 34.9 (operating); 8/1/33, 22.2; 9/14/33, 19.5; 10/17/33, 18.3; 3/22/34, 28.0; 6/29/34, 21.6; 9/18/34, 19.9; 11/9/34, 19.7; 12/27/34, 18.8; 1/22/35, 16.5; 3/22/35, 16.5; 4/19/35, 13.0; 5/27/35, 12.4; 7/2/35, 36.1 (operating); 8/19/35, 16.5; 9/25/35, 19.5; 10/31/35, 17.6; 12/26/35, 17.6; 1/30/36, 15.3; 2/25/36, 10.9; 4/6/36, 11.9; 8/10/36, 19.5; 9/3/36, 19.9; 9/24/36, 14.9; 10/27/36, 18.8; 12/28/36, 18.8; 2/9/37, 12.4; 4/5/37, 7.1; 5/19/37, 7.8; 9/13/37, 14.1; 12/30/37, 9.7; 2/24/36, 4.7; 3/23/38, 3.8; 4/25/38, 3.7; 6/3/38, 4.8; 6/21/38, 8.9; 7/22/38, 12.2; 9/8/38, 12.3; 2/25/39, 12.5; 4/10/39, 13.8; 8/2/39, 17.6; 10/11/39, 15.8; 11/29/39, 15.4; 2/8/40, 11.5; 3/22/40, 7.8; 5/20/40, 7.9; 8/24/40, 15.0.

13N/4E-13F3—Reference point—hole in pump base. 12/1/32, 18′ 6¾″; 1/12/33, 17′ 9½″; 2/3/33, 17′ 4½″; 3/10/33, 16′ 9½″; 4/3/33, 18′ 2″; 5/23/33, 20′ 8½″; 10/23/33, 22′ 1½″; 3/20/34, 23′ 3½″; 6/27/34, 30′ 6″; 9/26/34, 24′ 6″; 12/10/34, 20′ 11″; 2/14/35, 18′ 5″; 3/25/35, 17′ 4½″; 4/30/35, 15′ 6¾″; 5/28/35, 19′ 2″; 8/18/35, 26′ 3½″; 9/26/35, 20′ 7½″; 1/15/36, 16.7; 3/28/36, 14.2; 3/27/36, 20.6; 8/10/36, 25.3; 8/20/36, 22.6; 9/23/36, 21.0; 10/27/36, 19.4; 1/2/37, 16.7; 2/10/37, 15.6; 4/8/37, 11.6; 11/27/37, 17.0; 3/16/38, 11.0; 4/27/38, 10.7; 5/31/38, 14.0; 7/21/38, 32.2*; 9/8/38, 18.1; 12/29/38, 15.6; 2/16/39, 15.3; 6/15/39, 34.9; 10/12/39, 22.7; 12/6/39, 20.9; 2/19/40, 17.1; 3/27/40, 15.1; 5/15/40, 15.3; 8/6/40, 28.7.

13N/4E-13R2—Reference point—top of casing. 1/12/33; 16′ 3″; 2/3/33, 14′ 8¼″; 3/10/33, 15′ 0″; 4/3/33, 16′ 4½″; 5/23/33, 18′ 1″; 6/28/33, 26′ 3″*; 8/9/33, 25′ 1¾″; 9/15/33, 22′ 8″. Following measurements from new well, reference point—hole in side of pump, 3/20/34, 22′ 3½″; 12/10/34, 18′ 8″; 2/14/35, 16′ 3½″; 3/25/35, 14′ 11½″; 4/30/35, 13′ 5¼″; 5/28/35, 14′ 10″; 7/3/35, 22′ 4½″; 1/25/36, 11.2; 2/28/36, 16.2; 8/10/36, 20.7; 8/20/36, 19.0; 9/23/36, 19.6; 10/27/36, 15.4; 1/2/37, 13.4; 2/10/37, 11.9; 4/8/37, 7.6; 5/26/37, 9.7; 11/27/37, 13.6; 3/16/38, 6.9; 4/27/38, 6.6; 5/31/38, 7.8; 12/29/38, 11.6; 2/16/39, 9.2; 12/6/39, 16.5; 2/19/40, 13.3; 3/27/40, 11.3; 5/15/40, 9.7; 8/6/40, 21.5; 5/19/41, 6.4.

* Nearby well pumping.

13N/4E-14D1—Reference point—air gage. 2/14/33, 12.01; 3/8/33, 12.01; 4/5/33, 39.63 (operating); 6/27/33, 15.00.

13N/4E-15R1—Reference point—air gage. 2/14/33, 18.94; 3/8/33, 18.25; 4/5/33, 43.2 (operating); 5/23/33, 23.56; 6/26/33, 32.8; 9/26/33, 24.0; 10/23/33, 28.18; 3/20/34, 23.56; 6/27/34, 31.65; 9/26/34, 30.49; 12/10/34, 25.11; 2/14/35, 22.15; 3/25/35, 20.79; 4/30/35, 18.94; 5/28/35, 18.94; 6/24/35, 27.03; 8/6/35, 31.65; 9/26/35, 25.18; 1/15/36, 21.25; 2/28/36, 18.25; 3/29/36, 28.18; 7/23/36, 30.5; 8/20/36, 30.5; 9/23/36, 31.65; 10/27/36, 28.41; 1/2/37, 23.56; 2/10/37, 21.25; 5/26/37, 16.63; 7/21/37, 26.4.

13N/5E-7L1—Reference point—top of casing. 12/1/32, 22′ 2″; 2/3/33, 20′ 10½″.

13N/5E-16D1—Reference point—top of casing. 12/1/32, 1′ 3¾″; 1/12/33, 1′ ½″; 2/3/33, 0′ 10½″; 3/10/33, 0′ 6½″; 4/5/33, 0′ 6″; 5/23/33, 1′ 4″; 6/27/33, 2′ 8½″; 8/9/33, 7′ 1″; 9/15/33, 5′ 0″; 10/23/33, 4′ 8½″; 3/20/34, 1′ 4″; 6/27/34, 4′ 6½″; 9/26/34, 6′ ½″; 12/10/34, 4′ 4″; 2/14/34, 1′ 10¾″; 3/25/35, 0′ 2½″; 4/30/35, 0′ 9½″; 5/28/35, —0′ 1¾″; 7/3/35, 1′ 9″; 8/6/35, 3′ 0″; 9/26/35, 2′ 7″; 1/15/36, 13.0; 2/28/36, 9.1; 3/27/36, 9.3; 7/30/36, 14.3; 8/20/36, 13.7; 9/23/36, 13.3; 10/27/36, 13.1; 1/2/37, 12.7; 2/10/37, 11.3; 4/8/37, 6.5; 5/26/37, 9.1; 7/21/37, 14.7; 3/16/38, 5.1; 4/27/38, 6.4; 7/21/38, 12.5; 9/8/38, 13.5; 12/29/38, 11.5; 2/16/39, 11.4; 4/27/39, 14.4; 6/15/39, 15.9; 10/12/39, 17.5; 12/6/39, 15.6; 2/9/40, 12.9; 3/27/40, 9.8; 5/15/40, 8.7; 8/6/40, 16.8; 5/19/41, 6.7; 7/28/41, 14.2.

13N/5E-18C1—Reference point—hole in top of pump base. 12/1/32, 17′ 4½″; 1/12/33, 16′ 7″; 2/3/33, 16′ 2″; 3/10/33, 15′ 7″; 4/3/33, 18′ 4½″; 5/23/33, 19′ 9″; 6/28/33, 25′ 1″; 9/15/33, 22′ 6″; 10/23/33, 21′ 4″; 6/27/34, 30′ 3″; 9/26/34, 23′ 7½″; 12/10/34, 20′ ¼″; 2/14/35, 17′ 11½″; 3/25/35, 15′ 7½″; 4/30/35, 14′ 1½″; 5/28/35, 16′ 2″; 6/24/35, 21′ 4″; 8/6/35, 26′ 5½″; 9/26/35, 18′ 8½″; 8/10/36, 22.05; 8/20/36, 22.2; 9/23/36, 20.9; 10/27/36, 15.0; 1/2/37, 14.3; 2/16/37, 13.04; 4/8/37, 8.2; 5/26/37, 12.9; 11/27/37, 14.6; 3/16/38, 8.0; 4/27/38, 8.2; 5/31/38, 10.2; 7/21/38, 20.3; 9/8/38, 16.4; 12/29/38, 13.2; 5/19/41, 8.2; 7/28/41, 19.7.

15N/3E-7M2—Reference point—top of casing. 7/15/31, 17′ 6½″; 8/27/31, 17′ 11″; 9/17/31, 17′ 6″; 10/26/31, 16′ 11″; 11/19/31, 16′ 6½″; 12/16/31, 16′ ¾″; 4/18/32, 14′ 8½″; 2/23/32, 14′ 2″; 3/23/32, 14′ 2½″; 4/15/32, 14′ 6½″; 5/18/32, 14′ 7½″; 6/2/32, 15′ 3½″; 7/13/32, 15′ 9½″; 9/12/32, 16′ 2½″; 10/17/32, 17′ 11″; 11/30/32, 16′ 4″; 12/29/32, 16′ 3¾″; 1/26/33, 16′ 5½″; 3/3/33, 16′ 2¾″; 4/7/33, 16′ 5″; 5/12/33, 16′ 9½″; 6/20/33, 18′ 3″; 7/31/33, 18′ 6½″; 9/13/33, 17′ 2″; 10/17/33, 16′ 9½″; 11/8/33, 16′ 11½″; 3/12/34, 16′ 3″; 6/26/34, 17′ 8″; 11/2/34, 18′ 5½″; 1/28/35, 17′ 5″; 3/14/35, 16′ 3″; 4/18/35, 15′ 5½″; 5/23/35, 15′ 1¾″; 6/25/35, 16′ 0″; 7/27/35, 17′ 0″; 10/25/35, 15.2; 12/19/35, 15.2; 1/23/36, 14.8; 2/27/36, 13.2; 3/31/36, 11.7; 7/9/36, 12.0; 8/18/36, 12.8; 9/17/36, 12.5; 10/20/36, 13.3; 12/28/36, 13.2; 2/16/37, 12.2; 3/29/37, 9.4; 5/3/37, 8.8; 7/16/37, 10.7; 9/28/37, 12.2; 12/4/37, 14.2; 4/15/38, 4.6; 5/26/38, 6.6; 7/14/38, 8.5; 9/20/38, 10.3; 10/28/38, 9.5; 12/24/38, 10.5; 1/31/39, 10.6; 3/3/39, 10.9; 4/13/39, 11.6; 8/1/39, 14.7; 9/27/39, 14.6; 11/8/39, 14.2; 1/18/40, 13.2; 3/20/40, 9.6; 5/16/40, 7.9; 8/2/40, 11.2; 10/17/40, 12.7; 9/20/41, 10.3.

15N/3E-31A1—Reference point—top of pit plus 4-inch timber. 5/12/31, 21′ 10¾″; 6/26/31, 22′ 10¾″; 7/28/31, 24′ 0″; 8/31/31, 24′ 11″; 9/23/31, 24′ ¾″; 10/20/31, 23′ 8½″; 11/8/31, 23′ 1″; 12/17/31, 22′ 9½″; 1/19/32, 22′ 2″; 2/23/32, 21′ 4″; 3/22/32, 20′ 11½″; 4/18/32, 21′ 4½″; 5/23/32, 21′ 2″; 6/21/32, 21′ 5½″; 7/19/32, 22′ 4″; 9/13/32, 22′ 11″; 10/18/32, 22′ 6¾″; 11/22/32, 22′ 2½″; 12/27/32, 21′ 10″; 1/30/33, 21′ 3″; 4/10/33, 21′ 5″; 5/17/33, 22′ 2½″; 6/29/33, 23′ ¾″; 7/25/33, 24′ 5″; 10/18/33, 23′ 7½″; 12/8/33, 23′ 7½″; 3/13/34; 22′ 3½″; 6/26/34, 23′ 11″; 10/2/34, 24′ 7″; 11/5/34, 24′ ¾″; 12/11/34, 23′ 7½″; 2/15/35, 22′ 5″; 3/19/35, 21′ 11″; 4/19/35, 21′ 2″; 5/23/35, 20′ 5½″;

TABLE 3—Continued

DEPTHS TO GROUND WATER AT MEASUREMENT WELLS IN SUTTER-YUBA AREA

Measurements Made by Sutter Caunty Farm Advisar
(Depths to water in feet and/ar inches measured fram reference point)

6/27/35, 21′ 2″; 7/30/35, 22′ 6″; 9/21/35, 23′ 1¾″; 10/25/35, 21.9; 12/20/35, 21.1; 1/23/36, 17.2; 2/25/36, 20.1; 4/14/36, 19.1; 7/22/36, 20.1; 8/18/36, 20.7; 9/17/36, 20.2; 10/21/36, 20.2; 12/28/36, 19.7.

16N/3E-30A1—Reference point—top of casing, 6 inches above ground level. 6/27/31, 11′ 10″; 7/28/31, 12′ 2″; 8/27/31, 12′ 3½″; 9/17/31, 12′ 6″; 10/26/31, 12′ 9″; 11/17/31, 13′ ½″; 12/16/31, 13′ 1½″; 1/18/32, 10′ ¼″; 2/18/32, 9′ 11″; 3/18/32, 10′ 1½″; 5/15/32, 10′ 10½″; 6/30/32, 10′ 6½″; 7/13/32, 10′ 9½″; 9/8/32, 11′ 10″; 10/17/32, 12′ 4¾″; 11/22/32, 12′ 8½″; 12/21/32, 13′ 2″; 1/26/33, 13′ 2½″; 3/3/33, 13′ 7¼″; 4/7/33, 12′ 11″; 5/11/33, 12′ 8½″; 6/20/33, 12′ 11″; 7/31/33, 12′ 11″; 9/13/33, 13′ 6½″; 10/17/33, 13′ 10″; 12/8/33, 14′ 4″; 3/12/34, 12′ 7½″; 6/26/34, 11′ 9″; 7/31/34, 12′ 1½″; 9/27/34, 12′ 6½″; 11/2/34, 13′ 4″; 12/11/34, 13′ 7¾″; 1/28/35, 11′ 4¼″; 3/14/35, 9′ 2″; 4/18/35, 9′ 6¼″; 5/22/35, 10′ 5″; 6/25/35, 10′ 8″; 7/29/35, 10′ 11½″; 9/19/35, 12′ 2″; 10/23/35, 11.9; 12/19/35, 12.6; 1/22/36, 11.2; 2/27/36, 7.5; 3/31/36, 9.1; 5/15/36, 9.7; 6/12/36, 10.2; 7/9/36, 10.7; 8/18/36, 11.7; 9/17/36, 12.1; 10/20/36, 12.2; 12/22/36, 12.7; 2/16/37, 9.1; 3/29/37, 6.6; 5/3/37, 8.6; 7/16/37, 10.1; 12/4/37, 10.2; 5/17/38, 7.9; 7/14/38, 9.5; 9/15/38, 11.2; 10/26/38, 11.8; 12/24/38, 12.4; 1/31/39, 12.6; 3/3/39, 12.7; 4/13/39, 13.1; 6/3/39, 12.1; 8/1/39, 12.5; 9/22/39, 11.6.

16N/3E-30C1—Reference point—top of casing, 4 inches above ground. 5/22/31, 11′ 8½″; 6/25/31, 11′ 7″; 7/29/31, 12′ 0″; 8/27/31, 11′ 9″; 9/17/31, 11′ 7½″; 10/21/31, 11′ ½″; 11/19/31, 10′ 7½″; 12/23/31, 10′ 2″; 1/18/32, 8′ 7″; 2/23/32, 8′ 4½″; 3/19/32, 8′ 4½″; 4/15/32, 8′ 11¾″; 5/17/32, 9′ 1″; 6/21/32, 8′ 9½″; 7/13/32, 9′ 1″; 9/12/32, 9′ 2⅝″; 10/17/32, 9′ 4½″; 11/30/32, 10′ 2½″; 12/29/32, 10′ 6½″; 1/26/33, 10′ 9¼″; 3/3/33, 10′ 6½″; 4/7/33, 10′ 10″; 5/12/33, 10′ 9½″; 6/20/33, 9′ 10″; 7/31/33, 9′ 7½″; 9/13/33, 9′ 3″; 10/17/33, 9′ 6″; 12/8/33, 10′ 4½″; 3/12/34, 10′ 0″; 6/26/34, 11′ 8½″; 9/27/34, 11′ 9″; 11/2/34, 12′ 9″; 12/11/34, 11′ 11½″; 1/28/35, 10′ 10¾″; 3/4/35, 9′ 8½″; 4/18/35, 9′ 4″; 5/23/35, 9′ 8″; 6/25/35, 10′ 5″; 7/29/35, 11′ 5½″; 9/21/35, 11′ 2½″; 10/25/35, 10′ 10¾″; 12/19/35, 11.1; 1/23/36, 10.7; 2/27/36, 9.5; 3/31/36, 8.3; 7/9/36, 9.4; 8/18/36, 9.8; 9/17/36, 9.6; 10/20/36, 9.7; 12/28/36, 10.3; 2/16/37, 6.5; 3/29/37, 6.9; 5/3/37, 8.5; 7/16/37, 8.6; 9/28/37, 8.2; 12/4/37, 8.6; 1/25/38, 6.5; 4/14/38, 3.2; 5/26/38, 6.3; 7/14/38, 6.9; 9/20/38, 8.5; 10/26/38, 8.0; 12/24/38, 8.7; 1/31/39, 8.9; 3/3/39, 9.2; 4/13/39, 10.3; 8/1/39, 11.2; 9/22/39, 12.1; 11/8/39, 10.6; 1/18/40, 10.2; 3/20/40, 6.5; 5/16/40, 6.7; 8/2/40, 9.7; 10/17/40, 10.3.

16N/3E-32G5—Reference point—top of casing, 1 foot 6 inches above ground surface. 6/25/31, 22′ 5″; 7/28/31, 26′ 2½″; 8/27/31, 24′ 6½″; 9/17/31, 20′ 5½″; 10/19/31, 18′ 11″; 11/19/31, 18′ 6″; 12/16/31, 18′ 2¾″; 1/2/32, 17′ 8½″; 1/18/32, 17′ 0″; 2/18/32, 15′ 9″; 3/18/32, 12′ 8½″; 4/15/32, 19′ 6″; 5/17/32, 15′ 1½″; 6/23/32, 23′ 10½″*; 7/13/32, 18′ 1″; 9/8/32, 18′, 2½″; 10/17/32, 17′ 10½″; 11/22/32, 17′ 8″; 12/29/32, 17′ 5″; 1/26/33, 17′ 3½″; 3/3/33, 18′ 1½″; 4/7/33, 25′ 4″ (operating); 5/11/33, 17′ 9½″; 6/20/33, 22′ 5½″; 7/31/33, 28′ 10″ (operating); 9/13/33, 21′ 10½″; 10/17/33, 21′ 0″; 11/18/33, 19′ 2½″; 3/12/34, 18′ 2″. Reference point—top of casing, ground level. 6/26/34, 24′ 5″; 7/31/34, 25′ 7″; 9/27/34, 23′ 9¾″; 11/2/34, 19′ 5″; 12/11/34, 18′ 5½″; 1/28/35, 16′ 10″; 3/14/35, 14′ 4½″; 4/18/35, 14′ ½″; 5/22/35, 12′ 2½″; 7/3/35, 16′ 5½″; 7/29/35, 20′ 0″; 8/27/35, 17′ 1″; 9/19/35, 19′ 17″; 1/22/36, 15.4; 2/27/36, 12.9; 3/31/36, 13.4; 7/9/36, 18.5; 8/18/36, 18.8; 9/17/36, 19.5; 10/23/36, 16.4; 12/22/36, 15.3; 2/16/37, 13.8; 3/29/37, 11.2; 5/3/37, 10.7; 7/16/37, 15.3; 12/4/37, 15.0; 1/25/38, 12.2; 2/25/38, 5.1; 4/14/38, 3.5; 5/26/38, 5.7; 7/14/38, 12.8; 9/15/38, 13.2; 10/26/38, 12.8.

* Nearby well operating.

APPENDIX F

RECORDS OF APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN SUTTER-YUBA AREA

APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN SUTTER-YUBA AREA IN 1948 AND 1949

Crop	Season	Map number	Well number	Method of irrigation	Soil type	Acres	Depth per irrigation, in inches							Total depth, in inches
							1st	2d	3d	4th	5th	6th	7th	
Alfalfa	1948	1	15N/1E-13E1	Border check	Clay adobe	8	5.8	8.1	7.3	7.3				28.5
	1948	2	11N/3E-15P1	Border check	Fine sandy loam	32	16.1	4.4	30.8	7.5	12.7	2.3		73.8
	1949	3	14N/5E-32R1 14N/5E-32R2	Border check	Loam	20	4.15	4.01	8.81	4.70	4.99	12.96	5.98	53.6
	1949	3	14N/5E-32R1 14N/5E-32R2	Border check	Loam	18	7.83	8.47	9.89	9.29	10.54	11.90	11.10	69.0
	1949	4	15N/5E-18B1	Border check	Loam	27								91.8
							Weighted mean depths: 1948 64.8 inches (5.4 feet) 1949 73.8 inches (6.1 feet) 1948–49 70.0 inches (5.8 feet)							
Almonds	1948	5	16N/3E-29R1	Contour check	Loam	13	5.1	5.0	6.2					16.3
	1948	6	16N/3E-26Q1	Contour check	Loam	50	7.5	7.3						14.8
	1948	7	15N/2E-8J1	Contour check	Loam	70	1.8	8.9						10.7
	1949	6	16N/3E-26Q1	Contour check	Loam	50	7.8	7.33	5.0					20.1
	1949	8	14N/3E-4F1	Contour check	Loam	20	6.4	7.65	3.75	3.75				21.5
							Weighted mean depths: 1948 12.8 inches (1.1 feet) 1949 20.5 inches (1.7 feet) 1948–49 15.4 inches (1.3 feet)							
Young Almonds Interplanting Beans	1948	9	16N/3E-23R2	Contour check	Loam	20	6.1	4.2	3.8					14.1
Beans	1948	10	13N/4E-7E1	Furrow	Silt loam	36								8.4
	1948	11	15N/4E-17J1 15N/4E-8R1	Furrow	Fine sandy loam	103	4.2	0.8	5.0	6.5				16.5
	1948	12	13N/5E-6D2	Furrow	Fine sandy loam	60	6.0	5.2						11.2
	1949	13	13N/4E-12C1	Furrow	Fine sandy loam	50	4.5	2.0	1.5	1.7	1.7			11.4
							Weighted mean depths: 1948 13.4 inches (1.1 feet) 1949 11.4 inches (1.0 foot) 1948–49 13.0 inches (1.1 feet)							
Cherries	1948	14	15N/3E-15G1	Contour check	Loam	18	6.8	6.8	2.5	4.4	1.9			22.4
	1948	15	15N/3E-3D1	Contour check	Loam	60	7.4	7.7	5.9	7.3	0.7			29.0
							Weighted mean depth: 1948 27.5 inches (2.3 feet)							
Egyptian Corn	1948	11	15N/4E-17J1 15N/4E-8R1	Furrow	Fine sandy loam	13	6.2	5.7	9.2	8.9	1.3			31.3
	1949	12	13N/5E-6D2	Furrow	Fine sandy loam	60	5.6	8.1	7.5					21.2
							Weighted mean depth: 1948–49 23.0 inches (1.9 feet)							
Flax	1948	16	12N/4E-2Q1	Contour check	Clay loam	55								10.4
Hops	1948	17	13N/5E-4J1	Furrow	Fine sandy loam	19	3.7	3.1	3.4	0.8				11.0
	1949	17	13N/5E-4J1	Furrow	Fine sandy loam	27.5	3.8	3.0	3.6					10.4
							Weighted mean depth: 1948–49 10.6 inches (0.9 foot)							
Pasture	1948	18	12N/4E-10A1	Border check	Loam	60								51.5
	1948	19	14N/4E-34C1	Contour check	Loam	120								26.2
	1949	18	12N/4E-10A1	Border check	Loam	75								71.0
	1949	4	15N/3E-18B1	Border check	Loam	30								84.6
	1949	20	14N/5E-21B1	Border check	Loam	172								79.8
							Weighted mean depths: 1948 34.6 inches (3.9 feet) 1949 78.0 inches (6.5 feet) 1948–49 60.7 inches (5.1 feet)							

APPLICATION OF GROUND WATER TO REPRESENTATIVE CROPS IN SUTTER-YUBA AREA IN 1948 AND 1949—Continued

Crop	Season	Map number	Well number	Method of irrigation	Soil type	Acres	Depth per irrigation, in inches							Total depth, in inches
							1st	2d	3d	4th	5th	6th	7th	
Peaches	1948	21	13N/4E-15K1	Contour check	Fine sandy loam	37	17.4	14.1	12.7					44.2
	1948	22	15N/3E-4C2	Contour check	Clay loam	38.5	1.8	7.3	11.5					20.6
	1948	23	13N/5E-7C2	Contour check	Fine sandy loam	55	6.8	5.7	7.7	6.5				26.7
	1948	24	13N/4E-16N1	Contour check	Fine sandy loam	22	4.1	8.0	7.8	7.1				27.0
	1948	25	15N/3E-33D1	Contour check	Loam	47	1.5	17.0	5.2	8.6				32.3
	1948	26	13N/3E-2L1	Contour check	Loam	15	4.0	7.4	5.6	5.2	6.5			28.7
	1948	27	15N/3E-9A1	Contour check	Loam	40	6.8	2.1	4.3	3.5				16.7
	1948	28	14N/3E-26M2	Contour check	Loam	56								31.6
	1948	29	15N/3E-34L1	Contour check	Loam	30								29.5
	1949	26	13N/3E-2L1	Contour check	Loam	15	6.0	5.0	4.7	6.9	11.9			34.5
	1949	23	13N/5E-7C2	Contour check	Fine sandy loam	55								27.0
	1949	30	13N/4E-13F1	Contour check	Fine sandy loam	34								36.1
	1949	24	13N/4E-16N1	Contour check	Fine sandy loam	22								30.6
	1949	29	15N/3E-34L1	Contour check	Loam	30								37.1
							Weighted mean depths: 1948 28.7 inches (2.4 feet)							
							1949 32.2 inches (2.7 feet)							
							1948–49 29.7 inches (2.5 feet)							
Prunes	1948	25	15N/3E-33F1	Contour check	Loam	108	7.1	4.7						12.0
	1948	31	16N/3E-36L1	Contour check	Loam	100	3.7	6.4						10.1
	1948	27	15N/3E-9A1	Contour check	Loam	20	2.5	1.8	3.7					8.0
	1948	32	16N/3E-17Q1	Contour check	Loam	20	13.1	9.8	8.1					31.0
	1949	32	16N/3E-17Q1	Contour check	Loam	20	11.75	9.9	10.2	9.35				41.1
							Weighted mean depths: 1948 12.5 inches (1.0 foot)							
							1949 41.1 inches (3.4 feet)							
							1948–49 14.6 inches (1.2 feet)							
Rice	1948	33	12N/4E-24F1	Contour check	Loam	80								63.5
	1948	34	11N/4E-9L1 11N/4E-9C1	Contour check	Clay adobe	150								88.5
	1948	35	15N/4E-23A1 14N1,14P1,24C1	Contour check	Loam	325								48.7
	1949	36	16N/4E-6N2	Contour check	Clay loam	120								66.0
	1949	37	12N/4E-20J1 R1, Q1	Contour check	Clay loam	185								171.5 56.2
	1949	35	15N/4E-23A1 14N1, 14P1, 24C1	Contour check	Loam	315								
							Weighted mean depths: 1948 60.6 inches (5.1 feet)							
							1949 92.5 inches (7.7 feet)							
							1948–49 77.5 inches (6.5 feet)							
Sugar Beets	1948	10	13N/4E-7E1 7M1, 18F1		Silt loam	224								17.5
Walnuts	1948	6	16N/3E-26Q1	Furrow	Loam	65	8.6	5.9	3.2					17.7
	1948	14	15N/3E-15G1	Contour check	Loam	12	6.7	6.7	2.6	4.4	1.9			22.3
	1948	11	15N/4E-17J1	Contour check	Fine sandy loam	35	16.6	13.7						30.3
	1948	38	15N/4E-20F1	Contour check	Fine sandy loam	40	6.3	8.1	6.0	6.2	4.3			30.9
	1949	6	16N/3E-26Q1	Furrow	Loam	65	6.2	5.1	4.0	4.6	2.8			22.7
							Weighted mean depths: 1948 24.4 inches (2.0 feet)							
							1949 22.7 inches (1.9 feet)							
							1948–49 23.9 inches (2.0 feet)							

APPENDIX G

RESERVOIR YIELD STUDIES

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YIELD STUDY
HONCUT CREEK RESERVOIR PLUS DIVERSION FROM FRENCH DRY CREEK (NOVEMBER-APRIL)

Capacity: 38,000 acre-feet **Yield: 24,000 acre-feet**

(In acre-feet)

Season	November-May				June-October							Spill, end of May	Deficiency, in percent
	Runoff	Diversion	Demand, 30% of annual demand	Storage, end of May	Demand, 70% of annual demand	Apparent storage, end of October	Apparent deficiency, end of October	Average summer storage	Evaporation	Storage, end of October	Deficiency, end of October		
1920-21	43,170	44,950	7,200	38,000	16,800	21,200		29,600	2,500	18,700		42,920	
1921-22	35,470	28,390	7,200	38,000	16,800	21,200		29,600	2,500	18,700		37,360	
1922-23	18,060	18,350	7,200	38,000	16,800	21,200		29,600	2,500	18,700		9,910	
1923-24	4,700	4,720	7,200	20,920	16,800	4,120		12,520	1,400	2,720			
1924-25	18,490	19,010	7,200	33,020	16,800	16,220		24,620	2,300	13,920			
1925-26	11,350	11,890	7,200	29,960	16,800	13,160		21,560	2,100	11,060			
1926-27	31,120	29,700	7,200	38,000	16,800	21,200		29,600	2,500	18,700		26,680	
1927-28	22,180	22,990	7,200	38,000	16,800	21,200		29,600	2,500	18,700		18,670	
1928-29	6,860	6,260	7,200	24,620	16,800	7,820		16,220	1,700	6,120			
1929-30	16,430	17,110	7,200	32,460	16,800	15,660		24,060	2,200	13,460			
1930-31	4,520	4,680	7,200	15,460	16,800		1,340	7,060	1,000		2,340		9.8
1931-32	21,130	19,720	7,200	33,650	16,800	16,850		25,250	2,300	14,550			
1932-33	8,100	6,120	7,200	21,570	16,800	4,770		13,170	1,500	3,270			
1933-34	6,200	6,320	7,200	8,590	16,800		8,210	190	50		8,260		34.4
1934-35	21,200	20,600	7,200	34,600	16,800	17,800		26,200	2,400	15,400			
AVERAGE	17,900	17,400	7,200		16,800						710	9,040	

YIELD STUDY
CAMP FAR WEST RESERVOIR

Capacity: 104,000 acre-feet **Yield: 90,000 acre-feet**

(In acre-feet)

Season	November-May				June-October							Spill, end of May	Deficiency, in percent
	Runoff	Diversion	Demand, 30% of annual demand	Storage, end of May	Demand, 70% of annual demand	Apparent storage, end of October	Apparent deficiency, end of October	Average summer storage	Evaporation	Storage, end of October	Deficiency, end of October		
1920-21	467,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		336,000	
1921-22	409,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		312,800	
1922-23	364,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		267,800	
1923-24	23,000		27,000	30,800	63,000		32,200				32,200		35.8
1924-25	239,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		108,000	
1925-26	223,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		116,800	
1926-27	450,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		353,800	
1927-28	296,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		199,800	
1928-29	112,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		15,800	
1929-30	355,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		258,800	
1930-31	145,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		48,800	
1931-32	234,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		137,800	
1932-33	51,000		27,000	58,800	63,000		4,200	27,300	3,100		7,300		8.1
1933-34	126,000		27,000	99,000	63,000	36,000		67,500	5,800	30,200			
1934-35	354,000		27,000	104,000	63,000	41,000		72,500	6,200	34,800		253,200	
AVERAGE	256,000		27,000		63,000						2,600	160,600	

YIELD STUDY

COON CREEK RESERVOIR PLUS COMBIE-OPHIR DIVERSION OF 100 SECOND-FEET (NOVEMBER-APRIL)

Capacity: 59,000 acre-feet

Yield: 56,000 acre-feet

(In acre-feet)

Season	November-May				June-October							Spill, end of May	Deficiency, in percent
	Runoff	Diversion	Demand, 30% of annual demand	Storage, end of May	Demand, 70% of annual demand	Apparent storage, end of October	Apparent deficiency, end of October	Average summer storage	Evaporation	Storage, end of October	Deficiency, end of October		
1920-21	44,600	35,700	16,800	59,000	39,200	19,800		39,400	2,500	17,300		4,500	
1921-22	40,000	35,700	16,800	59,000	39,200	19,800		39,400	2,500	17,300		17,200	
1922-23	33,500	35,700	16,800	59,000	39,200	19,800		39,400	2,500	17,300		10,700	
1923-24	5,900	35,700	16,800	42,100	39,200	2,900		22,500	1,800	1,100			
1924-25	24,600	35,700	16,800	44,600	39,200	5,400		25,000	2,000	3,400			
1925-26	22,300	35,700	16,800	44,600	39,200	5,400		25,000	2,000	3,400			
1926-27	48,200	35,700	16,800	59,000	39,200	19,800		39,400	2,500	17,300		11,500	
1927-28	30,200	35,700	16,800	59,000	39,200	19,800		39,400	2,500	17,300		7,400	
1928-29	11,500	35,700	16,800	47,700	39,200	8,500		28,100	2,100	6,400			
1929-30	19,000	35,700	16,800	44,300	39,200	5,100		24,700	2,000	3,100			
1930-31	5,900	35,700	16,800	27,900	39,200		11,300	8,300	900		12,200		21.8
1931-32	23,300	35,700	16,800	42,200	39,200	3,000		22,600	1,800	1,200			
1932-33	11,500	35,700	16,800	31,600	39,200		7,600	12,000	1,200		8,800		15.7
1933-34	11,200	35,700	16,800	30,100	39,200		9,100	10,500	1,100		10,200		18.2
1934-35	31,800	35,700	16,800	50,700	39,200	11,500		31,100	2,200	9,300			
AVERAGE	24,200	35,700	16,800		39,200						2,100	3,400	

APPENDIX H

ESTIMATES OF COST

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ESTIMATED COST OF PEACH BOWL PROJECT

(Based on prices prevailing in April, 1952)

Pumping plant capacity: 135 second-feet
Gross seasonal diversion: 24,000 acre-feet
Maximum monthly demand: (July) 6,450 acre-feet, 105 second-feet

Acreage served: Presently irrigated lands, 4,500 acres; irrigated lands to be developed, 2,500 acres

Item	Quantity	Unit price	Cost	
Capital Costs				
Pumping Plant				
Pumps, motors, and electrical equipment	3 each	$14,330	$43,000	
Discharge pipe and footings	3 each	5,700	17,100	
Sump and trash racks		lump sum	7,100	
Structure		lump sum	14,400	
Discharge structure and sand trap		lump sum	3,400	$85,000
Subtotal				$85,000
Administration and engineering, 10%				$8,500
Contingencies, 15%				12,800
Interest during construction				1,600
TOTAL				$107,900
Conveyance System				
Excavation	137,800 cu. yd.	$0.30	$41,400	
Trimming	195,900 sq. yd.	0.25	49,000	
Lining, concrete	10,900 cu. yd.	35.00	381,500	
Turnouts, 100 second-feet	14 each	1,100	15,400	
50 second-feet	20 each	830	16,600	
Crossings, 100 second-feet				
Railroad	1 each	5,800	5,800	
County road	1 each	3,200	3,200	
Crossings, 50 second-feet				
County road	4 each	2,300	9,200	
Farm road	6 each	1,400	8,400	
Right of way				
Orchard lands	52 acres	1,500	78,000	
Open lands	44 acres	750	33,000	$641,500
Subtotal				$641,500
Administration and engineering, 10%				$64,200
Contingencies, 15%				96,200
Interest during construction				12,000
TOTAL				$813,900

Item	Quantity	Unit price	Cost	
Capital Costs—Continued				
Distribution System				
Presently irrigated lands	4,500 acres	$70.00	$315,000	
Irrigable lands to be developed	2,500 acres	20.00	50,000	$365,000
Subtotal				$365,000
Administration and engineering, 10%				$36,500
Contingencies, 15%				54,800
Interest during construction				6,800
TOTAL				$463,100
Annual Costs				
Pumping Plant				
Interest, 3%				$3,200
Amortization, 0.887%				1,000
Replacement, 0.513%				600
Operation and maintenance, 5%				5,400
Electric energy				5,800
TOTAL				$16,000
Conveyance System				
Interest, 3%				$24,400
Amortization, 0.887%				7,200
Replacement, 0.50%				4,100
Operation and maintenance, 1.0%				8,100
TOTAL				$43,800
Distribution System				
Interest, 3%				$13,900
Amortization, 0.887%				4,100
Operation and maintenance				
Ditch tender service, $0.70 per acre-foot				16,800
Maintenance charge, $0.40 per acre				2,800
District overhead, $0.50 per acre				3,500
TOTAL				$41,100

ESTIMATED COST OF SOUTH HONCUT CREEK DAM AND RESERVOIR

(Based on prices prevailing in April, 1952)

Elevation of crest of dam: 910 feet, U.S.G.S. datum
Elevation of crest of spillway: 898 feet
Height of dam to spillway crest, above stream bed: 168 feet
Capacity of reservoir to crest of spillway: 38,000 acre-feet
Capacity of spillway with 4-foot freeboard: 10,000 second-feet

Item	Quantity	Unit price	Cost	
Capital Costs				
Dam				
Unwatering and care of stream		lump sum	$10,000	
Stripping and preparation of foundation				
Common	37,570 cu. yd.	$1.00	37,600	
Rock	7,760 cu. yd.	3.00	23,300	
Excavation for embankment				
From borrow pits	338,200 cu. yd.	0.45	152,200	
Tailings	451,900 cu. yd.	0.45	203,400	
Sand and gravel filter	101,200 cu. yd.	1.50	151,800	
Embankment				
Impervious from borrow	294,000 cu. yd.	0.25	73,500	
Sand and gravel filter	101,200 cu. yd.	0.50	50,600	
Tailings	451,900 cu. yd.	0.20	90,400	
Rock from salvage	71,600 cu. yd.	0.30	21,500	
Drilling grout holes	4,020 lin. yd.	3.00	12,100	
Pressure grouting	2,680 cu. ft.	4.00	10,700	$837,100
Spillway				
Excavation	86,620 cu. yd.	2.50	216,600	
Concrete	2,770 cu. yd.	35.00	97,000	
Reinforcing steel	207,000 lbs.	0.15	31,100	344,700
Outlet Works				
Excavation				
Common	200 cu. yd.	2.00	400	
Rock	1,980 cu. yd.	6.00	11,900	
Concrete				
Inlet structure	44 cu. yd.	100.00	4,400	
Trench backfill and cut-offs	1,590 cu. yd.	30.00	47,700	
Steel pipe, 42-inch diameter	112,000 lbs.	0.25	28,000	
Reinforcing steel	163,800 lbs.	0.15	24,600	
Capital Costs—Continued				
Outlet Works—Continued				
High pressure slide gates and controls, 30-inch diameter				
Trash rack steel	2 each	lump sum	$15,000	
Control house		lump sum	1,000	
Howell-Bunger outlet valve, 36-inch diameter		lump sum	1,000	
		lump sum	3,600	$137,600
Reservoir				
Land				
Improvements	906 acres	$125.00	$113,300	
Road to dam site		lump sum	60,000	
Clearing	2 miles	50,000	100,000	
	906 acres	150.00	135,900	409,200
Subtotal				$1,728,600
Administration and engineering, 10%				$172,900
Contingencies, 15%				259,300
Interest during construction				64,800
TOTAL				$2,225,600
Annual Costs				
Interest, 3%				$66,800
Amortization, 0.887%				19,700
Replacement, 0.07%				1,600
Operation and maintenance				6,300
TOTAL				$94,400

ESTIMATED COST OF FRENCH DRY CREEK DIVERSION AND CONDUIT

(Based on prices prevailing in April, 1952)

Elevation of crest of weir: 2,132 feet, U.S.G.S. datum
Height of crest of weir, above stream bed: 7 feet
Capacity of weir with 11-foot head: 10,000 second-feet
Capacity of diversion canal: 200 second-feet
Length of canal: 2 miles

Item	Quantity	Unit price	Cost	
Capital Costs				
Diversion Works				
Excavation	436 cu.yd.	$5.00	$2,200	
Concrete, weirs and headwall	363 cu.yd.	40.00	14,500	
Reinforcing steel	27,800 lbs.	0.15	4,200	
Trash rack steel	360 lbs.	0.30	100	
Headgates and sluice gate	3 each	1,000	3,000	$24,000
Conduit				
Excavation	12,680 cu.yd.	0.50	6,300	
Compacted fill	6,340 cu.yd.	0.50	3,200	
Shotcrete lining	21,100 sq.yd.	3.50	73,900	
Rights of way	15 acres	200.00	3,000	
Fencing	4 miles	1,500	6,000	
Clearing	15 acres	200.00	3,000	
Road crossings	3 each	500.00	1,500	96,900
Subtotal				$120,900
Capital Costs—Continued				
Administration and engineering, 10%				$12,100
Contingencies, 15%				18,100
Interest during construction, none				
TOTAL				$151,100
Annual Costs				
Interest, 3%				$4,500
Amortization, 0.887%				1,300
Replacement, 0.50%				800
Operation and maintenance, 1.0%				1,500
TOTAL				$8,100

ESTIMATED COST OF SOUTH HONCUT CREEK DIVERSION AND CONDUIT

(Based on prices prevailing in April, 1952)

Elevation of crest of weir: 609 feet, U.S.G.S. datum
Height of weir crest, above stream bed: 9 feet
Capacity of weir with 10-foot head: 10,000 second-feet
Capacity of conduit: 150 second-feet
Length of conduit: 4.7 miles

Item	Quantity	Unit price	Cost	
Capital Costs				
Diversion Works				
Excavation, rock	425 cu.yd.	$5.00	$2,100	
Concrete, weirs and headwall	518 cu.yd.	40.00	20,700	
Reinforcing steel	14,900 lbs.	0.15	2,200	
Trash rack steel	360 lbs.	0.30	100	
Headgates and sluice gate	3 each	1,000	3,000	$28,100
Conduit				
Excavation	35,200 cu.yd.	0.50	17,600	
Compacted fill	21,000 cu.yd.	0.50	10,500	
Shoterete lining	40,800 sq.yd.	3.50	142,800	
Siphon	1,500 lin.ft.	36.70	55,000	
Flume, metal	1,100 lin.ft.	23.40	25,800	
Rights of way	23.4 acres	200.00	4,700	
Fencing	9.4 miles	1,500	14,100	
Clearing	23.4 acres	200.00	4,700	275,200
Subtotal				$303,300
Capital Costs—Continued				
Administration and engineering, 10%				$30,300
Contingencies, 15%				45,500
Interest during construction, none				
TOTAL				$379,100
Annual Costs				
Interest, 3%				$11,400
Amortization, 0.887%				3,400
Replacement, 0.50%				1,900
Operation and maintenance, 1.0%				3,800
TOTAL				$20,500

ESTIMATED COST OF NORTHEAST ZONE DIVERSION, CONDUIT, AND DISTRIBUTION SYSTEM

(Based on prices prevailing in April, 1952)

Capacity of conduit: 75 second-feet at diversion, decreasing uniformly to 25 second-feet at terminus
Diversion: Temporary earthfill dam on Prairie Creek
Length of conduit: 6.3 miles
Distribution system: Unlined canals and ditches
Acreage served: 2,300 acres

Item	Quantity	Unit price	Cost	
Capital Costs				
Diversion Dam				
Stripping	60 cu.yd.	$1.00	$100	
Compacted fill	160 cu.yd.	1.00	200	$300
Subtotal				$300
Administration and engineering, 10%				$100
Contingencies, 15%				100
Interest during construction, none				
TOTAL				$500
Conduit				
Excavation	39,400 cu.yd.	$0.50	$19,700	
Compacted fill	30,800 cu.yd.	0.50	15,400	
Trimming	82,500 sq.yd.	0.30	24,800	
Concrete				
Shoterete, at road crossings	100 sq.yd.	3.50	1,400	
Reinforced, road crossings	80 cu.yd.	50.00	4,000	
Canal headwall and cutoff	15 cu.yd.	50.00	800	
Reinforcing steel	7,100 lbs.	0.15	1,100	
Headgate, 4′ x 5′ slide gate		lump sum	500	
Rights of way	46 acres	200.00	9,200	
Clearing	46 acres	200.00	9,200	
Fencing	12.6 miles	1,500	18,900	$105,000
Subtotal				$105,000
Administration and engineering, 10%				$10,500
Contingencies, 15%				15,800
Interest during construction, none				
TOTAL				$131,300
Capital Costs—Continued				
Distribution System	2,300 acres	$20.00	$46,000	$46,000
Subtotal				$46,000
Administration and engineering, 10%				$4,600
Contingencies, 15%				6,900
Interest during construction, none				
TOTAL				$57,500
Annual Costs				
Diversion Dam				
Construction cost				$500
Subtotal				$500
Conduit				
Interest, 3%				$3,900
Amortization, 0.887%				1,200
Replacement, 0.50%				700
Operation and maintenance, 1.0%				1,300
TOTAL				$7,100
Distribution System				
Interest, 3%				$1,700
Amortization, 0.887%				500
Operation and maintenance				
Ditch tender service, $0.50 per acre-foot				5,400
Maintenance charge, $0.40 per acre				900
District overhead, $0.50 per acre				1,200
TOTAL				$9,700

ESTIMATED COST OF BROWNS VALLEY DISTRIBUTION SYSTEM

(Based on prices prevailing in April, 1952)

Distribution system: Unlined canals and ditches — Acreage served: 2,600 acres

Item	Quantity	Unit price	Cost	
Capital Costs				
Distribution System	2,600 acres	$20.00	$52,000	$52,000
Subtotal				$52,000
Administration and engineering, 10%				$5,200
Contingencies, 15%				7,800
Interest during construction, none				
TOTAL				$65,000

Item	Quantity	Unit price	Cost
Annual Costs			
Interest, 3%			$2,000
Amortization, 0.887%			600
Operation and maintenance			
Ditch tender service, $0.80 per acre-foot			8,100
Maintenance charge, $0.60 per acre			1,600
District overhead, $0.80 per acre			2,100
TOTAL			$14,400

ESTIMATED COST OF CAMP FAR WEST DAM AND RESERVOIR

(Based on prices prevailing in April, 1952)

Elevation of crest of dam: 311 feet, U.S.G.S. datum
Elevation of crest of spillway: 300 feet
Height of dam to spillway crest, above stream bed: 155 feet
Capacity of reservoir to crest of spillway: 104,000 acre-feet
Capacity of spillway with 4-foot freeboard: 60,000 second-feet

Item	Quantity	Unit price	Cost	
Capital Costs				
Dam				
Diversion and care of stream		lump sum	$50,000	
Stripping and preparation of foundation	149,000 cu.yd.	$1.00	149,000	
Excavation for embankment				
From borrow pits	743,600 cu.yd.	0.65	483,300	
Stream bed gravel	1,243,100 cu.yd.	0.40	497,200	
Rock riprap	63,100 cu.yd.	2.00	126,200	
Embankment				
Common compacted	649,300 cu.yd.	0.25	162,300	
Pervious				
From excavation	1,055,600 cu.yd.	0.20	211,100	
From salvage	112,000 cu.yd.	0.30	33,600	
Sand and gravel filter	187,500 cu.yd.	0.50	93,800	
Rock riprap	63,100 cu.yd.	0.50	31,600	
Drilling grout holes	4,140 lin.ft.	3.00	12,400	
Pressure grouting	2,760 cu.ft.	4.00	11,000	$1,861,500
Spillway				
Excavation	200,000 cu.yd.	1.00	200,000	
Concrete	7,570 cu.yd.	35.00	265,000	
Reinforcing steel	559,400 lbs.	0.15	83,900	548,900
Outlet Works				
Tunnel, 8-foot diameter	950 lin.ft.	200.00	190,000	
Portal, excavation	8,500 cu.yd.	2.00	17,000	
Concrete (intake, gate chamber, saddles, plug, and walkway)	280 cu.yd.	60.00	16,800	

Item	Quantity	Unit price	Cost	
Capital Costs—Continued				
Outlet Works—Continued				
Reinforcing steel	28,000 lbs.	$0.15	$4,200	
Steel pipe, 66-inch diameter	210,000 lbs.	0.25	52,500	
High pressure 5′ x 5′ slide gate		lump sum	25,000	
Stilling basin		lump sum	8,800	
Needle valve				
60-inch diameter		lump sum	27,500	
36-inch diameter		lump sum	10,000	
Venturi meter		lump sum	5,000	$356,800
Reservoir				
Land and improvements	2,160 acres	$50.00	$108,000	
Clearing reservoir land	2,160 acres	100.00	216,000	$324,000
Subtotal				$3,091,200
Administration and engineering, 10%				$309,100
Contingencies, 15%				463,700
Interest during construction				115,900
TOTAL				$3,979,900
Annual Costs				
Interest, 3%				$119,400
Amortization, 0.887%				35,300
Replacement, 0.07%				2,800
Operation and maintenance				12,500
TOTAL				$170,000

ESTIMATED COST OF BEAR RIVER CANAL

(Based on prices prevailing in April, 1952)

Elevation of stilling basin: 187 feet, U.S.G.S. datum
Elevation of division box: 183 feet

Capacity of canal: 400 second-feet

Item	Quantity	Unit price	Cost	
Capital Costs				
Canal				
Excavation	43,600 cu. yd.	$1.50	$65,400	
Compacted fill	40,000 cu. yd.	0.50	20,000	
Lining, shoterete	24,000 sq. yd.	3.50	84,000	
Drainage structures	3 each	lump sum	1,500	$170,900
Division Box				
Excavation	230 cu. yd.	3.00	700	
Concrete	87 cu. yd.	60.00	5,200	
Gates and trash racks	4 each	600.00	2,400	8,300
Rights of Way				
Land	18 acres	50.00	900	
Clearing	18 acres	100.00	1,800	
Fencing	3 miles	1,500	4,500	7,200
Subtotal				$186,400
Administration and engineering, 10%				$18,600
Contingencies, 15%				28,000
Interest during construction, none				
TOTAL				$233,000
Annual Costs				
Interest, 3%				$7,000
Amortization, 0.887%				2,100
Replacement, 0.50%				1,200
Operation and maintenance, 1.0%				2,300
TOTAL				$12,600

ESTIMATED COST OF EAST CENTRAL ZONE SIPHON, CONDUIT, AND DISTRIBUTION SYSTEM

(Based on prices prevailing in April, 1952)

Capacity of siphon: 200 second-feet
Length of siphon: 800 feet
Capacity of conduit, initial 2.9 miles: 200 second-feet
Capacity of conduit, remaining 0.8 mile: 100 second-feet

Distribution system: Unlined canals and ditches
Acreage served: 8,500 acres

Item	Quantity	Unit price	Cost	
Capital Costs				
Siphon				
Excavation, trench	3,000 cu. yd.	$3.00	$9,000	
Backfill				
Concrete	540 cu. yd.	35.00	18,900	
Earth	1,800 cu. yd.	1.00	1,800	
Steel pipe, 66-inch diameter	140,500 lbs.	0.20	28,100	$57,800
Conduit				
Excavation	113,800 cu. yd.	0.50	56,900	
Trimming of canal	61,420 sq. yd.	0.30	18,400	
Compacted fill	16,780 cu. yd.	0.50	8,400	
Concrete				
Shoterete	9,060 sq. yd.	3.50	31,700	
Flume intake and outlet	40 cu. yd.	50.00	2,000	
Road crossings	63 cu. yd.	50.00	3,200	
Flume footings	20 cu. yd.	80.00	1,600	
Parshall flume	15 cu. yd.	70.00	1,100	
Reinforcing steel	11,800 lbs.	0.15	1,800	
Timber				
Road crossings	6.37 MBM	350.00	2,200	
Flume substructure	14.1 MBM	400.00	5,600	
Flume, metal	300 lin. ft.	30.00	9,000	
Flume, hardware	1,690 lbs.	1.00	1,700	
Rights of way	42 acres	200.00	8,400	
Clearing	42 acres	200.00	8,400	
Fencing	7.4 miles	1,500	11,100	$171,500
Subtotal				$229,300
Administration and engineering, 10%				22,900
Contingencies, 15%				34,400
Interest during construction, none				
TOTAL				$286,600
Distribution System	8,500 acres	$20.00	$170,000	$170,000
Subtotal				$170,000
Administration and engineering, 10%				17,000
Contingencies, 15%				25,500
Interest during construction, none				
TOTAL				$212,500
Annual Costs				
Siphon and Conduit				
Interest, 3%				$8,600
Amortization, 0.887%				2,500
Replacement, 0.50%				1,400
Operation and maintenance, 1.0%				2,900
TOTAL				$15,400
Distribution System				
Interest, 3%				$6,400
Amortization, 0.887%				1,900
Operation and maintenance				
Ditch tender service, $0.55 per acre-foot				16,500
Maintenance charge, $0.40 per acre				3,800
District overhead, $0.50 per acre				4,200
TOTAL				$32,800

ESTIMATED COST OF SOUTH SIDE ZONE CONDUIT AND DISTRIBUTION SYSTEM

(Based on prices prevailing in April, 1952)

Capacity of conduit, initial 11.0 miles: 200 second-feet
Capacity of conduit, remaining 7.8 miles: 100 second-feet

Distribution system: Unlined canals and ditches
Acreage served: 8,500 acres

Item	Quantity	Unit price	Cost	
Capital Costs				
Conduit				
Excavation	341,360 cu. yd.	$0.50	$155,700	
Compacted fill	81,840 cu. yd.	0.50	40,900	
Trimming	330,240 sq. yd.	0.30	99,100	
Concrete				
Shoterete	13,650 sq. yd.	3.50	47,800	
Flume transition structures	33 cu. yd.	50.00	1,700	
Road crossing	100 cu. yd.	50.00	5,000	
Substructure footings	20 cu. yd.	80.00	1,600	
Parshall flume	15 cu. yd.	70.00	1,100	
Siphon transition structure	30 cu. yd.	50.00	1,500	
Reinforcing steel	20,000 lbs.	0.15	3,000	
Timber				
Road crossings	12.5 MBM	350.00	4,400	
Flume substructure	11 MBM	400.00	4,400	
Flume, metal	420 lin. ft.	15.00	6,300	
Flume, hardware	1,320 lbs.	1.00	1,300	
Pipe, 48" corrugated metal	150 lin. ft.	20.00	3,000	
Jacking costs	100 lin. ft.	50.00	5,000	
Diversion dam at Markham Ravine		lump sum	1,500	
Rights of way	190 acres	300.00	57,000	
Fencing	37.6 miles	1,500	56,400	
Clearing	190 acres	200.00	38,000	$534,700
Subtotal				$534,700
Administration and engineering, 10%				53,500
Contingencies, 15%				80,200
Interest during construction, none				
TOTAL				$668,400

Item	Quantity	Unit price	Cost	
Capital Costs—Continued				
Distribution System	8,500 acres	$20.00	$170,000	$170,000
Subtotal				$170,000
Administration and engineering, 10%				17,000
Contingencies, 15%				25,500
Interest during construction, none				
TOTAL				$212,500
Annual Costs				
Conduit				
Interest, 3%				$20,100
Amortization, 0.887%				5,900
Replacement, 0.50%				3,300
Operation and maintenance, 1.0%				6,700
TOTAL				$36,000
Distribution System				
Interest, 3%				$6,400
Amortization, 0.887%				1,900
Operation and maintenance				
Ditch tender service, $0.55 per acre-foot				16,500
Maintenance charge, $0.40 per acre				3,800
District overhead, $0.50 per acre				4,200
TOTAL				$32,800

ESTIMATED COST OF COON CREEK DAM AND RESERVOIR

(Based on prices prevailing in April, 1952)

Elevation of crest of dam: 560 feet, U.S.G.S. datum
Elevation of crest of spillway: 552 feet
Height of dam to spillway crest, above stream bed: 207 feet
Capacity of reservoir to crest of spillway: 59,000 acre-feet
Capacity of spillway with 4-foot freeboard: 14,000 second-feet

Item	Quantity	Unit price	Cost	
Capital Costs				
Dam				
Diversion and care of stream		lump sum	$5,000	
Stripping and preparation of foundation	304,200 cu.yd.	$1.50	456,300	
Excavation for embankment				
From borrow pits	903,900 cu.yd.	0.75	677,900	
From Bear River, gravel	1,245,230 cu.yd.	0.75	933,900	
Embankment				
Impervious zone, compacted	786,040 cu.yd.	0.25	196,500	
Pervious zone				
From excavation	1,130,730 cu.yd.	0.20	226,100	
From salvage	128,300 cu.yd.	0.30	38,500	
Sand and gravel filter	115,500 cu.yd.	0.50	57,700	
Rock riprap (from salvage)	40,500 cu.yd.	0.50	20,300	
Drilling grout holes	8,400 lin.ft.	3.00	25,200	
Pressure grouting	5,600 cu.ft.	4.00	22,400	$2,659,800
Auxiliary Dams				
Stripping and preparation of foundation	55,260 cu.yd.	1.50	82,900	
Excavation for embankment				
From borrow pits	180,160 cu.yd.	0.75	135,100	
From quarry	251,410 cu.yd.	0.75	188,600	
Embankment				
Impervious zone	156,660 cu.yd.	0.25	39,200	
Pervious zone				
From excavation	176,510 cu.yd.	0.20	35,300	
From salvage	22,800 cu.yd.	0.30	6,800	
Sand and gravel filter	74,900 cu.yd.	0.50	37,400	
Rock riprap (from salvage)	17,900 cu.yd.	0.50	9,000	
Drilling grout holes	3,400 lin.ft.	3.00	10,200	
Pressure grouting	2,260 cu.ft.	4.00	9,000	553,500
Capital Costs—Continued				
Spillway				
Excavation	2,600 cu.yd.	$2.00	$5,200	
Concrete	3,962 cu.yd.	30.00	119,000	
Reinforcing steel	98,600 lbs.	0.15	14,800	$139,000
Outlet Works				
Excavation	2,000 cu.yd.	5.00	10,000	
Concrete				
Trench backfill	1,000 cu.yd.	30.00	30,000	
Intake structure	50 cu.yd.	100.00	5,000	
Outlet structure	20 cu.yd.	100.00	2,000	
Reinforcing steel	110,000 lbs.	0.15	16,500	
Steel pipe, 48-inch diameter ¼" plate	127,500 lbs.	0.25	31,900	
High pressure slide gates and controls, 30-inch diameter	2 each	lump sum	17,000	
Howell-Bunger valve, 42-inch diameter	1 each	lump sum	7,600	120,000
Reservoir				
Land and improvements	820 acres	75.00	61,500	
Clearing	820 acres	200.00	164,000	
Road across dam		lump sum	10,000	235,500
Subtotal				$3,707,800
Administration and engineering, 10%				370,800
Contingencies, 15%				556,100
Interest during construction				139,000
TOTAL				$4,773,700
Annual Costs				
Interest, 3%				$143,200
Amortization, 0.887%				41,200
Replacement, 0.07%				3,300
Operation and maintenance				8,500
TOTAL				$196,200

ESTIMATED COST OF COON CREEK DIVERSION, CONDUIT, AND DISTRIBUTION SYSTEM

(Based on prices prevailing in April, 1952)

Capacity of conduit: 100 second-feet
Length of conduit: 7.8 miles
Canal lined for first 0.5 mile

Distribution system: Unlined canals and ditches
Acreage served: 12,000 acres

Item	Quantity	Unit price	Cost	
Capital Costs				
Diversion Structure				
Stripping	320 cu.yd.	$0.50	$200	
Embankment	900 cu.yd.	0.50	400	
Timber, flashboards	1.2 MBM	250.00	300	
Crane for removing flashboards		lump sum	1,000	$1,900
Levee				
Stripping	1,500 cu.yd.	0.50	800	
Embankment	2,000 cu.yd.	0.50	1,000	
Concrete headwall and wing walls	22 cu.yd.	60.00	1,300	
Reinforcing steel	2,200 lbs.	0.15	300	
Headgate, 4' x 5'		lump sum	500	3,900
Conduit				
Excavation	72,810 cu.yd.	0.50	36,400	
Compacted fill	32,740 cu.yd.	0.50	16,400	
Trimming	101,830 sq.yd.	0.30	30,500	
Concrete				
Shotcrete	5,330 sq.yd.	3.50	18,700	
Flume transition structures	16 cu.yd.	50.00	800	
Road crossings	60 cu.yd.	50.00	3,000	
Substructure footings	4 cu.yd.	80.00	300	
Siphon transition structure	30 cu.yd.	50.00	1,500	
Reinforcing steel	14,000 lbs.	0.15	2,100	
Timber				
Road crossings	7.5 MBM	350.00	2,600	
Flume substructure	2.6 MBM	400.00	1,000	
Flume, metal	100 lin.ft.	15.00	1,500	
Flume hardware	310 lbs.	1.00	300	
Pipe, 48-inch corrugated metal	150 lin.ft.	20.00	3,000	
Jacking costs	100 lin.ft.	50.00	5,000	
Diversion dam at Markham Ravine		lump sum	1,500	
Rights of way	60 acres	300.00	18,000	
Fencing	15.6 miles	1,500	23,400	
Clearing	60 acres	200.00	12,000	178,000
Subtotal				$183,800
Capital Costs—Continued				
Administration and engineering, 10%				$18,400
Contingencies, 15%				27,600
Interest during construction, none				
TOTAL				$229,800
Distribution System	12,000 acres	$20.00	$240,000	$240,000
Subtotal				$240,000
Administration and engineering, 10%				24,000
Contingencies, 15%				36,000
Interest during construction, none				
TOTAL				$300,000
Annual Costs				
Diversion and Conduit				
Interest, 3%				$6,900
Amortization, 0.887%				2,000
Replacement, 0.50%				1,100
Operation and maintenance, 1.0%				2,300
TOTAL				$12,300
Distribution System				
Interest, 3%				$9,000
Amortization, 0.887%				2,700
Operation and maintenance				
Ditch tender service, $0.55 per acre-foot				23,100
Maintenance charge, $0.40 per acre				4,800
District overhead, $0.50 per acre				6,000
TOTAL				$45,600

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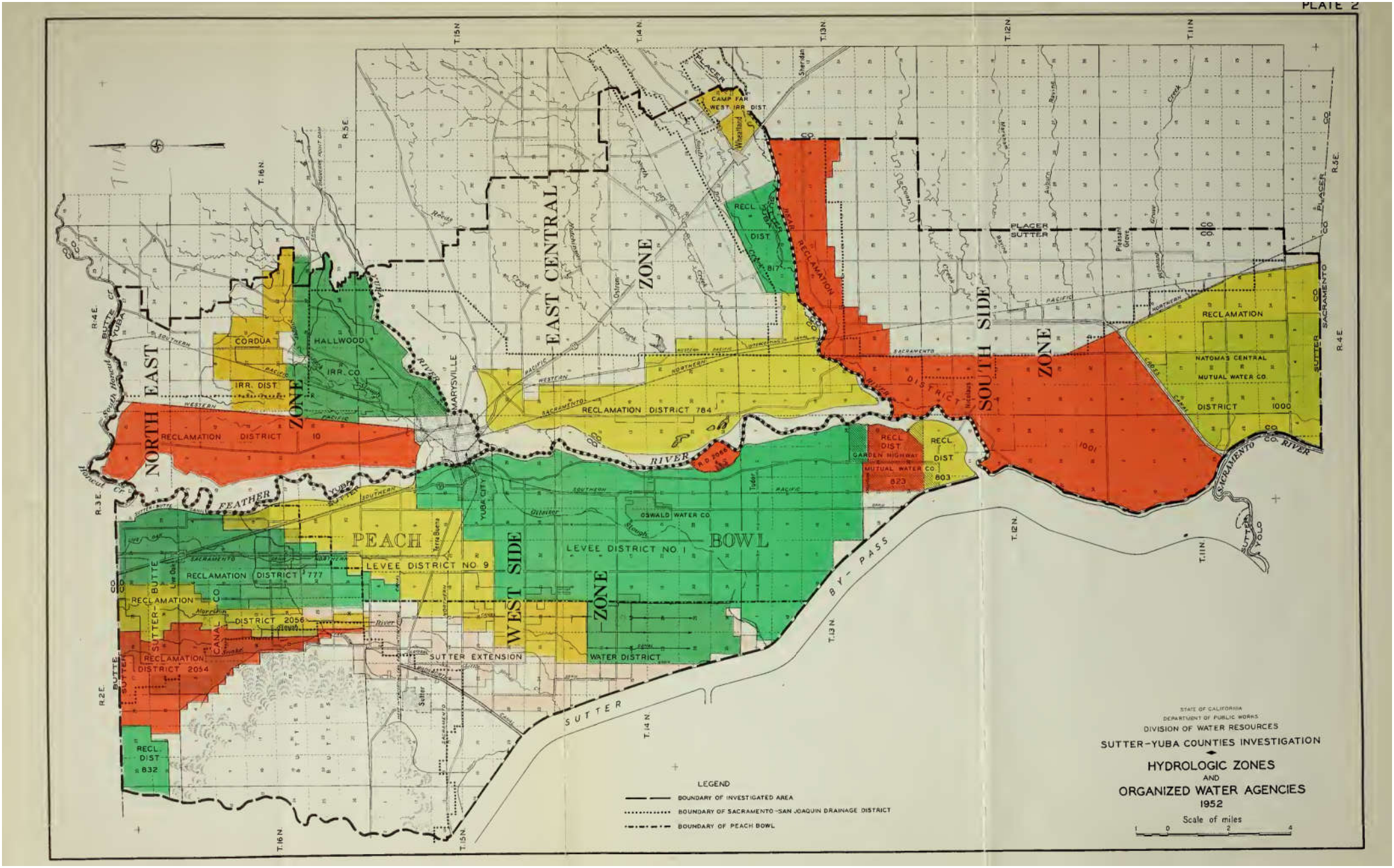
PLATE 1


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LOCATION OF
SUTTER-YUBA AREA
1952
OREGON
NEVADA
PACIFIC OCEAN
MEXICO
SISKIYOU
MODOC
TRINITY
SHASTA
LASSEN
HUMBOLDT
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
COLUSA
LAKE
NEVADA
PLACER
SONOMA
YOLO
SACRAMENTO
EL DORADO
ALPINE
MARIN
SOLANO
CONTRA COSTA
SAN FRANCISCO
ALAMEDA
AMADOR
CALAVERAS
TUOLUMNE
MONO
SAN MATEO
SANTA CLARA
SAN JOAQUIN
STANISLAUS
MARIPOSA
INYO
SANTA CRUZ
SAN BENITO
MERCED
MADERA
FRESNO
TULARE
MONTEREY
KINGS
KERN
SAN LUIS OBISPO
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL

PLATE 2



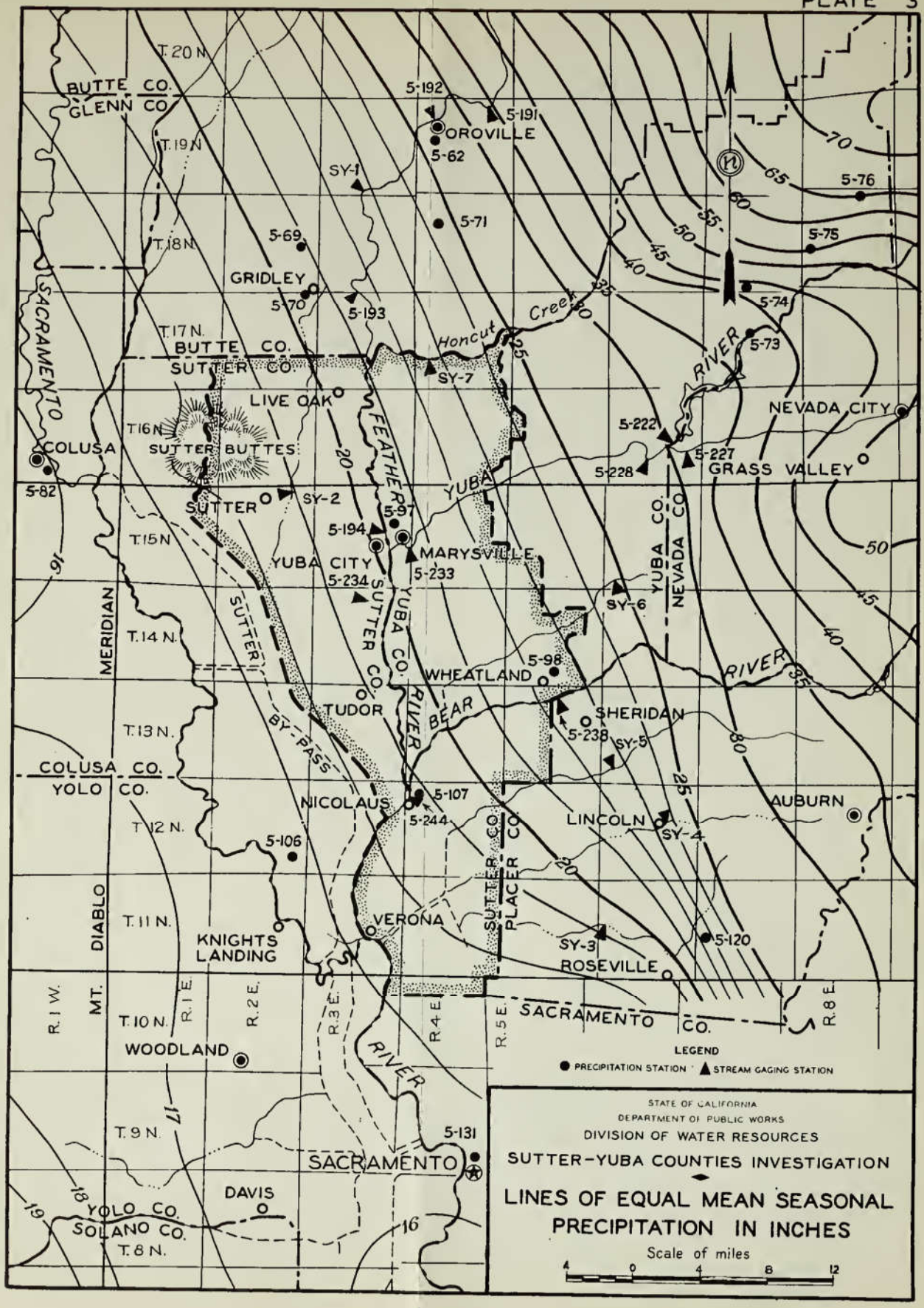
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

SUTTER-YUBA COUNTIES INVESTIGATION

HYDROLOGIC ZONES AND ORGANIZED WATER AGENCIES 1952

Scale of miles

PLATE 3



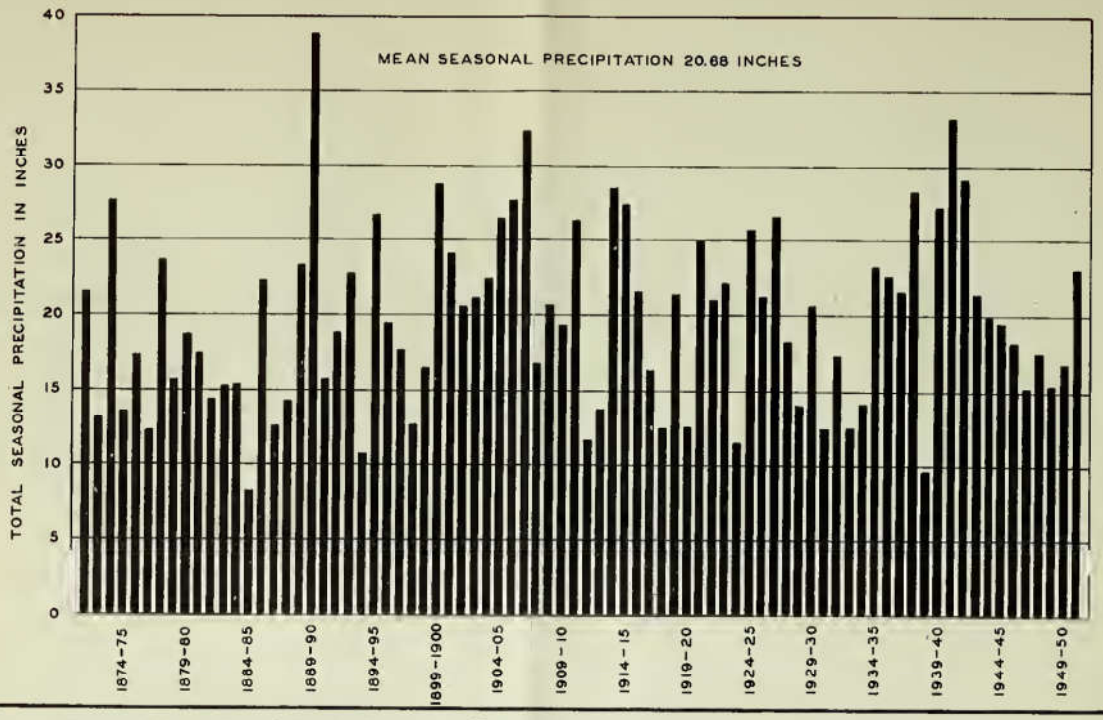
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION

LINES OF EQUAL MEAN SEASONAL PRECIPITATION IN INCHES

Scale of miles

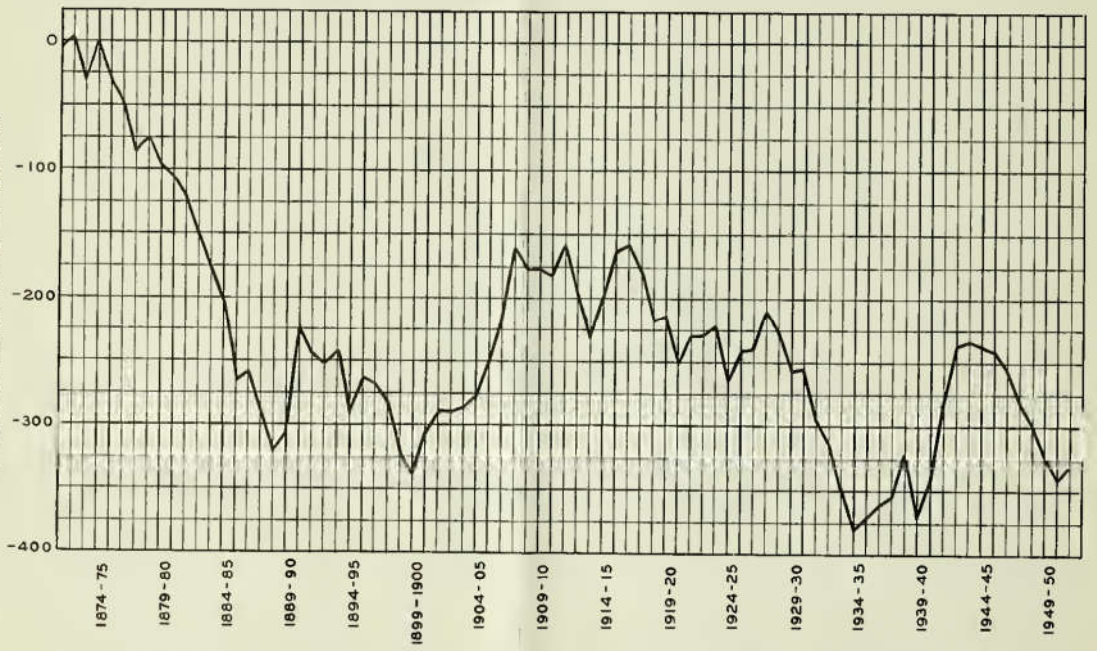
4 0 4 8 12

PLATE 4

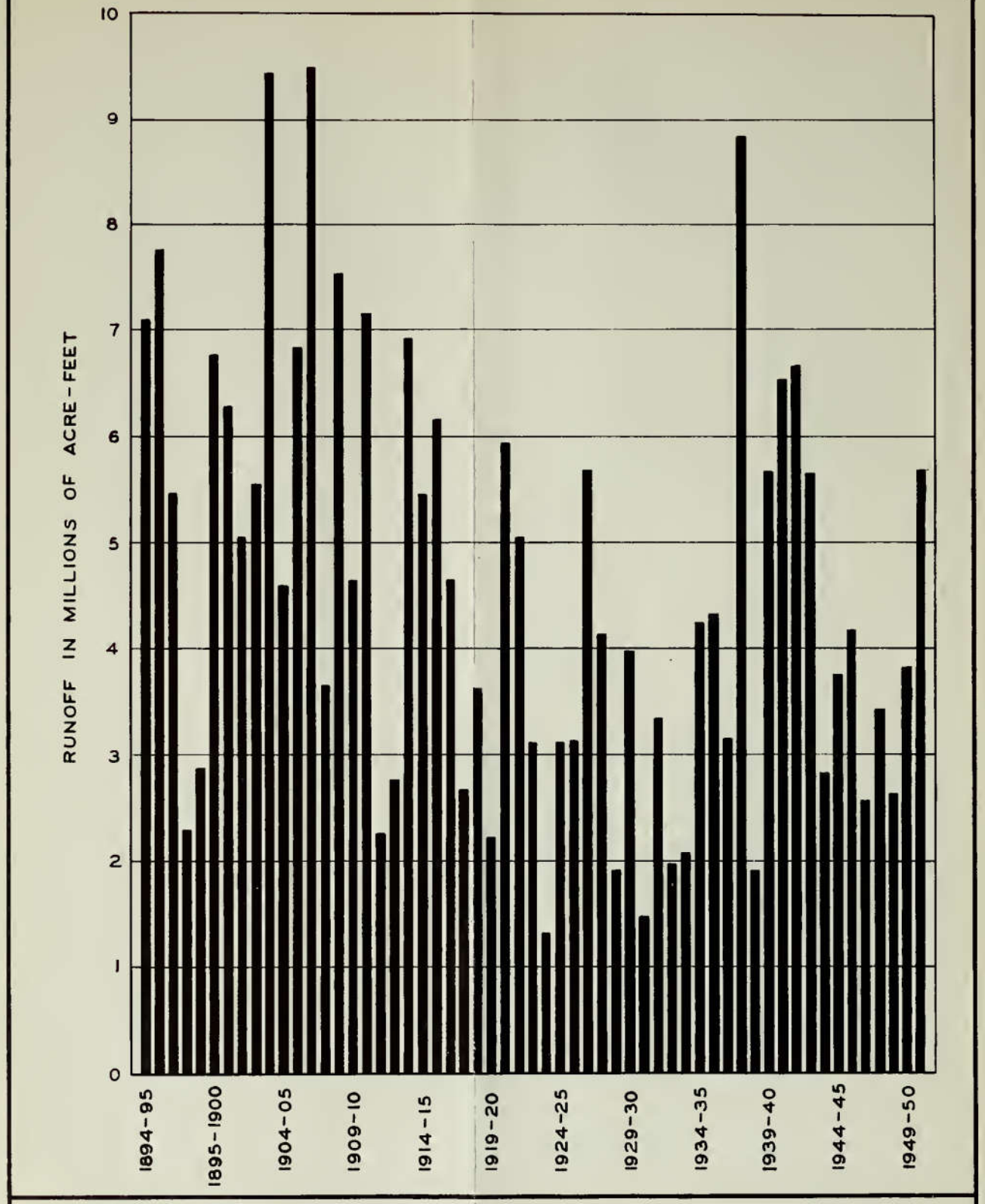


RECORDED SEASONAL PRECIPITATION AT MARYSVILLE

PLATE 5

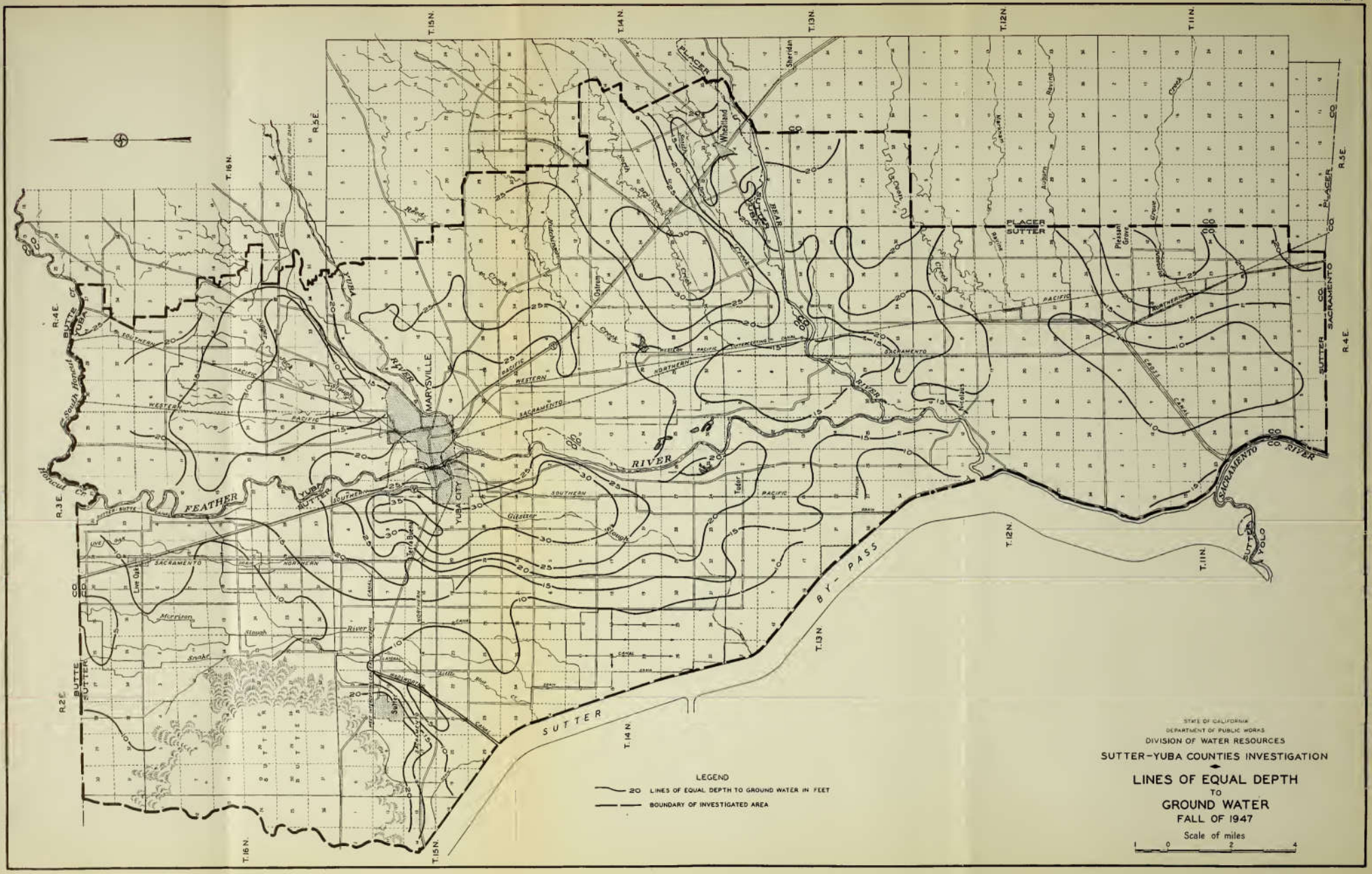


ACCUMULATED DEPARTURE FROM MEAN SEASONAL PRECIPITATION AT MARYSVILLE



ESTIMATED SEASONAL NATURAL RUNOFF OF FEATHER RIVER AT OROVILLE

PLATE 7



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LINES OF EQUAL DEPTH
TO
GROUND WATER
FALL OF 1947
Scale of miles
1 0 2 4
LEGEND
20 LINES OF EQUAL DEPTH TO GROUND WATER IN FEET
BOUNDARY OF INVESTIGATED AREA
MARYSVILLE
YUBA CITY
FEATHER
RIVER
SUTTER
BY-PASS
SACRAMENTO
PLACER
SUTTER
YUBA
BUTTE
YOLO
Wheatland
Sheridan
Pleasant Grove
Nicolaus
Tudor
Live Oak
Sutter
Ostrum
T.16N.
T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
R.2E.
R.3E.
R.4E.
R.5E.

PLATE 8

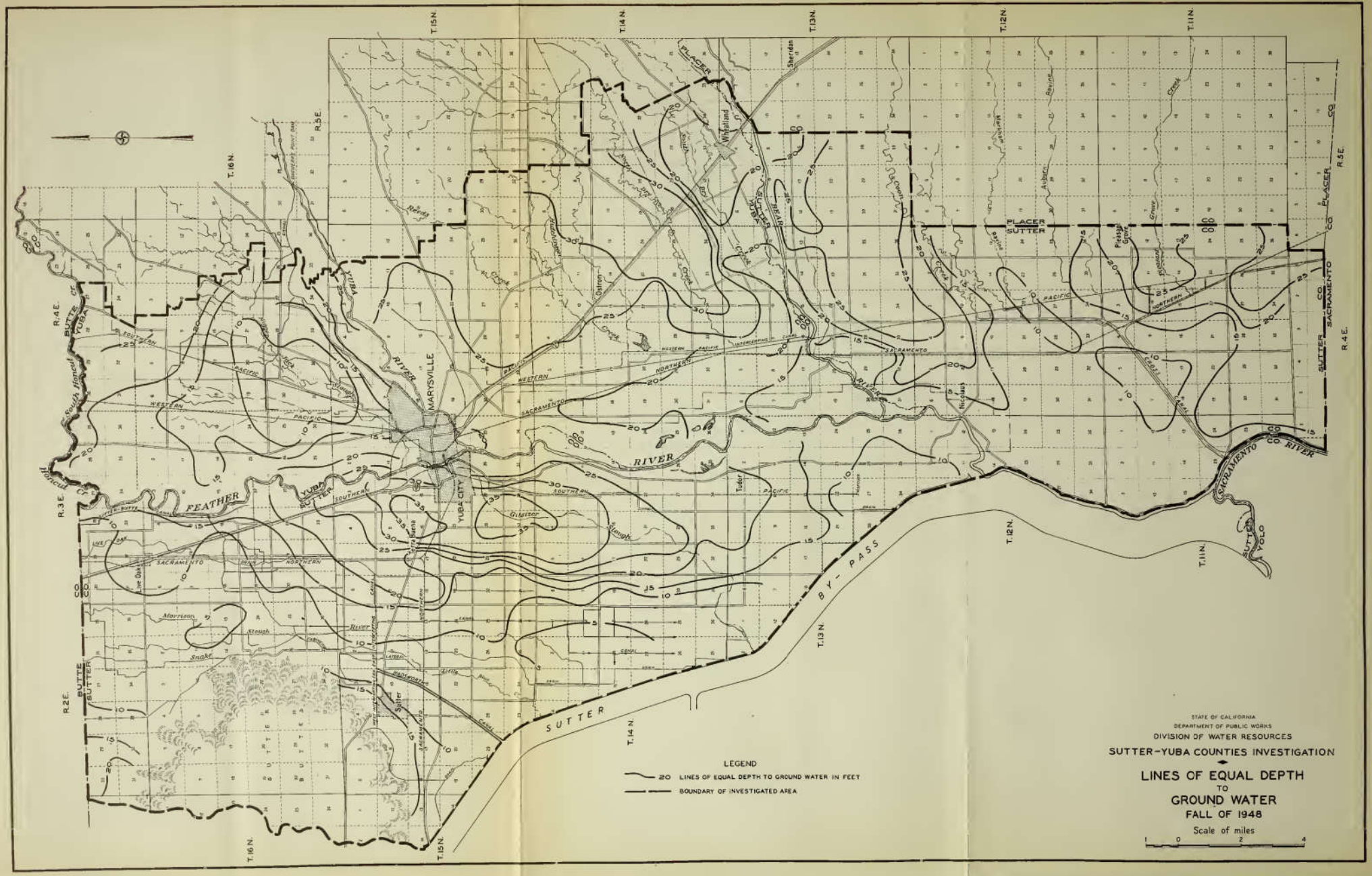
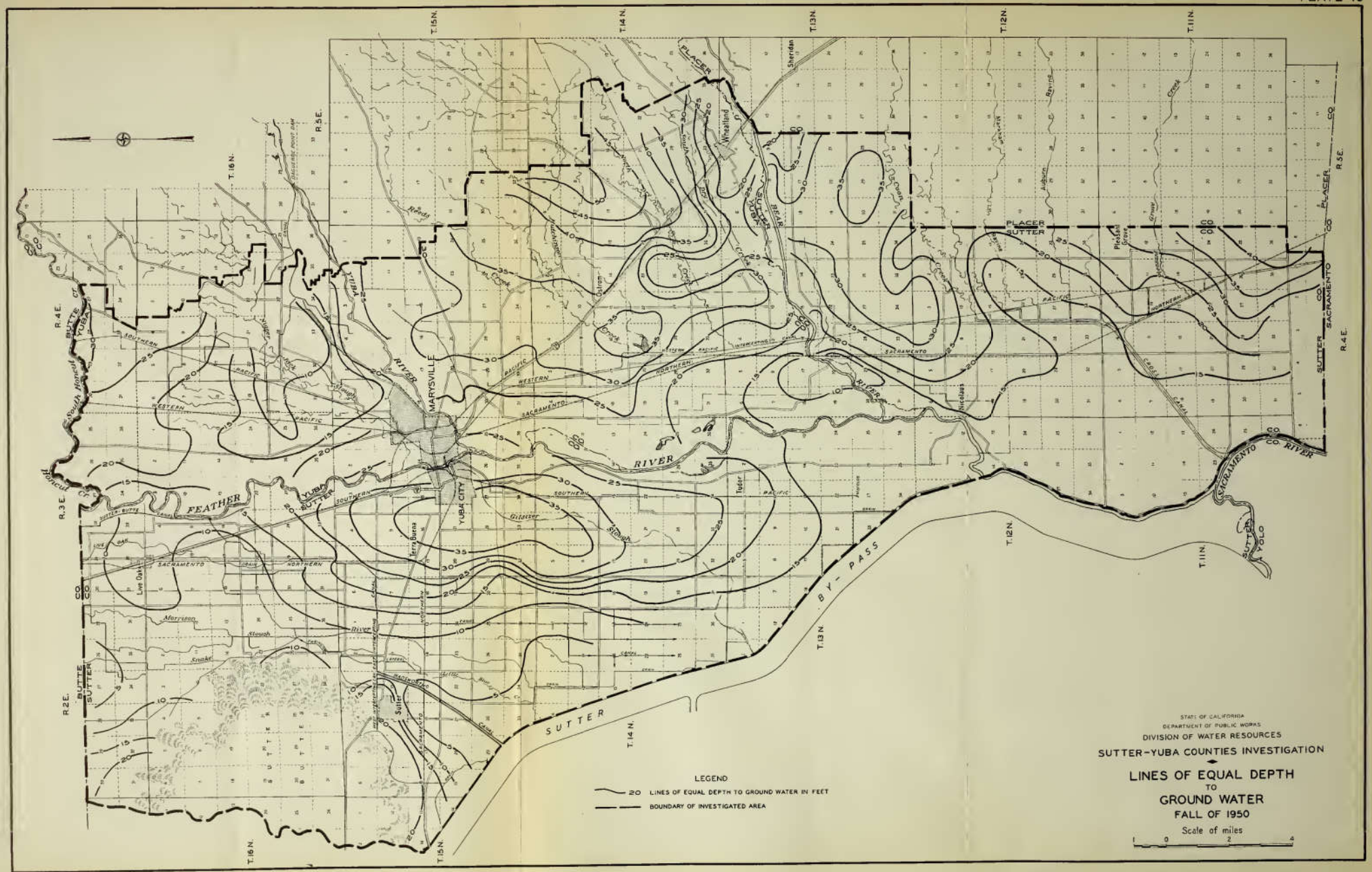

LEGEND
20 LINES OF EQUAL DEPTH TO GROUND WATER IN FEET
BOUNDARY OF INVESTIGATED AREA
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LINES OF EQUAL DEPTH
TO
GROUND WATER
FALL OF 1948
Scale of miles
0 2 4
MARYSVILLE
YUBA CITY
FEATHER RIVER
YUBA RIVER
BUTTE CREEK
SUTTER BY-PASS
PLACER
SUTTER
YUBA
BUTTE
SACRAMENTO
COLUSA
T.16N.
T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
R.2E.
R.3E.
R.4E.
R.5E.

PLATE 9



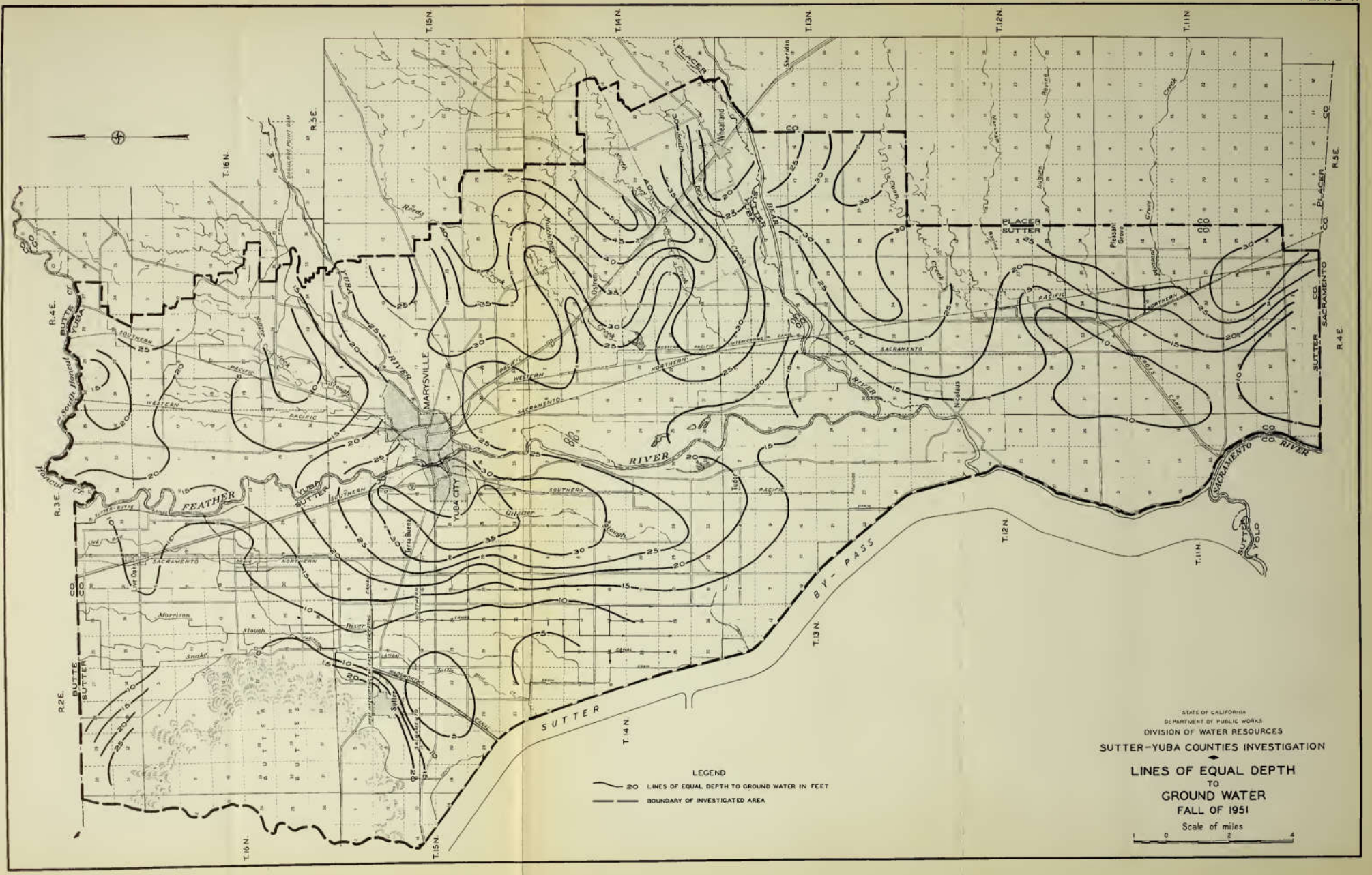
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LINES OF EQUAL DEPTH
TO
GROUND WATER
FALL OF 1949
Scale of miles
1 0 2 4
LEGEND
20 LINES OF EQUAL DEPTH TO GROUND WATER IN FEET
BOUNDARY OF INVESTIGATED AREA
MARYSVILLE
YUBA CITY
FEATHER
RIVER
SUTTER
BY-PASS
SACRAMENTO
RIVER
PLACER
SUTTER
YUBA
BUTTE
SACRAMENTO
YOLO
Wheatland
Sheridan
Nicolaus
Tudor
Live Oak
Terra Buena
Sutter
Pleasant Grove
Ostrom
Gilsizer Slough
Morrison
Snake
Stough
Reeds
Creek
Auburn
Ravine
Grove
Cross Canal
Sacramento Northern Pacific
Western Pacific
Southern Pacific
Sutter Butte Canal
Live Oak Canal
Wadsworth Canal
Little Bear Canal
Sacramento Northern Canal
Gilsizer Slough
Nicolaus Canal
Tudor Canal
Sacramento Northern Canal
Sutter Butte Canal
Yuba Sutter Canal
South Honcut Cr.
Honcut Cr.
T.16N.
T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
R.2E.
R.3E.
R.4E.
R.5E.

PLATE 10



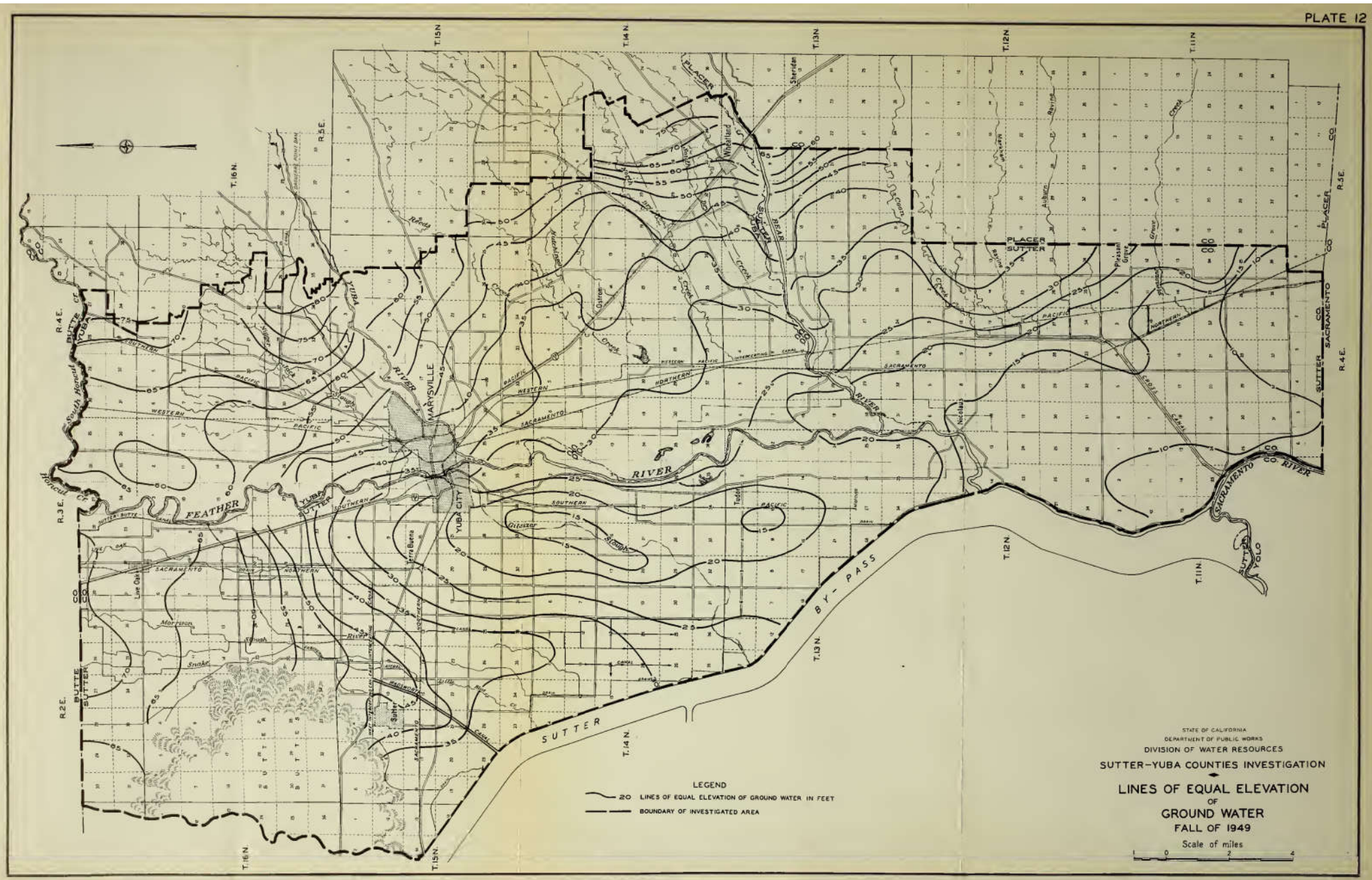
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LINES OF EQUAL DEPTH
TO
GROUND WATER
FALL OF 1950
Scale of miles
1 0 2 4
LEGEND
20 LINES OF EQUAL DEPTH TO GROUND WATER IN FEET
BOUNDARY OF INVESTIGATED AREA
MARYSVILLE
YUBA CITY
FEATHER RIVER
SUTTER BY-PASS
SACRAMENTO RIVER
BEAR RIVER
Wheatland
Sheridan
Nicolaus
Tudor
Live Oak
Sutter
Terra Buena
Pleasant Grove
Ostrom
Gilsizer Slough
Morrison Slough
Snake River
South Honcut Cr.
Honcut Cr.
PLACER CO.
SUTTER CO.
YUBA CO.
BUTTE CO.
SACRAMENTO CO.
YOLO CO.
T.16N.
T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
R.2E.
R.3E.
R.4E.
R.5E.

PLATE II

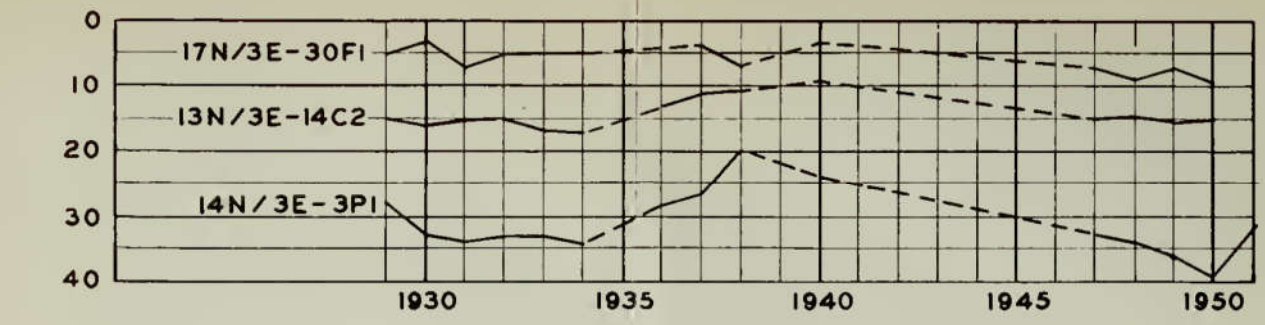


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LINES OF EQUAL DEPTH
TO
GROUND WATER
FALL OF 1951
Scale of miles
LEGEND
20 LINES OF EQUAL DEPTH TO GROUND WATER IN FEET
BOUNDARY OF INVESTIGATED AREA
MARYSVILLE
YUBA CITY
FEATHER
RIVER
SUTTER
BY-PASS
SACRAMENTO
YUBA
BEAR
PLACER
SUTTER
YOLO
Wheatland
Nicolaus
Sheridan
Live Oak
Terra Buena
Tudor
Pleasant Grove
T.16N.
T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
R.2E.
R.3E.
R.4E.
R.5E.

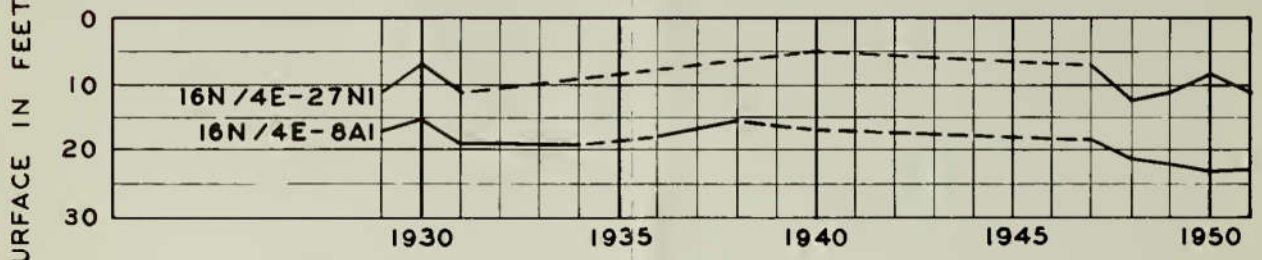
PLATE 12



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
LINES OF EQUAL ELEVATION
OF
GROUND WATER
FALL OF 1949
Scale of miles
1 0 2 4
LEGEND
20 LINES OF EQUAL ELEVATION OF GROUND WATER IN FEET
BOUNDARY OF INVESTIGATED AREA
MARYSVILLE
YUBA CITY
Wheatland
Sheridan
Nicolaus
Tudor
Terra Buena
Live Oak
Sutter
FEATHER
RIVER
YUBA
SUTTER
BY-PASS
SACRAMENTO
PLACER
BUTTE
YOLO
T.16N.
T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
R.2E.
R.3E.
R.4E.
R.5E.

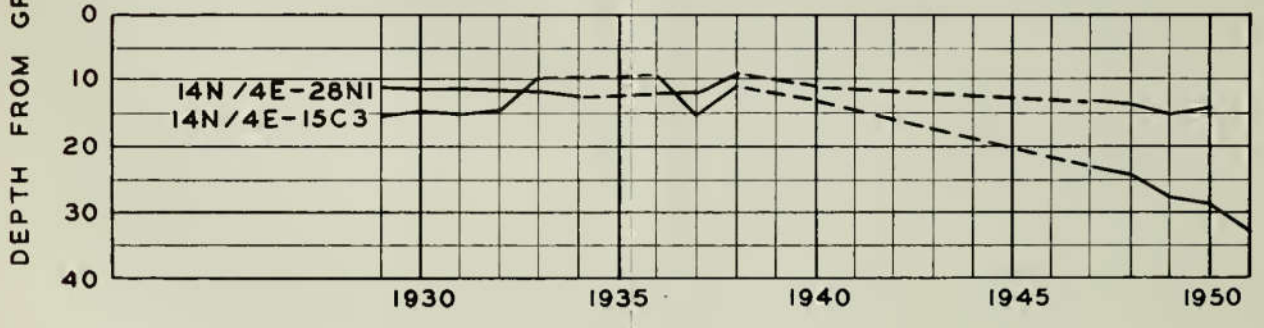


WEST SIDE ZONE

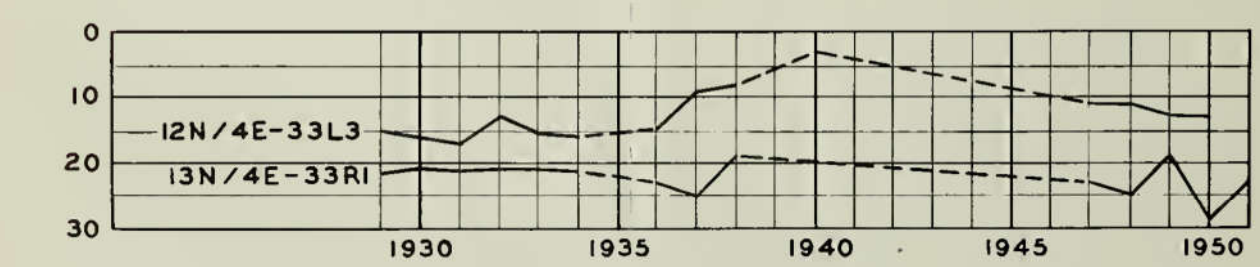


NORTHEAST ZONE

DEPTH FROM GROUND SURFACE IN FEET



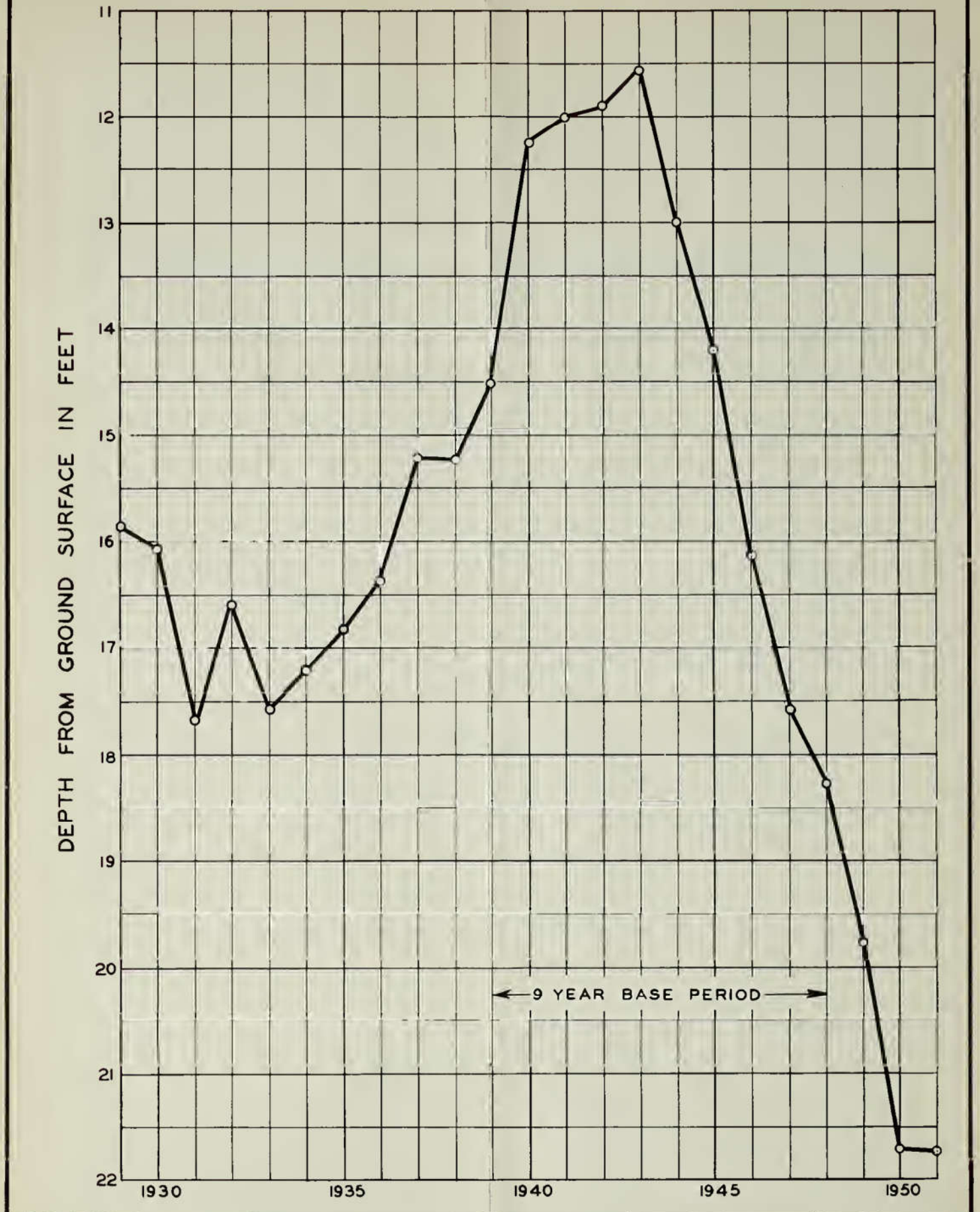
EAST CENTRAL ZONE



SOUTH SIDE ZONE

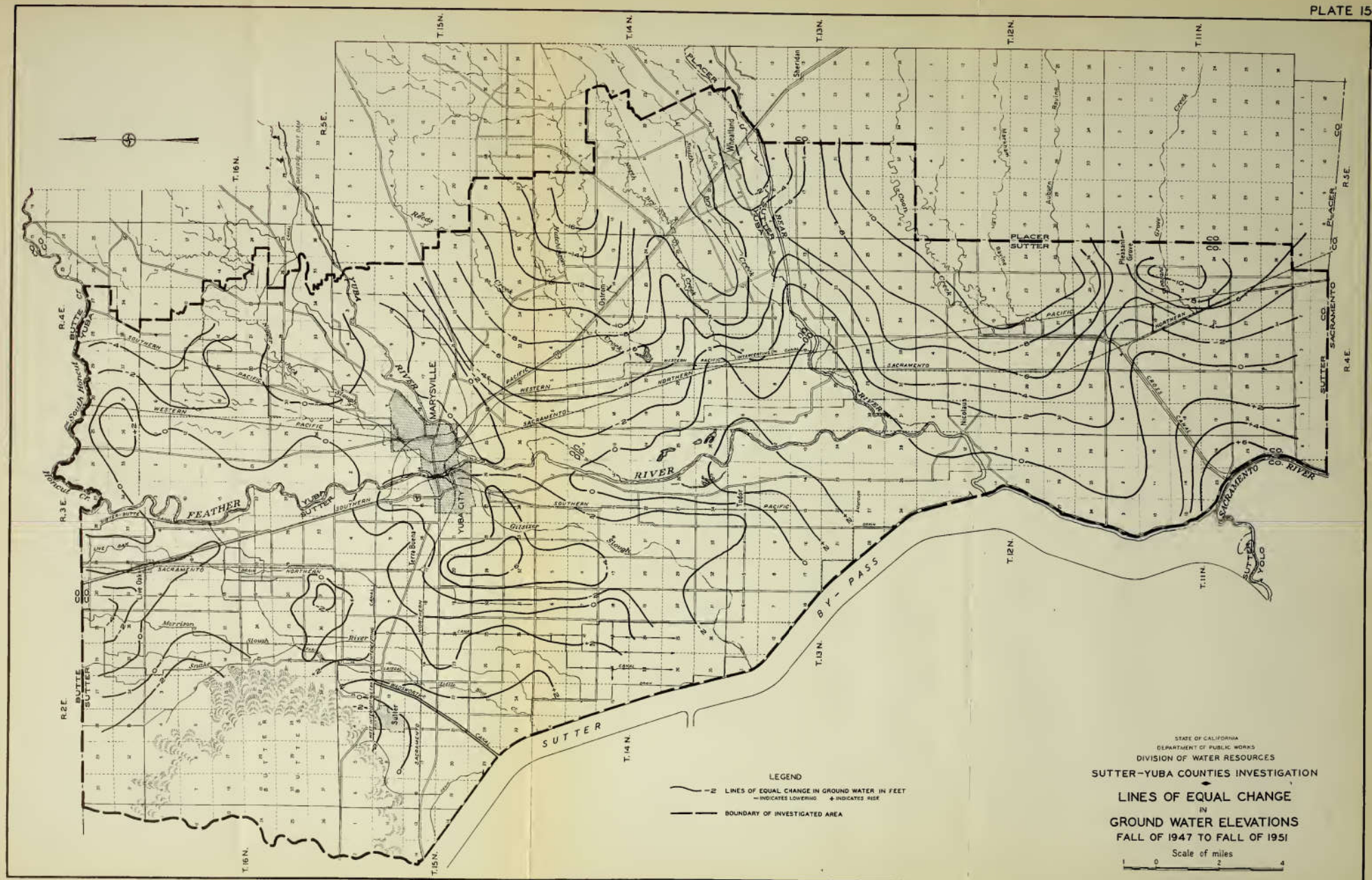
– – – – – – – INTERPOLATED DEPTHS

MEASURED FALL DEPTHS TO GROUND WATER AT REPRESENTATIVE WELLS



AVERAGE FALL DEPTH TO GROUND WATER

PLATE 15



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION

LINES OF EQUAL CHANGE IN GROUND WATER ELEVATIONS FALL OF 1947 TO FALL OF 1951

Scale of miles
1 0 2 4

PLATE 18

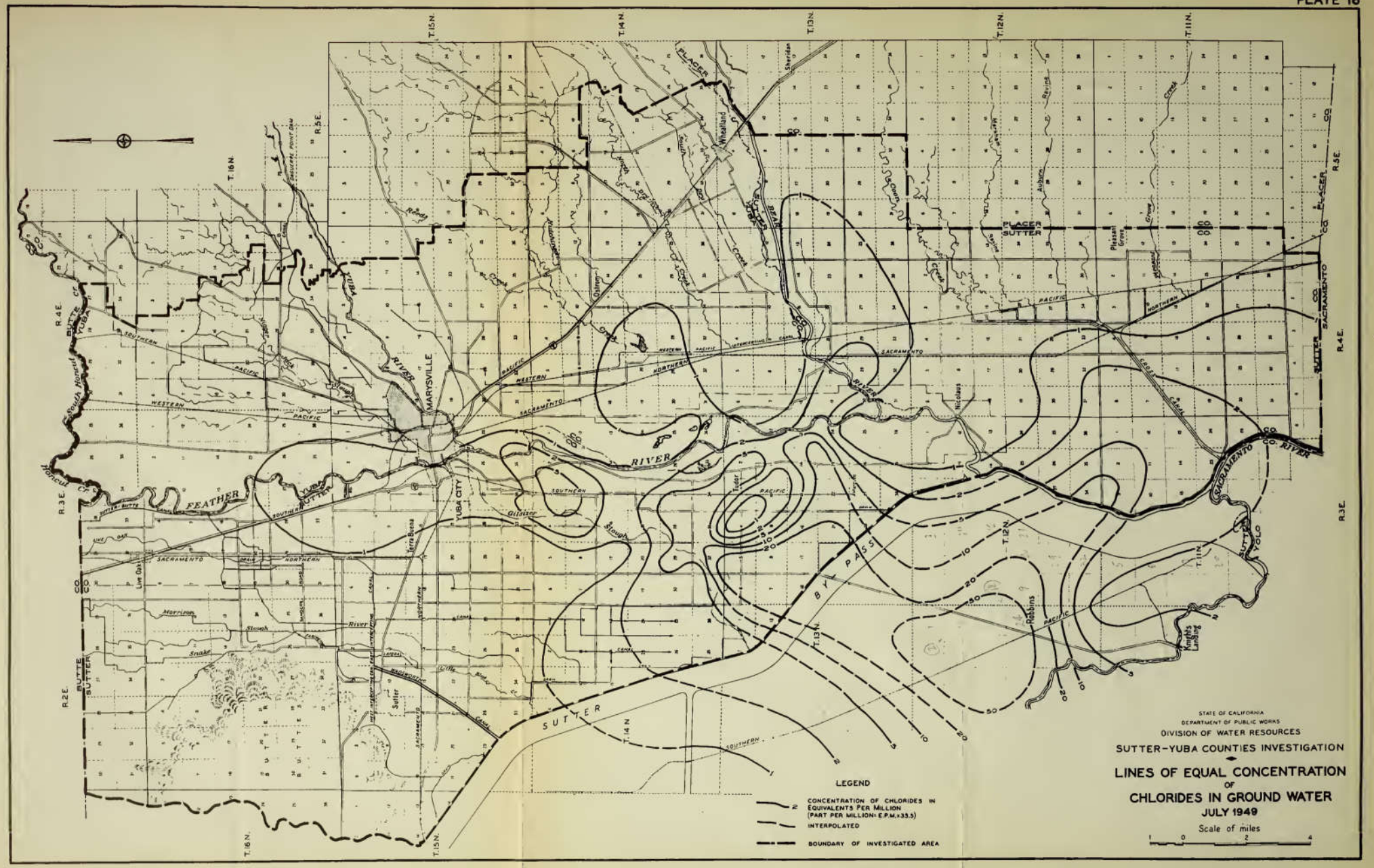
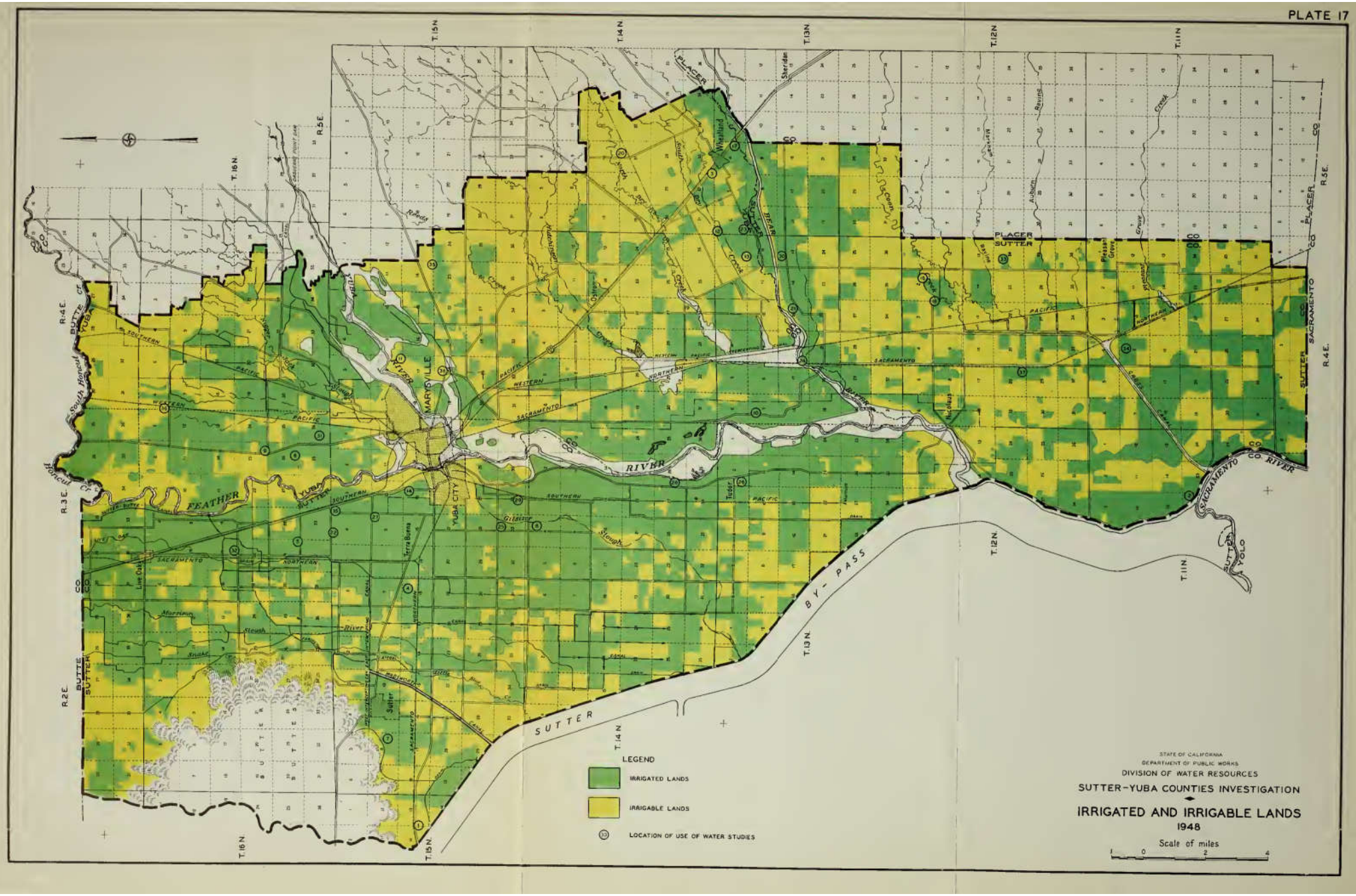

T.15N.
T.14N.
T.13N.
T.12N.
T.11N.
T.16N.
R.5E.
R.4E.
R.3E.
R.2E.
PLACER
SUTTER
YUBA
BUTTE
SACRAMENTO
YUBA CITY
MARYSVILLE
FEATHER RIVER
BEAR RIVER
BY PASS
SUTTER BUTTES
Wheatland
Sheridan
Auburn
Ravine
Pleasant Grove Creek
Dry Creek
Bear River
Honcut Creek
Gilsizer Slough
Live Oak
Morrison Slough
Snake River
Sutter Canal
Robbins
Knights Landing
Tudor
Nicolaus
Cross Canal
Pacific
Southern Pacific
Western Pacific
Northern Pacific
Sacramento Northern
Southern Pacific Co. Lighterage Canal
Sutter-Butte Canal
Sacramento Co. River
Yuba Co. River
Sutter Co. River
Placer Co. River

PLATE 17



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

SUTTER-YUBA COUNTIES INVESTIGATION

IRRIGATED AND IRRIGABLE LANDS
1948

Scale of miles
1 0 2 4

PLATE 18

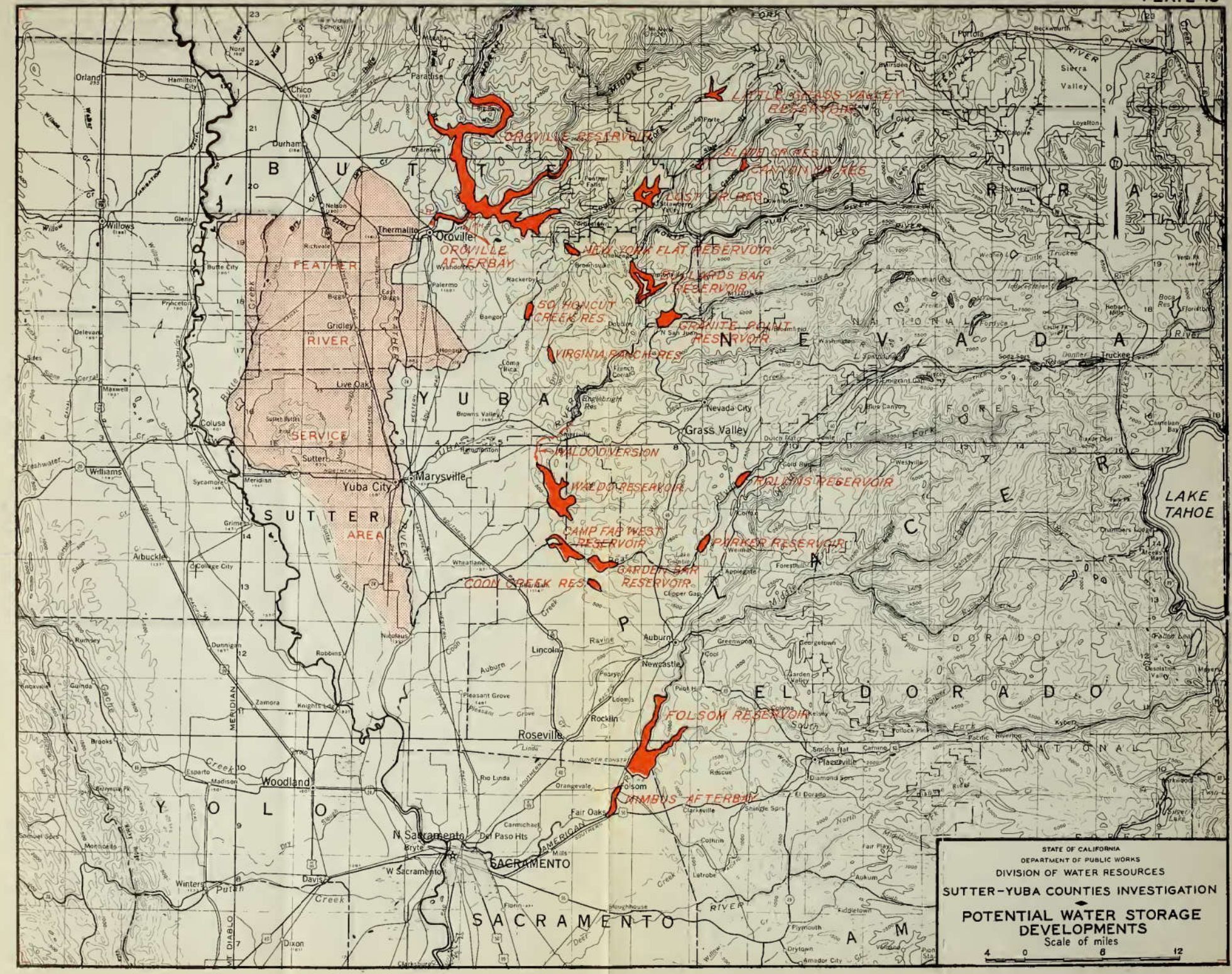
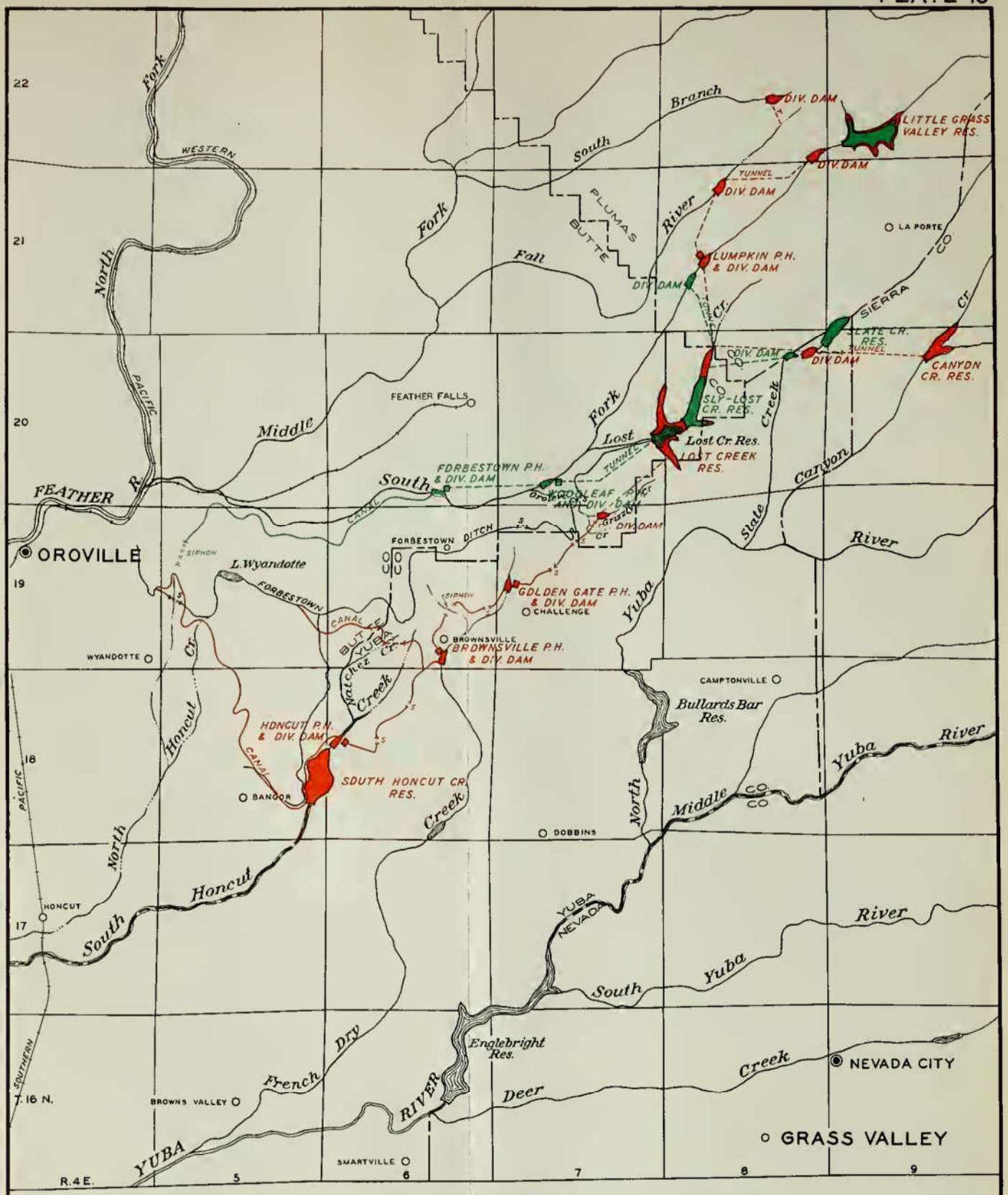

LITTLE GRASS VALLEY RESERVOIR
OROVILLE RESERVOIR
SLATE CREEK CANYON RES
LAST CHANCE RES
OROVILLE AFTERBAY
NEW YORK FLAT RESERVOIR
BULLARDS BAR RESERVOIR
SO. HONCUT CREEK RES
GRANITE POINT RESERVOIR
VIRGINIA RANCH RES
FEATHER RIVER SERVICE AREA
WILD DIVERSION
WILD RESERVOIR
ROLLINS RESERVOIR
CAMP FAR WEST RESERVOIR
PARKER RESERVOIR
GARDEN BAR RESERVOIR
COON CREEK RES
FOLSOM RESERVOIR
NIMBUS AFTERBAY
LAKE TAHOE
BUTTE
YUBA
SUTTER
YOLO
SACRAMENTO
EL DORADO
PLACER
NEVADA
Oroville
Marysville
Yuba City
Grass Valley
Nevada City
Truckee
Auburn
Roseville
Folsom
Woodland
Davis
Winters
Dixon
Sacramento
N. Sacramento
W. Sacramento
Colusa
Willows
Chico
Orland
Durham
Paradise
Thermalito
Gridley
Live Oak
Sutter
Yuba City
Williams
Arbuckle
College City
Lincoln
Rocklin
Newcastle
Loomis
Pleasant Grove
Rio Linda
Elverta
Folsom
Placerville
Diamond Springs
El Dorado
Shingle Springs
Cameron Park
Meyers
Kyburz
Strawberry
Tahoe City
Kings Beach
Incline Village
Crystal Bay
Carnelian Bay
Tahoe Vista
Homewood
Tahoma
Meeks Bay
Emerald Bay
Fallen Leaf Lake
Echo Lake
Desolation Valley
Loon Lake
Union Valley Reservoir
Ice House Reservoir
Jones Fork
Silver Fork
Rubicon River
Middle Fork
North Fork
South Fork
Feather River
Yuba River
Bear River
American River
Cosumnes River
Putah Creek
Cache Creek
Sacramento River
Mt. Diablo Meridian
Folsom South Canal
Western Pacific
Southern Pacific
Tunnel Canal
Lake Almanor
Bucks Lake
Quincy
Portola
Beckwourth
Loyalton
Sierraville
Downieville
Nelson Point
Paradise
Magalia
Stirling City
Cohasset
Forest Ranch
Butte City
Palermo
Biggs
Princeton
Delevan
Maxwell
Sycamore
Meridian
Grimes
Wheatland
Dunnigan
Robbins
Zamora
Knights Landing
Esparto
Madison
Brooks
Guinda
Rumsey
Knoxville
Capay
Monticello
Putah Creek
Cache Creek
Winters
Davis
Dixon
Vacaville
Fairfield
Suisun City
Benicia
Martinez
Pittsburg
Antioch
Rio Vista
Isleton
Walnut Grove
Courtland
Clarksburg
Freeport
Florin
Elk Grove
Galt
Lodi
Stockton
Manteca
Ripon
Oakdale
Modesto
Turlock
Merced
Los Banos
Gustine
Newman
Patterson
Crows Landing
Hughson
Waterford
La Grange
Coulterville
Groveland
Big Oak Flat
Sonora
Jamestown
Tuolumne
Columbia
Angels Camp
Murphys
Arnold
Copperopolis
Valley Springs
Mokelumne Hill
San Andreas
Jackson
Ione
Plymouth
Drytown
Amador City
Sutter Creek
Volcano
Pioneer
Fiddletown
Cobb Mountain
Lower Lake
Clear Lake
Kelseyville
Lakeport
Upper Lake
Middletown
Calistoga
St. Helena
Napa
Vallejo
Benicia
Martinez
Concord
Walnut Creek
Pleasant Hill
Lafayette
Orinda
Moraga
Berkeley
Oakland
Alameda
San Leandro
Hayward
Fremont
Newark
Union City
San Jose
Milpitas
Alviso
Santa Clara
Sunnyvale
Mountain View
Palo Alto
Menlo Park
Redwood City
San Mateo
Burlingame
San Francisco
Daly City
Pacifica
Half Moon Bay
Santa Cruz
Watsonville
Aptos
Capitola
Soquel
Scotts Valley
Boulder Creek
Big Basin
Felton
Ben Lomond
Brookdale
Los Gatos
Saratoga
Cupertino
Campbell
Morgan Hill
Gilroy
Hollister
San Juan Bautista
Salinas
Monterey
Carmel
Pacific Grove
Pebble Beach
Big Sur
Lucia
Gorda
Paso Robles
Templeton
Atascadero
San Luis Obispo
Arroyo Grande
Nipomo
Guadalupe
Santa Maria
Lompoc
Solvang
Buellton
Santa Ynez
Los Olivos
Ballard
Santa Barbara
Goleta
Carpinteria
Ventura
Oxnard
Port Hueneme
Camarillo
Moorpark
Simi
Thousand Oaks
Westlake Village
Malibu
Santa Monica
Beverly Hills
Hollywood
Los Angeles
Pasadena
Glendale
Burbank
San Fernando
Van Nuys
Sherman Oaks
Encino
Tarzana
Woodland Hills
Canoga Park
Chatsworth
Northridge
Sylmar
San Gabriel
Alhambra
Monterey Park
El Monte
Whittier
La Habra
Fullerton
Anaheim
Orange
Santa Ana
Tustin
Irvine
Laguna Beach
Laguna Niguel
Dana Point
San Clemente
Capistrano Beach
San Juan Capistrano
Mission Viejo
Lake Forest
Rancho Santa Margarita
Trabuco Canyon
Silverado
Modjeska Peak
Santiago Peak
Saddleback Mountain
Cleveland National Forest
Angeles National Forest
Los Padres National Forest
Sierra National Forest
Stanislaus National Forest
Tahoe National Forest
Plumas National Forest
Lassen National Forest
Shasta-Trinity National Forest
Mendocino National Forest
Klamath National Forest
Six Rivers National Forest
Redwood National Park
Point Reyes National Seashore
Golden Gate National Recreation Area
Channel Islands National Park
Death Valley National Monument
Joshua Tree National Monument
Mojave National Preserve
Lake Mead National Recreation Area
Lake Mohave
Lake Havasu
Colorado River
Imperial Dam
Laguna Dam
Yuma
Blythe
Needles
Parker
Parker Dam
Lake Havasu City
Kingman
Bullhead City
Laughlin
Searchlight
Boulder City
Las Vegas
Henderson
North Las Vegas
Nellis Air Force Base
Indian Springs
Pahrump
Beatty
Tonopah
Goldfield
Hawthorne
Yerington
Fallon
Lovelock
Winnemucca
Battle Mountain
Austin
Eureka
Ely
Wendover
Elko
Wells
Jackpot
Owyhee
Mountain City
Jarbidge
Rogerson
Gerlach
Empire
Sparks
Reno
Carson City
Virginia City
Dayton
Fernley
Wadsworth
Pyramid Lake
Nixon
Susanville
Herlong
Doyle
Portola
Beckwourth
Loyalton
Sierraville
Downieville
Nelson Point
Paradise
Magalia
Stirling City
Cohasset
Forest Ranch
Butte City
Palermo
Biggs
Princeton
Delevan
Maxwell
Sycamore
Meridian
Grimes
Wheatland
Dunnigan
Robbins
Zamora
Knights Landing
Esparto
Madison
Brooks
Guinda
Rumsey
Knoxville
Capay
Monticello
Putah Creek
Cache Creek
Winters
Davis
Dixon
Vacaville
Fairfield
Suisun City
Benicia
Martinez
Pittsburg
Antioch
Rio Vista
Isleton
Walnut Grove
Courtland
Clarksburg
Freeport
Florin
Elk Grove
Galt
Lodi
Stockton
Manteca
Ripon
Oakdale
Modesto
Turlock
Merced
Los Banos
Gustine
Newman
Patterson
Crows Landing
Hughson
Waterford
La Grange
Coulterville
Groveland
Big Oak Flat
Sonora
Jamestown
Tuolumne
Columbia
Angels Camp
Murphys
Arnold
Copperopolis
Valley Springs
Mokelumne Hill
San Andreas
Jackson
Ione
Plymouth
Drytown
Amador City
Sutter Creek
Volcano
Pioneer
Fiddletown
Cobb Mountain
Lower Lake
Clear Lake
Kelseyville
Lakeport
Upper Lake
Middletown
Calistoga
St. Helena
Napa
Vallejo
Benicia
Martinez
Concord
Walnut Creek
Pleasant Hill
Lafayette
Orinda
Moraga
Berkeley
Oakland
Alameda
San Leandro
Hayward
Fremont
Newark
Union City
San Jose
Milpitas
Alviso
Santa Clara
Sunnyvale
Mountain View
Palo Alto
Menlo Park
Redwood City
San Mateo
Burlingame
San Francisco
Daly City
Pacifica
Half Moon Bay
Santa Cruz
Watsonville
Aptos
Capitola
Soquel
Scotts Valley
Boulder Creek
Big Basin
Felton
Ben Lomond
Brookdale
Los Gatos
Saratoga
Cupertino
Campbell
Morgan Hill
Gilroy
Hollister
San Juan Bautista
Salinas
Monterey
Carmel
Pacific Grove
Pebble Beach
Big Sur
Lucia
Gorda
Paso Robles
Templeton
Atascadero
San Luis Obispo
Arroyo Grande
Nipomo
Guadalupe
Santa Maria
Lompoc
Solvang
Buellton
Santa Ynez
Los Olivos
Ballard
Santa Barbara
Goleta
Carpinteria
Ventura
Oxnard
Port Hueneme
Camarillo
Moorpark
Simi
Thousand Oaks
Westlake Village
Malibu
Santa Monica
Beverly Hills
Hollywood
Los Angeles
Pasadena
Glendale
Burbank
San Fernando
Van Nuys
Sherman Oaks
Encino
Tarzana
Woodland Hills
Canoga Park
Chatsworth
Northridge
Sylmar
San Gabriel
Alhambra
Monterey Park
El Monte
Whittier
La Habra
Fullerton
Anaheim
Orange
Santa Ana
Tustin
Irvine
Laguna Beach
Laguna Niguel
Dana Point
San Clemente
Capistrano Beach
San Juan Capistrano
Mission Viejo
Lake Forest
Rancho Santa Margarita
Trabuco Canyon
Silverado
Modjeska Peak
Santiago Peak
Saddleback Mountain
Cleveland National Forest
Angeles National Forest
Los Padres National Forest
Sierra National Forest
Stanislaus National Forest
Tahoe National Forest
Plumas National Forest
Lassen National Forest
Shasta-Trinity National Forest
Mendocino National Forest
Klamath National Forest
Six Rivers National Forest
Redwood National Park
Point Reyes National Seashore
Golden Gate National Recreation Area
Channel Islands National Park
Death Valley National Monument
Joshua Tree National Monument
Mojave National Preserve
Lake Mead National Recreation Area
Lake Mohave
Lake Havasu
Colorado River
Imperial Dam
Laguna Dam
Yuma
Blythe
Needles
Parker
Parker Dam
Lake Havasu City
Kingman
Bullhead City
Laughlin
Searchlight
Boulder City
Las Vegas
Henderson
North Las Vegas
Nellis Air Force Base
Indian Springs
Pahrump
Beatty
Tonopah
Goldfield
Hawthorne
Yerington
Fallon
Lovelock
Winnemucca
Battle Mountain
Austin
Eureka
Ely
Wendover
Elko
Wells
Jackpot
Owyhee
Mountain City
Jarbidge
Rogerson
Gerlach
Empire
Sparks
Reno
Carson City
Virginia City
Dayton
Fernley
Wadsworth
Pyramid Lake
Nixon
Susanville
Herlong
Doyle
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
SUTTER-YUBA COUNTIES INVESTIGATION
POTENTIAL WATER STORAGE DEVELOPMENTS
Scale of miles
4 0 8 12

PLATE 19



LEGEND

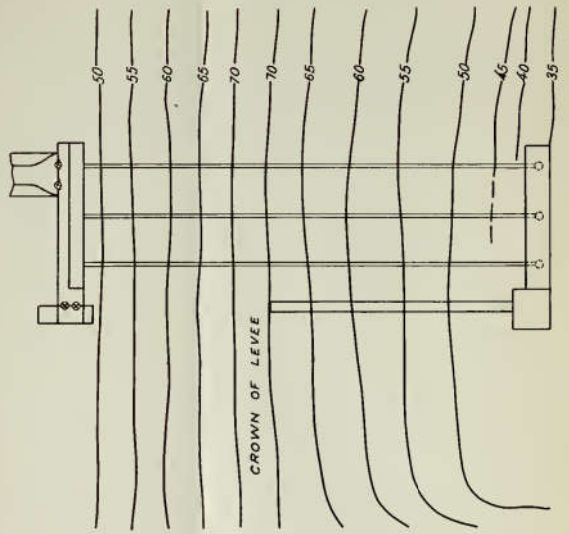
OROVILLE-WYANDOTTE IRRIGATION DISTRICT PLAN

ALTERNATIVE PLAN

PLANS FOR DEVELOPMENT
OF
SOUTH FORK OF FEATHER RIVER

SCALE 1 0 1 2 3 4 MILES

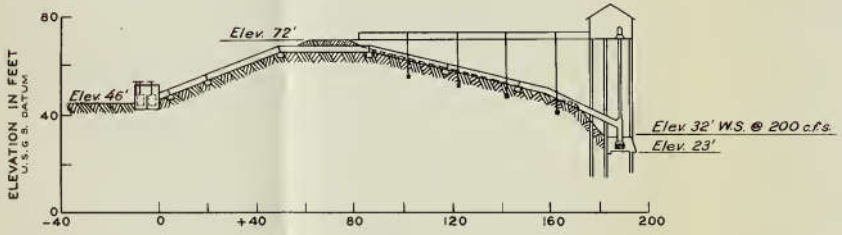
DIVISION OF WATER RESOURCES



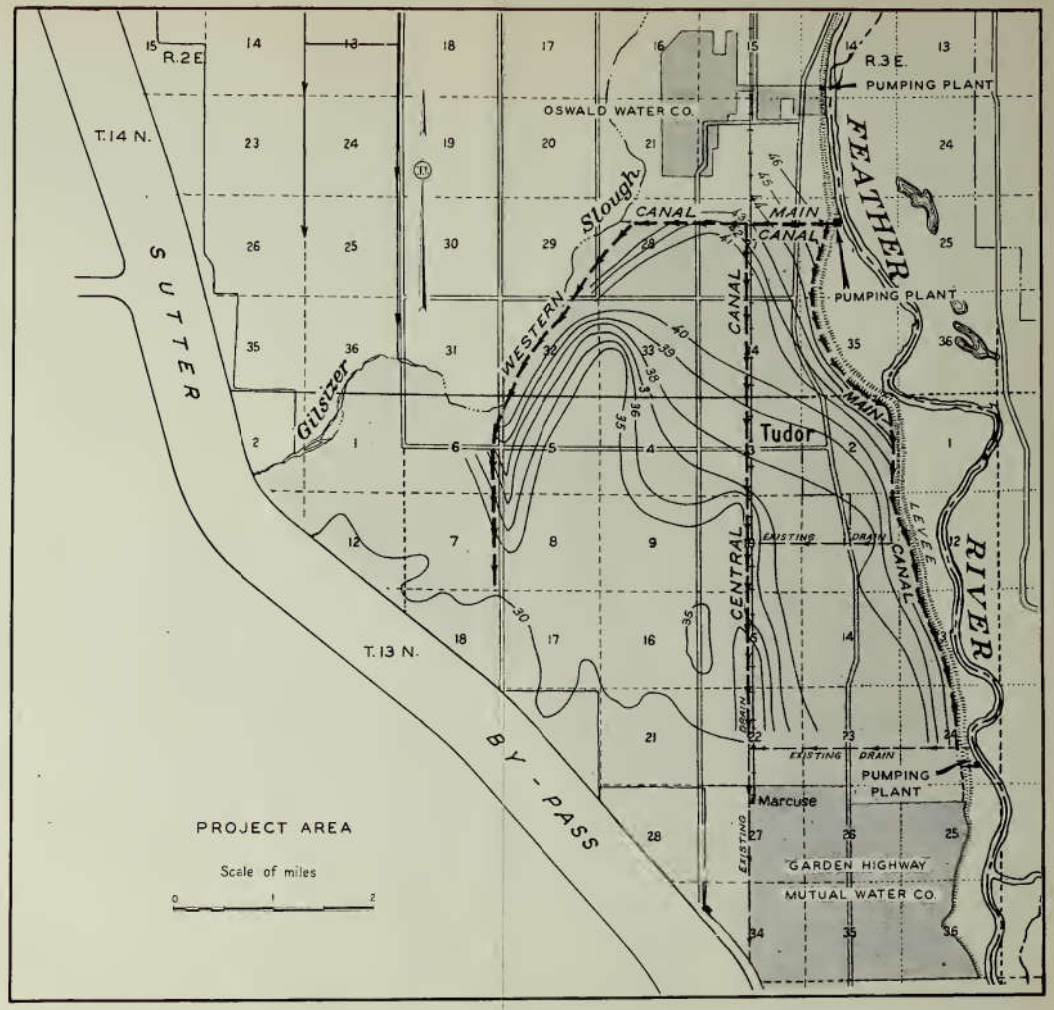
PLAN OF PUMPING PLANT

Scale of feet

0 40 80



PROFILE OF PUMPING PLANT



STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
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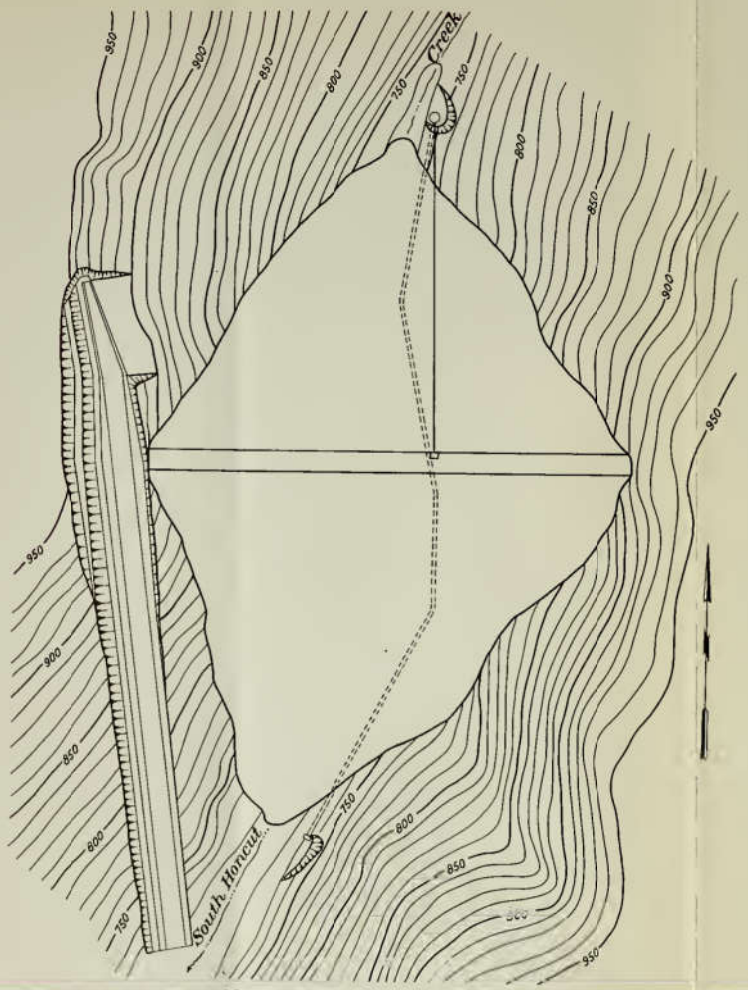

GENERAL PLAN OF DAM

SCALE OF FEET
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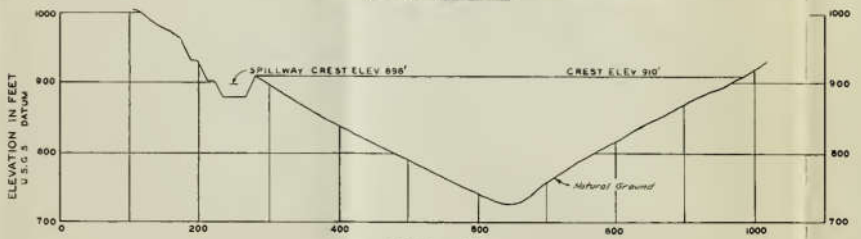
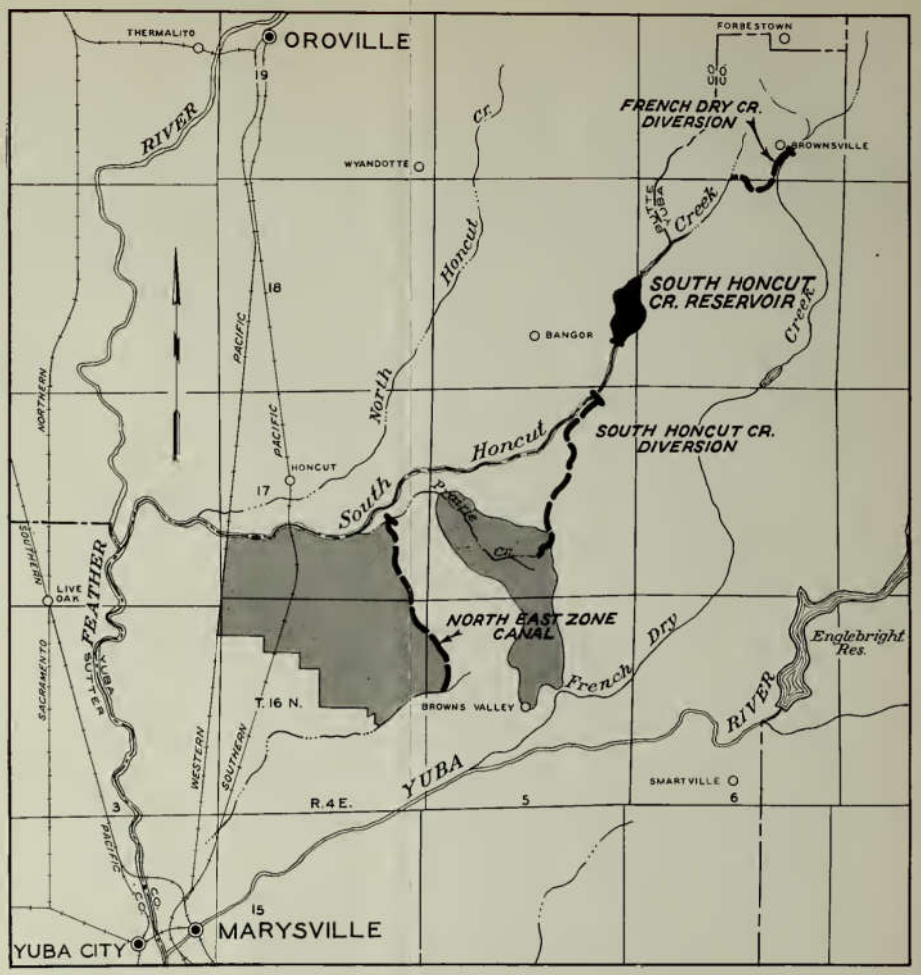


PROFILE OF DAM
LOOKING UPSTREAM



PROJECT AREA
Scale of miles
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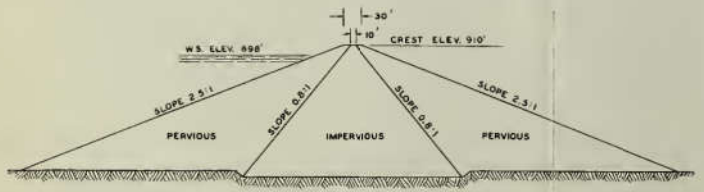

SECTION OF DAM
SCALE OF FEET
0 100 200

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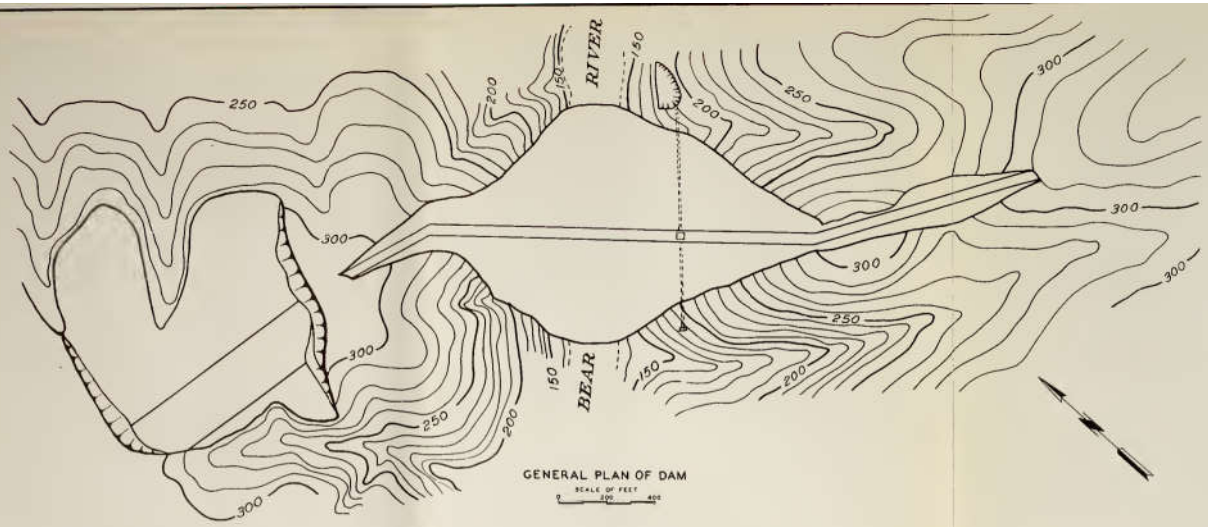

GENERAL PLAN OF DAM

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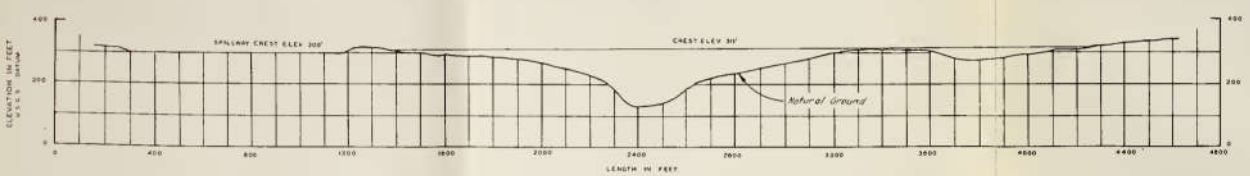

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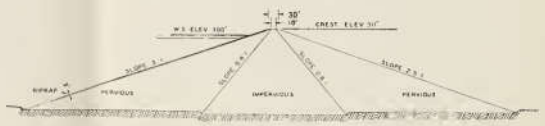

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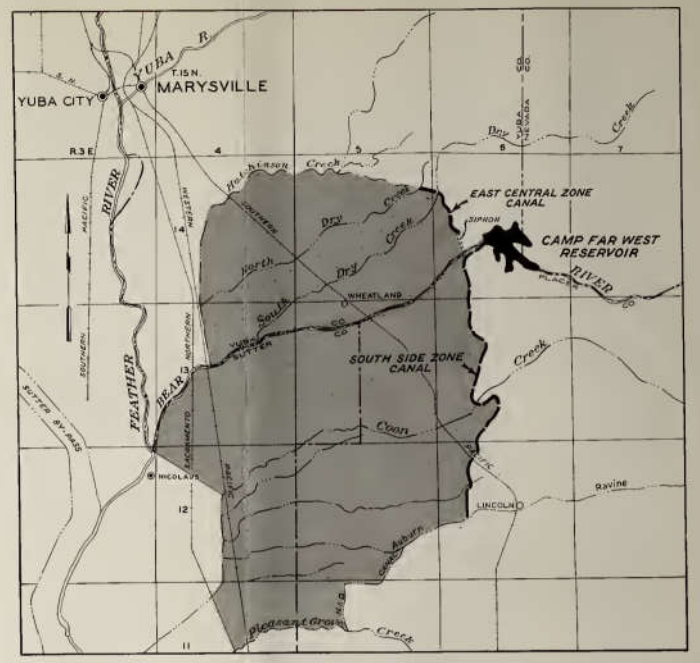

PROJECT AREA

Scale of miles

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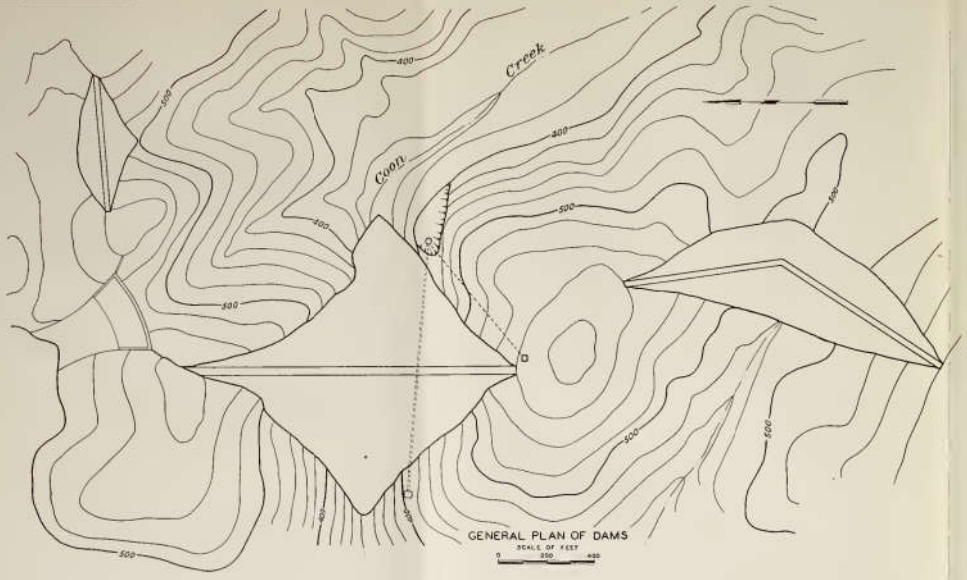
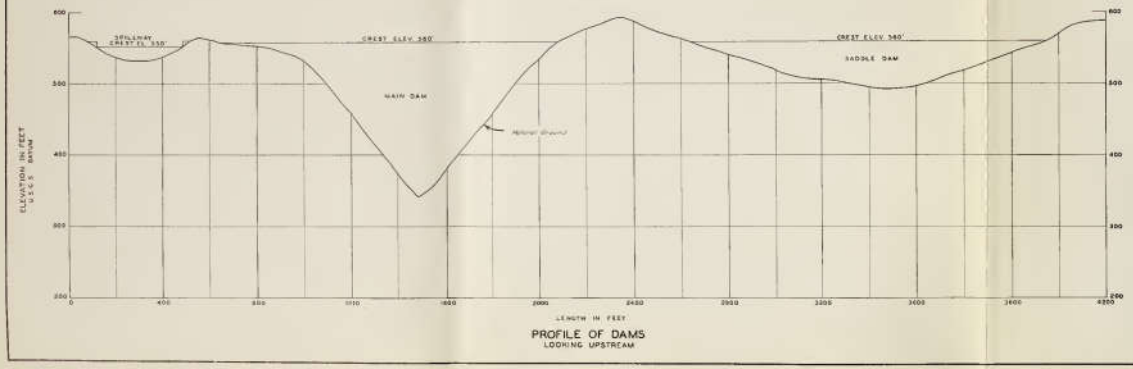
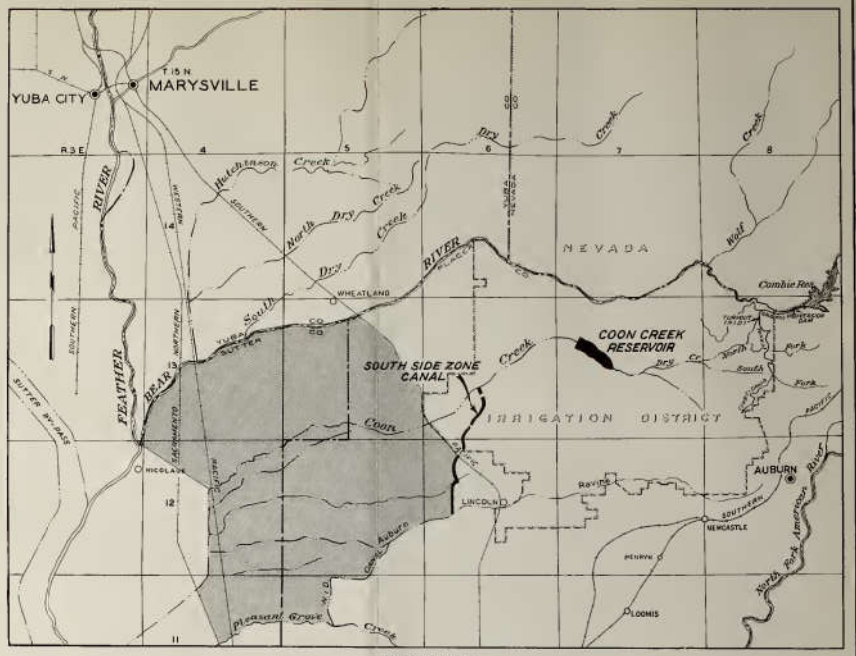
CAMP FAR WEST PROJECT





PROFILE OF DAMS
LOOKING UPSTREAM



PROJECT AREA
Scale of miles
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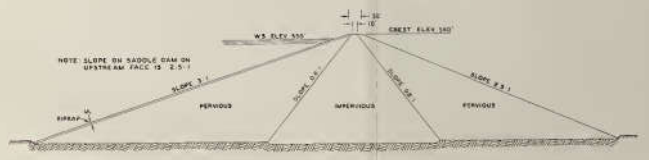

SECTION OF DAMS
SCALE OF FEET
0 100 200

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HYDROGEOLOGY OF THE SUTTER BASIN, SACRAMENTO VALLEY, CALIFORNIA

by

George Curtin

A Thesis Submitted to the Faculty of the

DEPARTMENT OF GEOSCIENCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN GEOLOGY

In the Graduate College

THE UNIVERSITY OF ARIZONA

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STATEMENT BY AUTHOR

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This thesis has been approved on the date shown below:

Jerome J. Wright — March 23, 1971

JEROME J. WRIGHT
Associate Professor of Geology

Date

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ABSTRACT

A mound of saline water exists in continental sediments between two fresh water rivers in the Sutter Basin of the Sacramento Valley, California. This saline water has moved from the marine sediments, at depth, upward along the Sutter Basin Fault and then through 2,000 feet of alluvium.

The hydraulic head required to move the connate water is supplied by the high topographic position of the Cretaceous sediments carried up by the Sutter Buttes intrusives and exposed at the surface some 250 to 400 feet above the valley floor. Around the Buttes the marine sediments have been flushed with fresh water to depths of over 2,000 feet. The displaced saline connate water has moved south where it intercepts the Sutter Basin Fault.

The geologic section consists of about 5,500 feet of Cretaceous and Eocene marine sediments which have been deposited atop the basement complex (the western extension of the Sierra Nevada fault block) and capped by 2,000 feet of post-Eocene alluvium.

Chemical analyses of the ground water indicate sodium chloride water is being introduced from depth, and as the rising connate water moves northerly into the

orchard area it changes to a calcium-magnesium chloride type water.

INTRODUCTION

Purpose of the Investigation

When a mound of saline ground water exists between two fresh water rivers in alluvial sediments 2,000 feet thick, there must be an explanation. Two principal theories have been offered to account for the saline ground water mound that exists in the South Central portion of the Sutter Basin in California. Wilcox (1948) was the first to propose that the saline water was rising from depth. Wolfe (1958) advanced the theory that the saline water resulted from residual evaporites.

It is the thesis of this investigator that the salinity of the mound is due to the hydraulic head between the elevation of the Kione Sands, at their outcrop (recharge area) in the Sutter Buttes, and the elevation of the top of the saline ground water mound in the Sutter Basin. Fresh water has infiltrated and flushed the Kione Sands to depths of approximately 2,000 feet. The displaced marine connate water has moved south and rises along the Sutter Basin Fault, thence through the overlying alluvial sediments to the surface of the basin. A number of other geologic features are involved in the process.

The physical evidence to support the hypothesis was obtained through a study of the subsurface geology, the

hydraulic continuity of the strata and structures and the chemistry of the water.

Maps display the strata, ground water hydrology and chemistry to support the statements that underly this thesis.

Location and Extent of the Area

The saline ground water mound with which this study is concerned lies north of the town of Robbins, California, in the middle of the Sacramento Valley, between the Sacramento and Feather Rivers. Under the saline ground water mound are approximately 2,000 feet of alluvial and non-marine basin sediments. The base of the fresh water that overlies the saline mound lowers in all directions from its center. The salinity of the ground water mound appears to increase with depth.

The area, generally known as the Sutter Basin, is bounded on the west by the Sacramento River, and by the Sutter Bypass on the east. It extends from the alluvial fans of the Sutter Buttes, some 30 miles southeast, to the confluence of the Sacramento and Feather Rivers. The basin lies wholly in Sutter County, California and consists of 114,500 acres of flat, topographical, low, poorly drained land.

To properly evaluate the ground water conditions of the Sutter Basin, the area of investigation was extended to include 1,026 square miles of land lying in all or part of

Township 10 North to Township 16 North, and Range 1 West to Range 4 East, Mount Diablo Base & Meridian. This includes parts of Colusa, Sacramento, Sutter, Yolo and Yuba Counties (Fig. 1).

Previous Investigations

The Division of Soil Management and Irrigation of the United States Department of Agriculture conducted a series of studies in cooperation with the Sutter Mutual Water Company during 1931, 1932, 1933, 1946 and 1947. These studies showed that the amount of dissolved solids in water drained from lands in the southern half of the Sutter Basin greatly exceeded the amount brought onto the land in irrigation water. The salt output during the study periods, expressed as proportion of the input, is reported to have ranged between 248 and 655 percent, with the average about 407 percent. It should be pointed out that all irrigation water for this area is diverted from the Sacramento River. The water table of the basin is controlled by extensive drainage ditches; the drain water is pumped out of the system back into the Sacramento River.

The investigator for the U. S. Department of Agriculture (Wilcox, 1948) concluded that the increase in salt content of the drainage water was due to rising connate water and said (pg. 48):



FIGURE 1 MAP OF CALIFORNIA SHOWING AREA OF INVESTIGATION

> Analyses show that the underground water is moderately to very saline, the lowest concentration observed being several times that of the input irrigation water. Also, all of the wells show a strong artesian pressure. Water in the domestic wells stands at or near the soil surface while the deep wells flow. It appears probable, therefore, that due to the upward pressure, substantial quantities of underground water are intercepted and carried off by the drains.

In September, 1952 the California State Water Resources Board published Bulletin No. 6, "Sutter-Yuba Counties Investigation." In this Bulletin reference is made to the Sutter Basin studies of the U. S. Department of Agriculture and indicates it is in agreement with the report as to the origin of these high chloride waters. Bulletin 6 states (pg. 35):

> The opinion was expressed in a report on the foregoing 1946 salt balance study that the salt in the drainage water was probably derived from saline waters underlying the area. Preliminary studies made by the Division of Water Resources similarly indicated that the chloride salinity in many of the wells was due to admixture of deep-seated brines with native fresh ground waters. There is evidence that such brines may underlie aquifers of good quality throughout large areas of the Sacramento and San Joaquin Valleys--such brines sometimes appear in water pumped from the deep wells in the two valleys, or from areas wherein the fresh ground water levels are markedly lowered through over-draft. In many instances these relatively deep-seated brines are under considerable pressure and readily rise to the surface through defective, abandoned, or improperly constructed wells. A case in point is a natural gas well located near the town of Robbins which yields water under artesian and/or gas pressure at a rate of 200 gallons a minute.

Included in the Resources Board's report was a geochemical study by Davis and Olmsted (1952) to determine the

cause of the high saline water. A complete chemical analysis was run on water samples collected from 38 scattered wells located in Sutter Basin. The water analyses were classified into eight groups according to the range of concentration of total anions. Group 1 was considered unaltered normal ground water and Group 8 was considered briny contaminate. The chemical constituents, in e.p.m. (equivalent parts per million), of Group 1 were subtracted from the chemical constituents of Groups 2 through 7. The resulting chemical constituents, together with Group 8, were tabulated as to percentage. This tabulation indicated that (pg. 37):

> Irrespective of variations in concentration, the character formula of the degradant in each of the ground water Groups 2 through 7 is strikingly similar to that of the brines comprising Group 8. This is especially true of the anions which are not subject to base exchange reactions. This similarity in composition, together with apparent absence of any other like degradant, indicates that the degradation of the native ground water is due to admixture of deep-seated brines of the type exemplified by Group 8.

However, in the U. S. Geological Survey Water-Supply Paper 1497, Olmsted and Davis (1961, page 136) say:

> Its origin is problematical, however; it may be the result of upward migration of deep marine connate waters through defective, abandoned, or improperly constructed deep wells, as suggested by the California State Water Resources Board (1952, page 35); or, on the other hand, it may be merely a large body of evaporation residue in the Sutter Basin.

This conclusion is interesting because some nine years later these two geologists have added evaporation

residue as an alternate theory for the occurrence of saline water in the Sutter Basin.

John Wolfe prepared an office report (Wolfe, 1958) for the California Department of Water Resources and summarized reasons for the theory of rising saline connate water as: (1) subsurface geologic structural highs in marine sediments; (2) artesian and/or gas pressure on connate brines which enable them to rise to the surface through poorly constructed or improperly abandoned water or gas wells; (3) artesian and/or gas pressure on connate brines which permit them to rise through permeable zones in the sediments; and (4) acceleration of rising connates due to lowering of the water table by heavy pumping.

Wolfe still believes (oral communique, 1969) that the geologic conditions favorable to the theory of rising connate water do not exist in the Sutter Basin, and brings forth the following points: (1) there is no known evidence of any structural anomalies in the Sutter Basin; (2) bad water conditions existed in the area before any deep wells were drilled; (3) the area is largely underlain by highly impervious silt and clay; (4) artesian pressure would not be augmented by gas pressure; and (5) an excess of salt and water in the discharge from a basin is no proof of rising saline connate waters.

Wolfe concluded that the saline water in the Sutter Basin is most probably caused by evaporative residues. He

based his conclusion on the observation that salinity and well depth do not seem to correlate, and alkali or salts are known to accumulate in the basin sediments. To support his arguments he quoted Kirk Bryan (1923).

Kirk Bryan, geologist with the U. S. Geological Survey, conducted the first comprehensive ground water investigation of the Sacramento Valley. The field work for his water-supply paper was conducted during 1912 and 1913, a time when the Sacramento Valley was still subject to devastating floods and the basin lands were first being reclaimed and used for rice growing. Bryan (1923, page 85) commented on the accumulation of alkali in the Valley:

> Although there are in the valley large areas that have a shallow water table, which is favorable to evaporation and the accumulation of alkali, only comparatively small areas are unfitted for agriculture from this cause. This condition seems to be due to the following reasons: (1) The ground waters are of good quality. (2) The water table is very flat over the basins, and movements of the ground water are sluggish. Water is supplied more freely at the bases of the slopes, and for this reason the principal concentration of alkali occurs at the edges of the basins. This is particularly the case on the west side, where alkaline patches and areas of salt grass border the basins along their western edges. (3) The heavy winter rains leach out much of the salts concentration at the surface. Similarly flood waters wash out the salts in over-flowed lands, and on the edges of the plains the same waters deposit mud or sediment, which often covers up the alkali.

Bryan mentioned buried alkaline spots along the east side of Colusa Basin and suggested better water could be obtained by casing off the well and going deeper. He

also suggested that the salty spots are usually small in extent. He thought the same conditions might exist along the west side of Sutter Basin.

In the east Sutter Basin area, Bryan spoke of Gilsizer Slough. This slough cuts southwest across the area from Yuba City to the central part of the Sutter Basin (Fig. 4). It is a depression that ranges in width from a hundred yards to a quarter of a mile. Bryan states that the ground water lay close to the surface and evaporation concentrated alkali in the soil. The slough was later drained by a ditch and the land reclaimed and placed under cultivation. However, the water quality of the wells in the Gilsizer Slough area seems to have been little affected by this shallow saline condition (Fig. 6).

History and Methods of the Investigation

During the early 1960s the California Department of Water Resources was conducting a comprehensive study of the ground water in the Sacramento Valley. Among the duties of this investigator was the compilation of a base-of-the-fresh-water map of the Valley. Electric-logs, run in gas wells, were used for the interpretive work. An apparent resistivity of 25 ohm-meters was designated as the dividing point between fresh and brackish ground water. Results of the study confirmed the mound of saline water in the central portion of the Sutter Basin; and further, that the Ione Sand of Eocene age contained fresh water to a depth

of over 2,000 feet around the south central part of the Sutter Buttes. Elsewhere the Ione Sand contains saline connate water.

Correlation section #6, published by the American Association of Petroleum Geologists Committee on Stratigraphic Correlation, shows the stratigraphy of the Sacramento Valley from Red Bluff to Rio Vista. A portion of this section cuts across the Sutter Basin. On this section the Ione Sand crops out in the Sutter Buttes at an elevation of between 250 and 400 feet above the valley floor, is confined by the Nortonville Shale from the Buttes to Humble Oil and Refining Company's "Sutter Basin" #1 well in Section 24, T.13N., R.2E., M.D.B.&M. (well 201 on Fig. 4), and is in contact with the overlying continental sediments in the area of the saline ground water mound in the Sutter Basin. It was therefore believed that here were the conditions necessary for the hydraulic gradient requisite to move the saline water up through the non-marine sediments to the surface in the Sutter Basin.

Permission was obtained from the Department of Geology, University of Arizona, to investigate this phenomenon as a thesis topic.

During the Summer of 1969 the author was employed by the California Department of Water Resources and permitted to use the office facilities during weekends and evenings to collect and analyze data. Some 550 gas well

locations were plotted and electric-logs from more than 400 wells were collected and correlated. Further data were taken from the Department's detailed study of the water quality along both sides of the Feather River, 1964-67, as well as water analyses of wells made during the Department's regular yearly program for succeeding years. Part of this information is displayed graphically on Figure 6 (in pocket), the rest is contained in Appendix A.

Well-numbering System

The customary method of identifying gas and oil wells is to use the name of the operator and the name of the well. To be done legibly would require more space than is available on the base map used in this report. Therefore, each well was assigned a number. In general, the numbering began in Township 10 North, Range 1 West, and moved across to Range 4 East, etc. This places the low numbers in the lower left hand corner of the base map (Fig. 4, in pocket) and the highest numbers in the upper right hand corner. During the process of the investigation the size of the base map was reduced, so as to include only that area most relevant to the study; hence, not all of the wells originally numbered are plotted on the base map.

The water well numbering system used in the study is that of the California Department of Water Resources, and shows the location of wells according to the rectangular system for the subdivision of public land. For

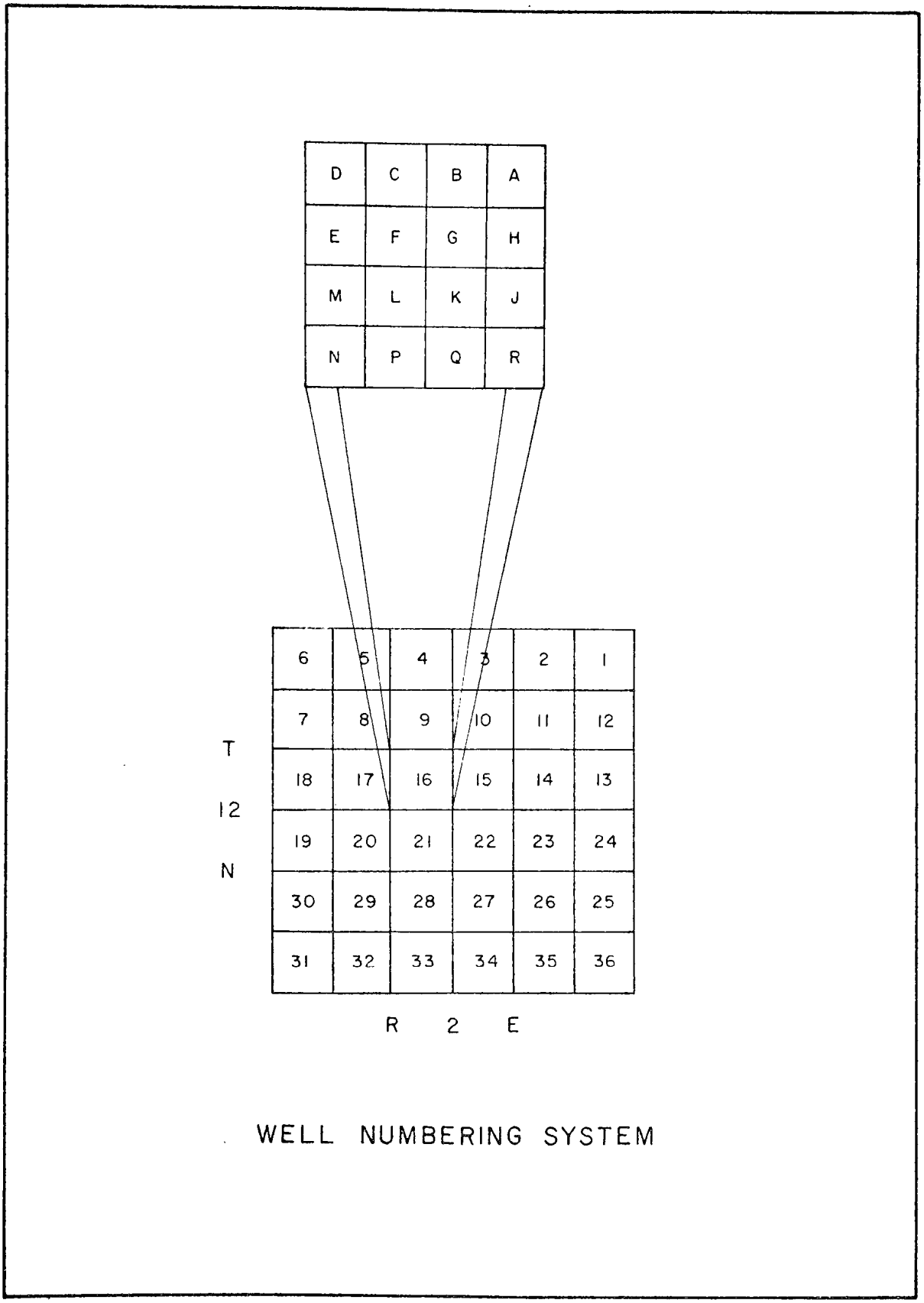

FIGURE 2 DIAGRAM SHOWING WELL NUMBERING SYSTEM

example, in well number 12N/2E-16B2, the segment of the number and letter preceding the bar indicates the Township (T.12N.); the number and letter between the bar and the hyphen, the Range (R.2E.); the digits between the hyphen and the letter, the Section (sec. 16); and the letter following the section number indicates the 40-acre subdivision of the section, as shown in Figure 2. Within each 40-acre tract the wells are numbered serially, as indicated by the final digit. Thus, Well 12N/2E-16B2 is the second well to be listed in NW1/4 NE1/4 Sec. 16, T.12N., R.2E., M.D.B.&M.

Parts of the study area lie in old Mexican land grants and have never been public land; for these, the rectangular system of subdivision has been projected for reference purposes only.

GEOGRAPHY

Topography

The Sacramento Valley is the northern one-third of the Great Central Valley of California and takes its name from the principal river which flows through it. The Sacramento Valley, as defined by Bryan (1923), extends from Red Bluff to the mouth of the Sacramento River at Suisun Bay, a distance of 150 air miles, or about 240 miles by river. The area of the Valley is approximately 5,000 square miles.

The Valley floor slopes southward from an elevation of nearly 300 feet at the north, near Red Bluff, to sea level at Suisun Bay and varies in width from five miles at the north end to 45 miles in the southern part.

The western boundary of the Valley is the North Coast Ranges, which consist of a series of parallel ridges and inter-montane valleys trending slightly west of north. The ridges rise to elevations of 3,000 feet.

The mountainous regions east and northeast of the Valley include the Sierra Nevada and the Cascade Range. The Sierra Nevada has been described (Lindgren, 1911; Matthes, 1930; Piper et al., 1939) as a single block of the earth's crust which has been uplifted along fractures on its eastern margin and tilted westward. The average slope

of the western surface is $1^{o}40'$ and becomes steeper as it extends beneath the floor of the Sacramento Valley. The crest of the Sierra Nevada, to the east of the valley, varies from 6,000 to 10,000 feet in elevation. The Cascade Range, to the northeast, consists mainly of volcanic rock. It contains Mount Lassen, which is considered the only active volcano in California.

The Sacramento Valley has been divided into 16 geomorphic units by the U. S. Geological Survey (Fig. 3).

The study area for this report (Fig. 4) lies in the central portion of the Sacramento Valley. In this area the major topographic feature is the Sutter Buttes. It is the erosional remnant of a laccolith and volcano formed during late Pliocene time. The outline of the Buttes is an almost perfect circle, 10 miles in diameter, with the highest peak--South Butte--rising to an elevation of 2,117 feet. The only other prominent topographic feature is the Dunnigan Hills on the west flank of the Valley, which consist of Pliocene and Pleistocene sediments which have been folded into a gentle anticline with the axis trending approximately South 40° East. The Hills are severely dissected but the summits are rounded and rise to nearly the same height. The summits decline from an average altitude of 400 feet at the north end to about 200 feet near the south end.

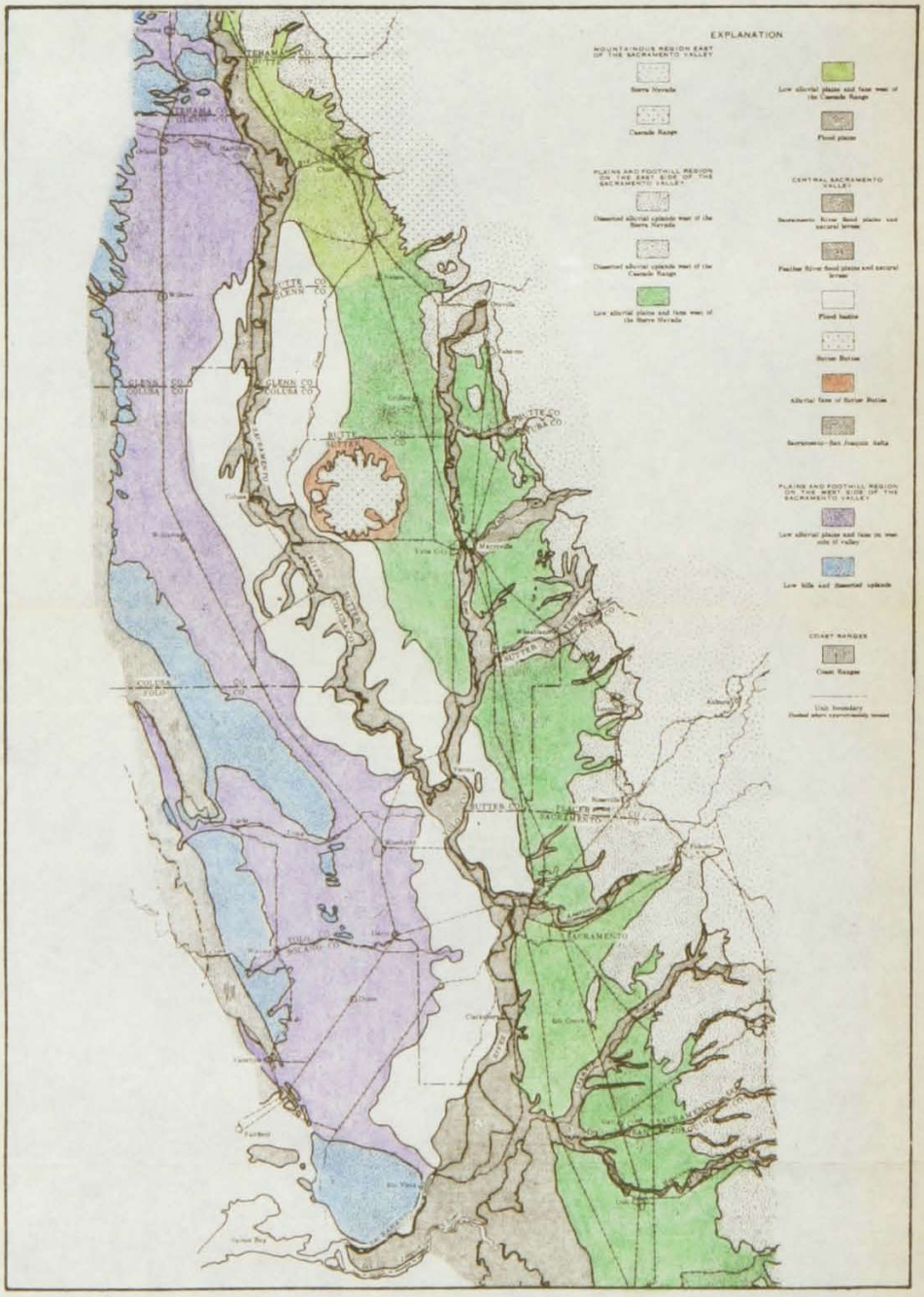

FIGURE 3

MAP OF THE SACRAMENTO VALLEY, CALIFORNIA, SHOWING GEOMORPHIC UNITS

The other topographic features in the study area are of low relief and are related to the fluvial deposition of the Sacramento River and its tributaries. They include the alluvial fans on the west and east sides of the Valley and around the Sutter Buttes, the flood plains and natural levees and the flood basins. These fluviatile features have had a marked influence on the agricultural development of the area.

Drainage

The average annual runoff of the Sacramento River and its tributaries during a 40-year period starting in 1904 was 21,750,000 acre-feet. In the years past most of this flow took place during December to April. Only in the driest years was the Sacramento Valley free from flooding. During the wetter years the flood water would extend from the alluvial fans on the west side of the Valley to the alluvial fans east of the Feather River. Bryan (1923) estimated that before any reclamation had been accomplished, sixty percent of the Valley was subject to overflow--including, in addition to the basins, the river lands and a considerable portion of the low plains. In recent years the construction of levees along the major streams, flood-water bypasses through the Sutter and Yolo Basins, and the building of Shasta Dam on the Sacramento River and Oroville Dam on the Feather River, has greatly limited the large-scale flooding of the basins.

Between Colusa and Verona, the Sacramento River follows a sinuous course, with meanders and oxbow lakes. Over a distance of 63.5 miles the average descent is about 0.4 feet per mile. The channel is narrow--averaging 150 to 600 feet in width--with well-defined broad natural levees. The natural levees are concave upward and relatively flat. In effect, the river is flowing along a broad upraised trench, flanked on either side by poorly drained, low-lying flood basins. The Colusa Basin lies to the West, and the Sutter Basin to the East.

South of Verona at the mouth of the Feather River, the aspect of the Sacramento River changes completely, and the course of the river consists of broad, gentle bends and relatively long straight reaches. The channel averages 600 to 1,200 feet in width, and bars and islands are uncommon. The natural levees are well defined, but are generally narrower than those upstream; the belt of river lands averages about two miles in width.

The Feather River, the principal tributary of the Sacramento River, leaves the Sierra Nevada foothills at Oroville. It follows a southwesterly course for about six miles, then turns sharply south and flows across the Victor Formation of Pleistocene age. Upstream from Marysville, the Feather River flood plain is one to two miles wide and lies 10 to 15 feet below the adjoining low plains. The river pursues a meandering course on its flood plain, and

lakes and abandoned channels are common features, indicating frequent changes in course.

South of Marysville, the Feather River is joined by the Yuba River, and in turn by the Bear River. Here the river occupies a broad channelway, as much as a mile wide, that is choked with sand and gravel contributed by the Yuba and Bear Rivers. This channel aggradation is a direct result of hydraulic mining in the Sierra Nevada.

In the seven-mile reach upstream from its junction with the Sacramento River, the Feather River occupies a channel ridge similar to that of the Sacramento River. The prominent natural levees slope a mile or more toward the Sutter Basin to the west, and the American Basin to the east. Well-formed channel ridges of flood distributaries extend laterally toward the flood basins, and bends and abandoned channels are noticeably absent, suggesting long-continued channel stability.

The average grade of the Feather River from Marysville to the Sacramento River is 1.1 feet per mile.

Climate

The climate of the Sutter area is characterized by dry summers with high daytime temperatures and warm nights, and wet winters with moderate temperatures. More than eighty percent of the precipitation occurs during the five-month period from November to March, inclusive. The eighty-year average precipitation for the City of Marysville is

20.68 inches, with an annual high of 38.91 inches and an annual low of 8.15 inches. The growing season is long, the forty-year recorded average for Marysville being 273 days between killing frosts. Temperatures at Marysville have ranged from 16°F. to 118°F., and the monthly average ranges from 46.9°F. in January to 79.3°F. in July.

Culture

The native vegetation in the study area consisted of grasses and occasional oak trees on the alluvial fans. The swamp and overflow land supported a heavy growth of tules, or rushes, that gave the area its coloquial name of the "Tules." The natural levees supported a heavy growth of trees, predominantly Sycamore and Cottonwood.

It was a natural step for the early settlers to substitute grain such as wheat and barley for the native grasses. The commercial production of wheat in this area was begun by General John Sutter in 1843 on his Hock Farm south of Yuba City. With the influx of settlers during and after the gold rush, a large portion of the higher land was converted to the growing of dry-farmed grain crops and livestock.

The continuing wave of settlers in the area caused an increase in land value and the subdivision of lands into small farms which had to be capable of producing consistently high-value crops in order to support the owners. To the purchasers of such tracts the advantages of

irrigation were apparent. The colonizing of subdivided lands became a business whereby large blocks of land were purchased and surveyed into small tracts with provisions for roads and perhaps for a town site. Irrigation works were provided for some of the subdivided acreages; in others, a demonstration well and pumping plant was built to persuade the settlers of the advantages of installing their own individual wells and pumps. Settlers were attracted by agents and by advertisements in the eastern newspapers of the United States.

The development of the flood basin and overflow land was slowed by recurring floods. However, many public agencies were organized in the area to deal with the problems of land reclamation and drainage. The provisions of California reclamation district laws have been used extensively to effect the unwatering of low lands and their protection from overflow. A canal was excavated to remove the flood and drainage water from Colusa Basin. The function of Sutter Bypass is to receive and convey excess floodwater of the Sacramento River and Butte Basin through Sutter Basin (Fig. 4).

The highest and best use for most of the basin land, because of the heavy soil, is rice production. In 1966, some 66,000 acres of basin land in Sutter County alone, or one quarter of the entire County, were used for the cultivation of rice. The rest of the basin land is

used mainly as irrigated pasture for the raising of livestock.

Other annual crops in the area consist of beans, tomatoes, safflower, corn, hops, sugar beets, and alfalfa seed. Along the Feather River the land is used mainly for deciduous orchards--peaches, apricots, pears, prunes, almonds and walnuts.

Industry in the area is supported largely by agricultural production. About 100 plants are operated during the harvest seasons to can fruits and vegetables and to dehydrate fruits, nuts, rice and seed crops. Packing houses for packing fresh fruits and melons, and cold storage and refrigeration plants, have also been placed in operation.

Following are the population figures for the three counties that comprise most of the study area, and the county seat for each.

	1960	1970
Sutter County	33,380	41,894
Yuba City	11,507	13,740
Yuba County	33,859	43,934
Marysville City	9,553	10,100 (est.)
Colusa County	12,075	11,896
Colusa City	3,518	3,825 (est.)

GEOLOGY

Stratigraphy

The west side of the Sacramento Valley contains one of the thickest and most nearly complete late Mesozoic sections in North America. The Upper Jurassic, Lower Cretaceous, and Upper Cretaceous sequences have a maximum aggregate thickness of sediments in excess of 50,000 feet (not illustrated).

The classification of the Upper Cretaceous by Kirby (1943), the Upper Cretaceous faunal zones of Goudkoff (1945), and the faunal zones of Laiming (1943) for the Paleocene and Eocene sediments have been used in this report (Fig. 5). Where there appear to be differences in opinion as to the stratigraphic relations of the sub-surface geology, Correlation Section No. 6, 1954, "Sacramento Valley from Red Bluff to Rio Vista," of the A.A.P.G. Committee on Stratigraphic Correlations was used as the guide. Where this investigator differs from the A.A.P.G. Committee, these differences are based on electric-log interpretations and discussions with geologic consultants who have worked in the Sacramento Valley.

Upper Cretaceous Units

Forbes Formation.(Figs. 5 and 7, in pocket) The Forbes Formation is the basal member for sub-surface

correlations illustrated, and has the most extensive distribution of any of the units correlated. It crops out along the western margin of the Sierra Nevada and along the eastern margin of the Coast Range. It is believed (Weagant, 1964) to have been deposited in a moderately deep-water environment, too far offshore to be affected by shoreline winnowing processes, and is the result of turbidity currents.

The thickness of the Forbes Formation varies from 2,750 feet to 3,000 feet in the study area. It is dominantly a gray, marine shale with fairly thick, fine-grained sandstone interbeds.

Kione Formation. (Figs. 5 and 7) The Kione Formation represents the shallowing of the Forbes basin, which resulted in the development of a shallow near-shore environment. The Kione sands were probably deposited in a series of deltas that lay at the mouths of the major drainages coming off the Sierran land areas to the east. These deltaic sands were further distributed along the east side of the valley by action of along-shore currents and by normal shoreline processes.

The Kione Formation was named and described by Johnson (1943). It is a medium-grained, well sorted, massive, friable sandstone of granitic origin with shale interbeds. The Kione is in gradational contact with the underlying Forbes Formation. Around the Sutter Buttes the

Kione has a thickness of between 800 and 1,000 feet. To the West, the Kione becomes more broken, tending to turn to shale, and to the south it thins and shales out. In the study area it is everywhere conformably overlain by the "Sacramento Shale", except in the Colusa area where it is reported to occur at a shallow depth and is overlain by the Tehama Formation.

"Sacramento Shale." (Figs. 5 and 7) This marine deposit has not been identified in outcrop, although it is possible that it crops out around the Sutter Buttes. For the purpose of this report it will be identified by the description as shown on A.A.P.G., Pacific Section, 1960, Correlation section from Red Bluff to Rio Vista, Sacramento Valley, "the siltstone which conformably overlies the Kione Sand and is conformably overlain by the 'Winter Sand'." The "Sacramento Shale" is typically 150 to 300 feet thick and light gray in color. It is everywhere present in the study area, and is an excellent electric-log marker.

"Winter Sands and Shales." (Figs. 5 and 7) The main source of the marine "Winters Sands and Shales" appears to have been older Cretaceous deposits, reworked and redeposited. In the Dunnigan Hills the shale is described (Rofe, 1962) as a medium-dull, gray, firm, massive, silty, muscovitic, fossiliferous claystone, grading locally into siltstone. The sand beds are light gray, fine to medium-grained, poorly sorted, massive, silty, micaceous sand with subordinate amounts of claystone that grade upward to well sorted, clean sand.

It is possible that the "Winters" crops out on the south side of the Sutter Buttes but has not been identified. It is not present north of the Buttes, it thins to the north and east, thickens to the south, and its western extent is obscured by uplift and erosion during post-Cretaceous time. The unit unconformably underlies the Starkey Sands in the area south of the Sutter Buttes.

"Starkey Sands." (Figs. 5 and 7) The "Starkey" represents a very shallow sea environment with deposition of a series of regressive-transgressive beach or near-beach sands. The deposits were derived from the east and northeast as the Sierran and northern Sacramento Valley areas were uplifted and eroded. The "Starkey" grades from a medium-grained, clean sand into a shale from east to west. The "Starkey" is everywhere confined by the Martinez Silt of Paleocene age or the Capay Shale of Eocene age, except in the southern Sutter Basin where it is unconformably overlain by the post-Eocene non-marine sediments (Fig. 7). The sand thins or has been removed by erosion to the north and west. To the south it occurs at ever-increasing depths and thickens to approximately 1,900 feet before thinning and shaling out in the Delta area.

Tertiary Units

Meganos-Martinez Formations Undifferentiated.

(Figs. 5 and 7) This group of sediments conformably

overlies the "Starkey Sands" in the southeast portion of the study area.

The type locality of the Martinez Formation is near the town of Martinez on Carquinez Strait, west of Suisun Bay, and was described by Dickerson (1914). Lithologically, it is predominantly a massive, well-sorted, quartzose sandstone with interbedded shale and local conglomerate lenses. Much of the detritus of the Martinez was derived from Cretaceous Formations. A basal shale member is referred to as the Martinez Silt and is an excellent electric-log marker where it overlies the "Starkey Sand." The Martinez contains Laiming's (1943) E fauna zone and is Paleocene in age.

The type locality for the Meganos Formation is in Contra Costa County in the Mount Diablo region and was described by Clark (1918). It consists of friable, fine to medium-grained, micaceous, carbonaceous gray sand and hard, mostly light to dark brown shale with streaks of lignite. For the purpose of this report, it is considered to be those sediments containing Laiming's D fauna zone, and is Lower Eocene in age.

The thickness of the Meganos-Martinez group, in the study area, varies from zero to 240 feet. It occurs only in the south central portion of the study area where it is truncated or pinches out to the north and dips to the south.

Capay Shale. (Figs. 5 and 7) The type section for the Capay Formation is in Capay Valley, to the west of Dunnigan Hills, and was described by Crook and Kirby (1935). Unfortunately, the type section is atypical of most of the Capay in the Sacramento Valley. It consists of as much as 2,000 feet of beds resting unconformably on the Upper Cretaceous rocks, ranging from channel conglomerate to fine-grained estuarine deposits. The source of the detritus was said by Crook and Kirby to have been local. It is now believed that this part of the Capay was deposited in the southern extension of the Princeton Gorge. When the Eocene sea transgressed, the gorge was inundated first and coarse sediments were contributed from immediately adjacent sources. As the sea continued to rise, it topped the gorge and spread out over the floor of the Valley. It was then that the Capay Shale was so extensively deposited.

At Dunnigan Hills the Capay Shale is described by Rofé (1962) as medium gray to dark gray, massive, micaceous, glauconitic, pyritic, fossiliferous claystone with a dark gray, medium-grained, poorly sorted, massive basal gritstone, which is a more typical description of the Capay Shale and is probably the upper part of the Capay Formation. In the study area the Capay Shale is considered Lower Eocene in age.

The Capay Shale acts as a cap rock for many of the gas fields in the Valley. It is present throughout the area except where it has been removed by erosion in the Sutter Basin south of the Sutter Basin Fault, in the "Markley Gorge," and along the western margin of the study area. The Capay Shale varies in thickness from zero to 558 feet and thins to the East. The base of the Capay is one of the major unconformities in the Valley. The Capay progressively overlies older Cretaceous rocks in a northern and eastern direction.

Ione-Domengine Formation. (Figs. 5 and 7) Stewart (1949) divided the Domengine Formation of Clark (1926) into two formations: the Lower Ione Formation, consisting of quartz sand; and the Upper Domengine Formation, consisting of green and brown sand. Both are placed in Middle Eocene and contain Laiming's B-1 faunal assemblage.

In the Dunnigan Hills (Rofé, 1962), the Domengine Formation is 19 to 62 feet thick and consists of dark gray to greenish gray, fine-grained, well sorted, silty sands. It appears that the Lower Ione Formation of Stewart (1949) is not present at this location.

Throughout most of the area, the Middle Eocene is represented by the Ione Formation of Stewart. In the Sutter Buttes, the Ione is described by Johnson (1943) as a white, quartzose, friable sandstone, and probably represents deltaic deposits that have been winnowed by

off-shore currents. Figure 5 indicates that the Ione-Domengine Formation is of rather limited extent in the study area, having been removed by erosion to the west and south. It ranges in thickness from zero to 250 feet.

The Ione-Domengine Formation conformably overlies the Capay Shale of Lower Eocene age and is conformably overlain by the Nortonville Shale of Upper Eocene age.

Nortonville Shale. (Figs. 5 and 7) Stewart (1949) divided the Kreyenhagen Formation of Upper Eocene age into the Nortonville Shale member, the Markley Sandstone member, and the Sidney Shale member, in ascending order. Only the Nortonville Shale has been identified in the study area, and then only in gas wells at Dunnigan Hills and in the Sutter Basin. The extent of the Nortonville sea is obscured by subsequent erosion, but probably did not extend further north than the Sutter Buttes and was not as widespread as the Capay sea.

In the Dunnigan Hills, the Nortonville Shale is described (Rofé, 1962) as blue and brown, firm, mottled, micaceous, sandy claystone, interbedded with grayish green, gritty sands. Its thickness varies from 92 to 235 feet, and contains Laiming's A-1 faunal assemblage.

"Markley Gorge" Fill. (Fig. 5) The "Markley Gorge," a deep canyon that was eroded during Upper Eocene, extends from north of the Bear River, near the foothills of the Sierras, southwest to the northflank of Mount

Diablo. This sub-surface feature is more than 45 miles long and nine miles wide, and reaches a maximum depth of 5,700 feet below sea level. Probably a better name for this feature would be the Sacramento Canyon, but at present it is referred to as the so-called "Markley Gorge."

Davis (1953) first described the Gorge, and believed that it was filled with Upper Eocene deposits. Almgren and Schlax (1957) believed the fill is Oligocene and, in part, possibly Miocene in age. Despite the later conclusions, most geologists with a working knowledge of the "Markley Gorge" Fill believe that it is no older than Late Eocene (Sacramento Petroleum Association, 1962).

The "Markley Gorge" Fill consists of shales, sandstone, and conglomerate which have considerable lateral and vertical lithologic variation. The shales are light olive-gray to grayish, brown, silty, and generally barren of microfauna. Sandstones are of two dominant types: one confined to the lower part of the fill is grayish green to greenish brown, earthy, poorly sorted and consists largely of grains of various volcanic rock types, and subangular to sub-rounded pebbles of gray shale and siltstone occur locally; the other dominant type of sandstone is blue, generally coarse-grained and fairly well sorted.

Post-Eocene Non-Marine Sediments. (Figs. 5 and 7) This classification is a catch-all for the alluvial sediments that have been deposited in the Valley by the

Sacramento River and its tributaries from both an eastern and western source. In the study area it has no commercial accumulation of gas and therefore is of little or no interest to the petroleum industry. Petroleum geologists usually call the entire interval the Tehama Formation, which does make up a large percentage of the sediments.

It appears that the Oligocene epoch was a time of uplift and erosion with little or no sediments being deposited in the study area. The Miocene epoch is represented by sedimentary rocks of volcanic origin. The rocks from the Sierra Nevada are a sequence of fragmental volcanic rocks, the source of which lay near the present crest of the Sierras, about 50 miles east of the Sacramento Valley. These rocks, predominantly andesitic, are extensively exposed on the western slope of the Sierra Nevada and extend westward beneath much of the Valley. They probably extend beyond the Sacramento River in the study area. This unit is believed to be related to the Mehrten Formation of Piper et al. (1939).

The sedimentary rocks of volcanic origin that crop out on the west side of the Valley are a sequence of volcanic shale, sandstone and conglomerate beds. Weaver et al. (1944) assigned most of these rocks to the Neroly Formation (Upper Miocene) of Clark and Woodford (1927), but their age and correlation are in considerable doubt.

Five wells (282, 291, 292, 293, and 296) have been drilled through a basalt flow that is approximately 150 feet thick. This island of basalt in Township 13 North, Range 2 East, is believed to be Upper Miocene in age and lies at the base of the Tehama Formation.

The Pliocene sediments consist of continental deposited Laguna Formation of Piper et al. (1939) and the Tehama Formation of Anderson and Russell (1939).

The Laguna Formation (not illustrated) is a sequence of predominantly fine-grained, poorly bedded, somewhat compacted continental sedimentary deposits derived from the Sierra Nevada. The Laguna appears to form a wedge of alluvial material thinning near the Sierra Nevada and thickening toward the axis of the Valley. The maximum thickness of these deposits may be more than 1,000 feet.

The Tehama Formation (Fig. 4) consists of alluvial material derived from the Coast Ranges. It was inaugurated by the orogeny at the beginning of Late Pliocene time, which raised the present Northern Coast Ranges, and was closed by a Middle Pleistocene orogeny. The Formation has been assigned to the Upper Pliocene and possibly the Lower Pleistocene by Anderson and Russell (1939). They state the Formation consists of poorly sorted fluviatile sediments, comprising massive sandy silt, silty sand, and clayey silt enclosing lenses of crossbedded sand and gravel.

The Tehama forms a thick wedge of sediments that thicken to the east and interfinger with the Laguna Formation beneath the Valley floor. In the study area, the Tehama Formation has a maximum thickness of approximately 2,500 feet.

The Sutter Beds of Williams (1929) which crop out in the Sutter Buttes are correlative to the Tehama Formation according to Johnson (1943). They are comprised of continental fine-grained sediments, tuff, sand, silt, and gravel some 1,800 feet in outcrop. Both Williams (1929) and Johnson (1943) believed that the Sutter Beds had a Sierran source because they are petrologically similar to the Sierran andesites. If this be true, then the Sutter Beds are better correlated to the Laguna Formation of Piper et al. (1939).

Quaternary-Recent Units

During Pleistocene time, some 1.2 million years ago, as indicated by radioactive dating according to Dr. Howel Williams (oral communique, 1969), a series of volcanic episodes--the intrusion of rhyolite porphyry volcanic necks followed by the intrusion of an andesite porphyry plug--resulted in the formation of the Sutter Buttes. The final igneous episode was the explosive phase--the formation of a volcano within the andesite plug--the ejecta of which mantles the slopes with andesitic tuff and breccia.

Along the east side of the study area, the alluvial fans and flood-plain deposits of Pleistocene age have been termed the Victor Formation by Olmsted and Davis (1961), after the type Victor Formation of Piper et al. (1939). The Victor Formation consists of an heterogeneous assemblage of clay, silt, sand and gravel, transported by shifting streams from the Sierra Nevada, and has a maximum thickness of 150 feet. The base of the Victor in most places is in conformable contact with the Laguna Formation. Toward the center of the Valley, it is at many places conformably overlain by basin and river deposits of Recent age. In general, the Victor Formation is not appreciably consolidated, although some of the beds have a high proportion of clay and silt which act as a binder. Hardpan layers, representing buried soil zones, occur at various depths, though most are within six feet of the surface.

The Red Bluff Formation is a poorly sorted gravel which has a distinctly reddish silty or sandy matrix and lies on an erosion surface cut on the Tehama Formation. This Pleistocene deposit is of no importance with regard to this report.

The sediments of Recent age include the river and flood-basin deposits. The river deposits consist predominantly of well-sorted sand, gravel, and silt along the channels, flood plains, and natural levees of the major streams. The basin deposits are largely silt and clay

deposited in the flood basins during floods on the major streams. The sediments of Recent age range in thickness from zero to 100 feet.

Geologic Structure

Regional Features

The Sacramento Valley is a large structural basin filled with sedimentary rocks ranging in age from Early Cretaceous to Recent. The Valley trough is asymmetrical; the deepest part of the basin lies near the western margin of the Valley, west of the present axis and plunges to the south. The plunge of the Valley trough results in the southern part of the Valley--the Rio Vista Basin--containing the thicker and more complete geologic section.

The basement complex, beneath the Valley floor, is a continuation of the Sierra Nevada fault block that has been tilted toward the southwest. Geophysical evidence indicates that the basement lies some 20,000 feet below the surface along the western edge. Deep wells that have cored the basement complex in the Sacramento Valley indicate that the surface of the block slopes more steeply beneath the central part of the Valley than it does to the east.

The western part of the Valley is bounded by strike ridges underlain by Cretaceous and Lower Tertiary marine sedimentary rocks. Compressive forces deformed the

Coast Ranges sediments into tightly folded anticlines, synclines, and local thrust faults. Vaughan (1943) suggested that these same compressive forces caused the tilting of the rigid Sierra Nevada block by forcing its western part down below its position of isostatic equilibrium.

Sutter Buttes

The Sutter Buttes comprise the major structural and topographic feature in the study area, rising some 2,000 feet above the flat Valley floor. The Buttes are the surface expression of an intrusion of rhyolite porphyry, followed by andesite porphyry (Johnson, 1943) that forced its way upward from an unknown, but great depth, through at least a portion of the underlying "Basement Complex" platform, into and through some 7,500 feet of Cretaceous and Tertiary sediments. The rising laccolith greatly disturbed the sediments intruded and not only sharply tilted them away from the locus of intrusion, but produced an intricate series of radial and peripheral faults. Furthermore, radial and lateral anticlines and synclines were developed, some of them of sufficient amplitude to involve all of the exposed sediments.

After a period of quiescence and erosion, a series of violent explosions of steam and mud took place and a mile-wide central crater located just west of the middle of the great andesitic plug. Great angular masses of andesite and rhyolite, some of them measuring 30 feet

or more in diameter, were thrown from this opening and were swept by mudflows down the slopes of the volcano to find a resting place about its periphery.

Erosive processes have brought the Sutter Buttes to their present form. The present-day Buttes are 10 miles in diameter and form an almost perfect circle. The Buttes can be divided into three concentric zones of rock types: the central core, the saddles and low areas surrounding the central core, and an outermost ring of tuff-breccia slopes.

The central core is a roughly circular area three to four miles in diameter, dominated by a cluster of sharp, steep-sided erosional remnants of a laccolith, with South Butte rising to a height of 2,117 feet.

The saddles, low hills, and ridges surrounding the central core are underlain by sedimentary rocks of Tertiary and Late Cretaceous age that were pushed up and fractured when the core was emplaced. This zone is approximately one mile in width and ranges in elevation from 200 to 500 feet above the valley floor.

The tuff-breccia slopes which form the outermost ring are two to three miles wide and have been dissected by erosion. The altitudes range from about 500 to 800 feet at the top of the slopes, and 50 to 100 feet at the foot of the slopes.

Dunnigan Hills Anticline

The Dunnigan Hills structure is an asymetrical anticline, steep on the east flank and gentle on the west flank, and is about 20 miles in length. The anticline plunges to the south, resulting in the subsequent burial of the deformed Tehama and Red Bluff Formations beneath younger valley alluvium along the southern portion. The time of folding is believed to have been during Late Pleistocene.

Faults

The only fault identified in this report is the Sutter Basin Fault (Figs. 5, 6 and 7). The location of this fault is based on electric log correlation and geophysical evidence. It is depicted as a vertical fault, striking N70°W, 11 miles in length, with the south block moving up approximately 500 feet in relation to the north block. The eastern extension of the fault is concealed by the "Markley Gorge," and to the west of the fault appears to die out as it is not discernable in wells further west. The age of the faulting appears to be Upper Eocene.

Around the Sutter Buttes numerous faults occur as the result of the igneous intrusives. The surface expressions of some of these faults have been mapped on Figure 4.

Published investigations of gas fields in the area reveal numerous faults to the south of the Buttes and along

the west side of the Valley. Most of the faulting to the south of the Buttes is confined to the Forbes Formation. The few faults that extend above the Forbes (Weagant, 1964) are strike-slip faults trending to the north or northwest, and terminate at the base of the Capay Shale. Since the strike of the faults is approximately parallel to the direction of the ground water flow and the Capay Shale appears to act as a barrier to the upward migration of saline water, these faults have not been illustrated on Figure 5.

In general, the fault systems can be divided into three groups: (1) those that are confined to the Upper Cretaceous sediments only; (2) those that cut the Eocene and Cretaceous rock units; and (3) those that were formed by the Sutter Buttes intrusives during Upper Pliocene time.

Historical Geology

The first geologic event pertinent to the hydrogeology of the Sutter Basin was the deposition of the Upper Cretaceous sediments. According to Weagant (1964), in F-zone time (Forbes Formation), there was transgression of the sea and sediments were deposited by progressive onlap on the Lower Cretaceous shale. East of the central portion of the study area the Lower Cretaceous sediments are fully overlapped by the F-zone. The Forbes Formation was deposited in a moderately deep water environment too far from the shore to be affected by shore-line winnowing

processes. These sediments consist of interbedded dark gray claystones and siltstones, and gray, fine-grained friable, lenticular sands. The eastern limit of the F-zone transgression is not known but members of the Forbes Formation crop out along the eastern side of the Sacramento Valley.

The rate of sedimentation was slightly greater than the rate of subsidence, so that the basin gradually shallowed and the E-zone Kione sands as well as some of the uppermost F-zone sands are near-shore sands associated with the shallowing.

The Kione sands were probably deposited in a series of deltas that lay at the mouth of the major drainages coming off of the Sierran land areas to the east. These deltaic sands were further distributed along the east side of the valley by action of along-shore currents and by normal shoreline processes.

Basinal shallowing was accompanied by uplift along the western basin margin with the regression of the sea to a position southwest of the Grimes gas field (Fig. 4). The basin then subsided rapidly, and the Sacramento Shale sea transgressed the area. The Sacramento shales were deposited in a moderately deep water basin.

Again the basin became shallow as the Winters Shales and Sands were deposited. The Starkey represents a very shallow sea environment with deposition of a series

of regressive-transgressive beach or near-beach sands.

Following the deposition of the Upper Cretaceous sediments, probably in Late Paleocene time, the basin was uplifted, tilted southerly, and folded into a broad syncline with a north-south trending axis. The eastern margin of the sea was upwarped (Olmsted and Davis, 1961) and a land mass created east of the present position of the Sutter Buttes. The area then underwent extensive peneplanation.

The sea did not completely withdraw from the Sacramento Valley during Paleocene time, as attested by the deposition of the marine sediments of the Martinez Formation, in the southern part of the Valley. The Paleocene sea in which the Martinez Formation was deposited was confined to a restricted portion of the Delta area by barrier beaches (Safonov, 1962). Behind these beaches, lagoonal, swamp, and flood-plain deposits of sand and silt were laid down. The numerous beds of coal and the erratic character of the sediments as shown on electric logs attest to the predominantly nonmarine nature of the Martinez in this area. In late Paleocene time, the sea readvanced, continuing to do so into early Eocene Meganos time.

At the close of Meganos time, gradual subsidence allowed the Eocene sea to continue to spread over the entire Sacramento Valley area. The basin remained

relatively quiet as the Capay Shale was deposited. The Capay Shale marks the last major sea transgression into the Sacramento Valley. Being widespread and conspicuous on electric-logs, it is an excellent marker bed. The Capay Shale reflects the post-Capay movement of the Valley, the southerly tilt, and the trough effect.

During Middle Eocene time the sea shallowed again and the deltaic deposits of the Ione-Domengine Formation of Stewart (1949) were laid down. To the east, the alluvial and lagoonal sediments of the Ione Formation of Allen (1929) were deposited. Lignite seams and severely weathered sediments of the Ione Formation attest to a warm, humid climate.

Following the Capay transgression a minor transgression of the sea in Upper Eocene time is reflected in the deposition of the Nortonville Shale member of the Kreyenhagen Formation. Then the sea began to withdraw from the Sacramento Valley.

Near the end of Eocene time the area was again uplifted, and eroded. The "Markley Gorge" of Davis (1953) was being carved and the entire study area was undergoing erosion. Almgren and Schlax (1957) believe that the "Markley Gorge" Fill was predominantly nonmarine deposits of Oligocene and possibly Miocene time.

Commencing in the Middle or Late Eocene and continuing sporadically into Miocene time, volcanic eruptions

deposited rhyolitic, andesitic, and basaltic pyroclastic and flow rocks near the present crest of the Sierra Nevada (Piper et al., 1939). The streams eroded this material and redeposited it in the valley as water-laid tuff, tuffaceous sand and volcanic gravel. After a period of erosion and relative quiet, predominantly andesitic eruptions began during the Late Miocene in the northern Sierra Nevada and sent a flood of mudflow breccia and ash down the western slopes. Streams continually reworked these deposits and spread them over broad areas to the west.

The volcanic activity waned and died out and the latter part of the Pliocene epoch was marked by erosion in the Sierra Nevada and subaerial deposition (Laguna Formation) in the Sacramento Valley.

In the Middle or Late Pliocene time (Olmsted and Davis, 1961) an uplift of the present northern Coast Ranges inaugurated a period of erosion in the mountains and deposition of coarse detritus to the east. The Sacramento Valley trough began to assume approximately its present outline. Fluviatile deposition continued through the Pliocene and possibly into the early Pleistocene. The streams continually shifted across broad, low flood plains and deposited the Tehama Formation.

During Middle Pleistocene both the Coast Ranges and the Sierra Nevada appear to have been subjected to orogenic processes, and it is possible that this is the

time that the Sutter Buttes were formed. The Coast Ranges were folded, faulted, and elevated and began to assume their present general outline and form. The Pliocene to Pleistocene (?) fluviatile sediments (Tehama Formation) and older rocks were involved in the folding and uplift. Dunnigan Hills anticline was formed at this time. During and after this mountain-building activity, erosion was vigorous, and much of the Tehama Formation was removed and redeposited in the center of the Valley or carried southward by the Sacramento River. Poorly sorted, gravelly material (Red Bluff Formation) eventually was deposited on the eroded surface of the Tehama.

The rejuvenated streams cut laterally and truncated the soft sediments of the Laguna Formation that had been deposited during the Late Pliocene. Most of the detritus was carried westward to be deposited near the axis of the Valley, and in this report is considered part of the Victor Formation.

The present cycle is one of continued erosion of the Coast Ranges, the Sierra Nevada and low hills, and deposition in the Valley.

WATER QUALITY

Connate Water

The term "connate water" has been used several times in this report. Connate water, as originally defined by A. C. Lane (1908) is "water that has remained since burial with the specific rocks in which it occurs, and that its chemical composition has remained unchanged." D. E. White (1965) has summed up the more recent ideas about connate water by saying (pg. 345):

> Much recent evidence indicates that (1) the original interstitial water of sediments normally undergoes diagenetic changes related to bacterial activity and decomposition of organic matter; (2) inorganic reactions between mineral phases and interstitial water occur during early and late diagenesis and also during metamorphism; (3) compaction always occurs, at least to some extent, in response to sediment load, so water must migrate either locally or extensively in directions of decreasing potential; (4) 'salt-sieving' mechanisms, only slightly understood until very recent years, account for changes in salinity of probably all deep waters of sedimentary basins; and (5) other mechanisms, even less well understood, account for changes in chemical composition of saline waters.
>
> Connate water, as here defined, generally is similar in age or somewhat younger, since last direct contact with the atmosphere, than the age of its associated rocks. Most connate waters are probably marine in origin and are associated with normal marine sediments, but some are suspected of being connate to marine and nonmarine evaporites. The dilute meteoric water 'born with' normal nonmarine sediments is probably never preserved in

> its original relationships but is normally displaced after burial by other dilute waters and eventually by any saline water (with higher density) that has access to the sediments.

In this report the water with a high chloride content is believed to have been derived from a marine source when the sediments were deposited in the open sea or in embayments with limited access to the sea. The latter case seems true for the sands of the Upper Cretaceous and Eocene deposits, because their chloride content is about half of that of normal sea water. These waters are termed "connate" under the definition of White (1965).

Basic Data

One hundred thirty-seven water quality analyses were obtained from the files of the California Department of Water Resources for use in this investigation. As many as space would allow are depicted with circle diagrams on Figure 6. Most of the analyses were determined during the 1964-67 period and consist of the standard analyses (i.e., only the major ions were determined). All of the chemical analyses are tabulated in Appendix A.

Approximately 400 electric-logs were used to correlate the formations and zones in the study area. These logs were also used as a guide to the quality of the ground water. The large differences in resistivity for potable and saline water are easily interpreted. Problems

arise when one attempts to relate resistivity to degree of salinity. Besides the many assumptions that must be made, it is necessary to compute the resistivity of the formation from cores or drill cuttings, or have water quality samples from the formation in question. Lacking this, the electric-logs can be used only in a general way for determining water quality.

Variations of Water Quality

Vertical Variation

The entire study area is underlain at varying depths with saline water of marine origin. East of the Feather River, the base of the fresh water is at or near the base of the post-Eocene non-marine sediments. The fresh-water base slopes from near surface, at the areas of outcrop along the eastern margin of the Valley, to depths of 1,100 feet below the town of Verona and approximately 650 feet beneath Yuba City.

Throughout most of the Sutter Basin the base of the fresh water is at a depth of less than 500 feet and in the southern part of the Basin it rises to the surface. Along the western edge of the Sutter Basin the base of the fresh water again deepens and reaches a maximum depth of over 2,300 feet in T.10N., R.1E. A trough of fresh water trends to the northwest beneath Colusa Basin and also shallows to the northwest.

To the west of the trough the base of the fresh water again shallows and is at or near the base of the Tehama Formation along the western boundary of the Valley.

Around the Sutter Buttes the marine sands of the Ione-Domengine and the Kione Formations have been flushed with fresh (meteoric) water to depths of over 2,100 feet. Between the Buttes and the City of Colusa is another mound of saline water which is associated with the near-surface occurrence of Cretaceous beds.

If the base of the fresh water south of the Sutter Buttes were to coincide with the base of the nonmarine sediments, then there would be a gradual deepening of the base of the fresh water across the Sutter and Colusa Basins toward the trough of the Valley. Instead, the base of the fresh water shallows in the Sutter Basin and then deepens in the Colusa Basin.

Horizontal Variation

The river water that flows through the area is very good in quality. It is a calcium bicarbonate type with a total dissolved solid (TDS) content of between 50 and 150 parts per million (ppm). When the river water enters the ground water basin by influent seepage it is in a new environment and changes in quality to reach equilibrium with its new environment. It increases in total dissolved solids and changes to a magnesium bicarbonate type

water. This is due to the large percentage of andesitic and basaltic debris that is present in the alluvial material.

In contrast to the magnesium bicarbonate type fresh water is the poor quality sodium chloride water that occurs in the Sutter Basin between Tisdale Weir and the town of Robbins (Fig. 6). The sodium chloride type water is unlike either the river water or ground water elsewhere in the area. The development of a pumping trough to the northwest along the Feather River has caused the saline water to move into this area and contaminate the ground water. This movement has been continuous over the years and has caused the farmers to abandon their water wells and resort to Feather River water for irrigation.

HYDROCHEMICAL PROCESS

Recharge Waters and Equilibrium

Recharge of the ground water basin is coming from three main sources: infiltration of rain water, river water, and excess irrigation. These three sources consist of water of high quality. One of the conclusions of this paper is that rising connate water is contaminating the ground water basin.

For saline water to move up and displace the fresh water in 2,000 feet of alluvial material requires a driving force or hydraulic head. The saline connate water was originally contained in the marine sediments of Upper Cretaceous and Eocene age. When the igneous intrusives of the Sutter Buttes forced their way up through the overlying sediments they dragged up the marine sediments and exposed them at the surface around the central zone of the Buttes. The marine sediments now stand some 250 to 400 feet above the surrounding flocr of the Valley. In time (some 1,200,000 years) runoff water of meteoric origin infiltrated the Ione-Domengine and Kione sands, both at outcrop and along faults and fractures, and displaced the saline water of marine origin.

Electric-logs run in wells around the southern half of the Buttes indicate that the fresh water has displaced

the connate water to depths of over 2,000 feet. The displaced connate water in the Ione-Domengine Formation has many avenues of escape (Fig. 5) and has contributed saline water to the lower part of the nonmarine sediments in the ground water basin. The hydraulic gradient or head that developed in the Kione Formation, from the Buttes south to the Sutter Basin, has only one avenue of release and that is up the Sutter Basin Fault (Figs. 5, 6 and 7). Therefore it is proposed that the connate water in the Kione Formation moves south from the Sutter Buttes and up the fault, causing a mound of saline water to move to the surface. This movement of high chloride water continues to the present as fresh water infiltrates the Kione sands at the Sutter Buttes. It is possible that the connate water in the Ione-Domengine Formation is also contributing some saline water to the mound, but it appears that the major contributor is the Kione Formation.

There is not enough information available now to determine whether the Sutter Basin Fault zone is pervious and allows the connate water to move through it or that it acts as a barrier and forces the saline water to rise along the north side of the fault.

For a time this investigator thought that the Starkey Sands of Upper Cretaceous age was the main contributor of the saline water. But it now appears that the presence of the Starkey Sands in contact with the

overlying nonmarine alluvium (Fig. 6) beneath the mound of saline water in the Sutter Basin has nothing to do with the saline phenomenon. It was hypothesized that the overburden on the confined portion of the Starkey would develop the required pore pressure to move the connate water up through the valley alluvium to the surface. However, a check of "closed in" pressures conducted in gas wells drilled into the Starkey Sands revealed that the pore pressure was approximately equal to the hydraulic load. This means that no abnormal pore pressure has been developed in the Starkey, and therefore there is no hydraulic head to move the saline water through the alluvium and up to the surface in the Sutter Basin.

Base Exchange

When ground water comes in contact with solid phase materials different from the ones it had been in contact with previously, chemical reactions may occur. This is particularly true when the water comes in contact with finely divided solids such as silt and clay that have an adsorptive capacity. One type of adsorption is termed "ion exchange" and is the replacement of adsorbed ions by ions in solution. The capacity for ion exchange is mostly a result of unsaturation of the chemical bonding in the crystal lattice of the solid having this capacity. In most cases there is an excess of negative bonds in certain areas of the crystal lattice, and positively

charged ions are attracted to these areas. Most of the ion exchange reactions involve cations (calcium, magnesium, potassium, and sodium) and are therefore called base exchange.

After the ground water has been in contact with the solids a sufficient length of time, cations in solution and the adsorbed ions held by the exchange material constitute a system in chemical equilibrium. The degree and readiness for displacement of the equilibrium to the right or left is governed by the law of mass action, which means that if water or mineral holds some base in large excess, the exchange of that base for another proceeds more readily. The replacing power of the different metallic cations differ widely. Calcium possesses high replacing power; magnesium stands next, followed by potassium and then by sodium. Normally, calcium and magnesium ions from solution replace adsorbed sodium on the exchange material and the water is naturally softened. However, under certain conditions explained by the Le Chatelier's principle the system can be reversed and the ground water will undergo a hardening process. According to the principle of Le Chatelier any equilibrium system subjected to a stress tends to change so as to relieve the stress. For a system in chemical equilibrium, changing the concentration of one of the components constitutes a stress (Sienko and Plane, 1966). Thus, if we introduce a large supply of sodium ions into

the ground water body that has reached chemical equilibrium a stress has been applied. Now the adsorbed calcium and magnesium ions will be replaced by the sodium ions in solution and the replacement will continue until the system is again in chemical equilibrium. This is exactly the procedure used in many domestic water softening systems. The water flows in contact with zeolites which act as an ion exchanger. Calcium ions are exchanged for sodium ions being held by the zeolite molecules. Once the exchanger has given up its supply of sodium ions it cannot soften water further. However, it can be regenerated by exposure to a concentrated solution of sodium chloride which reverses the reaction.

Piper et al. (1953) in their study of the contaminated ground water in the Long Beach-Santa Ana area of California found that the introduction of sea water or oil field brines high in sodium chloride resulted in the substitution of calcium (and locally some magnesium) for a large part of the sodium in the contaminating water. In other words, the strongly contaminated waters had been hardened by base exchange reactions, and the degree of hardening was greater than could be explained by the simple admixture of sea water and fresh water. They postulated that the influx of ocean water into the zones of native calcium bicarbonate type water released previously adsorbed calcium and magnesium by base exchange. This

condition is also found in the Sutter Basin, where the rising connate water, high in sodium chloride, comes in contact with the calcium-magnesium bicarbonate type ground water of low total dissolved solids, and is changed to a calcium-magnesium chloride type with a high total dissolved solids. In both instances, we see a case of water being hardened by base exchange.

Source and Movement of Ions

Bicarbonate-Carbonate

There is a very limited occurrence of bicarbonate minerals in the Sutter Basin and the drainage areas of the Sacramento River and its tributaries. Based on the work of Bear (1964), this investigator concludes that the bicarbonate and carbonate anions in the ground water come mostly from the carbon dioxide contained in the soil, and in a small part from the precipitation that has been in contact with carbon dioxide in the atmosphere.

The following chemical equations indicate how these reactions might take place:

$$CO_2(gas) + H_2O = CO_2(aqueous) + H_2O$$
$$CO_2(aqueous) + H_2O = H_2CO_3$$
$$H_2CO_3 = H^+ + HCO_3^-$$
$$HCO_3^- = H^+ + CO_3^{--}$$

Of the 137 water analyses tabulated in Appendix A, 106 samples have the bicarbonate ion as the major anion. This bicarbonate type water is considered the normal condition for the ground water basin and is

found on all sides of the mound of high chloride type water.

Sulfate

Feth, J. H., Robertson, C. E., and Polzer, W. L. (1964) propose that most of the sulfate ions in the runoff water of the Sierra Nevada come from water rising along fault zones. The author is aware of a source of sulfur in the upper Feather River drainage called Sulfur Point. The concentration of the sulfur compounds at Sulfur Point is so high that the stream is uninhabitable for fish within a mile below the Point.

The Bear River carries more sulfate ions than the other rivers flowing through the study area. Surface water samples contain as much as 0.56 equivalent parts per million (epm) with a TDS of 180 ppm. Water in well 13N/4E-21A1 is classified as a magnesium sulfate type and is the only well water that has sulfate as the major anion. Well 13N/4E-17J1, which is also near the Bear River (Fig. 6), has the second highest sulfate content among the ground water analyses used in this report.

Throughout the rest of the area the sulfate ions make up the minor constituent of the anion group. This is particularly true for the ground water with a high chloride content. A case in point is well 12N/2E-2J1 that has a TDS of 3525 ppm and a sulfate content of 2.0 ppm. Several other wells with high chloride water, in the same area,

have no discernible amounts of sulfate in the water analyses.

Hem (1970) has proposed the following reaction for sulfate reduction:

$$SO_4^{--} + CH_4 \text{ (bacteria) } HS^- + H_2O + HCO_3^-$$

This formula suggests that in the reduction of the sulfate the anaerobic bacteria is the most active agent. Methane gas is known to be present in the area. Bear (1964, p. 279) suggests that though the mechanism of sulfate reduction has still not been completely worked out, the activities of sulfate-reducing organisms are chiefly restricted to heavy clays or water logged soils. Such conditions are found in the Sutter Basin. One of the by-products of sulfate-reducing organisms is hydrogen sulfide with its characteristic odor. Bryan (1923) reported that much of the ground water in the eastern part of the Sutter Basin contained small quantities of hydrogen sulfide and that "many local people prefer the 'sulphur' water for drinking."

Chloride

A study of Figure 6 shows that there is a body of high chloride water in the central part of the Sutter Basin. Possible explanations for this are: (1) concentration of the chloride ion by evaporation of the ground water at or near the surface, (2) buried beds of sodium chloride salt, and (3) connate water rising from marine sediments. Byran (1923) noted that the conditions for

residual evaporates existed in the basins of the Sacramento Valley but they were found only in small, isolated bodies. His reasons for the absence of extensive evaporates has already been cited. Drilling has not revealed any buried salt bodies such as exist in the Phoenix area of Arizona. Therefore, it appears most logical that the chloride ions are the result of marine connate water. In the past, the major stumbling block to this theory was that the high chloride occurs in nonmarine alluvial material with a thickness of approximately 2,000 feet.

Chloride ions are resistant to ion exchange, hence maintain their identity as ions after introduction into a ground water body. They are, therefore, ideal for use as tracers in ground water studies. Notice on Figure 6 the area between the Sutter Basin Fault and the Pumping trough to the north, west of the Feather River. The pumping for irrigation water has reversed the natural gradient of ground water and has resulted in the saline water slowly moving north and degrading the ground water. What is of interest to this thesis is that even though the degrading saline water has been diluted and subject to base exchange, the water still maintains a high percentage of chloride ions.

Sodium and Potassium

Feth et al. (1964) state that the igneous rock in the Sierra Nevada contained almost equal portions of sodium and potassium, however, once the ions have been taken into solution by the ground water, the potassium ions are subject to base exchange and rapidly disappear from the ground water, while the sodium ions persist and are carried by the rivers down to the valley ground water basin. This is confirmed in the water analyses in the study area. In both the surface water and the ground water, the sodium ions far outnumber the potassium ions. The two ions have been grouped together in the circle diagrams on Figure 6.

Throughout most of the area, sodium is the minor constituent in the cation group. As the water percolates through interstices of the alluvial material, normally the sodium ions are released to the ground water at the expense of the calcium and magnesium ions in solution. This process of base exchange is known as natural "softening" of the water. There is some evidence that this process is taking place, but in general it is masked by the infiltration of irrigation water diverted from the rivers.

Water analyses of the two deep wells (12N/2E-18 SW1/4 and 12N/2E-24L1, Appendix A) show that the deep waters contain 73.8 and 73.5 percent (of total anion reactance) sodium ions, respectively. South of the Sutter Basin Fault

the deep connate water does not change chemically as it rises to the surface. Yet, as this same water moves Northward it becomes harder by changing from a sodium chloride type to a calcium-magnesium chloride type. As previously stated, this phenomenon was observed by Piper et al. (1953) in the Long Beach-Santa Ana area where fresh ground water was being contaminated with sea water. There, as in the Sutter Basin, the contaminated zone contains water which is higher in calcium and magnesium than can be explained by assuming a simple admixture of the saline water and fresh water involved. The best explanation is that previously adsorbed calcium and magnesium ions are being released by base exchange in the presence of the high sodium ion solution. That is to say, the water moving to the North is undergoing a base exchange, or hardening process. And on the other hand, the water moving Southwesterly from the Sutter Basin Fault is moving through soil that now has a deficiency of exchangeable calcium and magnesium ions and maintains its identity as a sodium chloride type water--the difference being that the saline water has been moving north only since the ground water trough was developed by irrigation pumping, whereas the ground water had been moving in a southerly direction for many thousands of years.

Calcium and Magnesium

The river water flowing through the area and recharging the ground water basin is a calcium-magnesium

bicarbonate type with a TDS of between 50 and 150 ppm. Once it has infiltrated the basin, it changes to a magnesium-calcium type. The probable explanation for this is that the alluvium has a high content of ferromagnesium minerals due to the presence of andesitic volcanic debris. By the law of mass action and through base exchange, the magnesium ions are released to the ground water and the calcium ions are adsorbed by the soil particles.

Boron

The Feather River and its tributaries are free of boron although a trace is reported from time to time along the lower reaches. The ground water being recharged by the Feather River and its tributaries is also free of boron. Along the eastern edge of the Sacramento Valley, some of the water from wells contains boron that is believed to be coming from marine sediments that occur at shallow depths.

The streams and rivers draining the Coast Ranges generally have a high boron content. Cache Creek, in Capay Valley, has a boron content of up to 4 ppm. The ground water recharged by the western streams normally contains one to two parts per million boron.

Within the mound of saline water in the Sutter Basin the boron content ranges from 10.8 ppm at a depth of 1,500 feet to 1.5 ppm at a depth of 285 feet. As the

rising connate water moves laterally away from the mound of saline water, the boron content gradually decreases until it is no longer detected in the analyses. The rapid decrease in boron over a vertical distance of some 1,200 feet is assumed to be largely the result of adsorption.

CONCLUSIONS

On the basis of the findings of this investigation, it is concluded that:

Subsurface Geology

The Kione Formation of Upper Cretaceous age is the chief contributor to the rising connate water in the Sutter Basin.

The Ione-Domengine Formation of Middle Eocene age also contributes saline water to the ground water basin but not in sufficient quantities to raise the base of the fresh water to the surface.

The "Starkey Sands" of Upper Cretaceous age are in direct contact with the overlying alluvial sediments in the southern portion of the Sutter Basin. This happenstance has nothing to do with the mound of saline water in the same area.

Hydraulic Continuity

The Sutter Basin Fault cuts the Upper Cretaceous marine sands and allows the saline water in the Kione Formation to rise along the fault into the post-Eocene alluvium.

Hydraulic Gradient

The head required to move the saline connate water from the underlying marine beds up through 2,000 feet of alluvium is supplied by the position of the Kione Formation which has been dragged up by the Sutter Buttes Intrusives and exposed at elevations between 250 and 400 feet above the Valley floor. The marine sands have been flushed with fresh water to depths of over 2,000 feet below sea level around the south side of the Buttes. The displaced saline water has moved south and up the Sutter Basin Fault and then through the overlying alluvial sediments to the surface.

Water Chemistry

The mound of saline water in the Sutter Basin is coming from connate water related to the marine sediments which underlie the entire area. The connate water is of a sodium chloride type that changes into a calcium-magnesium chloride type due to base exchange as the water moves into an area which previously contained calcium-magnesium bicarbonate type water.

APPENDIX A

ANALYSES OF GROUND WATER

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value						parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
10N/1E-15H2	176	1.95 33.6	2.14 36.9	1.71 29.5	4.24 71.7	0.54 9.1	1.13 19.1	1.5	270	204
10N/2E-17J3	243	2.05 34.8	2.14 36.3	1.71 29.0	4.24 74.3	0.40 7.0	1.07 18.7	1.5	278	207
11N/1E-4R1	-	1.30 11.1	4.59 39.2	5.82 49.7	9.43 77.8	1.39 11.5	1.30 10.7	4.2	695	295
11N/1E-16P1	172	1.85 32.2	2.06 35.9	1.83 31.9	4.74 80.2	0.23 3.9	0.93 15.8	1.3	304	195
11N/2E-14F4	330	1.35 24.9	1.73 31.9	2.35 43.3	4.78 86.3	0.20 3.6	0.56 10.1	0.7	277	153
11N/2E-32G1	-	1.45 13.1	5.85 52.9	3.75 33.9	7.26 68.7	1.00 9.5	2.31 9.5	3.3	604	366
11N/3E-3N2	112	0.75 39.5	0.25 13.2	0.90 47.4	1.73 91.0	0.08 4.2	0.02 5.3	0.1	131	50
11N/3E-14N2	-	3.59 28.8	3.40 27.2	5.49 44.0	4.30 34.1	0.18 1.4	8.10 64.0	0.3	705	351
11N/3E-14R1	236	1.20 10.0	0.30 2.5	10.51 87.5	4.83 40.0	0.06 0.9	7.17 59.1	0.2	718	75
11N/3E-24D1	145	2.18 30.8	2.88 40.4	2.05 28.8	6.92 93.4	0.15 2.3	0.31 4.3	0.2	365	253
11N/3E-36L1	140	0.37 9.5	0.23 5.9	3.33 84.7	3.20 82.5	0.20 5.2	0.48 12.4	0.3	246	30
11N/4E-3P2	305	2.30 40.6	2.38 42.0	0.99 17.5	4.49 82.1	0.11 2.0	0.87 15.9	0.0	295	234

Well Number	Depth ft.	Chemical constituents equivalents per million / percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
11N/4E-9D1	-	1.40 42.2	1.32 39.7	0.60 18.1	2.60 76.3	0.50 14.7	0.31 9.0	0.1	184	138
11N/4E-14D2	204	0.83 26.1	0.99 31.1	1.36 42.8	2.16 77.7	0.08 2.9	0.54 19.4	0.2	152	91
11N/4E-19E2	-	1.35 31.4	1.41 32.8	1.54 35.8	3.00 69.3	0.31 7.2	1.02 23.5	0.1	262	138
12N/1W-21A1	405	1.50 32.7	2.30 50.3	0.78 17.0	4.20 97.5	0.00 0.0	0.11 2.5	0.0	214	189
12N/2E-2J1	100	30.37 28.2	35.30 33.4	39.90 37.8	4.10 4.0	0.05 0.0	99.45 96.0	0.6	5610	205
12N/2E-9B2	-	1.35 20.6	0.03 4.0	5.17 79.0	3.89 65.2	0.33 5.5	1.75 29.3	0.5	402	69
12N/2E-11N1	-	1.55 12.5	1.15 9.3	9.70 78.2	4.30 36.0	0.00 0.0	7.61 64.0	0.9	728	135
12N/2E-14B1	-	7.58 18.3	9.21 22.2	24.65 59.5	3.12 7.9	0.00 0.0	38.63 92.1	0.8	2790	841
12N/2E-16R1	-	2.25 21.5	0.72 6.9	7.46 71.6	7.13 70.0	0.35 3.5	2.68 26.5	0.6	577	148
12N/2E-18SW	1500	19.83 19.2	7.22 7.0	76.12 73.8	2.71 2.5	0.08 0.1	99.98 97.4	10.8	5870	166
12N/2E-23Q1	-	1.15 12.1	0.55 5.8	7.82 82.1	4.50 48.4	0.01 0.0	4.79 51.6	0.7	571	85

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
12N/2E-24G1	446	0.70 7.6	0.72 7.9	7.61 84.5	4.00 47.4	0.35 4.1	4.09 48.5	0.1	670	-
12N/2E-24L1	1565	19.81 19.3	7.23 7.2	75.21 73.5	2.70 2.6	0.08 0.1	100.03 97.3	10.8	5940	-
12N/2E-24L2	146	19.81 36.5	9.29 17.1	25.23 46.4	3.47 8.1	0.02 0.0	39.48 91.9	1.1	2452	-
12N/2E-26A1	-	1.40 13.3	0.72 6.8	8.41 79.9	4.64 44.8	0.00 0.0	5.72 55.2	0.6	608	107
12N/2E-35SW	44	4.09 15.3	5.84 21.7	16.88 63.0	4.20 15.4	0.01 0.0	23.41 84.6	0.4	1628	-
12N/3E-13F1	285	0.85 20.3	0.47 11.2	2.87 68.5	2.91 69.8	0.02 0.5	1.24 29.7	0.2	266	66
12N/3E-16H2	-	2.15 19.0	4.45 39.3	4.73 41.7	5.28 47.1	2.21 19.7	3.71 32.2	0.0	620	330
12N/3E-23G1	120	6.47 36.6	4.72 26.7	6.49 36.7	2.82 15.9	0.23 1.3	14.72 82.8	0.4	1060	561
12N/3E-25A1	155	2.05 41.3	1.45 29.2	1.46 29.4	4.02 79.2	0.25 5.0	0.76 15.1	0.1	286	175
12N/25C2	97	3.79 50.1	2.20 29.1	1.58 20.9	4.13 54.9	0.75 10.0	2.65 35.2	0.1	435	252
12N/3E-26R1	-	2.99 42.2	1.64 23.1	2.46 34.7	3.52 48.6	0.17 2.4	3.55 49.0	0.1	423	234

Well Number	Depth ft.	Chemical constituents equivalents per million			percent reactance value			parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
12N/3E-30H1	232	4.64 13.9	2.96 8.9	25.71 77.2	3.18 9.7	0.19 0.6	29.34 89.7	1.5	1970	380
12N/4E-4N2	89	1.45 36.2	1.75 43.6	0.81 20.22	2.72 68.3	0.19 4.8	1.07 26.9	0.0	257	160
12N/4E-6G1	82	2.50 26.2	4.30 45.0	2.76 28.8	6.20 69.0	2.17 24.1	0.62 6.9	0.2	491	340
12N/4E-7R1	100	0.95 32.3	1.35 45.9	0.64 21.8	2.63 92.9	0.02 0.7	0.18 6.4	0.0	181	115
12N/4E-32J1	-	4.39 42.8	4.19 40.8	1.68 16.4	4.25 41.6	2.08 20.4	3.89 38.1	0.0	682	427
13N/1W-15R2	-	1.80 33.3	1.23 22.8	2.37 43.9	4.03 75.9	0.21 4.0	1.07 20.5	0.5	287	153
13N/1W-36Q2	36	1.75 38.6	1.15 24.9	1.72 36.5	3.31 74.3	0.15 3.4	0.99 22.3	0.3	276	145
13N/1E-22J1	-	2.84 52.4	1.48 27.3	1.10 20.3	3.71 69.6	0.17 3.2	1.44 27.0	0.1	327	216
13N/1E-36Q1	-	1.75 37.9	1.15 24.9	1.72 37.2	3.31 74.4	0.15 3.4	0.99 22.2	0.3	276	145
13N/2E-23B1	72	17.41 28.0	21.18 38.7	20.87 33.3	3.54 5.6	0.00 0.0	59.80 94.4	0.4	5970	2080
13N/3E-2C4	190	3.64 36.8	3.67 37.1	2.58 26.1	5.94 61.2	0.98 10.1	2.79 28.7	0.2	486	-

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
13N/3E-14G1	-	5.56 21.5	14.18 54.9	6.08 23.6	2.98 11.2	3.39 12.9	20.01 75.9	0.1	1994	987
13N/3E-15B1	95	6.99 31.5	9.01 40.6	6.20 27.9	2.75 12.5	0.06 0.3	19.18 87.2	0.1	1400	800
13N/3E-15C2	90	8.53 37.6	10.85 44.0	5.29 21.4	4.18 16.8	0.06 0.2	20.68 83.0	0.1	1580	970
13N/3E-23C1	105	13.40 41.9	13.00 40.6	5.60 17.5	5.92 18.7	0.10 0.3	25.60 80.8	0.2	1884	1320
13N/3E-23H1	-	5.10 30.7	7.70 46.4	3.80 22.9	3.43 20.7	0.46 2.8	12.65 76.5	0.1	900	640
13N/3E-24D1	-	7.80 26.2	11.80 39.6	10.21 34.2	1.46 4.8	0.23 0.8	28.50 94.4	0.5	2140	980
13N/4E-3D1	130	1.30 22.2	3.30 56.3	1.26 21.5	3.93 68.0	0.19 3.3	1.66 28.7	0.0	320	230
13N/4E-17J1	200	2.45 39.5	2.75 44.3	1.01 16.3	3.33 56.7	2.00 34.1	0.54 9.2	0.02	387	260
13N/4E-21A1	-	3.59 36.3	5.26 53.2	1.04 10.6	4.31 42.9	5.45 54.3	0.28 2.8	0.0	565	445
13N/4E-27M1	196	0.70 29.4	1.02 42.9	0.66 27.7	1.92 84.2	0.02 0.9	0.34 14.9	0.0	163	86
13N/4E-32N1	84	0.95 23.4	1.43 35.2	1.68 41.4	2.41 83.1	0.12 4.1	0.37 12.8	0.0	200	119

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
13N/4E-33J2	154	1.95 35.7	2.55 46.6	0.97 17.7	4.56 85.6	0.09 1.7	0.68 12.8	0.0	312	-
14N/1W-2D1	-	2.84 31.8	2.47 27.6	3.63 40.6	3.67 40.6	1.64 18.2	3.72 41.2	0.2	493	268
14N/1W-12A1	-	1.05 17.6	0.09 1.5	4.83 80.9	4.41 74.7	0.02 0.3	1.47 24.9	0.5	319	57
14N/1E-1A1	-	3.24 45.5	2.63 36.9	1.25 17.6	6.05 88.1	0.37 5.4	0.45 6.6	0.0	344	294
14N/1E-24N1	125	1.60 34.0	1.73 36.0	1.42 30.0	3.99 86.0	0.441 10.0	0.19 4.0	0.1	248	166
14N/2E-13L1	79	1.20 29.6	1.81 44.7	1.04 25.7	3.90 96.3	0.06 1.5	0.09 2.2	0.0	205	150
14N/2E-17E1	330	1.25 25.9	1.25 25.9	2.32 48.2	3.93 83.6	0.33 7.0	0.48 9.4	0.1	298	196
14N/2E-30R1	188	1.90 27.8	1.58 23.1	3.37 49.1	5.22 77.5	0.21 3.1	1.30 19.4	0.1	386	174
14N/3E-4E5	160	2.20 26.0	4.12 48.7	2.14 25.3	5.61 71.0	1.44 18.2	0.85 10.8	0.0	455	316
14N/3E-5A3	106	4.39 34.5	5.18 40.8	3.14 24.7	8.30 66.4	2.08 16.6	2.12 17.0	0.1	670	481
14N/3E-5D2	150	1.50 29.8	2.10 41.7	1.44 28.6	4.54 91.9	0.17 3.4	0.23 4.7	0.0	266	180

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
14N/3E-6A1	100	2.50 32.9	3.29 43.4	1.80 27.7	6.54 89.3	0.58 7.9	0.20 2.7	0.0	363	180
14N/3E-7H1	105	1.90 23.9	4.18 52.6	1.86 23.4	6.06 77.5	0.58 7.4	1.18 15.1	0.0	401	304
14N/3E-9K1	230	2.99 33.2	3.57 39.6	2.45 27.2	3.65 41.5	0.19 2.2	4.96 56.3	0.1	628	328
14N/3E-13D1	650	1.00 37.6	0.68 25.6	0.98 36.8	2.01 76.4	0.00 0.0	0.62 23.6	0.2	198	84
14N/3E-14E2	90	1.10 44.7	1.07 43.5	0.29 11.8	2.25 91.8	0.10 4.1	0.10 4.1	0.0	118	104
14N/3E-16B2	99	4.09 29.3	7.15 51.1	2.74 19.6	4.18 29.8	1.60 11.4	8.23 58.7	0.1	895	564
14N/3E-18A2	125	2.69 35.1	3.29 42.9	1.69 22.0	6.39 81.2	0.58 7.4	0.90 11.4	0.1	396	301
14N/3E-20H3	105	2.59 34.4	3.19 42.3	1.74 23.1	5.35 73.5	0.58 8.0	1.35 18.5	0.1	385	289
14N/3E-23M2	83	0.90 37.2	1.16 47.9	0.36 14.9	2.41 97.6	0.02 0.8	0.04 1.6	0.0	385	289
14N/3E-24M1	-	1.75 34.3	2.06 40.3	1.30 25.4	3.56 71.8	0.69 13.9	0.71 14.3	0.1	280	191
14N/3E-24P1	-	1.15 41.7	0.53 19.2	1.08 39.1	1.95 72.8	0.00 0.0	0.73 27.2	0.2	184	84

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
14N/3E-25D3	85	1.10 41.4	0.90 33.8	0.66 24.8	2.11 79.6	0.06 2.3	0.48 18.1	0.0	159	102
14N/3E-26D4	110	0.77 32.9	0.05 2.1	1.52 65.0	1.61 95.3	0.05 3.0	0.03 1.8	0.2	136	11
14N/3E-27K1	180	2.89 24.8	3.91 33.6	4.84 41.6	5.60 49.1	0.31 2.7	5.50 48.2	0.2	665	340
14N/3E-28E1	-	1.25 22.2	2.46 43.6	1.93 34.2	3.52 62.4	0.24 4.3	1.88 33.3	0.2	286	185
14N/3E-29Q1	-	5.12 26.9	6.52 34.2	7.40 38.9	2.92 15.6	0.10 0.5	15.67 83.8	0.4	1000	581
14N/3E-31B1	63	1.30 20.5	2.86 45.2	2.17 34.3	5.51 88.9	0.21 3.4	0.48 7.7	0.0	317	208
14N/3E-32F1	-	5.63 26.4	7.08 33.2	8.60 40.4	3.42 16.1	0.05 0.2	17.76 83.7	0.3	1135	635
14N/3E-33A1	-	3.99 30.3	6.04 45.9	3.13 23.8	2.60 19.7	0.05 0.4	10.54 79.9	0.1	682	501
14N/3E-33C1	-	3.04 21.0	7.76 53.7	3.64 25.2	3.06 21.0	0.13 0.9	11.37 78.1	0.2	806	540
14N/3E-34F1	84	3.49 28.1	4.31 34.7	4.63 37.3	4.96 40.5	0.00 0.0	7.28 59.5	0.1	750	390
14N/3E-34J1	-	1.80 18.9	5.80 60.8	1.94 20.3	3.62 38.3	1.29 13.6	4.55 48.1	0.1	481	380

Well Number	Depth ft.	Chemical constituents equivalents per million			percent reactance value			parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
14N/4E-6H1	112	1.00 44.4	0.58 25.8	0.67 29.8	1.86 81.6	0.07 3.1	0.35 15.4	0.0	116	79
14N/4E-7M1	83	2.25 35.3	2.87 45.0	1.26 19.7	3.51 56.3	2.19 35.1	0.54 8.7	0.0	528	395
14N/4E-9J1	100	1.64 33.3	2.06 41.8	1.23 25.0	3.54 73.1	0.15 3.1	1.15 23.8	0.0	242	165
14N/4E-22H1	400	0.70 31.3	0.64 28.6	0.90 40.2	1.52 70.4	0.02 0.9	0.62 28.7	0.0	191	67
14N/4E-27N1	510	0.80 36.0	0.50 22.5	0.92 41.4	1.92 86.9	0.06 2.7	0.23 10.4	0.0 0.0	148	65
15N/1E-16R1	-	1.90 27.5	3.78 54.7	1.23 17.8	5.84 85.8	0.35 5.1	0.62 9.1	0.1	355	283
15N/1E-35H1	108	2.20 35.1	2.96 47.2	1.11 17.7	5.22 85.6	0.20 3.3	0.28 4.6	0.0	225	-
15N/1E-35R1	-	3.84 47.4	3.53 43.6	0.73 9.0	5.28 66.1	0.62 7.8	2.09 26.2	0.0	466	370
15N/2E-1R1	49	2.10 36.5	2.55 44.3	1.01 17.5	4.69 88.2	0.46 8.7	0.17 3.2	0.0	310	231
15N/2E-22D1	306	1.05 36.0	0.99 33.9	0.83 28.4	2.54 89.4	0.10 3.5	0.10 7.0	0.0	184	100
15N/2E-26D2	-	3.24 40.9	2.79 35.2	1.90 24.0	5.23 74.2	0.44 6.2	1.38 19.6	0.1	447	304

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
15N/3E-4C2	147	3.04 34.2	4.52 50.9	1.32 14.9	5.72 69.3	1.77 21.5	0.76 9.2	0.1	558	379
15N/3E-9C2	200	2.20 34.9	2.28 36.2	1.82 28.9	5.52 88.0	0.44 7.0	0.31 4.9	0.1	350	224
15N/3E-11H4	60	0.94 39.2	1.13 47.1	0.33 13.7	2.17 90.0	0.11 4.6	0.13 5.4	0.0	127	103
15N/3E-13F1	350	1.80 50.9	0.92 26.0	0.82 23.1	2.68 77.5	0.50 14.5	0.28 8.0	0.0	239	136
15N/3E-13J2	300	1.10 44.2	0.54 21.7	0.85 34.1	1.90 74.2	0.01 0.4	0.65 25.4	0.0	201	82
15N/3E-14N1	350	0.70 24.4	0.72 25.1	1.45 50.5	2.34 81.3	0.00 0.0	0.54 18.8	0.3	182	71
15N/3E-15C1	170	1.15 28.3	0.65 16.0	2.27 55.8	3.59 87.4	0.01 0.2	0.51 12.4	0.3	257	90
15N/3E-15E2	188	1.64 24.4	1.92 28.6	3.15 46.9	4.96 76.0	0.27 4.1	1.30 19.9	0.4	329	178
15N/3E-15H4	133	3.49 41.8	3.95 47.3	0.91 10.9	6.65 81.4	0.20 2.5	1.32 16.1	0.0	483	373
15N/3E-15J2	160	0.55 9.1	4.35 71.7	1.17 19.3	3.99 75.9	0.71 13.5	0.56 10.7	0.0	354	245
15N/3E-15Q1	-	0.70 16.8	0.86 20.6	2.61 62.6	3.61 84.6	0.04 0.9	0.62 14.5	0.3	262	-

Well Number	Depth ft.	Chemical constituents equivalents per million / percent reactance value						parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
15N/3E-19M1	75	0.94 30.2	1.39 44.7	0.78 25.1	2.79 92.1	0.09 3.0	0.15 5.0	0.1	150	117
15N/3E-21C1	185	1.30 23.6	2.86 51.9	1.35 24.5	4.47 81.1	0.25 4.5	0.79 14.3	0.0	328	208
15N/3E-22N1	115	3.49 34.4	4.75 46.8	1.90 18.6	7.42 74.6	0.75 7.5	1.78 18.0	0.0	529	412
15N/3E-23C1	118	0.75 46.3	0.65 40.1	0.22 13.6	1.41 92.2	0.05 3.3	0.07 4.6	0.0	99	70
15N/3E-23D1	125	2.25 38.3	3.30 51.5	0.60 10.2	5.19 90.1	0.29 5.0	0.28 4.9	0.0	325	264
15N/3E-24F1	130	2.84 42.8	2.59 39.0	1.21 18.2	4.71 69.4	0.58 8.5	1.50 22.1	0.1	334	261
15N/3E-26C1	163	1.35 30.0	1.71 38.0	1.44 32.0	4.03 90.2	0.10 2.2	0.34 7.6	0.0	262	153
15N/3E-26M1	250	1.45 32.6	1.23 27.6	1.77 39.8	3.97 89.4	0.10 2.3	0.37 8.3	0.2	241	134
15N/3E-27C1	80	3.89 32.2	6.02 49.8	2.17 18.0	8.85 77.2	0.92 8.0	1.69 14.8	0.2	557	496
15N/3E-27L1	150	2.15 31.6	3.05 51.3	1.59 17.0	4.93 86.1	0.33 6.3	1.41 7.6	0.0	370	260
15N/3E-29G1	90	3.09 34.3	4.27 47.4	1.65 18.3	7.20 85.7	0.75 8.9	0.45 5.4	0.0	488	367

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
15N/3E-29G2	110	2.84 31.6	4.61 51.3	1.53 17.0	7.35 86.1	0.54 6.3	0.65 7.6	0.0	487	373
15N/3E-30D1	65	2.64 37.9	3.44 49.4	0.89 12.8	6.10 94.0	0.23 3.5	0.16 2.5	0.0	384	304
15N/3E-34N2	80	3.80 22.9	10.38 62.5	2.43 14.6	7.02 42.8	2.02 12.3	7.36 44.9	0.1	831	709
15N/4E-8D1	333	1.87 43.8	1.82 42.6	0.58 13.6	3.04 73.3	0.90 21.7	0.21 5.1	0.1	220	184
15N/4E-16P1	450	1.15 41.8	1.07 39.0	0.53 19.2	2.21 81.6	0.42 15.5	0.08 2.9	0.0	184	111
15N/4E-20J2	271	1.60 36.9	2.14 49.3	0.60 13.8	3.13 73.0	0.98 22.8	0.18 4.2	0.0	271	187
15N/4E-29H1	145	1.35 36.2	1.75 46.9	0.63 16.9	2.96 80.2	0.54 14.6	0.19 5.2	0.0	187	155
15N/4E-31A1	157	1.05 39.5	1.07 40.2	0.54 20.3	2.32 89.9	0.02 0.8	0.24 9.3	0.0	172	105
16N/1W-29J1	-	1.30 31.3	1.48 35.7	1.37 33.0	3.82 94.1	0.00 0.0	0.24 5.9	0.1	199	139
16N/3E-14G1	63	4.34 46.7	4.22 45.4	0.73 7.9	6.78 76.9	1.19 13.5	0.85 9.6	0.0	472	428
16N/3E-16B1	46	0.84 46.9	0.80 44.7	0.15 8.4	1.49 87.1	0.12 7.0	0.10 5.9	0.0	90	82

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value						parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
16N/3E-23B1	160	1.13 40.1	1.08 38.3	0.61 21.6	2.38 90.5	0.10 3.8	0.15 5.7	0.0	160	110
16N/3E-26Q1	416	1.40 46.1	0.80 26.3	0.84 27.6	2.40 81.6	0.17 5.8	0.37 12.6	0.1	218	110
16N/3E-31C1	72	1.32 30.8	2.04 47.7	0.92 21.5	3.92 92.7	0.16 3.8	0.15 3.5	0.0	318	168
16N/3E-36E1	85	2.16 37.1	2.84 48.7	0.83 14.2	5.04 92.5	0.02 0.4	0.39 7.2	0.0	280	250

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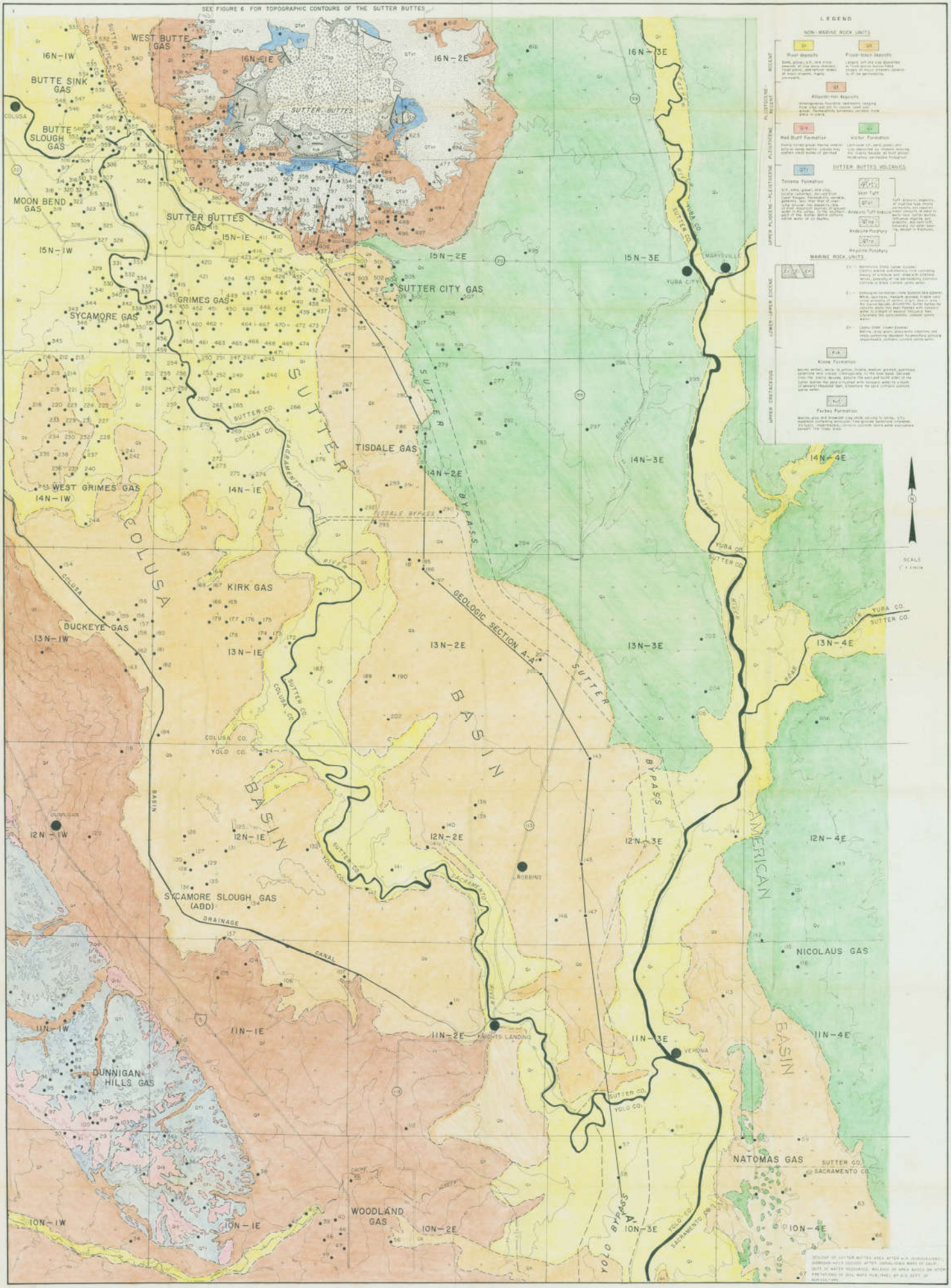

FIGURE 4

SURFICIAL GEOLOGY OF THE SUTTER BASIN AREA, SACRAMENTO VALLEY, CALIFORNIA

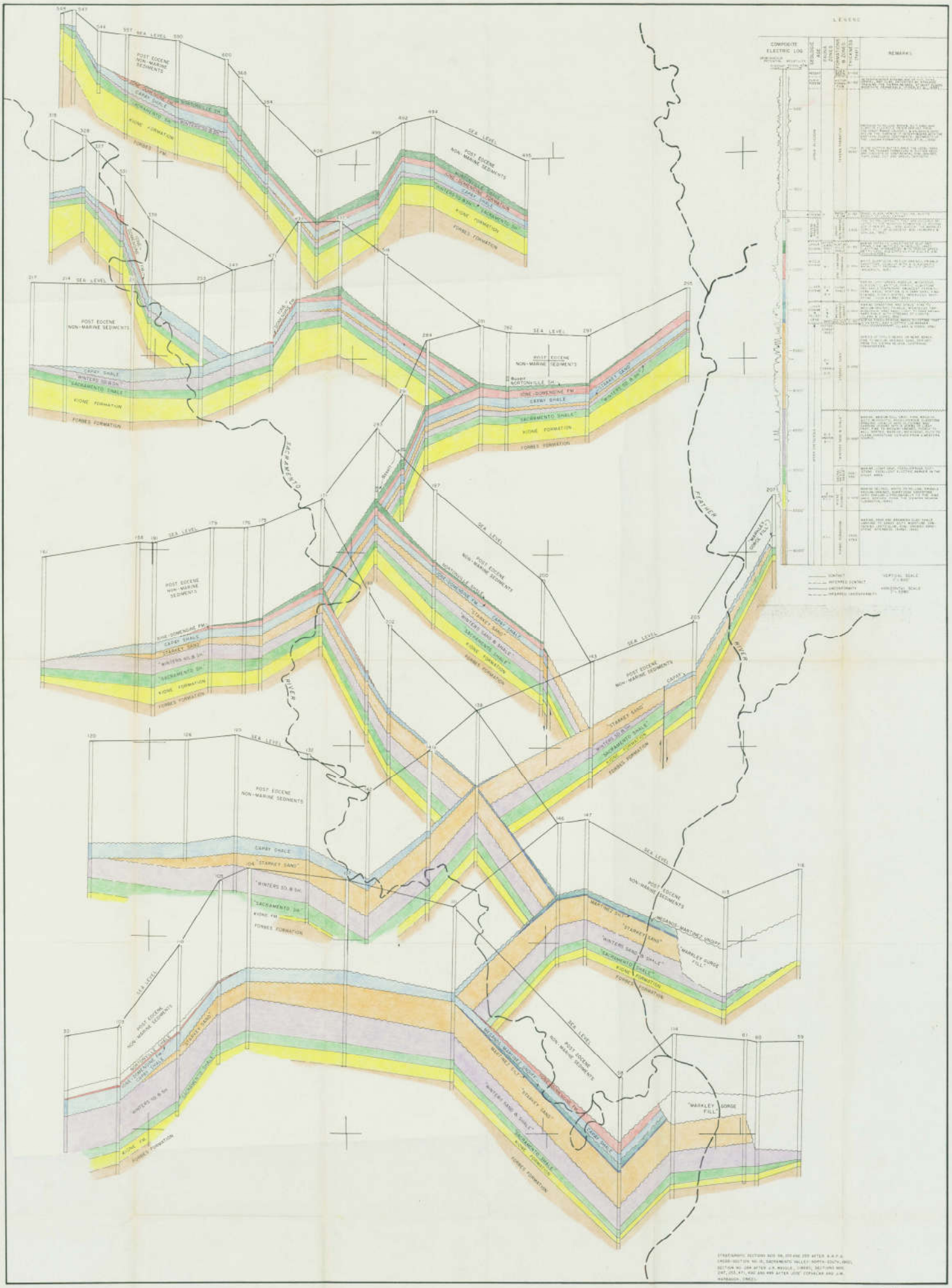

FIGURE 5

PANEL DIAGRAM SHOWING THE STRATIGRAPHY OF THE SUTTER BASIN AREA, SACRAMENTO VALLEY, CALIFORNIA

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THESIS, GEOLOGY 1961

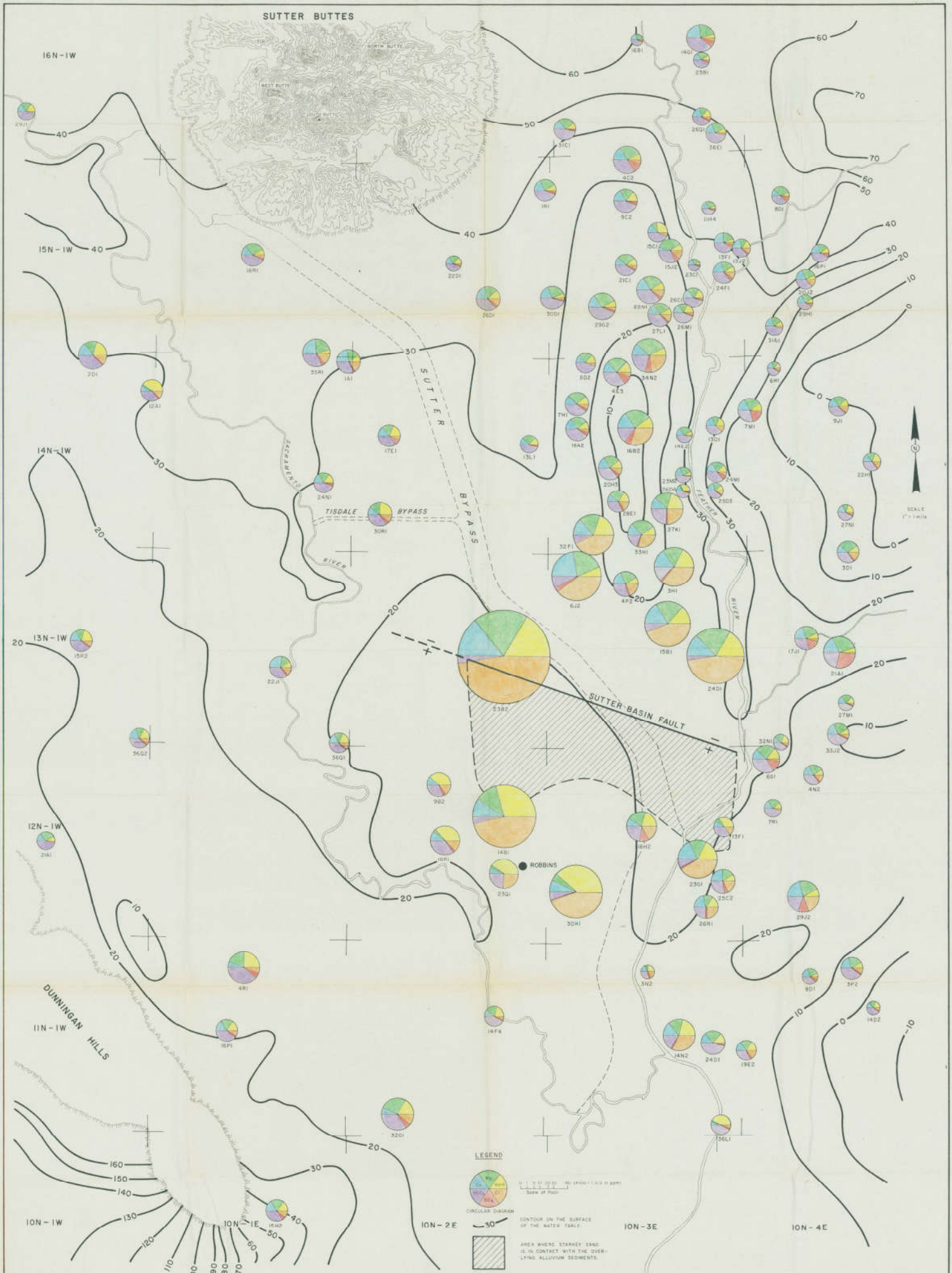

FIGURE 6 WATER QUALITY AND CONTOUR ELEVATION OF WATER IN WELLS, SPRING 1966 (SEA LEVEL DATUM) SUTTER BASIN AREA, SACRAMENTO VALLEY, CALIFORNIA

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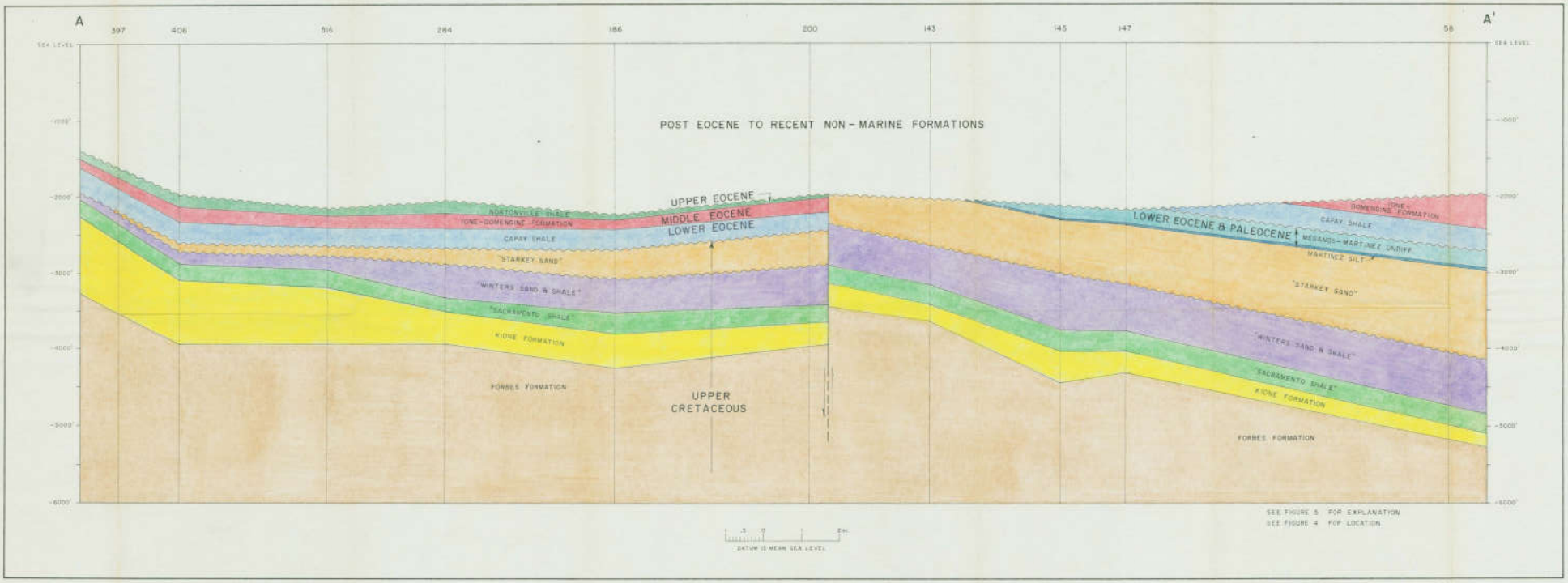

FIGURE 7

GEOLOGIC SECTION A-A', SUTTER BASIN, SACRAMENTO VALLEY, CALIFORNIA

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GEOCHEMISTRY OF GROUND WATER IN THE SACRAMENTO VALLEY, CALIFORNIA

REGIONAL AQUIFER-SYSTEM ANALYSIS



U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1401–B

Geochemistry of Ground Water in the Sacramento Valley, California

By LAURENCE C. HULL

CENTRAL VALLEY OF CALIFORNIA RASA PROJECT

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1401–B



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CONVERSION FACTORS

Factors for converting inch-pound units to the International System (SI) of units are given below:

Multiply	*By*	*To obtain*
acres	0.004047	km^2 (square kilometers)
acre-ft (acre-feet)	0.001233	hm^3 (cubic hectometers)
ft (feet)	0.3048	m (meters)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)

Degrees Fahrenheit are converted to degrees Celsius by using the formula: °C=(°F-32)/1.8

Additional abbreviations:

µg/L	(micrograms per liter)
mm	(millimeters)
mg/L	(milligrams per liter)
(mg/L)/yr	(milligrams per liter per year)

National Geodetic Vertical Datum of 1929 (NGVD of 1929). A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is sometimes referred to as sea level in this report.

CENTRAL VALLEY OF CALIFORNIA RASA PROJECT

GEOCHEMISTRY OF GROUND WATER IN THE SACRAMENTO VALLEY, CALIFORNIA

By LAURENCE C. HULL

ABSTRACT

A geochemical investigation was done to evaluate temporal changes in water quality and to determine the processes that control water chemistry in shallow ground water of the Sacramento Valley, California. A total of 671 chemical analyses from 651 wells were used to study the processes controlling water chemistry. Temporal variations in dissolved-solids and nitrate concentrations were studied in 140 and 62 wells, respectively, having multiple observations with time.

The Sacramento Valley can be divided into six hydrochemical facies having distinctive chemical compositions. Waters from the Tuscan volcanic rocks and Victor Plain facies, along the eastern margin, have lower concentrations of dissolved solids and higher concentrations of silica than the waters from other areas of the Sacramento Valley. Ground waters in the basin hydrochemical facies (Butte Basin and Sutter Basin) along the valley axis are higher in iron, manganese, arsenic, and potassium. West side facies, the north alluvial fans and south alluvial fans, are low in silica. The south alluvial fans facies is higher in dissolved solids and has very high boron concentrations.

Significant increases have occurred in dissolved-solids and nitrate concentrations since the mid-1950's. Dissolved solids increased in five of the six hydrochemical facies, with rates ranging from 0.95 milligrams per liter per year in the Tuscan volcanic rocks facies to 4.75 milligrams per liter per year in the south alluvial fans facies. Nitrate-nitrogen did not significantly increase in the Tuscan volcanic rocks, Butte Basin, or Sutter Basin hydrochemical facies. Rates of increase of 0.036, 0.036, and 0.099 milligrams per liter per year occurred in the Victor Plain, south alluvial fans, and north alluvial fans, respectively.

Two processes control over 50 percent of the spatial variation in ground-water chemistry. Thirty-six percent of the variation in the data is explained by the effects of recharge water chemistry on the chemistry of ground water. Low dissolved solids and high silica from east-side recharge produces fairly uniform conditions in east-side ground waters. Recharge from the northwest is intermediate in dissolved solids and silica. Southwest recharge is high in dissolved solids, boron, and fluoride. High boron concentrations in the ground water originate in thermal springs in the Coast Ranges. A second important process consists of reactions occurring in the fine-grained sediments of the flood basin in the central part of the Sacramento Valley. Reducing conditions here produce higher concentrations of manganese, iron, and arsenic. Nitrate concentrations are low, probably reflecting denitrification reactions.

Precipitation and dissolution of aluminosilicates appear to control the relation between silica and aluminum in parts of the valley. Silica and aluminum in ground waters of the Sutter Basin hydrochemical facies show parallel behavior and have a ratio of 3 to 1. In the Tuscan volcanic rocks facies silica and aluminum are inversely related and are controlled by the solubility of halloysite. The clay minerals halloysite and illite were identified in the sediments. The clay mineral predicted to be the most stable in equilibrium with valley ground water is montmorillonite. Halloysite represents an intermediate step in the weathering of primary minerals to more stable secondary phases.

INTRODUCTION

GEOGRAPHY

The Sacramento Valley comprises the northern third of the Central Valley of California in the north-central part of the State (fig. 1). It is a sedimentary basin bounded by mountains to the east (Sierra Nevada), northeast (Cascade Range), and west (Coast Ranges). To the south, the valley merges with the delta of the Sacramento and San Joaquin Rivers. The area lies between 38°30′ and 40°15′ N. latitude, and 121°15′ and 122°30′ W. longitude. The valley covers about 4,400 square miles, is 150 miles in length from Red Bluff to the delta, and ranges in width from about 8 miles at Red Bluff to about 50 miles near the southern end. The topography consists of generally flat plains, with low dissected hills near the margins. The elevation of the valley at the southern end is near sea level, increasing northward and reaching 300 feet above sea level near Red Bluff. The relatively flat topography of the valley is interrupted near the center, where a volcanic neck of late Tertiary age, Sutter Buttes, rises 2,100 feet above the valley floor.

The Sacramento River enters the valley from the north and flows along the entire length of the valley before entering the delta region to the south. The Feather River is the only other principal stream that flows through the valley. The Sacramento and Feather Rivers are fed by tributaries draining the surrounding mountain areas. From the Sierra Nevada come the American, Bear, Yuba, and Feather Rivers. The Cascade Range is drained primarily by Big Chico, Butte, Mill, and Deer Creeks in the area adjacent to the Sacramento Valley. The streams entering the valley from the west rise in the Coast Ranges and are much smaller than the streams from the east. Thomes, Stony, Cache, and Putah Creeks are the only sizable streams entering

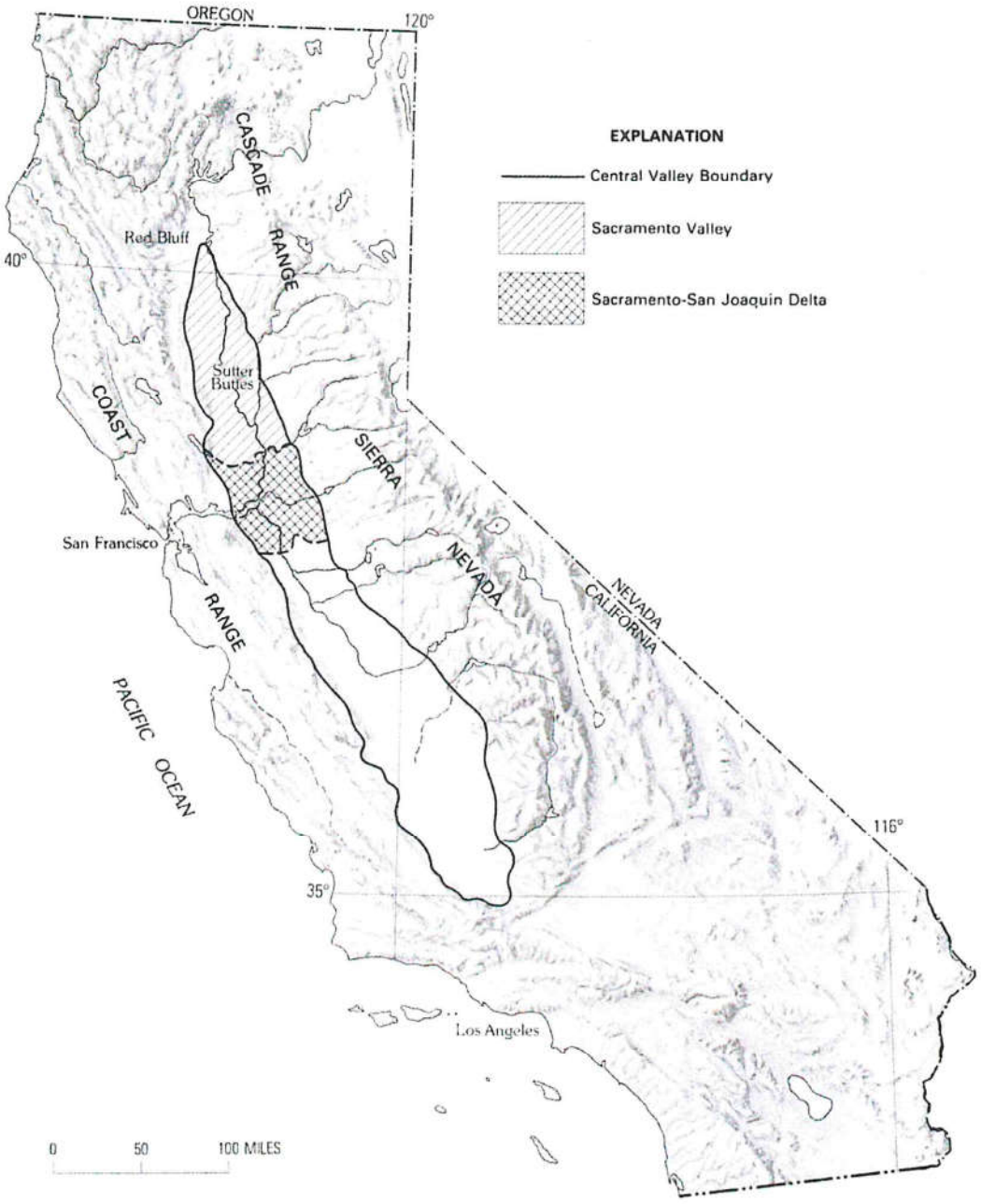

FIGURE 1.—Location map showing Sacramento Valley of California.

the west side of the valley. (See pl. 1*B* for stream locations.)

Little precipitation falls in the valley during the summer growing season, and irrigation is necessary to support extensive agricultural development. Early irrigated farming began in the mid-1800's as the gold miners moving to California created a demand for foodstuffs. Development of irrigation was slow, however, until the drought of 1864 stimulated the construction of new irrigation projects. During both world wars, heavy demand for agricultural products spurred periods of rapid development. Ground water has always lagged behind surface water as a source of irrigation water, amounting to only about 10 percent of the total use in the late 1910's. Since the late 1950's, however, the use of ground water has been increasing, and in 1970,

it accounted for about 40 percent of all irrigation water used in the Sacramento Valley.

PURPOSE AND SCOPE

The U.S. Geological Survey began a series of hydrologic investigations—the regional aquifer systems analysis (RASA) program—to aid effective management of the Nation's ground-water resources by providing information on the hydrology and geochemistry of regional aquifer systems (Bennett, 1979). The Central Valley aquifer project, covering the Central Valley of California, is one of 29 such projects throughout the country and was started because of the long history of ground-water development and the importance of the area's agricultural production to the national economy (Bertoldi, 1979). Specific water-quality information needed for effective management in the future includes (1) the general inorganic chemical character of water from aquifers currently in use, (2) delineation of areas where degradation is occurring and where degradation may occur in the future, (3) the changes that have occurred in ground-water quality with time, and (4) the processes that control ground-water chemistry. This report evaluates temporal changes and geochemical processes as they influence the chemical quality of shallow ground water in the Sacramento Valley, the northern third of California's Central Valley. A companion report (Fogelman, 1983) deals with spatial variations in the chemical character of ground water and the delineation of areas of potential water-quality problems for this same study region.

DATA COMPILATION

Collection of additional water-quality samples was unnecessary because of the extensive data base of the U.S. Geological Survey and California Department of Water Resources. Chemical analyses from 653 wells throughout the Sacramento Valley sampled by the Geological Survey between 1974 and 1976 were already in the Survey's water-quality file (Fogelman, 1975, 1976; Fogelman and Rockwell, 1977). From the unpublished files of the California Department of Water Resources, an additional 2,136 analyses from 281 wells were added to the water-quality file. During the summer of 1979, 63 additional samples were collected by the Geological Survey in Yolo County to extend coverage into an area where high boron concentrations suggested a need for water-quality evaluation. All wells from which chemical analyses were used in this study have driller's logs on file with the California Department of Water Resources. Thus, reasonably reliable information is available about depths and perforated intervals for these wells. Some of the samples represented multiple observations over time from single wells, and these were used for the temporal studies. Samples for the period 1974–79 were examined, and complete analyses with less than 5 percent error in the electrical balance between cations and anions were used to study the spatial variation in the valley. These latter data consisted of 671 analyses from 651 wells.

Manipulation of data files and the statistical analyses used in this report were accomplished using the Statistical Analysis System (SAS)[1] programs on the U.S. Geological Survey's Reston computer system.

WELL-NUMBERING SYSTEM

Wells are identified according to their location in the rectangular system used for the subdivision of public lands. The identification consists of the township number, north or south; the range number, east or west; and the section number. A section is further divided into sixteen 40-acre tracts lettered consecutively (except I and O), beginning with A in the northeast corner of the section and progressing in a sinusoidal manner to R in the southeast corner. Within the 40-acre tract, wells are sequentially numbered in the order they are inventoried. The final letter refers to the base line and meridian relative to which the townships and ranges are numbered. For the Sacramento Valley, this is the Mount Diablo base line and meridian (M). Figure 2 shows how the well number 11N/02E–23N01M is derived.

ACKNOWLEDGMENTS

The California Department of Water Resources has cooperated with the U.S. Geological Survey in past studies during which much of the data analyzed in this report were collected. The Department also provided additional unpublished chemical-quality data from their files. The author would like to thank J. R. Slack of the Geological Survey for his helpful suggestions on trend analysis. The cooperation of the residents of the Central Valley who have permitted the Geological Survey to collect water samples from their wells is also appreciated.

DESCRIPTION OF THE STUDY AREA

GEOLOGY AND GEOMORPHOLOGY

The Geology and geomorphology of the Sacramento Valley have been covered in detail by Olmsted and Davis (1961), the California Division of Mines and Geol-

[1]Use of trade names does not imply endorsement and is used for information only.

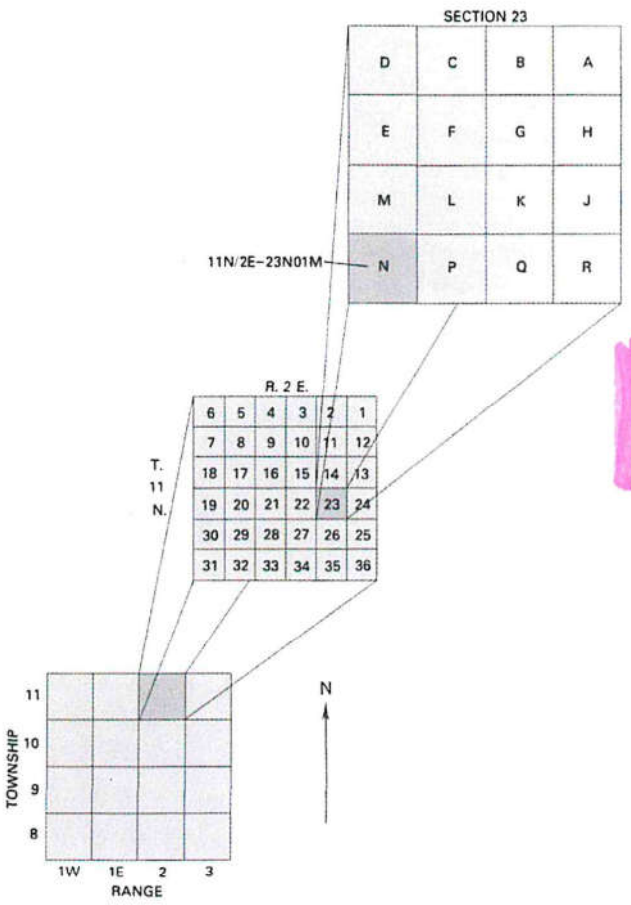

FIGURE 2.—Well-numbering system.

ogy (1966), and the California Department of Water Resources (1978a). Detailed maps and complete descriptions of the geology can be found in these publications. In this section, the geology and geomorphology are only briefly reviewed, with particular attention given to water-bearing characteristics and importance for water quality.

GEOLOGIC SYNOPSIS

The Sacramento Valley is an elongated structural trough trending to the northwest through central California. The trough is filled with a thick accumulation of sediments, perhaps as much as 50,000 feet in the deepest parts. Deposition has been occurring since early in the Cretaceous Period, with the bulk of the deposition occurring in a marine environment. A maximum of only 3,000 feet of continental deposits has been laid down as a veneer over the marine sediments. During early Tertiary time, the Cretaceous sediments west of the valley were folded and uplifted, forming the Coast Ranges and isolating the Sacramento Valley from the ocean to the west.

Early- and middle-Tertiary sedimentation was primarily confined to the southern and eastern parts of the valley, with only those sediments adjacent to the Sierra Nevada being continental deposits. During late Tertiary time, continental deposits were laid down throughout the valley, and deposition continued into Quaternary time. These continental deposits include the Tehama, Tuscan, Laguna, and Mehrten Formations and form some of the most important aquifers in the valley. Also, near the end of the Tertiary Period, andesitic lava was extruded through the older marine sediments to form Sutter Buttes, a prominent volcanic neck in the middle of the Sacramento Valley.

During Pleistocene time, continental deposition continued throughout the valley. Alluvial fans and plains developed from sediments eroded from the Sierra Nevada to the east and the Coast Ranges to the west. Continued action of rivers flowing through the valley produced alluvial channel deposits and natural levees along the axis of the valley and produced flood basins adjacent to the rivers.

GEOMORPHIC UNITS

The Sacramento Valley is generally characterized by alluvial plains and fans bounded by rugged mountains. The geomorphic units described by Olmsted and Davis (1961) are (1) Sierra Nevada, (2) Coast Ranges, (3) Cascade Range, (4) low hills and dissected uplands, (5) alluvial plains and fans, (6) flood basins, (7) stream channels and natural levees, and (8) Sutter Buttes. In this section, the location and extent of the geomorphic units are described, and the geologic formations composing each unit discussed. Attention will be given to the lithology, mineralogy, and water-bearing characteristics of the geologic units where information is avaliable. The location of the geomorphic units are illustrated on plate 1*A*.

(1) *Sierra Nevada.* The Sacramento Valley is bounded on the east by the mountainous Sierra Nevada, a massive block of the Earth's crust that has been uplifted and tilted westward. The block extends under the sediments of the valley and underlies the eastern part at depth. The Sierra Nevada is composed of intrusive igneous rocks, metamorphosed volcanic rocks, and Paleozoic sedimentary rocks. The intrusive rocks are mainly granodiorite and quartz diorite with andesitic and rhyolitic extrusive rocks. In addition to the feldspars, quartz, and biotite of the igneous rocks, a wide variety of other minerals is present. These include cal-

cite, magnesite, barite, serpentine, metal sulfides, and others. The massive rocks of the Sierra Nevada contain little water, with the little that is available occurring in joints and fractures. The water quality of streams draining the Sierra Nevada is generally very good.

(2) *Coast Ranges.* The Coast Ranges, adjacent to the west of the valley, consist of Cretaceous marine sedimentary rocks folded and uplifted into ridges trending northwest-southeast, parallel to the valley. The Cretaceous rocks dip eastward and underlie much of the Sacramento Valley at depth. Also present in the Coast Ranges is the Franciscan Complex, which consists of highly metamorphosed marine sedimentary rocks of late Mesozoic age. The major rock type is this geologic unit is greywacke, interbedded with shales and minor limestone units. The primary minerals of the sedimentary rocks are plagioclase and quartz. Many lithic fragments present contain chert, chlorite, and mica. Ultramafic minerals have been metamorphosed to serpentine and magnesite. The marine sedimentary rocks are mostly consolidated and contain little water. Some units retain connate saline water, and streams draining the Coast Ranges may be contaminated by saline springs.

(3) *Cascade Range.* Between Oroville and Red Bluff, the northeastern part of the Sacramento Valley is bounded by the Cascade Range geomorphic unit. Adjacent to the valley, this unit is composed of the gently southwestward dipping Tuscan Formation of Pliocene age. On the surface, the Tuscan Formation is extensively eroded, and southwestward flowing streams have incised deep canyons. Beneath the valley, the Tuscan extends westward under younger valley sediments as far as the Sacramento River, and there the Tuscan interfingers with the Tehama Formation. The Tuscan is composed of volcanic breccia, coarse- to fine-grained tuffs, and volcanic sands, all of primarily andesitic composition. The most abundant mineral in the black sands found in wells drilled into this unit is plagioclase, and accessory quartz and pyroxenes. Volcanic glass is also abundant from the mudflow and tuff deposits. The Tuscan is an important aquifer in the northeastern part of the valley, and it contains fresh water at all depths.

(4a) *Low hills and dissected uplands, east side.* The dissected alluvial uplands leading up to the Sierra Nevada on the east side of the valley are composed of Tertiary and lower Quaternary sediments. This gently rolling terrain merges with the foothills of the Sierra Nevada to the east and the low alluvial plains to the west. The oldest rocks here are of the Eocene Ione Formation, overlain by the Oligocene, Miocene, and Pliocene volcanic deposits of the Valley Springs and Mehrten Formations. These units extend westward to the trough of the valley, but they are generally too deep to be tapped as aquifers except in the foothills area. Overlying the volcanic sediments are upper Tertiary and Quarternary continental deposits eroded from the Sierra Nevada. The older Tertiary volcanic sediments are composites of volcanic sands, ash and mudflows, and tuff layers of rhyolitic and andesitic composition. Particular minerals noted in these units include biotite, hornblende, orthoclase, plagioclase, and quartz. The Ione Formation contains kaolinitic clay layers. The younger deposits, the Laguna Formation and Fair Oaks Formation of Shlemon (1967), are sand, gravel, and silt deposits intercalated by clay layers. The Quaternary deposits are poorly sorted, and wells finished in these units produce only moderate quantities of water.

(4b) *Low hills and dissected uplands, northeast.* The low hills on the northeast margin of the valley consist of reworked sediments eroded from the underlying Tuscan Formation. The hills show the characteristic form of alluvial fans but are deeply trenched by the streams draining the Cascade Range. These fanglomerate deposits, as they are called, are mainly cemented sands, gravels, and silts, and have a mineral composition similar to that of the Tuscan Formation from which they are derived. The fanglomerate is also an important source of water in this area.

(4c) *Low hills and dissected uplands, west side.* The low hills on the west side of the valley are composed of the Tehama Formation of Pliocene age. These deposits extend from Red Bluff on the north almost as far south as Fairfield. The Tehama is made up of poorly sorted fluviatile sediments, primarily beds of sandy silt and silty clay with some lenses of crossbedded sands and gravels. Many of the coarser layers are cemented by calcium carbonate that reduces their permeability. The Tehama extends eastward to about the middle of the valley and is generally within 150 to 200 feet of land surface. Tectonic activity since deposition has folded the Tehama into a number of structures such as the Dunnigan Hills, Corning Ridge, and Plainfield Ridge along the valley margin. Sediments originated in the Coast Ranges and are rich in plagioclase and magnesium silicates, such as chlorite and serpentine. The Tehama is an important potential aquifer, although currently most water is the area is being pumped from more permeable alluvial fan deposits nearer the surface.

(5a) *Alluvial plains and fans, east side.* The alluvial plain on the east side of the valley is referred to as the Victor Plain by Olmsted and Davis (1961). The Victor Formation[2] of Olmsted and Davis (1961), which

[2]Recent work of Marchand and Allwardt (1981, p. 207) virtually eliminates the use of the Victor Formation for the northeastern part of the San Joaquin Valley. However, because no similar recent work has been done in the Sacramento Valley, the Victor Formation as defined and mapped by Olmsted and Davis (1961, p. 93) is used in this report.

ranges in thickness from 50 to 100 feet, covers the surface throughout the area and overlies the Laguna Formation, a Pleistocene continental deposit. The plain extends from the northern San Joaquin Valley to north of Chico, where it pinches out between the fanglomerate of the Cascade Range and the Sacramento River flood plain. The Victor Formation is composed of alluvial sediments carried down from the Sierra Nevada and contains numerous channel deposits. The sediments become generally finer grained towards the west with bluish- and greenish-gray clays indicating reducing deposition environments near the center of the valley. Opposite the Sierra Nevada, the material contains extensively weathered feldspars, quartz, mica, biotite, and layers of arkosic sandstones. Opposite the Cascade Range, the Victor Formation is composed of reworked volcanic detritus from the Tuscan Formation. Water is generally available throughout the Victor Formation, though many high-capacity irrigation wells also tap the underlying Laguna Formation.

(5b) *Alluvial plains and fans, west side.* The low alluvial fans on the west side of the valley have been laid down by streams draining the Coast Ranges. The fans are aggrading and have poorly developed soil horizons. The northernmost fan is that of Stony Creek, which extends from the valley margin to the Sacramento River. South of this fan, a series of small fans built up by ephemeral streams extends only a short distance away from the Coast Ranges. Cache Creek and Putah Creek, south of the Dunnigan Hills, also have developed rather large fans which coalesce to form Putah Plain. The lithology of these fans is varied but generally is coarse-grained and poorly sorted. The mineralogy reflects the source areas in the Coast Ranges. The alluvial fans are generally good aquifers, especially where old stream channel deposits are penetrated.

(6) *Flood basins.* Low areas adjacent to the Sacramento River were subject to frequent flooding before extensive construction of levees in modern times. In these basins, fine-grained sediments have settled out of flood waters to form poorly permeable deposits. Deposits between 50 and 170 feet thick of yellow clay, indicating oxidizing conditions, overlie blue clays reflecting reducing conditions at depth. Few wells are drilled in these areas, and the only water generally available is in tongues of sand and gravel from old channel deposits.

In Sutter Basin, ground water contains high chloride concentrations and is unsuitable for irrigation purposes. The origin of this high chloride water is thought to be from Cretaceous marine sedimentary rocks brought closer to the surface by faulting associated with the formation of Sutter Buttes.

(7) *Stream channels and natural levees.* Along the major rivers and streams throughout the valley, Holocene alluvial deposits form flood plains and natural levees. The levees slope gently away from the channels and merge into the surrounding flood basin deposits. The deposits are generally coarse grained and poorly sorted. The varied mineralogy reflects the many sources from which these sediments are derived. Wells drilled in these deposits are hydraulically connected to the adjacent rivers and can produce large quantities of water.

(8) *Sutter Buttes.* Sutter Buttes, a volcanic neck of late Tertiary age, rises abruptly 2,100 feet above the surrounding plains. The core of the buttes is andesite, surrounded by alluvial fans created from the erosion of the igneous rocks. The deposits are poorly sorted and contain tuff, volcanic breccia, and sands. Some Cretaceous marine sedimentary rocks exposed at the buttes were forced upwards by the rising lava. The volcanic rocks yield little water, but the adjoining alluvium produces moderate amounts.

HYDROGEOLOGY

The direction of ground-water movement can be determined from the configuration of the water table where ground water occurs in saturated sediments and is not confined. Ground-water movement is influenced by gravity, and so is downhill as determined by the altitude of the water table. Plate 1*B* is a map showing lines of equal altitude of the water table for the Sacramento Valley in the spring of 1975. Although extensive changes occurred in some areas during the drought of 1976 and 1977, the 1975 map reflects the general conditions throughout the valley as they existed when most of the water-quality samples were collected during the mid-1970's.

In the north part of the valley, ground waters flow to the south and away from the valley walls. The Sacramento River is a gaining stream north of Colusa and is a major ground-water discharge zone in the north part of the valley. Stony Creek alluvial fan is a particularly important area for recharge. South of Colusa, the Sacramento River becomes a losing stream, contributing water to the adjacent sediments. In the west-central part of the valley, between Colusa and Woodland, recharge from the west infiltrates the valley sediments and moves toward pumping depressions east of the Dunnigan Hills. In the east-central part of the valley, from Oroville to Marysville, the Feather, Yuba, and Bear Rivers recharge the ground water near the valley margin. Once on the valley floor, the Feather River becomes a gaining stream east of Sutter Buttes, but below Marysville it begins to lose water to pumping depressions to the east and west. A large pumping depression in the southeast draws water from the Ameri-

can and Sacramento Rivers in the vicinity of Sacramento. In the southwest, much ground-water recharge occurs in the Cache and Putah Creek alluvial fans. This water moves eastward toward pumping depressions near Woodland and Davis. Some recharge from Cache Creek flows around the end of the Dunnigan Hills to pumping depressions north of Woodland.

The water table in the Sacramento Valley is generally close to the surface, and in only a few places is it more than 80 feet below the surface. Depth to water in the flood basins and alluvium along the Sacramento and Feather Rivers ranges from 10 to 20 feet. This very shallow water table extends eastward to include much of the western part of the Victor Plain. In the alluvial fans along the west side of the valley, the depth to water is between 10 and 40 feet. Lowering of water levels in pumping depressions north of Woodland and south of Davis, however, has increased the depth to water in those places. Along the southeast margin of the valley, the depth to water increases from less than 10 feet, near the flood basins, to more than 80 feet in the foothills. In the fanglomerate of the Cascade Range around Chico, the depth to water is generally 10 to 40 feet.

The valley boundary illustrated on plate 1*B* is the approximate boundary of the principal alluvial aquifers currently used in the Sacramento Valley. There is no single definition of the Sacramento Valley, and different boundaries are drawn for different purposes. The boundary shown is approximately that used in a ground-water-flow model of the Sacramento Valley (California Department of Water Resources, 1978a, Appendix A). However, the definition of the Sacramento Valley ground-water basin by the State of California encompasses a much larger area. The boundary is a reference shape to show continuity among illustrations.

On the east side of the valley, the margin coincides with the contact between the alluvium of the low hills and dissected uplands geomorphic province, and the older rocks of the Sierra Nevada and Cascade Range provinces. On the west side, the division is at the contact between the younger alluvium of the alluvial fans and plains, and the older alluvium of the low hills and dissected uplands geomorphic province. This allows delineation of the Dunnigan Hills, and excludes a large, undeveloped and sparsely populated area to the northwest of the valley.

Some wells outside the principal alluvial aquifers were included in the data analysis, as the boundary of those aquifers is somewhat arbitrary. Because these wells lie in recharge zones, their characteristics are important to an understanding of ground-water chemistry in the rest of the valley, even though they are outside the area of the principal alluvial aquifers.

HYDROCHEMICAL FACIES

The concept of hydrochemical facies as described by Back (1966) is used to designate zones or areas in which ground waters share unique chemical characteristics. The differences between facies reflect different controls on water chemistry from the lithology and mineralogy of, flow patterns in, and sources of recharge to an aquifer. The prefix "hydro" is used as a modifier of "chemical" to emphasize the interdependence of chemistry and hydrology. The ground water in the Sacramento Valley shows a great diversity in chemical compositions. By dividing the valley into hydrochemical facies, the differences can be better related to differences in the sedimentary matrix holding the water and the sources of ground-water recharge.

CRITERIA AND PROCEDURE FOR DIVISION

While hydrochemical facies have commonly been defined in terms of water types (as determined by the predominance of ions in terms of equivalents per million; Back, 1966), the definition of hydrochemical facies can be based on any unique chemical signature. For the Sacramento Valley, this division was accomplished using differences in the concentrations of some of the dissolved chemical constituents.

An initial division of the valley was attempted by studying maps showing the geomorphic units, the water table, and the distribution of individual chemical constituents. Outlines of these areas were drawn up to the nearest quarter township, and a tentative hydrochemical facies was determined for each well. This initial division broke the valley into three areas extending northwest-southeast, parallel to the axes of the valley—along the west side, the east side, and in the central basins. Each of these areas was divided into a northern and southern part resulting in six tentative divisions.

After this initial division, these six areas were tested to determine if they could be successfully differentiated on the basis of their chemistries. Linear discriminant function analysis (Davis, 1973; Drake and Harmon, 1973) was used for this purpose. In linear discriminant function analysis, a linear combination of variables is used to distinguish between previously defined groups. After the function is defined, it can be used to classify new samples of unknown origin into one of the original groups.

To determine which chemical constituents would be the best to use in the discriminant analysis, the amount of variation in the major chemical species associated with the differences between hydrochemical facies was determined. The results of this analysis of variance are shown in table 1. The first five species in this table

TABLE 1.—*Variation in chemical constituents explained by variations between hydrochemical facies*

Constituent	Percent variation explained
Silica	62.7
Boron	48.5
Sodium	44.7
Bicarbonate	39.4
Nitrate	36.8
Chloride	30.1
Magnesium	27.2
Calcium	15.1
Sulfate	9.6

were picked for the analysis. Because chloride is closely associated with sodium in the valley, it was passed over and magnesium added to give a total of six chemical constituents to use in the discriminant analysis.

Of the 671 chemical analyses available, only 340 had measurements for all the species and could therefore be used in the analysis. Most of the reduction in sample size was due to the much smaller number (358) of silica analyses. However, because silica showed by far the greatest amount of variation between the tentative hydrochemical facies, it was decided to use silica at the cost of reducing the number of samples that could be classified using the discriminant function. Samples, which lack measurements of all six of the chemical species used, were subsequently classified on the basis of nearby wells.

About one-fifth of the eligible samples were used to define the discriminant functions for the six hydrochemical facies. Using these functions, the remaining eligible samples were classified using the chemistry, and this classification was compared to the prior classification from the map data. Misclassified observations were of two types. Type 1 misclassifications were scattered throughout other facies and showed no pattern nor were particularly close to the boundary between two areas. Type 2 misclassifications were clustered in an adjacent hydrochemical facies near the boundary. In the latter case, the boundaries were redrawn and the chemical analyses reclassified.

The discriminant functions were recalculated several times with adjustments in boundaries between each calculation. The final analysis showed that 76 percent of the samples could be correctly classified by hydrochemical unit using the six chemical species. Thirteen percent of the samples were misclassified into the adjacent northern or southern portion in the same part of the valley, indicating an association between west side, east side, and basin pairs. On the basis of the classification of wells in a quarter township, each quarter township was assigned to its final hydrochemical facies. Other wells missing some of the chemical species used for the classification were classified by their quarter township location.

The discriminant analysis showed that enough chemical variation existed among the six hydrochemical facies to consider them chemically distinct. The final boundaries of the hydrochemical facies are shown on plate 1*B*. On the east side of the valley, one of the facies lies opposite the Cascade Range, and one opposite the Sierra Nevada. The flood basins along the axis of the valley are divided into two more facies, one in Butte Basin and including Sutter Buttes, the second in the Colusa, Sutter, and American Basins. The final two hydrochemical facies are opposite the Coast Ranges and are divided north and south near Colusa. In the next section, the chemical characteristics of the six hydrochemical facies are presented and compared, and differences in chemistry are discussed.

DESCRIPTIONS OF HYDROCHEMICAL FACIES

Table 2 shows the geometric mean, minimum, and maximum of chemical concentrations for each of the hydrochemical facies. To determine if the average concentrations of chemical species in the hydrochemical facies are significantly different, the differences between geometric means were tested using a t test. The results of these comparisons are illustrated quantitatively in the same table.

TUSCAN VOLCANIC ROCKS

The Tuscan volcanic rocks hydrochemical facies is along the northeastern margin of the Sacramento Valley (pl. 1*B*) adjacent to the Cascade Range. The geologic formations in this area are the Tuscan Formation and more recent alluvial sediments derived from erosion of the Tuscan. Recharge is from the Cascade Range geomorphic province, and ground water is either discharged to the Sacramento River or moves into Butte Basin south of Chico. The Tuscan and its derivatives contain andesitic sands and extensive tuff deposits. Volcanic glass and plagioclase are abundant in these sediments.

The chemistry of ground water in the area reflects the low concentrations of dissolved solids carried by recharge from the Cascade Range, having low mean concentrations of magnesium, sodium, bicarbonate, sulfate, and chloride. Silica concentrations are high due to solution of volcanic glass, and the facies has the highest average nitrate-nitrogen concentration of the six. The maximum boron concentration is rather high, although the mean concentration is only moderate. Boron in excess of 1.0 mg/L occurs in only three wells, all to the east of the Sacramento River northeast of Red Bluff.

TABLE 2.—*Geometric mean, minimum, and maximum of chemical concentrations for each of the hydrochemical facies, Sacramento Valley*

[Figure above line refers to geometric mean; figures below line refer to minimum-maximum range. H, high; L, low; VH, very high; VL, very low. NOTE.—These comparisons are relative to the other hydrochemical facies and do not necessarily describe the absolute values. Labels were assigned only where the difference between two geometric means tested significant at the 95 percent level]

Chemical species	Tuscan volcanic rocks	Victor Plain	Butte Basin	Sutter Basin	North alluvial fans	South alluvial fans
Dissolved solids (mg/L)	L 231 137–571	L 220 137–1100	290 129–723	H 400 97–2040	280 108–1170	H 400 175–1420
Calcium (mg/L)	26 14–75	L 21 5.7–170	32 5.5–98	32 6.9–220	H 39 8.2–99	H 39 13–140
Magnesium (mg/L)	L 19 9.1–60	VL 12 3.6–120	24 5.0–93	24 2.2–160	24 7.6–70	H 33 3.5–140
Sodium (mg/L)	L 14 3.9–68	19 7.2–180	20 6.3–93	H 55 5.9–360	22 7.5–240	H 52 15–320
Potassium (mg/L)	1.3 0.3–5.9	1.3 0.4–4.5	H 1.9 0.6–5.0	H 1.7 0.3–5.4	L 0.8 0.4–2.1	1.2 0.2–7.0
Bicarbonate (mg/L)	L 170 98–400	VL 130 68–504	230 44–522	H 270 70–897	240 83–560	VH 310 130–1060
Sulfate (mg/L)	L 8.1 0.0–71	L 8.0 0.2–140	12 0.5–150	17 0.3–590	18 1.6–400	21 1.8–180
Chloride (mg/L)	VL 6.5 0.9–97	15 2.0–380	L 11 1.0–210	H 31 2.4–920	15 2.7–170	H 37 2.2–580
Fluoride (mg/L)	0.11 0.1–0.3	0.18 0.1–10.0	0.12 0.1–0.3	0.11 0.0–0.4	0.16 0.0–0.6	H 0.29 0.1–1.0
Nitrate - N (mg/L)	H 2.7 0.2–27	0.81 0–61	1.0 0–20	L 0.12 0–14	1.7 0.01–11	1.8 0–12
Phosphate - P (mg/L)	0.05 0.0–0.31	0.11 0.01–0.39	0.11 0.01–0.45	0.15 0.01–0.50	0.06 0.02–0.30	0.07 0.01–0.42
Silica (mg/L)	H 51 35–67	H 55 25–74	H 51 31–75	39 23–73	L 26 8.5–52	L 28 12–54
Iron (µg/L)	4.8 0–170	5.2 0–600	8.0 0–1900	H 11 0–520	9.7 0–280	8.0 0–180
Manganese (µg/L)	3.4 0–10	5.5 0–280	9.1 0–1700	H 75 0–2300	8.0 0–70	2.8 0–2000
Arsenic (µg/L)	1.2 0–4	2.2 0–20	H 5.5 0–50	H 5.8 0–100	1.7 0–6	2.3 0–31
Boron (mg/L)	0.066 0–1.50	L 0.023 0–0.60	L 0.034 0–0.37	H 0.140 0–1.10	0.068 0–0.58	VH 0.400 0–8.10

The source of the high boron water is Tuscan Spring, located along Salt Creek in Tehama County in section 32 of township 28 N., range 2 W. (Waring, 1965).

VICTOR PLAIN

The Victor Plain hydrochemical facies is along the east and southeast margin of the valley, and extends westward to near the Feather and Sacramento Rivers. Recharge is primarily from the Sierra Nevada to the east, although pumping depressions southeast of Marysville and north of Sacramento induce recharge from the rivers. North of Marysville, water is discharged into the Feather River or passed into Butte Basin. South of Marysville, most of the ground-water discharge seems to be by pumping. Along the valley margin, the aquifers are volcanic sands with associated tuffaceous deposits. In the central and western parts of this facies, the volcanic units dip under the Victor Formation composed of alluvium from the Sierra Nevada.

The Victor Plain facies has a low average dissolved-solids content reflecting recharge from the Sierra Nevada. Concentrations of calcium, magnesium, bicarbonate, boron, and sulfate are all low in this area. Silica

is high, reflecting the volcanic material present in the sediments.

BUTTE BASIN

The Butte Basin hydrochemical facies roughly coincides with the Butte flood basin east of the Sacramento River. The basin extends from Chico on the north to Yuba City on the south and lies between the Feather and Sacramento Rivers. Sutter Buttes is included in this facies as too few chemical analyses were available from this area to justify a separate facies. The basin receives recharge from the Tuscan volcanic rocks facies and from Victor Plain to the east. A small amount of recharge also occurs in the vicinity of Sutter Buttes. Ground water leaves the Butte Basin facies to enter the Sacramento River and to enter the Sutter Basin facies east of Sutter Buttes. In the flood basins the sediments are fine grained and reducing.

Ground water in the Butte Basin facies has a somewhat higher average dissolved-solids concentration than the two eastern margin facies possibly reflecting longer subsurface residence times or a change in sediment lithology. Chloride and boron are the only two species that have low average concentrations in this facies. The high silica concentrations may be a result of recharge from the Tuscan volcanic rocks facies and from volcanic material around Sutter Buttes. High arsenic concentrations imply deposition in a reducing environment (Garrels and Christ, 1965). This facies has the highest average potassium concentration, which may reflect the longer residence times or a change in mineralogy of the sediments.

Information on the variation in water chemistry with depth was obtained from a U.S. Geological Survey test well drilled in section 32 of township 19 N., range 1 W. Three piezometer tubes were installed at different depths and isolated by cement packers. Data on the shallow water at the site are available from a previous study (Fogelman, 1976).

Analyses from the three piezometers and from the shallow water are shown in table 3. The percent composition of the major ionic species in terms of milliequivalents per liter are provided in figure 3. Between 80 and 595 feet, a decrease in magnesium is balanced by an increase in sodium, with calcium remaining about the same. There is a slight increase in the percent of chloride in the ground water over this same interval, but the net change in anion composition is very small. Below 595 feet, however, calcium and magnesium decrease, both in percent composition and concentration, and sodium increases. Chloride also increases, becoming the dominant anion by a depth of 968 feet. Even at 1,333 feet, however, the dissolved-solids concentration of the water is only moderate, at 526 mg/L, and the boron concentration remains low.

SUTTER BASIN

The Sutter Basin hydrochemical facies is between the Sacramento and Feather Rivers south of Sutter Buttes. This facies extends west of the Sacramento River near Colusa to include part of Colusa Basin and includes some of the American Basin east of the Feather River. Recharge comes from Sutter Buttes, from the Butte Basin hydrochemical facies east of Sutter Buttes, and from both the Sacramento and Feather Rivers. Sediments in the flood basins are generally fine grained and reducing at depth.

The Sutter Basin facies is tied with the south alluvial fans facies for the highest average dissolved-solids concentration. This facies is also high in sodium, chloride, bicarbonate, potassium, and boron. The effects of reducing conditions are evident in the relatively higher concentrations of iron, manganese, and arsenic in this area, all of which are more soluble in reducing environments (Garrels and Christ, 1965). The very low average nitrate concentration in this facies is also indicative of reducing conditions, where nitrate can be removed by denitrification reactions.

The origin of the high dissolved-solids water is thought to be connate marine water moving upward along fault zones created when Sutter Buttes was emplaced (Curtin, 1971). Throughout much of the southern part of Sutter Basin, water of very high salinity (specific conductance greater than 3,000 micromhos) is located within 400 feet of the surface.

TABLE 3.—*Chemical composition of water from wells of various depths, section 32 of township 19 N., range 1 W.*

Sample No. (fig. 3)	Site identification	Depth of well (feet)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Bicarbonate (mg/L)	Sulfate (mg/L)	Chloride (mg/L)	Nitrate-N (mg/L)	Boron (mg/L)	Dissolved solids (mg/L)
1	19N/01W-32A01M	80	28	24	34	260	12	12	0.59	0.12	276
2	19N/01W-32G03M	595	25	4.4	62	210	12	22	.03	.15	276
3	19N/01W-32G02M	968	12	2.6	110	150	3.6	110	.02	.18	340
4	19N/01W-32G01M	1,333	15	2.8	160	110	3.4	230	.12	.24	526

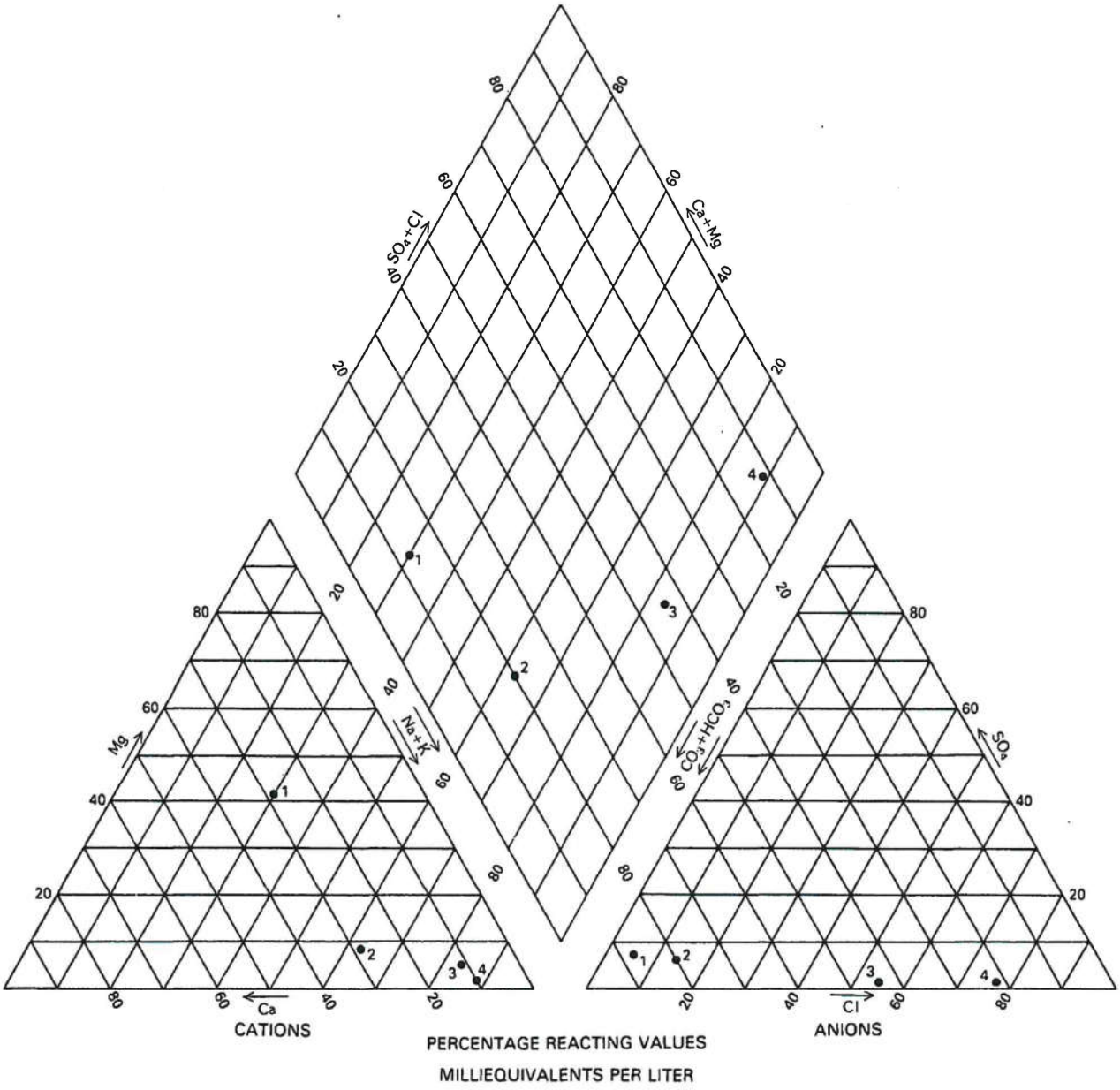

FIGURE 3.—Major-ion composition of water from wells of various depths in section 32 of township 19 N., range 1 W. Numbers refer to sample numbers in table 3.

NORTH ALLUVIAL FANS

The north alluvial fans hydrochemical facies is along the northwestern margin of the valley. Ground water occurs primarily in alluvial fan deposits and is recharged by streams draining the Coast Ranges. The alluvial fan of Stony Creek is a major source of recharge in this area, with flow radiating away from the fan to the north, east, and south. Ground-water flow in this facies is generally east and south. Most of the water is discharged to the Sacramento River along the eastern margin of the facies, although some moves into Colusa Basin along the southern boundary. Sediments in the alluvial fans are primarily derived from Mesozoic marine rocks of the Coast Ranges with sediments derived from Franciscan metamorphic rocks carried down by some of the larger streams.

The average dissolved-solids concentration in the north alluvial fans facies is moderate, and most of the chemical-constituent averages fall between those of the

other facies. Calcium is the only species with a high average concentration in this facies; this is from the waters of Stony Creek, which are high in calcium. Silica is much lower in waters on the west side of the valley, and this is shown by the low average silica concentration.

SOUTH ALLUVIAL FANS

Located along the southwestern margin of the valley in alluvial fans adjacent to the Coast Ranges, the south alluvial fans hydrochemical facies extends from Putah Creek north to township 15 N. Recharge from the Coast Ranges is provided by numerous ephemeral streams north of township 10 N., and by Cache and Putah Creeks in townships south of 11 N. Recharge from Cache Creek moves around the end of the Dunnigan Hills to pumping depressions north of Woodland. Some recharge is also drawn from the Sacramento River to these same pumping depressions.

The south alluvial fans hydrochemical facies is distinguished by having high average concentrations for many of the chemical species measured. Dissolved solids, calcium, magnesium, sodium, chloride, and fluoride all have high average concentrations here. Boron and bicarbonate concentrations in this facies average very high. With little volcanic material to provide silica, its average concentration is low, as in the north alluvial fans.

Boron and chloride concentrations in the ground water of this facies average the highest in the valley, and boron concentrations as high as 8.1 mg/L have been measured in township 11 N., range 2 E. The source of the chloride and boron has been attributed to the streams draining the Coast Ranges (Bertoldi, 1976). Information obtained from a deep test well drilled by the U.S. Geological Survey in section 34 of township 12 N., range 1 E., indicated another possible source. The test well 12N/01E–34Q was drilled to a total depth of 2,400 feet and piezometers tubes installed at 942 feet, 1,396 feet, and 2,120 feet. No sample was obtained from the 942-foot depth, but analyses from the two deeper piezometers are shown in table 4. At a depth of 2,120 feet, water containing 12 mg/L boron and 660 mg/L chloride was encountered. Piezometric heads in the test well indicate upward movement of water, which may be contaminating the shallow water.

The source of boron and chloride in the streams draining the Coast Ranges is warm saline springs, a number of which occur in the Clear Lake area. Partial chemical analyses from these springs are also shown in table 4. Boron concentrations are as high as 310 mg/L in these springs. To determine the source of the high boron concentrations in the ground water in township 11 N., range 2 E., the percent composition in milliequivalents per liter of the wells in this township were plotted along with the deep well water and the warm spring water (fig. 4). The Wilbur Oil Test is a wildcat oil well that produces cold water also high in boron and chloride.

TABLE 4.—*Data for wells and springs plotted in figures 4 and 5*

[Samples 1–2 from U.S. Geological Survey test well; 3–9, reported by Fogelman (1976); 10, average for 1960–76; 11–15, reported by White and others (1973), with locations as indicated therein]

Sample No. (fig. 4)	Site identification	Depth to first opening (feet)	Dissolved solids (mg/L)	Chloride (mg/L)	Boron (mg/L)	Temperature (°C)
1	12N/01E–34Q01M	2,120	1,310	660	12	21.0
2	12N/01E–34Q02M	1,396	482	95	1.1	21.5
3	11N/02E–20K06M	387	1,060	210	3.7	20.0
4	11N/02E–18R01M	264	321	39	1.4	18.5
5	11N/02E–18C02M	205	1,470	210	8.1	18.0
6	11N/02E–23N02M	200	746	66	2.5	21.0
7	11N/02E–14B03M	198	307	37	1.1	17.5
8	11N/02E–30C01M	184	741	96	3.3	18.0
9	11N/02E–29A02M	151	816	140	4.8	18.0
10	Cache Creek at Capay	---	268	36	1.5	---
11	Wilbur Springs	---	27,134	9,700	310	55.0
12	Elgin Mine Spring	---	28,872	11,000	240	68.5
13	Abbott Mine Spring	---	7,250	1,900	56	≈30
14	Grizzly Spring	---	12,400	3,940	178	17.5
15	Wilbur Oil Test	---	19,080	11,400	23	21.3

From figure 4 there is no clear indication of whether the water in the wells (sample Nos. 3–9) is derived from the thermal springs (sample Nos. 11–14) or from deep ground water in the area (sample No. 1). Two of the thermal springs, Wilbur Oil Test well and the deep well, are very high in percent sodium. Two of the thermal springs show an increase in percent magnesium, but the percent calcium remains very low.

The deep ground water and the Wilbur Oil Test well have a much higher percentage of chloride than the thermal springs, which are enriched in carbon dioxide from metamorphism at depth (Barnes and others, 1973). As no clear trends emerged in the plot of the percent compositions in milliequivalents per liter, a second plot of chloride versus boron concentrations was made (fig. 5). The dashed diagonal line in figure 5 represents the dilution of Wilbur Springs water with water containing no boron or chloride. The thermal springs all plot very close to this line, having both high chloride and boron concentrations. The shallow wells in township 11 N., range 2 E., all plot very close to the the line representing dilution of Wilbur Springs water, as does the average composition of Cache Creek. Wilbur Oil Test well and the deep wells in the valley plot to the right of the dilution line, which indicates more chloride relative to boron in these waters. From figure 5 the source of the high chloride and boron concentrations is confirmed as water from the thermal springs in the Coast Ranges carried into the valley by streams, such as Cache Creek. Distinct differences between the cold waters,

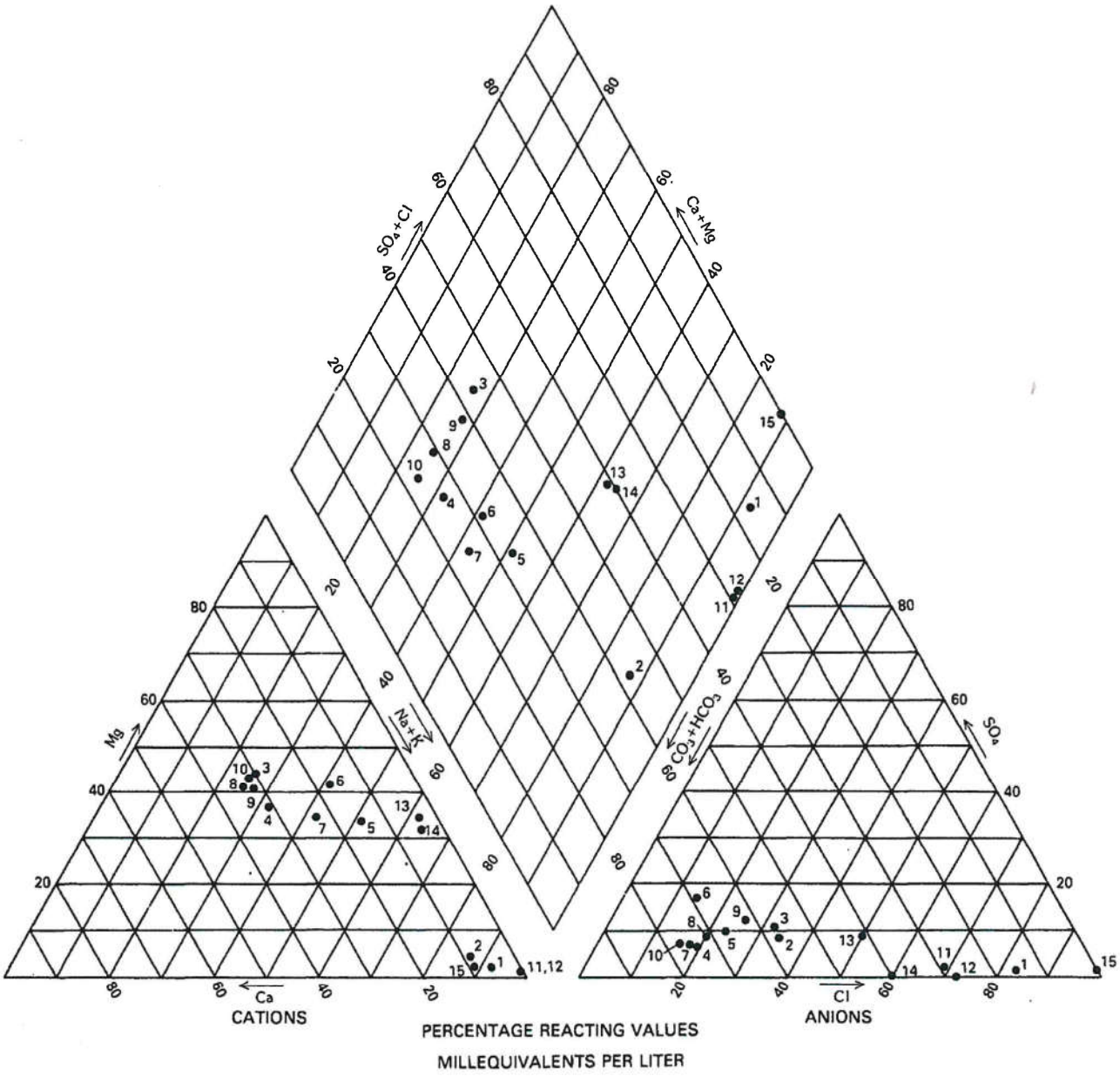

FIGURE 4.—Major-ion composition of water from springs in the Clear Lake area and from wells in a high boron area northwest of Woodland. Numbers refer to sample numbers in table 4.

such as Wilbur Oil Test and well 12N/01E–34Q01, and the thermal waters can be found in the boron-to-chloride ratio and the percent of bicarbonate ion in the waters. The hot waters probably receive inputs of carbon dioxide and boron from a gas phase produced during metamorphism of the marine sediments at depth. Cold waters are not enriched in volatile components and therefore have lower boron-to-chloride ratios and lower percent bicarbonate contents. The shallow wells in township 11 N., range 2 E., have the higher boron-to-chloride ratios indicative of a thermal water source.

TEMPORAL CHANGES

Ground-water-quality degradation may be occurring in the Sacramento Valley because of increasing development accompanied by more intensive agriculture and denser habitation. Such effects have been noted in the

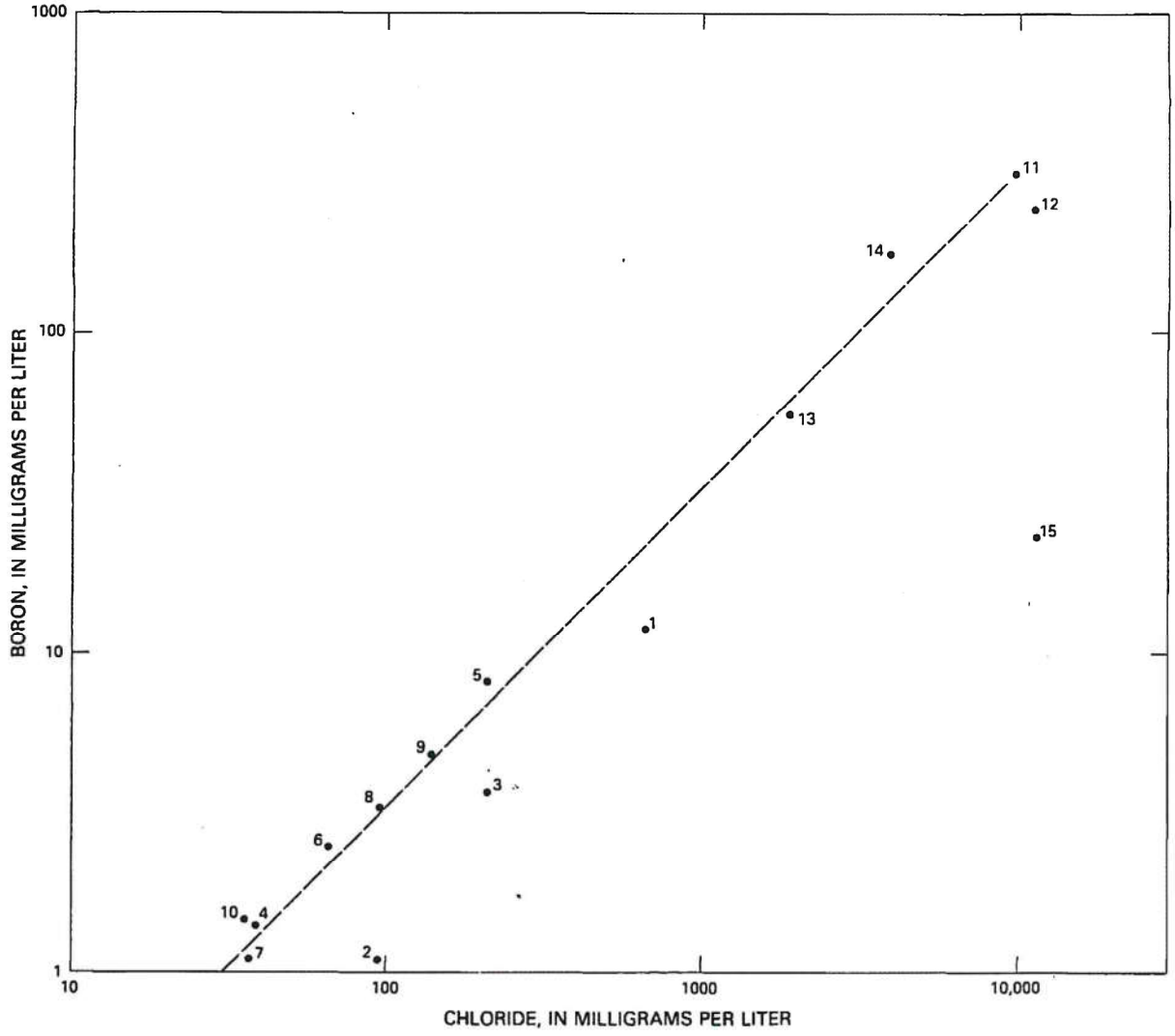

FIGURE 5.—Plot of chloride versus boron for springs in the Clear Lake area and for wells in a high boron area northwest of Woodland. Numbers refer to sample numbers in table 4. Dashed line indicates dilution of Wilbur Springs water with water containing no boron or chloride.

San Joaquin Valley (Kern County Water Agency, 1979), in San Bernardino County (Klein and Bradford, 1979), and in the Colorado River Basin (El-Ashry, 1980). Much of the problem is related to infiltrating irrigation water that (1) has been concentrated by evapotranspiration, (2) has dissolved salts added as fertilizers and soil conditioners, and (3) has leached natural salts from the unsaturated zone. Additional degradation can occur from nonagricultural activities, such as the disposal of sewage and industrial wastes.

In this section, water-quality data from the Sacramento Valley are examined for linear trends with time. Data in each of the hydrochemical facies are combined to derive an average trend for each of the areas. Individual wells are also examined for temporal changes to show more localized variations. The locations of wells used to study the temporal changes are plotted on a map of the valley, and those wells showing significant changes are labeled with symbols indicating the direction of change (pl. 2).

Two variables are used in this study, dissolved-solids and nitrate concentrations. Dissolved solids measures the total amount of dissolved chemicals in a water, and it gives a general indication of overall water quality. Nitrate is derived from a number of potential pollution sources, such as fertilizers and sewage. Increases in nitrate would indicate specific influences of man's activities. These two variables will give a fairly com-

prehensive evaluation of any temporal changes that may be occurring.

METHODS OF DATA ANALYSIS

To determine the average changes occurring in a hydrochemical facies, some technique was needed so that wells with different average dissolved-solids or nitrate concentrations could be compared. This was accomplished by standardizing the data for each well to have a mean of zero and a standard deviation of one. Data from all the wells for each year could then be averaged with equal weight being given to each well. This data manipulation procedure produced a data set with one observation per year for the period of record in each hydrochemical facies. The yearly observations represented the average for all the wells for which data were available in each hydrochemical facies.

Trends in the chemistry of the facies were then studied using a linear regression of the standardized and averaged dissolved-solids or nitrate concentrations versus time. One of the fundamental assumptions of regression analysis is that the observations are independently distributed. For sequences of data collected over time, this requirement is sometimes violated because the data are autocorrelated. Because of memory effects in natural processes, measurements taken at one time may be correlated to measurements taken at previous times.

To test the extent to which the dissolved solids and nitrate data suffered from autocorrelation problems, lag one serial correlations were calculated, and cumulative frequency histograms of these autocorrelations compiled. Matalas, Slack, and Wallis (1975) have generated a series of empirical cumulative frequency histograms for data sequences having a range of serial correlations. By comparing the cumulative frequency histograms for dissolved solids and nitrate in the Sacramento Valley to these empirical histograms, the probable population autocorrelations were determined to be about 0.3 for dissolved solids and between 0.3 and 0.5 for nitrate.

Serial correlations of this magnitude indicate a tendency for subsequent values to be positively correlated to previous values. As a result, the trends determined from the regression analyses may not be as strong as indicated. Positive autocorrelations of this magnitude, however, will not significantly affect the conclusions of the temporal study.

The equations describing the average temporal changes for the hydrochemical facies were transformed back to concentrations by destandardizing the regression equations. For each hydrochemical facies, the average of the means and standard deviations of the individual wells was calculated. By multiplying the regression equations by these average standard deviations and adding the average means, equations were obtained that give the average trend in a facies in terms of concentrations. This equation describes what might be observed in a typical well in each facies, and no individual well can be expected to show the same relation.

The equations produced by this analysis are not predictive equations, but merely reflect the average rate of change over the period of record, from about 1955 to 1977. An example of the problems that can arise if they are used as predictive equations is demonstrated by considering what happens if some of the equations are used to estimate past concentrations. The equation describing the average changes in nitrate-nitrogen concentrations for the Victor Plain hydrochemical facies indicates negative concentrations in the ground water prior to 1939. This is a physical impossibility and arises because the equation was used for a purpose for which it was not intended. While predictions of future concentrations of dissolved solids and nitrate-nitrogen may not produce negative results, the values obtained could be just as meaningless.

In addition to testing for average trends throughout a hydrochemical facies, individual wells were examined for temporal variations. Where a significant trend was noted for an individual well, the equation was recorded and the well's location plotted on a map of the valley with a symbol indicating the direction of the trend (pl. 2).

Few wells in the valley have multiple observations over time. To minimize the effects of random fluctuations, only wells with seven or more observations for dissolved solids and six or more observations for nitrate were used. There was no attempt to assure a random distribution of wells throughout the valley, and all wells in the valley or along the margins having a sufficient number of observations were used. Time is measured as the year minus 1900. For example, for the year 1975, time is equal to 1975–1900 or 75.

DISSOLVED SOLIDS

Dissolved solids is a measure of the total amount of dissolved chemicals in water. An increase in any of the individual constituents will be reflected by an increase in the dissolved solids. While not many historical dissolved-solids measurements are available, many specific-conductance measurements have been made. Specific conductance is proportional to the quantity and valence of ionized chemicals in a water. Because almost all the major dissolved chemical constituents in a water are ionized, dissolved solids and specific conductance are closely related.

It was felt that dissolved solids would have more meaning for most users of this report; therefore, specific conductivities were transformed to dissolved-solids concentrations. The relation between dissolved solids and specific conductance will depend on the specific ionized species present and the amount of uncharged species, mainly silica, present in the water. For this reason, separate equations were derived for different parts of the valley. These areas do not exactly coincide with the hydrochemical facies as they were finally defined, but the division follows the same basic pattern. Thus, the effects of different water chemistries on the relation between dissolved solids and conductance were taken into account during the transformation.

Equations that describe the relation between dissolved solids and specific conductance were derived from a linear regression on data from about 650 wells having measurements of both dissolved solids and conductance. A linear equation with both slope and intercept terms was used rather than a ratio. The intercept terms of all the linear equations were significantly different from zero, which indicates that the linear equations better fit the data than ratios.

Because the calculation of dissolved solids from conductance is a simple linear transformation, the calculation in no way affects the presence of trends in the data. All dissolved-solids values for a well were estimated from conductance measurements even if some measured dissolved-solids concentrations were available. This prevented any changes that might be induced by using dissolved-solids data from different sources.

Locations of wells examined for trends in dissolved solids are shown on plate 2A. The changes for each hydrochemical facies are discussed in the next section and coefficients for the equations describing the average temporal changes are given in table 5. Coefficients for individual wells are summarized in table 6.

HYDROCHEMICAL FACIES

Dissolved solids in the Tuscan volcanic rocks hydrochemical facies show an average annual increase of 0.95 mg/L. The trend line accounts for 31 percent of the variation in the standardized dissolved-solids data averaged over all wells by year. A plot of the trend line is shown in figure 6. Temporal variations are significant in five of the 19 wells for which historical data are available (table 6). Two of these wells show rising trends and three show decreasing trends.

TABLE 5.—*Analyses of variance and coefficients for the regression of average yearly dissolved solids with time for the six hydrochemical facies in the Sacramento Valley*

[t=(year–1900); for example, t=(1980–1900)=80. NS, linear trend not significant at the 90 percent confidence level]

Hydrochemical facies	Number of wells	Source	Degrees of freedom	Sum of squares	F ratio	Probability of exceeding F ratio	r^2	MODEL Dissolved solids=A+Bt: A	90 percent confidence limit	B	90 percent confidence limit
Tuscan volcanic rocks	19	Model	1	1.52	8.89	0.01	0.31	194	±36	0.95	±0.55
		Error	20	3.43							
		Total	21	4.95							
Victor Plain	20	Model	1	2.50	13.91	<0.01	.38	236	±48	1.61	±0.74
		Error	23	4.13							
		Total	24	6.63							
Butte Basin	12	Model	1	1.17	12.55	<0.01	.41	197	±45	1.37	±0.67
		Error	18	1.68							
		Total	19	2.85							
Sutter Basin Basin	10	Model	1	.03	.05	.83	.00	---	---	NS	---
		Error	23	15.21							
		Total	24	15.24							
North alluvial fans	62	Model	1	1.05	14.11	<0.01	.43	222	±31	1.02	±.46
		Error	19	1.41							
		Total	20	2.46							
South alluvial fans	18	Model	1	7.41	65.16	<0.01	.76	184	±67	4.75	±1.01
		Error	21	2.39							
		Total	22	9.80							

TABLE 6.—*Wells showing significant trends in dissolved-solids concentration*

[For the model: Dissolved solids=A+Bt, where t is the year minus 1900]

Well	A	Standard error	Student's *t*	B	Standard error	Student's *t*	Probability of exceeding t for B
TUSCAN VOLCANIC ROCKS							
23N/01W–09L01M	–24.6	73.2	0.34	5.72	1.12	5.12	<0.01
25N/02W–16P01M	666.4	174.5	3.82	–6.09	2.42	2.52	.01
26N/02W–09E01M	909.5	257.0	3.54	–7.44	3.56	2.09	.04
27N/03W–15N01M	1055.6	288.1	3.66	–9.56	3.92	2.44	.02
27N/03W–22B01M	–122.4	223.1	.55	6.30	3.06	2.06	.04
VICTOR PLAIN							
06N/07E–23A01M	892.6	373.4	2.39	–10.32	5.61	1.84	0.07
18N/04E–28M01M	325.8	209.4	1.56	22.03	3.02	7.29	.01
BUTTE BASIN							
16N/04E–09D01M	–389.3	181.4	2.15	8.57	2.80	3.06	<0.01
17N/01W–30K03M	1833.2	515.4	3.56	–21.27	7.04	3.02	<0.01
SUTTER BASIN							
15N/03E–15H04M	–910.0	485.4	1.87	20.92	6.82	3.07	<0.01
16N/02W–25B02M	2428.1	395.1	6.15	–24.98	5.56	4.49	<0.01
NORTH ALLUVIAL FANS							
17N/03W–33R01M	383.2	76.6	5.01	3.24	1.13	2.87	<0.01
18N/02W–01E01M	–716.6	77.8	9.21	16.37	1.16	14.16	<0.01
18N/04W–02F01M	–817.1	112.5	7.26	22.73	1.74	13.07	<0.01
19N/02W–23N01M	–464.2	77.8	5.97	14.03	1.16	12.14	<0.01
20N/02W–22E01M	–618.4	442.7	1.40	11.31	5.97	1.89	.06
21N/02W–15C01M	–241.0	84.5	2.85	8.77	1.25	7.04	<0.01
21N/03W–02Q01M	–121.4	84.6	1.43	7.41	1.25	5.95	<0.01
22N/01W–29C01M	40.2	87.8	.46	3.98	1.30	3.06	<0.01
22N/02W–03A01M	125.3	77.8	1.61	3.37	1.16	2.91	<0.01
22N/02W–04C02M	–459.7	376.8	1.22	10.53	5.11	2.06	.04
22N/03W–06H01M	–922.3	553.3	1.67	20.71	7.62	2.72	<0.01
22N/03W–22Q01M	20.0	77.8	.26	3.88	1.16	3.35	<0.01
23N/03W–35B01M	–69.5	84.3	.82	3.40	1.25	2.73	<0.01
24N/03W–24P01M	–724.6	364.0	1.99	16.36	4.95	3.30	<0.01
25N/03W–31R01M	89.9	77.8	1.16	3.49	1.16	3.02	<0.01
SOUTH ALLUVIAL FANS							
06N/01E–19L02M	–661.9	209.8	3.15	18.11	3.15	5.76	<0.01
06N/01E–19Q01M	101.0	207.1	.49	5.94	3.05	1.95	.05
06N/01W–01B04M	–166.4	280.1	.59	7.48	4.04	1.85	.07
07N/02E–34C02M	–152.3	185.0	.82	10.56	2.81	3.75	<0.01
09N/04E–33L01M	–740.0	169.8	4.36	28.96	2.75	10.55	<0.01
13N/01W–07A01M	335.8	139.7	2.40	7.43	2.04	3.64	<0.01
13N/01W–36Q02M	–32.3	117.0	.28	4.67	1.74	2.68	<0.01
14N/03W–11H01M	7.9	166.3	.05	4.45	2.46	1.81	.07

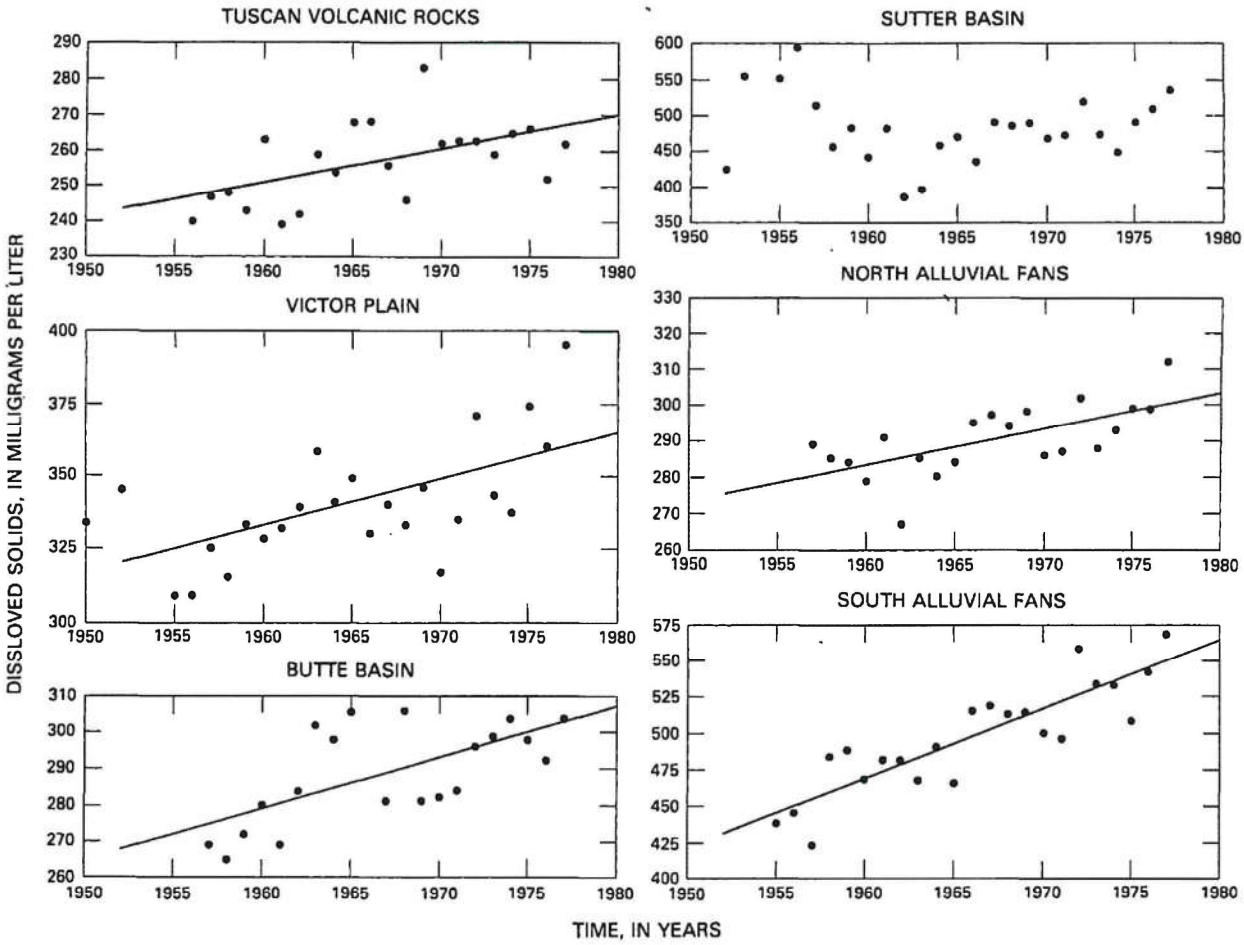

FIGURE 6.—Average yearly dissolved-solids concentrations versus time for the six hydrochemical facies in the Sacramento Valley. The coefficients and significance tests for the trend lines are given in table 5. If no line is shown, then the slope of the trend line is not significantly different from zero at the 90 percent confidence level. The technique by which the average yearly dissolved-solids values were derived is explained in the text.

The average yearly increase in dissolved solids for the Victor Plain facies is 1.61 mg/L. The trend line, which explains 38 percent of the variation in the standardized data, is shown in figure 6. Only two of the 20 wells studied in this facies showed significant changes, one of which showed an increase, and the other a decrease with time.

For Butte Basin, a temporal trend having a slope of 1.37 (mg/L)/yr explains 41 percent of the variation in the averaged data. In this facies also, two wells showed significant trends. One well demonstrated an increase and the other a decrease in dissolved solids with time.

Sutter Basin is the only hydrochemical facies to show no significant temporal change in average dissolved-solids concentration. Two of the 10 wells did show significant trends, but in opposite directions.

An increase in the average dissolved-solids concentration of the north alluvial fans facies of 1.02 (mg/L)/yr explains 43 percent of the variation in the yearly average data. A plot of the trend line is shown in figure 6. Of 62 wells that have seven or more observations in this area, 15 show significant upward trends, and none decrease.

Seventy-six percent of the variation in the average yearly dissolved-solids data are explained by a linear trend in the south alluvial fans facies. The slope is very steep 4.75 (mg/L)/yr and indicates a very rapid increase in dissolved solids (fig. 6). Of the 18 wells examined in this facies, 8 had significant increases in dissolved solids. There were no wells that showed decreases.

NITRATE

A certain amount of nitrate is present in precipitation, and chemical reactions in the soil zone may add to this amount. Thus, even under natural conditions, a finite amount of nitrate will exist in ground water. An estimate of natural nitrate concentrations in the Sacramento Valley can be made from data gathered during the period 1912–13 (Bryan, 1923). The median nitrate-nitrogen concentration in these 43 samples is 0.67 mg/L. The highest nitrate-nitrogen concentration measured was 14 mg/L, which suggests some wells were polluted as long as 70 years ago. From the frequency histogram of the 1912–13 nitrate data (fig. 7), it is estimated that under natural conditions, no more than about 3 mg/L nitrate-nitrogen would be expected in the ground water.

By the period 1974–78, the median nitrate-nitrogen concentration had more than doubled to 1.6 mg/L. The maximum observed nitrate-nitrogen concentration also increased, with two wells containing 27 mg/L and one well 61 mg/L. These increases likely reflect the influences of man's activities, and the extent of temporal changes was, therefore, investigated to determine the magnitude of the problem.

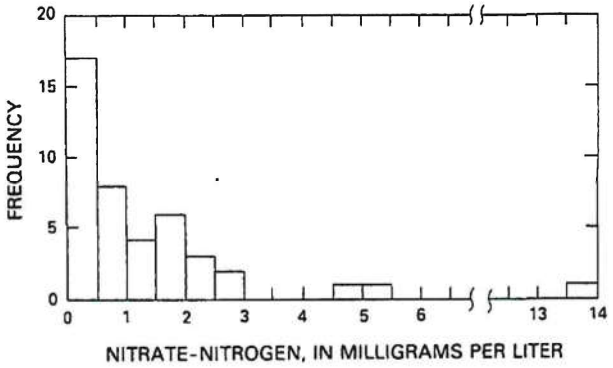

FIGURE 7.—Frequency histogram of dissolved nitrate-nitrogen concentrations in wells, 1912–13. Data from Bryan (1923).

Locations of wells examined for trends in nitrate are shown on plate 2*B*. The changes for each hydrochemical facies are discussed further and coefficients for the equations describing the average temporal changes are given in table 7. Coefficients for individual wells are summarized in table 8.

TABLE 7.—*Analyses of variance and coefficients for the regression of average yearly nitrate-nitrogen concentrations with time for the six hydrochemical facies in the Sacramento Valley*

[t=(year–1900); for example, t=(1980–1900)=80. NS, linear trend not significant at the 90 percent confidence level]

								MODEL Nitrate nitrogen=A+Bt			
Hydrochemical facies	Number of wells	Source	Degrees of freedom	Sum of squares	*F* ratio	Probability of exceeding *F* ratio	r^2	A	90 percent confidence limit	B	90 percent confidence limit
Tuscan volcanic rocks	5	Model	1	0.88	1.25	0.28	0.08	---	---	NS	---
		Error	15	10.57							
		Total	16	11.45							
Victor Plain	13	Model	1	6.05	29.31	<0.01	.63	–1.402	±0.751	0.036	±0.012
		Error	17	3.51							
		Total	18	9.56							
Butte Basin	3	Model	1	.69	1.85	.20	.12	---	---	NS	---
		Error	14	5.26							
		Total	15	5.95							
Sutter Basin	2	Model	1	.65	.84	.38	.08	---	---	NS	---
		Error	10	7.77							
		Total	11	8.42							
North alluvial fans	26	Model	1	5.02	49.67	<0.01	.73	–3.786	±1.625	.099	±0.024
		Error	18	1.82							
		Total	19	6.84							
South alluvial fans	13	Model	1	2.03	7.72	.01	.30	–0.506	±1.514	.036	±0.023
		Error	18	4.73							
		Total	19	6.76							

TABLE 8.—*Wells showing significant trends in nitrate-nitrogen concentration*

[For the model: Nitrate-nitrogen = A + Bt, where t is the year minus 1900]

Well	A	Standard error	Student's *t*	B	Standard error	Student's *t*	Probability of exceeding t for B
TUSCAN VOLCANIC ROCKS							
23N/01W–09L01M	–25.33	3.82	6.63	0.53	0.06	8.78	<0.01
25N/02W–07K01M	–7.96	3.74	2.13	.17	.06	2.89	<0.01
VICTOR PLAIN							
10N/05E–06M02M	–6.58	1.62	4.06	0.12	0.03	4.85	<0.01
11N/06E–16M01M	–9.38	1.35	6.96	.18	.02	8.56	<0.01
13N/05E–13D01M	–3.98	2.09	1.90	.08	.03	2.31	.02
14N/05E–32R03M	–14.48	2.19	6.60	.23	.03	7.38	<0.01
18N/04E–07A01M	–0.81	1.09	.75	.03	.02	1.87	.06
BUTTE BASIN							
None							
SUTTER BASIN							
None							
NORTH ALLUVIAL FANS							
18N/04W–02F01M	–73.57	6.37	11.54	1.38	0.10	13.96	<0.01
20N/03W–02D01M	–11.39	7.49	1.52	.23	.12	1.95	.05
21N/02W–15C01M	–15.47	5.62	2.75	.29	.08	3.43	<0.01
21N/03W–02Q01M	–33.53	7.80	4.30	.58	.12	4.89	<0.01
22N/01W–29C01M	–8.35	6.41	1.30	.17	.10	1.70	.09
22N/02W–03A01M	–10.26	6.16	1.67	.28	.10	2.92	<0.01
25N/03W–31R01M	–10.34	6.88	1.50	.24	.10	2.30	.02
SOUTH ALLUVIAL FANS							
09N/02E–10D01M	26.38	6.93	3.81	–0.38	0.11	3.44	<0.01
13N/01W–07A01M	–10.19	2.66	3.84	.21	.04	5.26	<.01
13N/01W–08B01M	–11.80	2.36	5.00	.22	.04	6.13	<.01
14N/03W–11H01M	–4.40	2.75	1.60	.10	.04	2.33	.02
14N/03W–14Q02M	–25.22	5.95	4.24	.38	.08	4.55	<.01

HYDROCHEMICAL FACIES

No significant average trend was found for the Tuscan volcanic rocks hydrochemical facies. However, two of the five wells examined did show significant upward trends in nitrate concentrations.

A linear trend with a slope of 0.036 (mg/L)/yr explains 63 percent of the temporal variation in the average yearly nitrate-nitrogen concentrations in the Victor Plain facies. A plot of this trend line is shown in figure 8. Of 13 wells in this area that had 6 or more observations, 5 showed significiant upward trends. None of the wells showed a significant decrease.

Neither Butte nor Sutter Basin had a significant average trend in nitrate. Also, there were no individual wells in either that showed any significant changes. However, with only three wells in Butte Basin and two in Sutter Basin having six or more observations, there are too few samples for the results of the test to be conclusive.

The nitrate-nitrogen concentrations in the north alluvial fans hydrochemical facies show a distinct upwards

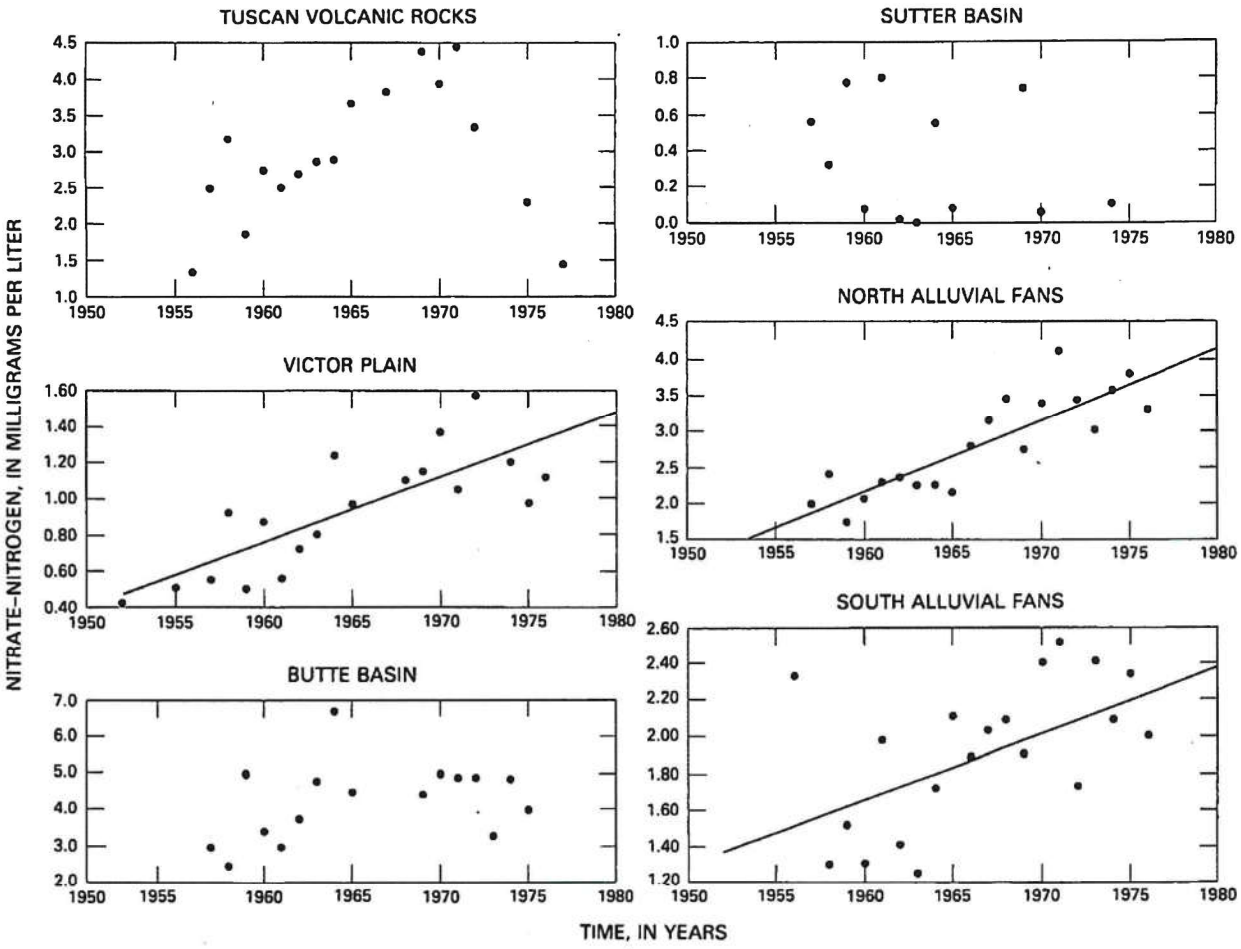

FIGURE 8.—Average yearly nitrate-nitrogen concentrations versus time for the six hydrochemical facies in the Sacramento Valley. The coefficients and significance tests for the trend lines are given in table 7. If no line is shown, then the slope of the trend line is not significantly different from zero at the 90 percent confidence level. The technique by which the average yearly nitrate-nitrogen values were derived is explained in the text.

trend with a slope of 0.099 (mg/L)/yr. Seven of the 26 wells in this facies showed significant upwards trends. The plot of the trend in figure 8 shows that the average concentration of nitrate-nitrogen in this facies has exceeded 3.0 mg/L, the maximum expected under natural conditions.

For the south alluvial fans hydrochemical facies, a linear trend having a slope of 0.036 (mg/L)/yr explains 30 percent of the temporal variation in the average annual nitrate-nitrogen concentrations. Thirteen wells had six or more observations over time, and 5 of them show significant temporal changes. Four have upwards trends, and 1 a downwards trend.

HYPOTHESIS TESTING

Because trends in the data for the individual wells were tested at the 90 percent confidence level, there is a 10 percent chance that no significant trend exists in the valley. The significant slopes that were observed could result from normally distributed random fluctuations about a true true slope of zero. If this were the case, 5 percent of the wells could show a significant increase, and 5 percent a significant decrease, although no real trend existed. If more than 5 percent of the dissolved-solids or nitrate wells show significant trends in the same direction, then it can be concluded that there has been a significant change for that species.

Of 140 wells in the Sacramento Valley tested for trends in dissolved solids, 28 (20 percent) showed an increase and 7 (5 percent) showed a decrease with time. Under the null hypothesis that no change in dissolved solids is occurring at the 90 percent confidence level, it would be expected that by random variation, 7 of the wells would show a significant decrease and 7 would

show a significant increase. For dissolved solids, the number of wells showing increases exceeds the number expected by random variation, and the increase in dissolved solids is significant.

Of 62 wells tested for trends in nitrate, 18 (29 percent) showed increases, but only 1 (2 percent) showed a decrease with time. Under the null hypothesis of no change, 3 can be expected to increase and 3 to decrease by random variation at the 90 percent confidence level. Because 29 percent of the wells showed significant increases in nitrate, the null hypothesis can be rejected, which indicates significant increases in nitrate are occurring in the Sacramento Valley.

PROCESSES CONTROLLING GROUND-WATER CHEMISTRY

Differences in the chemical composition of ground water among the six hydrochemical facies in the Sacramento Valley indicate that either different processes control the water chemistry in different areas, or that there are spatial variations in the same process. In this section, the major controlling processes are delineated from the chemical data using principal components analysis. Factor scores are than calculated for each well that reflect the magnitude of each component in that well. By studying the spatial trends in the factor scores using trend surface analysis, the areal variations in processes can be determined. Contour maps of these surfaces show the spatial distributions of the more important processes controlling ground-water chemistry.

METHODS OF DATA ANALYSIS

PRINCIPAL COMPONENTS ANALYSIS

Principal components analysis (Rummel, 1970; Davis, 1973) is used to separate the variance of a data matrix into common and unique components. Variables, in this case dissolved chemical species, that are controlled by the same process will share a common variance structure. Principal components analysis will group the variables on the basis of this shared variation and will calculate a correlation between variables and components. These components represent independent sources of variation in a data matrix and can be interpreted in terms of controlling processes using knowledge of geochemical principles.

From the correlations, or loadings as they are termed, between variables and components, factor scores can be calculated for each well that measure the intensity of a component in that well. These factor scores are a composite of all the chemical species that load on a component and summarize similar behavior in a number of different species. Where several of the chemical species are controlled by the same process, this transformation to factor scores reduces the number of variables needed to account for the significant variation in the data. The factor scores can be further analyzed as any other numerical variable.

TREND SURFACE ANALYSIS

Trend surface analysis (Davis, 1973) is a technique for separating variation in geographically distributed data into regional and local parts. Either of these parts might be the goal of a particular study. For the distribution of processes in the Sacramento Valley, however, the regional variation is of interest. A trend surface is delineated by a polynomial equation that predicts the magnitude of some variable in terms of the geographic coordinates of a set of observations. The criteria for fitting the polynomial is to minimize the squared deviations about the surface. In this study, the trend surface represents the spatial variation in processes controlling ground-water chemistry. By contouring the surface, maps can be prepared that show the spatial variation in the magnitude of the process.

PROCESSES AND THEIR SPATIAL VARIATION

For the Sacramento Valley, 15 variables (table 9) were included in the principal components analysis. A major assumption of components analysis is that the data are normally distributed. This requirement was reasonably well met by using logarithmic transformations of the chemical concentrations. Four principal components explained 73 percent of the total variation in the data and accounted for all the significant common variation (that is, only these four components had eigenvalues greater than one). The four individual components explained 36, 17, 11, and 9 percent of the total variation. Because neither the third nor fourth component yielded clear interpretations that could be attributed to processes, only the first two components are presented. These two components, however, explain

TABLE 9.—*Chemical variables included in the principal components analysis of the Sacramento Valley*

Dissolved solids	Potassium	Silica	Nitrate
Calcium	Manganese	Bicarbonate	Phosphate
Magnesium	Arsenic	Sulfate	Fluoride
Sodium	Boron	Chloride	

TABLE 10.—*Results of principal components analysis on chemical data from the Sacramento Valley*

[All loadings with absolute values less than 0.30 have been omitted for clarity]

	Components		Communalities
	1	2	
Dissolved solids	0.94		0.93
Calcium	.76		.60
Magnesium	.81		.67
Sodium	.83		.76
Bicarbonate	.85		.72
Chloride	.76		.62
Sulfate	.63		.41
Boron	.65		.42
Fluoride	.30	−0.46	.30
Silica	−0.54	.42	.46
Potassium		.67	.48
Nitrate		−0.71	.52
Phosphate		.50	.30
Manganese		.63	.41
Arsenic		.62	.38
Percent variation explained	36	17	
Cumulative percent variation explained	36	53	

over 50 percent of the variation in the chemical data from the Sacramento Valley.

Table 10 shows the results of the principal components analysis. On component one, dissolved solids, calcium, magnesium, sodium, bicarbonate, chloride, sulfate, boron, and fluoride all have positive loadings. Silica is the only species to have a significant negative loading on this component. The inverse loadings of dissolved solids and silica indicate that low silica concentrations tend to be found in conjunction with high dissolved-solids concentrations, and vice versa. The positive loadings of all the major chemical species on this factor indicate a source high in calcium, magnesium, sodium, bicarbonate, chloride, and sulfate. This source is also high in fluoride and boron, and low in silica.

The trend surface map of this component (fig. 9) shows a distinct linear trend across the valley, which accounts for 36 percent of the spatial variation in component one. Low values of component one along the eastern margin and in the northern end of the valley indicate low dissolved-solids and high silica concentrations. In the southwestern corner, high concentrations of dissolved species and boron are indicated. This distribution in the ground water is very similar to the distribution of water chemistry in surface streams draining into the valley. Table 11 shows the average concentrations of dissolved species in streams entering the valley from certain areas. East side streams are low in dissolved solids, and contain twice as much silica as streams from the southwestern margin. The silica in east side streams is likely from the weathering of volcanic detritus in the Sierra Nevada and Cascade Range. High dissolved-solids concentrations in the southwest originate in thermal springs in the Coast Ranges.

The first principal component represents the effects of the chemistry of recharge to the valley on the chemistry of the ground water. This process is active along both margins of the valley and produces fairly uniform chemical compositions along the eastern side. Along the western margin, changes in surface-water chemistry from north to south induce changes in ground-water chemistry. The effects of recharge chemistry are the single most important control on ground-water chemistry, accounting for over one-third of the total variation in the chemical data.

The second principal component (table 10) explains 17 percent of the variation in the chemical data, and contains positive loadings of silica, potassium, phosphate, manganese, and arsenic. Nitrate and fluoride have negative loadings on this component. The trend surface for component two (fig. 10) explains 38 percent of the spatial variation in this component. The pattern indicates high factor scores in the center of the valley with low values along the margins. The occurrence of high factor scores in wells in the flood basins suggests that the fine-grained sediments and reducing conditions in the basins are an important control on water chemistry.

Measurements of dissolved oxygen in the ground water in the south alluvial fans facies (table 12) show an average of 3.8 mg/L of dissolved oxygen. Although no data are available for other parts of the valley, it is reasonable to assume that the coarse-grained sediments along the valley margins would contain some dissolved oxygen. In the flood basins, where sediments are water saturated and fine grained, reducing conditions probably exist. The increase in manganese and arsenic, and decrease in nitrate, support an oxidation-reduction effect. The solubility of manganese and arsenic increases in reducing conditions, and nitrate could be removed by denitrification.

Longer residence times in the fine-grained sediments of the flood basins and weathering of volcanic detritus from Sutter Buttes could supply the higher silica and potassium concentrations indicated by component two. The inverse relation between phosphate and fluoride probably reflects spatial differences in their sources rather than equilibrium with a mineral phase, such as apatite. Phosphate, introduced along with nitrate, would not be removed by reduction reactions and would persist in the ground water. Fluoride is probably derived from thermal springs in the hills surrounding the valley and lacks a source in the central basins.

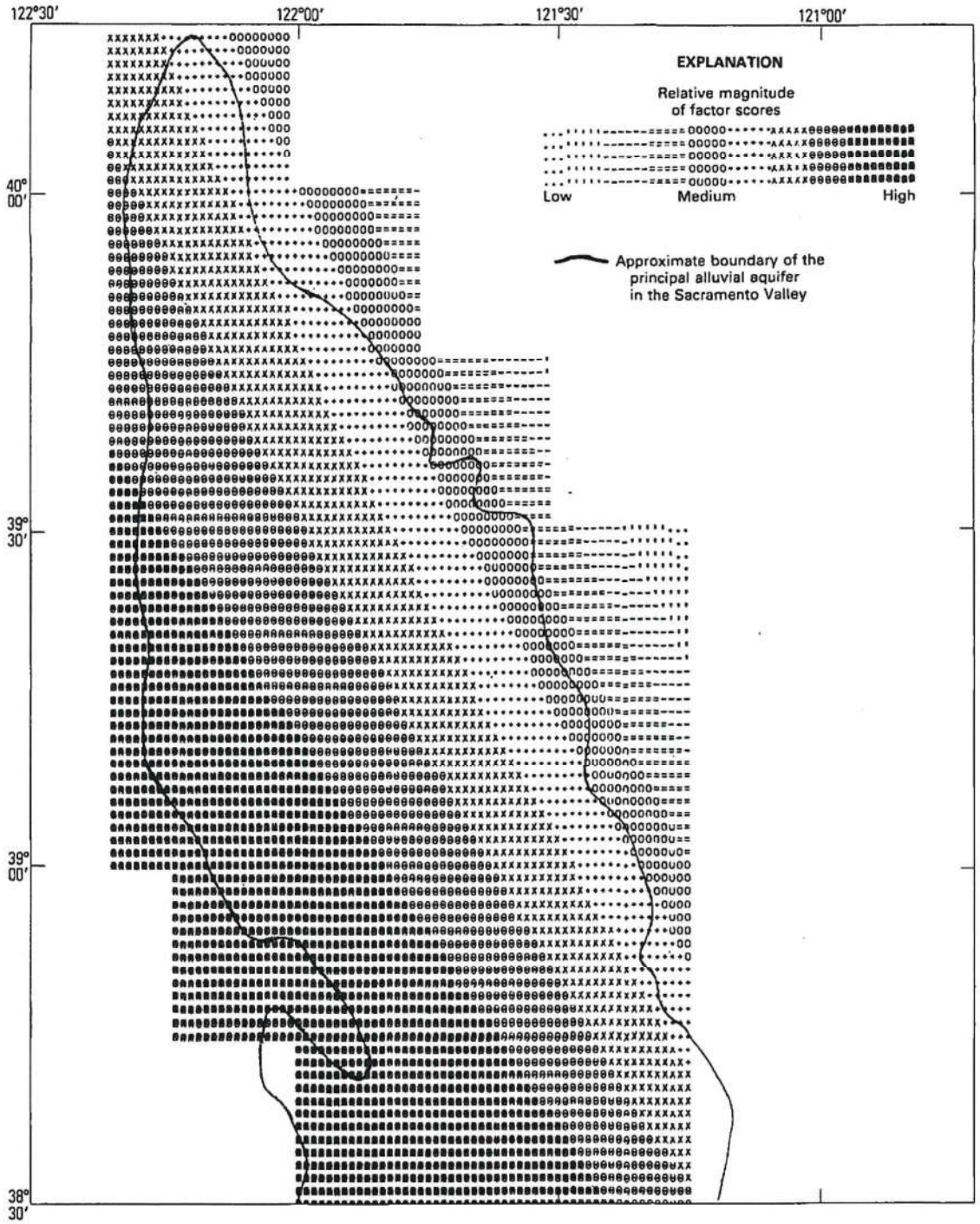

FIGURE 9.—Trend surface of factor scores for component one.

Principal components analysis shows that two components account for over 50 percent of the variation in the chemical data from the Sacramento Valley. While other processes will affect water chemistry, they seem to be either more localized or much less important than the two discussed. Recharge from the valley margins

TABLE 11.—*Average chemical compositions of surface water entering the Sacramento Valley*

Species (mg/L)	East side	Northern west side	Southern west side
Dissolved solids	85	215	592
Calcium	11	36	53
Magnesium	4.7	12	40
Sodium	6.3	13	101
Bicarbonate	55	164	314
Chloride	5.4	16	150
Sulfate	7.0	28	82
Boron	.10	.07	.51
Fluoride	.08	.08	.4
Silica	22	14	11

EXPLANATION OF LOCALITIES

East side: Antelope Creek, Mill Creek, Big Chico Creek, Butte Creek, Feather River, Yuba River, Bear River, and American River.

Northern west side: Red Bank Creek, Elder Creek, Thomes Creek, and Stony Creek.

Southern west side: Stone Corral Creek, Lurline Creek, Freshwater Creek, Salt Creek (west of Williams), Cortina Creek, Sand Creek, Oat Creek, Cache Creek, and Putah Creek.

is the most important control on ground-water chemistry, with reactions in the flood basin sediments also being important.

MINERAL STABILITY RELATIONS

Sediments deposited in the Sacramento Valley have been derived from erosion of the surrounding mountains. These mountains contain igneous and metamorphic rocks which were formed at higher temperatures and (or) pressures than are found at shallow depths in the valley sediments. Because the environment of deposition is radically different from that of formation, these minerals are generally not in equilibrium with their surroundings. As a result, the minerals react with the ground water, which dissolves the unstable primary minerals and forms secondary minerals that are more stable. Reaction rates may be very slow, so the process is gradual and can take tens of millions of years or longer. During this diagenesis, phases, such as pyroxenes, feldspars, micas, and volcanic glass, weather to more stable phases, such as clay minerals and iron hydroxides.

Water chemistry will be affected by water-rock interactions, and the three parts of the system (primary minerals, aqueous solution, and secondary minerals) are interdependent. Using thermodynamic calculations, the mineral phases that will be stable in equilibrium with solutions of various compositions can be predicted. It cannot be justifiably presumed, however, that the mineral assemblage and the ground-water chemistry are in thermodynamic equilibrium, particularly where aluminosilicate minerals are involved. Water chemistry may reflect incomplete reactions or partial equilibrium with metastable phases.

In this section, the relations between water chemistry and aquifer mineralogy are examined. Mineralogy is presented from two U.S. Geological Survey test wells. Mineral saturation indices are examined to determine any likely phases that may be controlling water chemistry. Finally, stability and metastability fields of mineral phases are compared to measured water chemistry to determine what secondary minerals will be most stable in contact with Sacramento Valley ground water.

MINERALOGY OF SEDIMENTS

Sidewall samples were collected from various depths in two test wells drilled by the U.S. Geological Survey during 1979. Data from two wells do not provide a comprehensive evaluation of sediment mineralogy, but they do provide a partial guide to what minerals may be present. Not all the samples have been analyzed as of the time of this writing and additional mineralogic data will be published in the future as basic data reports.

WELL 12N/01E–34Q

The mineralogy of sidewall samples from well 12N/01E–34Q was determined by optical microscope identification of the 0.5- to 0.125-mm size fraction. Table 13 shows the percent compositions of minerals, in this size range, for five samples collected from 323 feet to 897 feet. Data from an additional sample at 1,845 feet is also given. Feldspars compose an average of about two-thirds of the mineral grains, with about one-fifth being quartz and one-tenth being rock fragments. In all the shallower samples, the percent plagioclase having an anorthite content greater than 34 percent is smaller in the fine fraction than in the medium. The sample from 1,845 feet has an unusually small amount of anorthite-rich plagioclase in the medium fraction. The albitic plagioclase component increases between medium and fine fractions in all but one sample. The smaller size fractions, which are chemically more reactive, are dominated by albitic plagioclase.

Lithic fragments from a gravel at 1,856 feet, having a distinct greenish hue, were examined by X-ray diffraction. The sample near this depth was unusually rich in heavy lithic fragments (table 13). X-ray analysis of these fragments indicates that the composition is quartz, plagioclase, and chlorite (Ivan Barnes, U.S. Geological Survey, personal commun., 1979). The mineralogy of the sediments determined by optical methods may not reflect the complete mineralogy, especially where some minerals are contained in rock fragments which are not differentiated mineralogically. Mineral phases identified in samples from this well are shown in table 14.

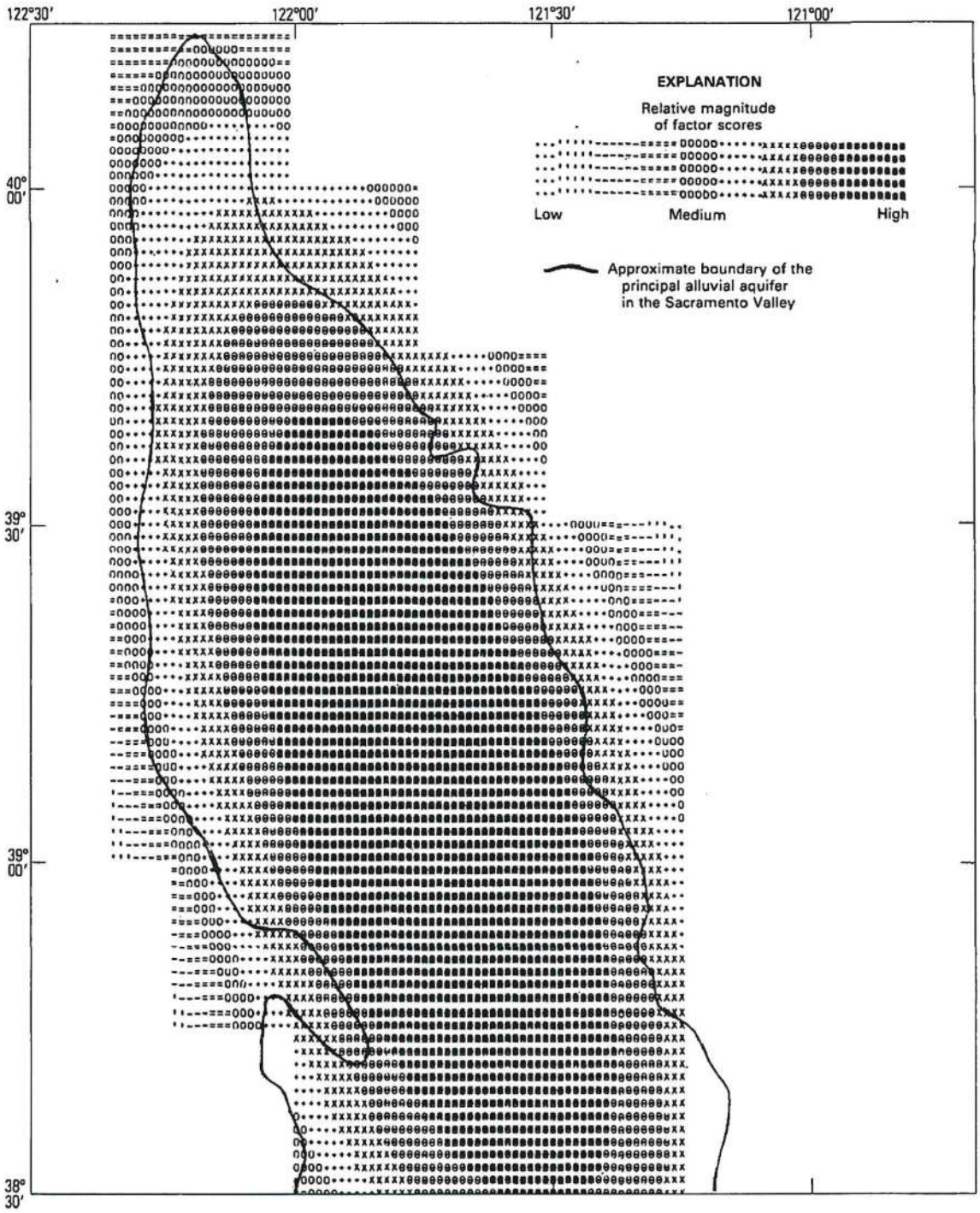

FIGURE 10.—Trend surface of factor scores for component two.

WELL 19N/01W–32G

The mineralogy of a number of fine-grained layers was determined by X-ray diffraction analysis of sidewall samples from well 19N/01W–32G. The results of the analyses are shown in table 15. Below a depth of about 562 feet, a large component of X-ray amorphous material is present in the sediments. Whether this is primary volcanic glass or an intermediate weathering

TABLE 12.—*Dissolved-oxygen concentrations in well water in the south alluvial fans facies*

Well	Date	Dissolved oxygen (mg/L)
08N/03E–05N04M	08–01–79	1.9
08N/03E–06M01M	08–01–79	2.0
08N/01E–06B01M	07–31–79	5.9
08N/01E–17C01M	07–26–79	5.0
09N/03E–31L01M	08–01–79	2.0
09N/02E–18N01M	07–31–79	4.4
09N/02E–33E01M	07–31–79	7.8
09N/01E–35H02M	07–31–79	3.8
09N/01W–25M01M	07–31–79	3.2
10N/02E–03E01M	07–25–79	2.8
11N/01W–01D01M	07–25–79	3.5
Mean		3.8

product, such as an amorphous aluminosilicate (Paces, 1978) was not investigated. The two clay minerals present in quantity are halloysite and illite. The presence of halloysite rather than kaolinite was determined using transmission electron microscopy. Figure 11 shows an electron micrograph of sediments from the 407-foot depth. The tubular structures at the center and top of the figure are halloysite, with poorly formed flakes of illite also visible. The dark, blocky particles are fine-grained quartz and plagioclase.

Optical examination of sand-size grains shows that the mineralogy is consistent with an andesitic sand. The major mineral is plagioclase, which is zoned and shows etching. Some pyroxenes are present and are clear to light green. Many of the grains are stained by ferric hydroxides.

SATURATION INDICES

According to the law of mass action, when an aqueous solution is in equilibrium with a mineral, the ion-activity product for that mineral will equal the thermodynamic equilibrium constant. The degree of saturation of a water can be represented by the saturation index (*SI*), which is the logarithm of the quotient of the ion-activity product (*IAP*) divided by the equilibrium constant (*K*):

$$SI = \text{Log}\,\frac{IAP}{K}, \tag{1}$$

where

SI=saturation index
IAP=ion-activity product, and
K=thermodynamic equilibrium constant.

The saturation index has a value of zero when the solution is in equilibrium with a solid phase. A positive saturation index indicates supersaturation and a negative index undersaturation with respect to some mineral. Minerals that are present in an aquifer and have negative saturation indices can dissolve. Minerals that have positive saturation indices may precipitate from solution, although whether this actually occurs depends on additional factors. By examining the saturation indices of water samples collected from the Sacramento Valley, some idea can be obtained about which minerals may be influencing ground-water chemistry.

TABLE 13.—*Mineralogic compositions of sidewall samples from U.S. Geological Survey test well 12N/01E–34Q*

c—coarse >0.5 mm.
m—medium 0.5–0.25 mm.
f—fine 0.25–0.125 mm.
vf—very fine 0.125–0.0625 mm.
p—pan <0.0625 mm.

VAB—very abundant, from 25–50 percent of the heavy minerals.
AB—abundant, from 10–25 percent of the heavy minerals.
SP—sparse, from 1–4 percent of the heavy minerals.

Sample depth, in feet	323		467		685		788		897		1845	
Texture, in percent c/m/f/vf/p	7/2/41/34/17		2/2/8/43/45		3/5/19/38/36		60/22/10/3/5		8/52/28/4/8		59/18/6/4/12	
Size interval	m	f	m	f	m	f	m	f	m	f	m	f
Composition, in percent:												
Potassium feldspar	12	13	6	16	27	13	15	14	15	12	10	12
Plagioclase (Anorthite<34)	25	44	40	33	22	32	21	36	28	39	19	24
Plagioclase (Anorthite>34)	28	10	24	14	25	16	23	12	23	14	3	13
Quartz	20	23	20	28	20	26	21	18	7	13	31	18
Lithic fragments	11	10	7	6	4	10	14	13	21	12	21	11
Heavy minerals[1]	3	1	3	3	2	2	5	6	6	13	15	23
Nonopaque heavy grains:												
Sausserite	VAB		VAB		VAB		VAB		AB		AB	
Uralite	VAB		VAB		VAB		VAB		AB		AB	
Goethite	VAB		VAB		VAB		VAB		AB		AB	
Lithic fragments	AB		SP		SP		AB		AB		VAB	

[1]Heavy minerals have specific gravities greater than 2.9.

TABLE 14.—*Minerals identified in sidewall samples from U.S. Geological Survey test well 12N/01E–34Q, in alphabetical order*

Actinolite-tremolite (series)[1]	Glaucophane
Amphiboles	Graphite
Analcite	Hematite (some specular)
Apatite	Hercynite
Augite-ferroaugite (series)[1]	Hornblende (green, brown, and oxy-varieties)
Basic glass	Hypersthene
Biotite	Lawsonite
Bronzite-ferrohypersthene (series)[1]	Marcasite
Chlorite	Pigeonite
Chromite	Plagioclase (series)[1]
Chrysotile	Potash feldspar (undifferentiated)
Clinozoisite	Pumpellyite
Cordierite	Richterite (part of series)[1]
Cummingtonite	Riebeckite
Diopside-hedenbergite (series)[1]	Serpentine (?)
Enstatite-bronzite (series)[1]	Sideromelane
Epidote	Sphene (titanite)
Fluorite	Spinel
Garnet (red)	Staurolite
Glauconite	Zircon
	Zoisite

[1]"Series" means several varieties within the series were found.

Saturation indices were calculated for 271 water analyses selected from those published by Fogelman (1975, 1976) and Fogelman and Rockwell (1977). Of the 271, 153 had aluminum analyses and 183 had iron analyses. Temperature, pH, and alkalinity were determined in the field. Samples for cation determinations were passed through a 0.1-micrometer filter and acidified with concentrated nitric acid. Some controversy exists as to the validity of aluminum and iron data gathered in this manner; however, the possible error introduced is generally small (Kennedy and others, 1974; Barnes, 1975). Some of the supersaturation in the aluminosilicate and iron minerals may be due to particulate iron and aluminum passing through the filter. Saturation indices were calculated using WATEQF (Plummer, and others, 1978).

Table 16 shows the mean, minimum, and maximum saturation indices for selected mineral phases along with log equilibrium constants at 20°C, the average temperature of ground waters in the Sacramento Valley. Although many minerals, such as the feldspars and montmorillonite, show variations in chemical composition, saturation indices were calculated for ideal mineral phases. Therefore, stability calculations for these minerals only approximate actual conditions, but they do provide useful indicators of the types of reactions that may be occurring.

TABLE 15.—*Percent mineral composition of sidewall samples from U.S. Geological Survey test well 19N/01W–32G*

[Tr, trace; unid., unidentified; inter., intermediate; ND, not detected]

Depth (feet)	Quartz	Plagioclase	Amorphous	Halloysite	Illite	Other
260	35–45	25–35	ND	15–20	5–10	Tr unid.
353	40	15–20	ND	10–15	ND	Tr minor.
407	35–40	20–25	ND	10–15	2–5	Tr minor.
478	35–40	25–30	ND	10–15	5–10	5–10 Chlorite.
562	10–20	15–25	Major	5–15	2–5	ND.
630	20–25	15–20	Inter.	5–10	2–10	Tr unid.
930	15–20	10–15	Inter.	10–15	5–10	ND.
984	5–15	5–10	Major	10–15	1–5	Tr unid.
1,098	5–10	5–10	Major	5–10	1–5	ND.
1,193	5–15	5–10	Major	5–10	1–5	Tr minor.
1,390	5–10	2–5	Major	2–5	2–5	ND.

Most waters are close to saturation with respect to silicaglass, as might be expected from the volcanic detritus in the sediments. All samples were supersaturated with respect to amorphous ferric hydroxide, which may reflect the variability in solubility with particle size or particulate iron passing through the 0.1-micrometer filter during sampling. The waters tend to be at saturation with respect to gibbsite and slightly below saturation with respect to amorphous aluminum hydroxide.

Ground water is fairly close to saturation with respect to the carbonate minerals, calcite, dolomite, and magnesite. No carbonate minerals were recorded in sediments from either of the wells examined for mineralogy. Apparently, the formation of secondary carbonate minerals is of limited extent despite a number of samples indicating supersaturation with respect to calcite.

Potassium and sodium feldspars, which are abundant in the sediments, average close to saturation in Sacramento Valley ground water. Dissolution of these phases probably contributes to water chemistry where ground water is undersaturated with respect to these feldspars. All water samples are undersaturated with respect to anorthite, which is less abundant in the sediments. Halloysite is the only clay mineral with which the ground water is not supersaturated. Any of the other clay minerals could potentially form from most of the waters. When stability fields are considered, however, only one phase will be the most stable. These phase relations can be illustrated using activity diagrams.

ACTIVITY DIAGRAMS

Activity diagrams can be used to illustrate the phase relations among primary and secondary minerals and to predict the most stable secondary phases as a function of water chemistry. Such diagrams have been used by Feth, Roberson, and Polzer (1964), Tardy (1971) and White (1979) to depict weathering reactions in ground



FIGURE 11.—Electron micrograph of sediments from the 407-foot depth of well 19N/01W–32G. (Photograph by Technology of Materials, Santa Barbara, Calif.)

waters. The technique for calculating such diagrams is given in Garrels and Christ (1965), and Helgeson, Brown, and Leeper (1969) give numerous examples of such diagrams. A slightly different type of diagram, though basically similar, was presented by Kittrick (1969), and it depicts equilibrium between solid phases and an aqueous solution.

As an example of the calculation of the equilibrium boundary between two phases, the calculation of the phase boundary between illite and montmorillonite is given below. Formulas for these minerals are taken from WATEQF (Plummer, and others, 1978). For the reaction illite ⇆ montmorillonite, the chemical equation is written

TABLE 16.—*Mean, minimum, and maximum saturation indices in Sacramento Valley ground water for selected mineral phases*

Phase[1]	n	[2]Log K at 20 °C	Saturation index		
			Mean	Minimum	Maximum
Silica glass	271	-3.07	-0.14	-0.58	0.16
$Fe(OH)_3$ amorph.	183	4.885	1.31	.62	3.67
$Al(OH)_3$ amorph.	153	-31.77	-1.13	-2.32	.03
Gibbsite	153	-32.95	.05	-1.15	1.22
Fluorite	269	-11.02	-2.38	-3.50	-0.10
Hydroxyapatite	270	-59.57	-2.22	-7.57	1.64
Strengite	183	-26.37	-0.61	-2.06	1.05
Calcite	271	-8.45	-0.33	-1.80	.50
Dolomite	271	-16.92	-0.54	-3.37	1.24
Magnesite	271	-8.16	-0.53	-1.96	.43
Adularia	153	-20.96	.22	-1.81	1.66
Albite	153	-18.32	-0.82	-2.93	.47
Anorthite	153	-19.55	-3.27	-5.95	-1.77
Halloysite	153	-33.38	-0.89	-3.76	1.38
Kaolinite	153	-37.52	3.26	.32	5.58
Illite	153	-40.99	2.31	-1.33	4.53
Montmorillonites:					
1. Calcium	153	-45.73	3.40	-0.37	5.84
2. Belle Fouche.	95	[3]-34.97	7.49	4.04	9.01
3. Aberdeen	95	[3]-29.69	6.69	3.43	8.10
Muscovite	153	-49.94	1.35	-3.12	4.61
Chlorite	153	-91.29	-1.83	-12.11	3.52

[1]Chemical formulas for these phases are as written in WATEQF (Plummer and others, 1978.)

[2]Data from the latest version of WATEQF.

[3]The log equilibrium constant at 25°C is used because no enthalpy is given in WATEQF.

$$(K_{0.6}Mg_{0.25}Al_{2.3}Si_{3.5}O_{10}(OH)_2)+2.48H_4SiO_4 +0.52Fe^{+3}+0.45Mg^{+2} \leftrightarrows 3.13H_2O+0.6K^{+1}+1.86H^{+1} +1.56(H_{0.42}Mg_{0.46}Fe_{0.34}Al_{1.47}Si_{3.82}O_{10}(OH)_2). \quad (2)$$

At the phase boundary, the ion-activity product for this reaction will equal the equilibrium constant (K):

$$\frac{[K^{+1}]^{0.6}[H^{+1}]^{1.86}}{[H_4SiO_4]^{2.48}[Fe^{+3}]^{0.52}[Mg^{+2}]^{0.45}}=K. \quad (3)$$

Brackets denote free ion activities, which are concentrations corrected for the nonideality of aqueous solutions. Rewriting in terms of log activities gives the equation:

$$0.61 \log [K^{+1}]/[H^{+1}]-0.52 \log [Fe^{+3}]/[H^{+1}]^3 -0.45 \log [Mg^{+2}]/[H^{+1}]^2-2.48 \log [H_4SiO_4]=\log K. \quad (4)$$

To plot this line on a two-dimensional graph, the equation must be reduced to two variables. The assumptions that may be considered when plotting phase diagrams include (1) controlling the concentration of a component by equilibrium with a solid phase, (2) conserving a component in solid phases during phase transformations, and (3) assigning a specified concentration for a species in solution, commonly the average for that species in the study area.

In all plots below, it is assumed that the logarithm of the activity quotient of free ferric iron to hydrogen cubed (log $[Fe^{+3}]/[H^{+1}]^3$) is controlled by the solubility of amorphous ferric hydroxide at 4.885 (Plummer and others, 1978). The average for the log activity ratio of potassium to hydrogen (log $[K^{+1}]/[H^{+1}]$) in the valley is 2.75, and ratio of magnesium to hydrogen squared (log $[Mg^{+2}]/[H^{+1}]^2$) is 11.25. The average log activity of silica in ground waters is -3.21. The use of these averages where a concentration must be assumed in the calculation of a phase transformation does not significantly affect the depicted relations between data points and phase boundaries in the following activity diagrams.

For the equilibrium between illite and montmorillonite, log $[Fe^{3}]/[H^{+1}]^3$ is assumed to be controlled by the solubility of ferric hydroxide, and log $[H_4SiO_4]$ is assigned a value of -3.21. Replacing these quantities in equation 4 gives the following equation for the phase boundary between illite and montmorillonite:

$$\log [K^{+1}]/[H^{+1}]=0.122+0.743 \log [Mg^{+2}]/[H^{+1}]^2. \quad (5)$$

Two types of diagrams are presented here to illustrate phase relations in the system MgO-K_2O-Fe_2O_3-Al_2O_3-SiO_2-H_2O. The diagrams depart, to some extent, from the traditional presentation in that metastable phases are included. Recent work by Paces (1973, 1978) and Busenberg (1978) indicates that during the weathering of feldspars, the initial solids formed are amorphous to poorly crystalline aluminosilicates which may be reversible with respect to the aqueous solution. Subsequent crystallization results in the formation of a metastable aluminosilicate commonly called halloysite. Eventually, the thermodynamically most stable mineral will form. This pathway between primary and secondary minerals generally follows Ostwald's Rule (Darken and Gurry, 1953), which states that when a system is proceeding from a less to a more stable state, the final most stable state is not necessarily reached directly but may be attained through a series of intermediate states. Neither halloysite nor illite are stable with respect to montmorillonite or kaolinite, yet they are present in the sediments. Activity diagrams showing metastable states indicate the intermediate steps, as well as the final secondary minerals that are expected to form.

All minerals included in the following diagrams are from WATEQF and have formulas and log equilibrium constants from that program. Because no information is available on the chemistry of clay minerals from the Sacramento Valley, particularly illite and montmorillonite, no better substitute is available. This use of surro-

gate minerals will introduce some uncertainty in the exact locations of phase boundaries in the diagrams. Considering the uncertainty in the knowledge of thermodynamic data on montmorillonites and illites, it is doubtful if full knowledge of mineral chemistry would improve the situation. The montmorillonite used in all the diagrams is Aberdeen montmorillonite (Kittrick, 1971) with modifications by Truesdell and Jones (1974).

Figure 12 shows the stability fields of minerals as a function of $pH-\frac{1}{3}pAl^{+3}$ and $p[H_4SiO_4]$, where p stands for -log as in $pH=-\log [H^{+1}]$, and $pAl^{+3}=-\log [Al^{+3}]$. This diagram depicts the formation of secondary minerals from an aqueous solution. The solution, in this case, is assumed to have the average ion activity ratios and silica activity observed in the Sacramento Valley. No solid phase will form from solutions with low aluminum to hydrogen ratios and low silica concentrations (bottom right corner of figure 12). At higher aluminum to hydrogen ratios, the stable solid phase changes from gibbsite to kaolinite to montmorillonite with increasing silica. Halloysite and amorphous aluminum hydroxide phase boundaries are dashed to emphasize that they are both metastable phases. A solution in equilibrium with halloysite will be supersaturated with respect to montmorillonite or kaolinite. All samples from the valley plot in the montmorillonite stability field. Only 10 percent of the samples are supersaturated with respect to halloysite.

Regression analysis was used to determine if any significant linear relation exists between aluminum and silica. Each hydrochemical facies was treated separately to preserve as much detail as possible. Only two of the regression equations were significant, those for the Tuscan volcanic rocks and the Sutter Basin facies.

The equation for the Tuscan volcanic rocks facies is

$$pH-\tfrac{1}{3}pAl^{+3}=2.10+0.39p\,[H_4SiO_4] \qquad (6)$$

with r^2 equal to 0.26 and coefficients and their 90 percent confidence limits of

$$2.10 \pm 0.83$$

and

$$0.39 \pm 0.27.$$

Rewriting the equation in terms of log activities gives

$$0.33 \log [Al^{+3}]/[H^{+1}]^3=2.10-0.39 \log [H_4SiO_4]. \qquad (7)$$

The inverse relation between the aluminum to hydrogen ratio and silica is indicative of control by a mineral phase. As silica increases in solution, $\log [Al^{+3}]/[H^{+1}]^3$ decreases to compensate.

The slope is close to and not significantly different from 0.33. Assuming that it is 0.33 and rearranging gives

$$\frac{[Al^{+3}][H_4SiO_4]}{[H^{+1}]^3}=10^{6.31}. \qquad (8)$$

The solution of halloysite or kaolinite is given by the equation:

$$\tfrac{1}{2}Al_2Si_2O_5(OH)_4+3H^{+1} \leftrightarrows \tfrac{1}{2}H_2O+Al^{+3}+H_4SiO_4. \qquad (9)$$

The ion activity product is

$$\frac{[Al^{+3}][H_4SiO_4]}{[H^{+1}]^3}=K. \qquad (10)$$

For halloysite log K equals 6.83 and for kaolinite, 4.76. The close agreement between the ion activity product of halloysite in ground water from the Tuscan volcanic rocks facies with the equilibrium constant is strong evidence that halloysite is controlling the aluminum and silica concentrations in ground water.

The Sutter Basin hydrochemical facies also showed a significant relation between $pH-\frac{1}{3}pAl^{+3}$ and $p[H_4SiO_4]$.

$$pH-\tfrac{1}{3}pAl^{+3}=6.13-0.92p[H_4SiO_4] \qquad (11)$$

with r^2 equal to 0.27 and coefficients and their 90 percent confidence limits of

$$6.13 \pm 2.91$$

and

$$0.92 \pm 0.91.$$

Rewriting the equation in terms of log activities gives

$$0.33 \log [Al^{+3}]/[H^{+1}]^3=6.13+0.92 \log [H_4SiO_4]. \qquad (12)$$

The positive slope is indicative of solution control of water chemistry, with both aluminum and silica increasing as some mineral phase is attacked by hydrogen ion. The slope is close to and not significantly different from one. This gives an aluminum to silica ratio in the dissolving phase of 1 to 3. The most likely minerals are, therefore, potassium and sodium feldspars, which have an aluminum to silica ratio of 1 to 3. This aluminum to silica ratio, along with the etched surfaces of feldspar grains observed under the microscope, may reflect stoichiometric dissolution of feldspars as found by Holdren and Berner (1979) and Berner and Holdren (1979).

Figure 13 shows the phase stability fields for minerals in terms of the log activity ratios of magnesium to

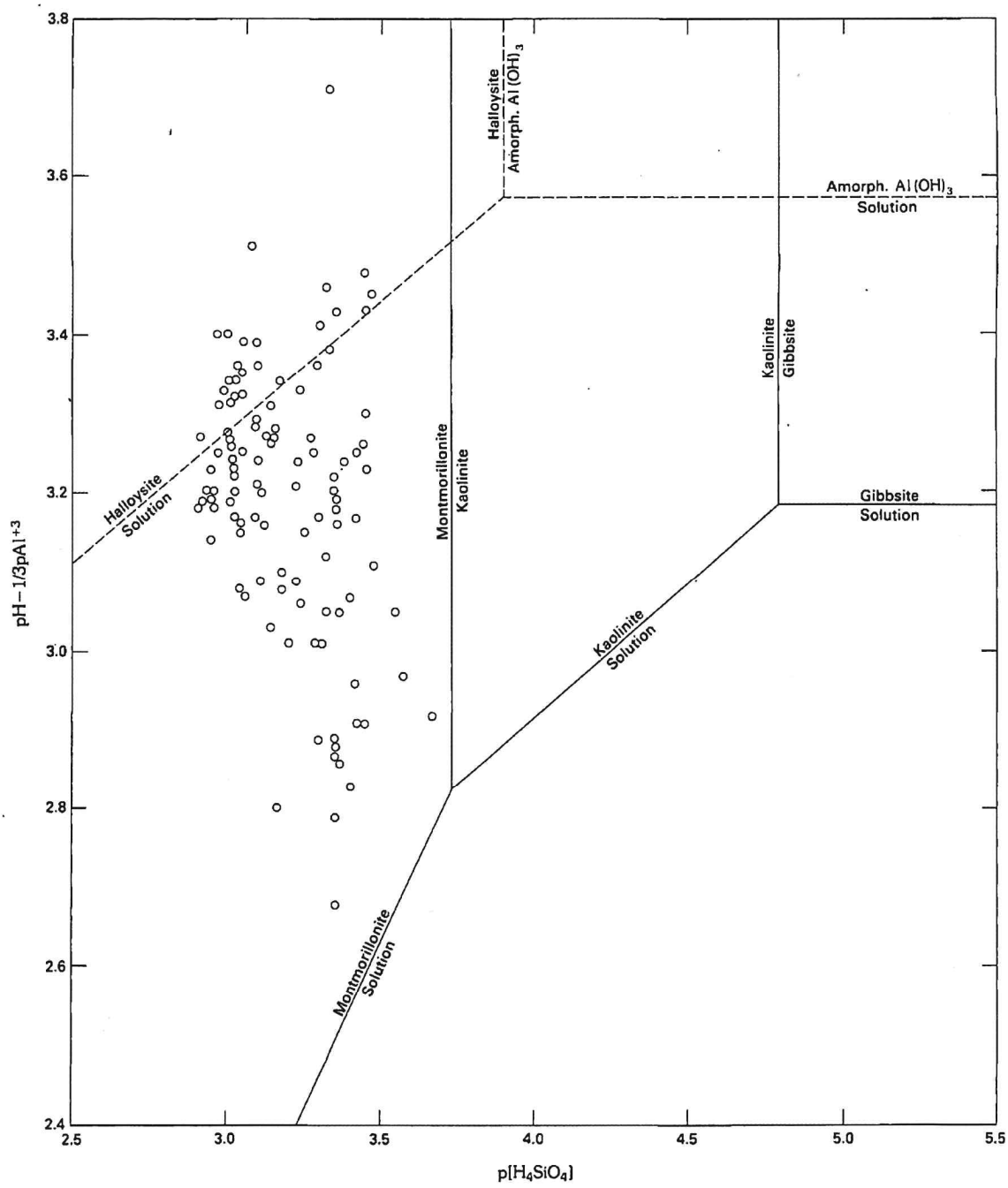

FIGURE 12.—Phase relations among minerals and aqueous solution in terms of pH-⅓pAl^{+3} and p[H_4SiO_4] at 20°C. (NOTE.—The aqueous solution is assumed to have the following ion activity ratios: log [Fe^{+3}]/[H^{+1}]^3 =4.885, log [K^{+1}]/[H^{+1}]=2.75, and log [Mg^{+2}]/[H^{+1}]^2=11.25.)

hydrogen squared and potassium to hydrogen. Aluminum is assumed to be strictly conserved in solid phases during phase transformations. Assumptions about iron and silica activities are as described at the beginning of this section on activity diagrams.

Figure 13 is actually two diagrams superimposed, so that illite, a metastable phase, can be shown. Illite is unstable with respect to montmorillonite or adularia if the three phases are considered simultaneously. The solid lines represent phase relations among the minerals

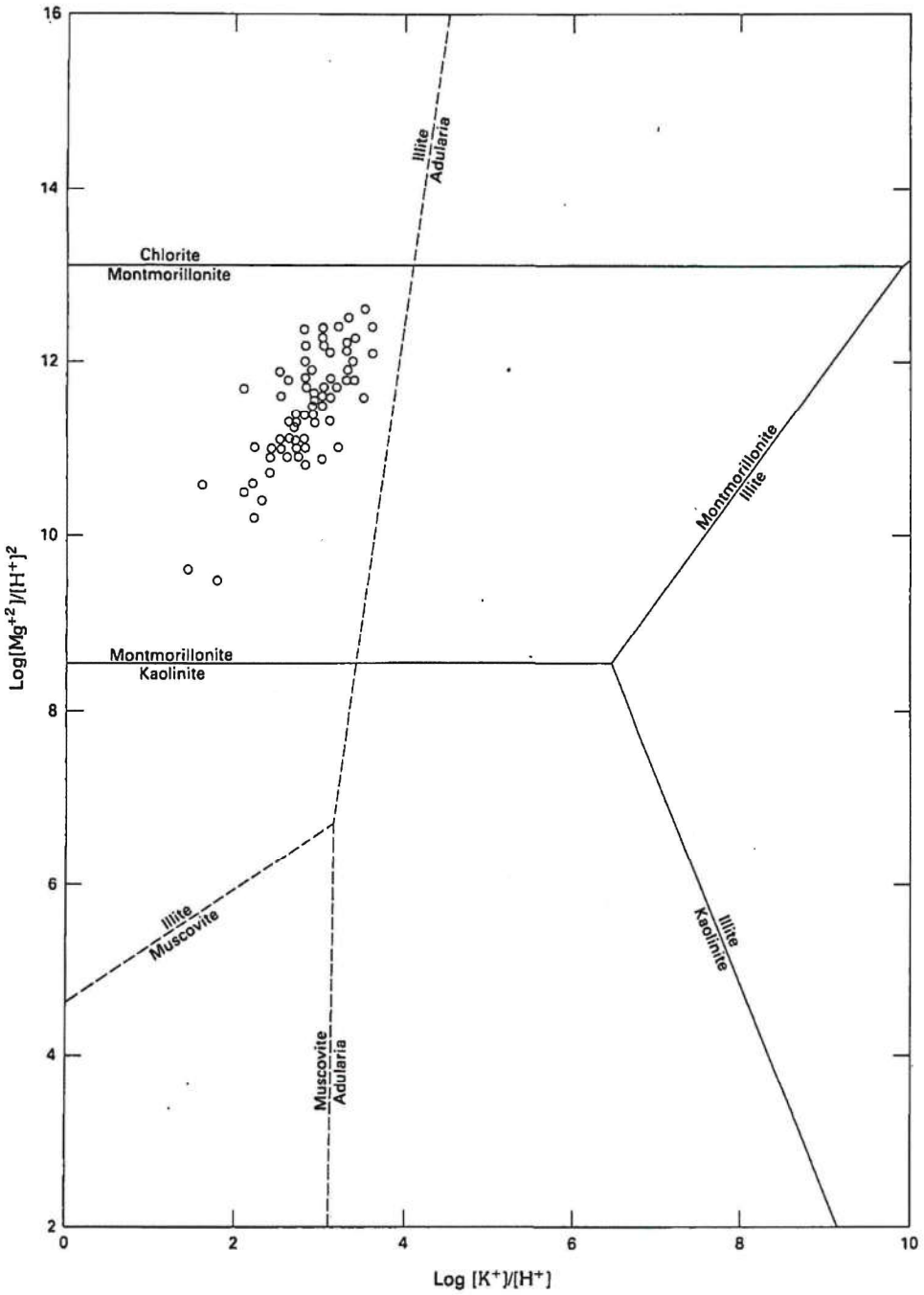

FIGURE 13.—Phase relations among minerals and coexisting aqueous solution in terms of log $[Mg^{+2}]/[H^{+1}]^2$ and log $[K^{+1}]/[H^{+1}]$ at 20°C. (NOTE.—Phase relations among chlorite, montmorillonite, illite, and kaolinite are shown by solid lines, and among illite, adularia, and muscovite by dashed lines. The aqueous solution is assumed to have the following activities of dissolved species: log $[Fe^{+3}]/[H^{+1}]^3$=4.885, log $[H_4SiO_4]$=-3.21.)

chlorite, montmorillonite, illite, and kaolinite. Among these minerals, montmorillonite is the most stable phase in equilibrium with ground water in the valley. The dashed lines represent phase relations among adularia, muscovite, and illite. Of these three minerals, illite is the most stable in contact with Sacramento Valley ground waters.

Illite is highly resistant to weathering (Berner, 1971),

and most of the illite found in samples from well 19N/01W-32G is probably detrital. Some of the illite may have formed from the weathering of primary minerals. Illite has been reported to form from orthoclase (Stumm and Morgan, 1970) and from muscovite (Berner, 1971).

Log activities from ground water in the Sacramento Valley plot in the stability field of a montmorillonite having the formula and stability of Aberdeen montmorillonite. Differences in activity ratios of ions in solution will probably produce montmorillonites of somewhat different composition in the Sacramento Valley, but some form of montmorillonite will be the most stable phase. Metastable phases either form as intermediate steps during the diagenesis of primary minerals (halloysite) or persist due to resistance to weathering (illite).

SUMMARY AND CONCLUSIONS

Shallow sediments in the Sacramento Valley were laid down as alluvial deposits in a freshwater environment. These sediments, from which ground-water samples were collected, have always been in contact with freshwater. Sediments along the valley margins are coarse grained, poorly sorted, and oxidized. In the central part of the valley, flood-basin deposits are finer grained and reduced. Most of the streams entering the valley are losing streams, at least over part of their courses, and much of the ground-water recharge is from this source.

The chemistry of ground water in the valley is greatly influenced by the chemistry of this recharge from the valley margins. Approximately one-third of the variation in ground-water chemistry can be attributed to this effect. The reducing conditions and finer grained sediments in the midvalley flood basins also influence ground-water chemistry. These processes have distinct spatial patterns that produce spatial variations in the chemical character of ground water in different areas.

Six areas, or hydrochemical facies, were delineated on the basis of geology, hydrology, and distinctions in chemical composition of ground water. Two of the facies lie along the eastern margin and receive recharge from the Cascade Range and Sierra Nevada. These waters are low in dissolved solids and high in silica. Two facies are located in the midvalley flood basins, and reducing conditions there produce higher concentrations of iron, manganese, and arsenic in the ground water. While the relative concentrations of these species are higher in the flood basins than in the rest of the valley, the absolute concentrations remain fairly low. Upwelling of saline water from underlying marine sediments contributes to high dissolved-solids concentrations in ground water in the southern parts of the flood basins.

Water along the west side of the valley is low in silica, and the water grades from moderate dissolved-solids levels in the north to high dissolved-solids levels in the south. Ground water in the southwest of the valley is also high in boron. The source of the high boron and dissolved-solids concentrations is thermal springs in the Coast Ranges. Two facies were delineated along the western margin to separate the waters having moderate and high dissolved solids. Because of the heterogeneity of ground-water chemistry in the valley, division into areas having more uniform chemical compositions provides additional detail in any investigation of water chemistry.

Dissolved-solids and nitrate concentrations were examined for linear trends with time for each of the hydrochemical facies. Significant increases in both were observed in parts of the valley. On the east side of the valley, the Tuscan volcanic rocks facies showed a significant increase in dissolved solids of 0.95 (mg/L)/yr but no significant change in nitrate concentrations. The Victor Plain facies showed significant increases in both dissolved solids [1.6 (mg/L)/yr] and nitrate-nitrogen [0.036 (mg/L)/yr]. Neither Butte Basin nor Sutter Basin hydrochemical facies, in the midvalley flood basins, showed a significant trend in nitrate with time. There were very few wells with multiple nitrate measurements, however, and the lack of significant changes may be due to the small sample size. Dissolved-solids concentrations in Butte Basin have been increasing at an average rate of 1.37 (mg/L)/yr, but are unchanged in Sutter Basin.

Both the north and south alluvial fans facies, adjacent to the Coast Ranges, show significant upward trends in dissolved solids and nitrate. The south alluvial fans facies has the greatest rate of increase for dissolved solids [4.75 (mg/L)/yr] of all the facies, and the north alluvial fans facies has the greatest rate of increase for nitrate-nitrogen [0.099 (mg/L)/yr]. The midvalley basins have fine-grained poorly permeable soils that protect the ground water from contamination. Infiltration rates are slow, and reducing conditions permit the removal of nitrate by denitrification reactions. Along the valley margins, however, significant increases in dissolved solids and nitrates have occurred since the mid-1950's.

Alkali feldspars and halloysite appear to be the most significant aluminosilicate minerals affecting water chemistry. Where waters are undersaturated, dissolution of feldspars takes place, bringing the water to near saturation with respect to adularia and albite. There is a general parallel increase in aluminum and silica reflecting the solution of aluminosilicates by ground water. In Sutter Basin, the relation between log $[Al^{+3}]/[H^{+1}]^3$ and log $[H_4SiO_4]$ indicates an increase in both aluminum and silica at a ratio 1 to 3. In the Tuscan

volcanic rocks facies, the relation between log $[Al^{+3}]/[H^{+1}]^3$ and log $[H_4SiO_4]$ is inverse. Rearranging the regression equation yields the same equation as for equilibrium between halloysite and an aqueous solution. The regression constant is very close to the equilibrium constant for halloysite, which supports the theory of solubility control by halloysite. Illite and halloysite were identified in sediments from the Sacramento Valley. Neither of these clay minerals is stable in the ground-water environment. The most stable clay minerals in equilibrium ground water of the valley is montmorillonite. Halloysite occurs as a mestastable intermediate step in the weathering of primary minerals to stable secondary minerals.

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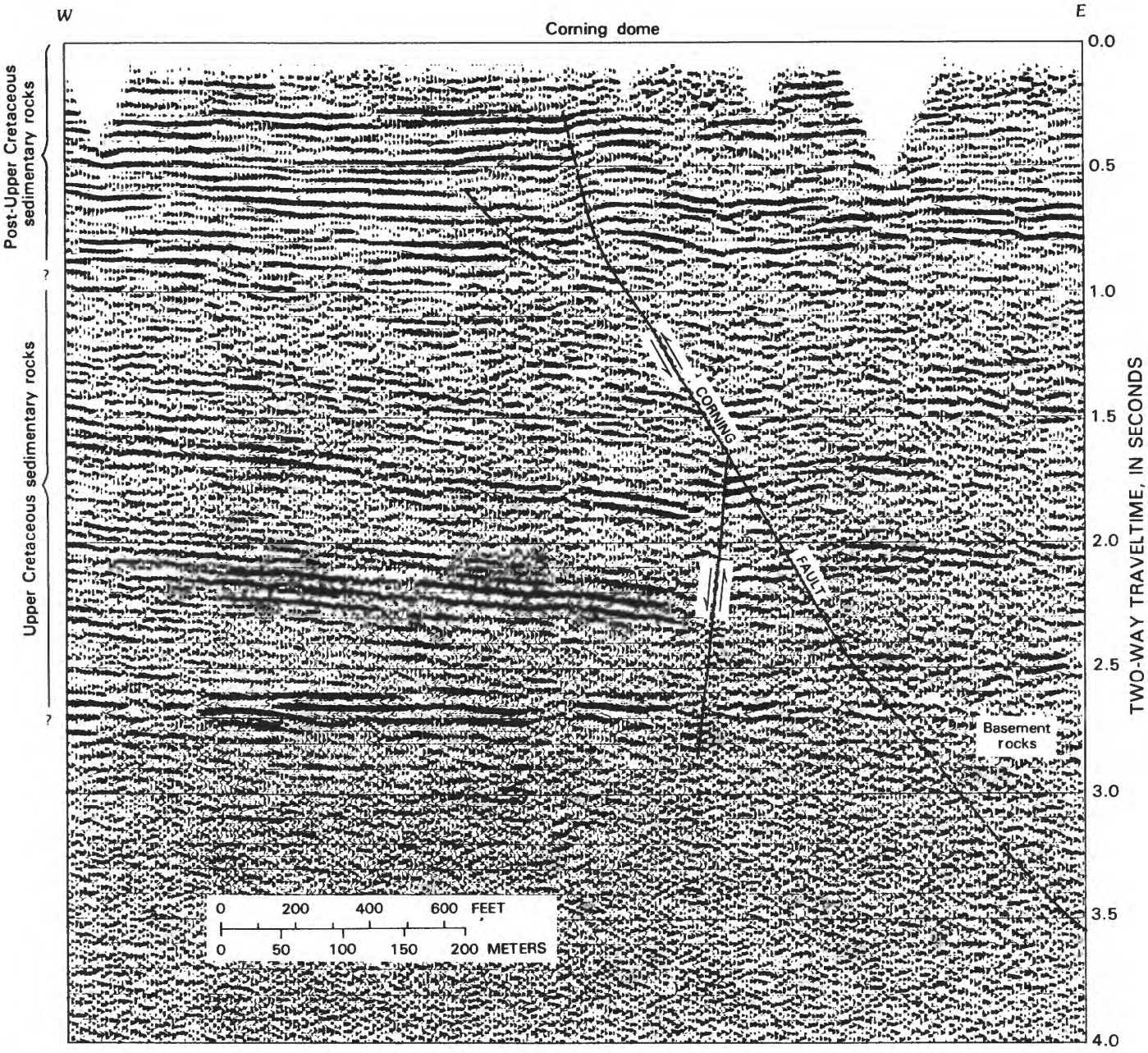

FIGURE 5.—Seismic reflection profile, from Seisdata Services Inc., showing structural and generalized stratigraphic relations across Corning fault between Corning and Red Bluff, Calif.

Late Cenozoic Tectonism of the Sacramento Valley, California

By DAVID S. HARWOOD *and* EDWARD J. HELLEY

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LATE CENOZOIC TECTONISM OF THE SACRAMENTO VALLEY, CALIFORNIA

By DAVID S. HARWOOD and EDWARD J. HELLEY

ABSTRACT

Structure contours drawn on top of the Cretaceous rocks in the Sacramento Valley define a large number of diversely oriented folds and faults that are expressed in topographic, hydrologic, and geologic features at the land surface. Although many of the structures in the valley have a protracted history of movement, some dating back to the late Mesozoic, a remarkable number of these structures show late Cenozoic deformation that can be accurately determined from folding and faulting of widespread, dated Pliocene and Pleistocene volcanic units. These time-stratigraphic units are used to define structural domains of essentially contemporaneous late Cenozoic deformation that was characterized by east-west compressive stress. The oldest structural domain is located in the southeastern part of the valley, where east-side-up reverse movement on the Willows fault ceased prior to deposition of continentally derived sediments of late Miocene and early Pliocene age. In the middle Pliocene to early Pleistocene, east-west compressive deformation progressed northward through the valley so that the youngest late Cenozoic deformation is recorded in east-northeast-trending folds and faults in the Battle Creek domain, at the northernmost part of the valley. The northward progression of east-west compressive deformation appears to be related to the northward eclipse of eastward subduction of the Juan de Fuca plate before the northwestward migration of the Mendocino triple junction along the continental margin west of the valley.

Much of the east-west compressive stress that affected the valley in the late Cenozoic was accommodated by east-side-up reverse movement on the steeply east-dipping, northwest-trending Willows fault and the north-trending Corning fault that splays off from the main stem of the Willows fault north of Sutter Buttes. Significant strain release also occurred on the northwest-trending fault beneath the Chico monocline and on the east-northeast-trending Red Bluff, Battle Creek, and Bear Creek faults in the past 2.0 m.y. Southeast of Sutter Buttes, the Willows fault follows the boundary between dense, magnetic, presumably ophiolitic basement to the west and Sierran basement to the east. The Chico monocline follows the same basement boundary north of Sutter Buttes, but that structure is stepped eastward from the trace of the Willows fault. It seems reasonably certain that the southeastern extension of the Willows fault and the Chico monocline fault are middle and late Cenozoic structures, respectively, that owe their existence and orientation, in part, to earlier, Mesozoic tectonic juxtapositioning of significantly different basement terranes.

INTRODUCTION

The Oroville earthquake ($M = 5.6$, August 1, 1975) added a new dimension to geologic studies of the Sacramento Valley. That event, more than any of the infrequent earthquakes that previously occurred in the area, awakened the geologic and engineering communities to the potential of active faulting in the valley and in the adjacent Sierran foothills. Because the Oroville earthquake occurred near the Lake Oroville dam (fig. 1) at a time when other large dams were being constructed along the Sierran foothills, several geologic studies, including this one, were conducted to specifically evaluate the late Cenozoic structural history of the region (Woodward-Clyde Consultants, 1977; Harwood and others, 1981; Helley and others, 1981; Helley and Harwood, 1985).

For about a half century prior to the Oroville earthquake, most geologic investigations of the Sacramento Valley (fig. 1) focused on locating natural gas in the deeper parts of the valley fill and water resources in the near-surface deposits. These investigations produced a wealth of stratigraphic and structural data that was gathered primarily from numerous gas fields scattered throughout the valley (map A, pl. 1). Several geologic syntheses resulted from these studies, but they were designed primarily to facilitate further exploration for these valuable resources and did not emphasize late Cenozoic tectonism (Bryan, 1923; Repenning, 1960; Olmsted and Davis, 1961; Safonov, 1968; Hackel, 1966; Redwine, 1972; California Department of Water Resources, 1978).

Recent developments in the concept of plate tectonics have given new emphasis and scope to regional geologic analyses by enabling integration of studies in the valley with those in the Coast Ranges to the west and the Sierra Nevada to the east (fig. 2). Within this concept, the Sacramento Valley was interpreted to be a late Mesozoic forearc basin (Dickinson, 1970; Ingersoll, 1976, 1978a, 1978b; Dickinson and Seely, 1979) that formed contemporaneously with and between the accretionary trench deposits of the Franciscan Complex to the west (Ernst, 1965, 1970; Blake and Jones, 1974; Blake and others, 1974) and an eastern magmatic arc complex, the roots of which are exposed in the Sierra Nevada (Hamilton, 1969). Although debate about the extent, geographic origin, and nature of the material accreted to the Mesozoic continental margin continues (Coney and others, 1980), the basic three-component model of an arc-trench system remains fundamental (Dickinson and Seely, 1979). Although the Sacramento Valley may be the most completely studied ancient forearc basin in the world (Ingersoll and others, 1977), the emphasis and scope of published paleogeo-

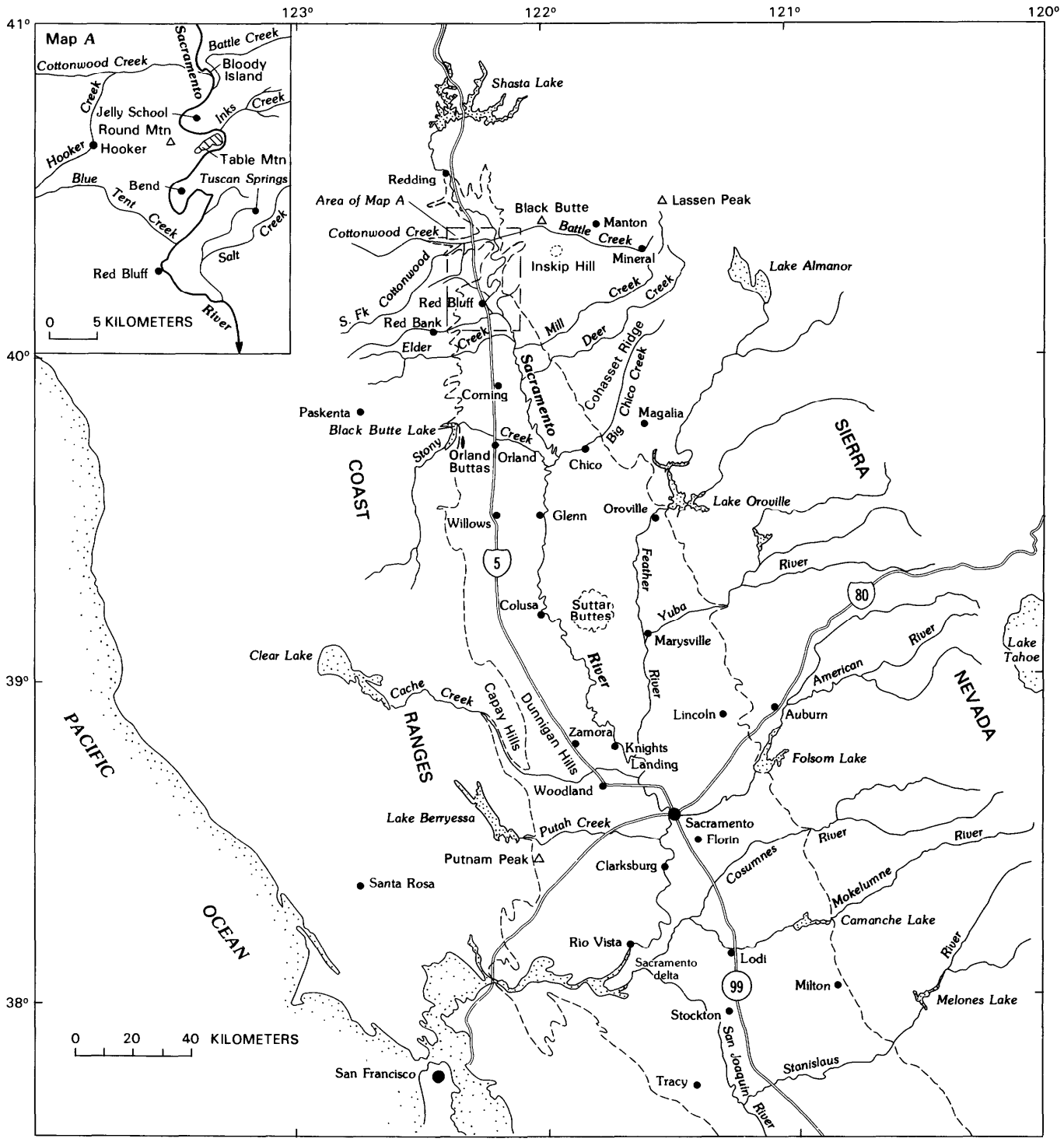


FIGURE 1.—Index map of northern California showing 500-foot topographic contour (dashed), which coincides approximately with boundary of Sacramento Valley.

graphic and paleotectonic studies generally precluded detailed analysis of late Cenozoic tectonism.

Structures discussed in this report are generally too young to provide new data for the late Mesozoic arc-trench model. In fact, a major objective of this report is to document that most of the folds and faults in the valley either formed in the late Cenozoic or are older structures that have undergone renewed deformation in the past few million years. In this respect, structures in the valley are more closely related to tectonic models of Cenozoic subduction, including subsequent lateral convergence along the San Andreas fault system and extension in the Basin and Range province to the east, than they are to the late Mesozoic tectonic models (Hamilton and Myers, 1966; Atwater, 1970; Christiansen and Lipman, 1972; Atwater and Molnar, 1973; Dickinson, 1979).

ACKNOWLEDGMENTS

The structure contour map presented in this report (pl. 1) integrates subsurface data from many summary reports of oil and gas operations published by the California Division of Oil and Gas. Credit is given to specific authors of gas field reports in the "Sources of Data" shown on plate 1, and we would like to express our appreciation to those authors, whose work contributed much of the basic data for our compilation. In addition to published reports, we analyzed well logs from a number of areas in the valley, and we acknowledge the courteous service provided by the staff of the Woodland office of the California Division of Oil and Gas.

Interpretation of the subsurface data was influenced to a great degree by exceptionally high-quality seismic-reflection profiles purchased from Seisdata Services Inc. We thank Seisdata Services Inc. for allowing us to reproduce a small segment of one of those profiles in this report.

We thank David Wagner of the California Division of Mines and Geology for sending us a preprint of his detailed map and discussion of the Capay Valley-Capay Hills area. Special thanks are given to the California Academy of Sciences for making available their collection of thin sections of basement rocks that were penetrated in wells in the Sacramento Valley.

We also acknowledge stimulating discussions with our colleagues J.A. Bartow, M.C. Blake, Jr., K.F. Fox, Jr., D.L. Jones, R.J. McLaughlin, T.H. Nilsen, A.M. Sarna-Wojcicki, and C.M. Wentworth. These discussions sharpened the focus of many points in this report, but responsibility for the analysis of subsurface structures and regional tectonism rests with Harwood, and the mapping of surficial deposits, which document the youthfulness of many structures, rests with Helley.

REGIONAL SETTING

The Sacramento Valley comprises the northern third of the Great Valley of California (fig. 2)—a broad, fertile lowland situated between mountainous terrains of the Coast Ranges to the west and the Sierra Nevada to the east. Marine sedimentary rocks, ranging in age from Late Jurassic to early Miocene, underlie the deeper parts of the Sacramento Valley. They are unconformably capped by a relatively thin cover of alluvial deposits and locally prominent volcanic rocks of early Miocene to Holocene age.

Marine sedimentary rocks exposed on the west flank of the Sacramento Valley record a nearly unbroken depositional sequence from Upper Jurassic through Upper Cretaceous (Lachenbruch, 1962; Ingersoll and others, 1977). On the east side of the valley, Upper Cretaceous sandstone and shale, described by Taft and others (1940) and Haggart and Ward (1984), rest unconformably on metamorphic and plutonic rocks of the Sierra Nevada basement and indicate a progressive eastward onlap of marine sedimentation during the late Mesozoic (Ingersoll and others, 1977). In a broad area south of Sutter Buttes, younger Upper Cretaceous sandstone and shale record a westward-prograding deltaic sequence and marine regression (Drummond and others, 1976; Garcia, 1981) during the Late Cretaceous, as the depositional basin was broadly uplifted and tilted to the south and west. Intermittent periods of uplift and subsidence, apparently caused by Paleogene subduction and possibly by lateral faulting to the west (Nilsen and Clarke, 1975; Nilsen and McKee, 1979), affected the depositional basin through the early Tertiary.

Four distinct submarine canyons developed during the uplift cycles, and they were subsequently filled with transgressive marine sequences during times of subsidence (fig. 2). Almgren (1978) has documented three ancient oscillatory tectonic-depositional cycles in the southern part of the Sacramento Valley. He concludes that the Martinez canyon was cut in the late early to middle Paleocene, the Meganos canyon was cut in early Oligocene and filled in late Oligocene and early Miocene, and the Markley canyon was cut in early Oligocene and filled in early Miocene time. Although the timing of the fourth submarine canyon is not as closely constrained by the sedimentary record as the other three, Redwine (1972) concluded that the Princeton canyon, located in the north-central part of the valley (fig. 2), was cut and filled between the late Paleocene and early Eocene, probably coincident with the formation of the Martinez canyon to the south (Almgren, 1978). Eocene marine deposits in the Princeton canyon apparently grade northward and eastward into alluvial deposits derived from the northern Sierra Nevada.

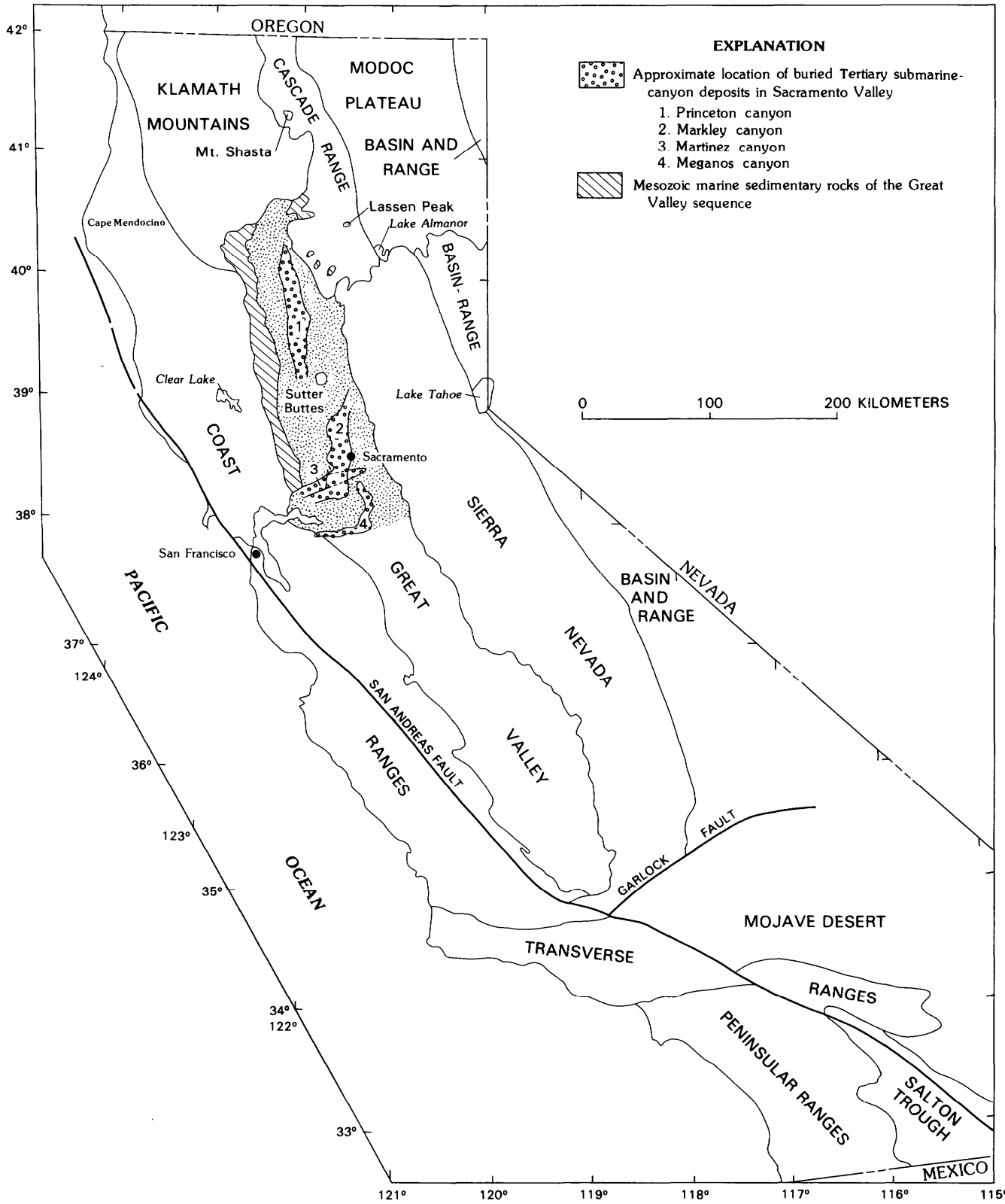


FIGURE 2.—Outline of geomorphic provinces in California and general location of buried Tertiary submarine canyon deposits in Sacramento Valley (stippled).

By the early Miocene, the northern part of the Sacramento Valley clearly was an emergent area, subjected to fluvial erosion and deposition. During this time, between 23.8 and 22.3 m.y. ago according to Dalrymple (1964), the Lovejoy Basalt was erupted from a vent or vents in the northern Sierra Nevada (Durrell, 1959) and flowed westward in a confined channel until it reached the Sacramento Valley near Oroville. Upon reaching the valley, the Lovejoy Basalt spread laterally, filling distributary alluvial channels (van den Berge, 1968) and flowed both westward, across the present axis of the valley now occupied by the Sacramento River at least to Orland Buttes, and southward at least to the vicinity of Putnam Peak (Weaver, 1949) (fig. 1), 260 km from the presumed source. Because of its distinctive characteristics, widespread distribution in both the surface and subsurface parts of the Sacramento Valley, and radiometrically determined age, the Lovejoy Basalt is an important marker unit (pl. 1) that places an age constraint on Cenozoic deformation in the valley.

After eruption of the Lovejoy Basalt, alluvial sediments of late middle Miocene to early Pliocene age accumulated in the central and southern part of the valley, capping marine sedimentary rocks deposited in the Princeton and Markley canyons (Redwine, 1972; Almgren, 1978). These alluvial deposits, however, are not present in surface exposures in the northern part of the valley, where Pliocene alluvium of the Tehama Formation in the northwest and coeval volcanic rocks of the Tuscan Formation in the northeast rest directly on the Lovejoy Basalt or on older rocks where the Lovejoy is missing.

A widespread felsic pumiceous tuff, the Nomlaki Tuff Member of the Tuscan and Tehama Formations, occurs at or near the base of the Pliocene rocks and serves as a second important time-stratigraphic marker in the valley, dated at 3.4 m.y. (Evernden and others, 1964). The Nomlaki, which was erupted from the vicinity of Lassen Peak, generally marks the beginning of volcanic activity that has occurred intermittently into historic time at the southern end of the Cascade Range (fig. 2). Pliocene and Pleistocene volcanic rocks, erupted from the Lassen area, flowed westward and interfingered with alluvial deposits of the ancestral Sacramento River system in the northern part of the valley (Anderson, 1933; Lydon, 1968; Harwood and others, 1981; Helley and others, 1981). Several of the volcanic units have been dated (Harwood and others, 1981), and they are important time indicators for the late Cenozoic depositional and tectonic evolution of the Sacramento Valley. Two informally designated volcanic units, the Rockland ash bed (referred to as the ash of Mount Maidu by Harwood and others, 1981) and the basalt of Deer Creek, dated at 0.45 and 1.09 m.y., respectively (Meyer and others, 1980; Harwood and others, 1981), are particularly significant because they bracket the age of the Red Bluff Formation. The Red Bluff forms a thin, widespread gravel pediment that unconformably caps the Pliocene rocks in the northern part of the valley. The fact that the Red Bluff Formation is faulted and folded clearly establishes the presence of late Cenozoic deformation, within the past million years, on most of the major features shown on the structure contour map (pl. 1).

A volcanic center, composed of andesitic fragmental deposits intruded by late-stage rhyolite domes, formed at Sutter Buttes in the central part of the valley between 2.4 and 1.4 m.y. ago (Williams, 1929; Williams and Curtis, 1977). This late Cenozoic volcanic center is located over a northwest-trending tectonic boundary that juxtaposes a basement of dense, magnetic, presumed oceanic crust (Cady, 1975; Griscom, 1973) on the west against metamorphic and plutonic rocks of the Sierran basement on the east. The boundary between the basement terranes is a Mesozoic tectonic feature that apparently has been reactivated by Cenozoic deformation (Harwood, 1984). Southeast of Sutter Buttes, the Willows fault approximately follows the contact between oceanic and Sierran basement terranes, and northeast of Sutter Buttes that basement boundary lies beneath the Chico monocline.

In the southeastern part of the valley, structure contours are drawn on the basement surface (pl. 1). In the rest of the valley, the datum is the top of the Cretaceous rocks. Contouring procedures are described on plate 1.

INTERPRETATION OF BASEMENT CONTOURS

The most pronounced deflection in basement contours is located beneath Sutter Buttes (pl. 1). This anomaly in basement topography was shown first by Smith (1964) and mentioned briefly by Williams and Curtis (1977, p. 6), who noted more than 395 m of local relief on the basement surface but offered no interpretation of the anomaly. Although some of the upwelling of the basement surface may be related to volcanic intrusion at Sutter Buttes, Harwood (1984) suggests that much of the basement uplift was related to east-side-up movement on the Willows fault, which passes just west and south of the Sutter Buttes.

Data from deep wells a few kilometers north of Sutter Buttes (pl. 1) indicate that the basement surface has a major deflection related to a northeast-trending fold or fault, or both. All of these possible structural configurations were investigated, and we conclude that the structure in the area is a northeast-trending fold, faulted along its southeast limb. The fault is interpreted to be a steeply dipping to vertical normal fault with southeast-side-down displacement. Both the fold and fault, however, appear to die out to the northeast.

In a zone southeast of Sutter Buttes that extends to the Stockton fault (pl. 1), variations in the slope of the base-

ment surface are shown by northwest-trending zones of broadly spaced and relatively close-spaced contours. The basement surface may dip eastward locally in those areas marked by broadly spaced contours (see Jacobsen, 1981), but well data are too sparse to locate closed contours in this area, even if they would show at the chosen contour interval of 150 m.

From Sacramento south to the Stockton fault, the slope of the basement steepens significantly west of the −1,500-m contour. This change in basement slope lies near the eastern edge of the positive gravity and magnetic anomalies in the Great Valley that Cady (1975) interpreted to represent ophiolitic oceanic crust tectonically juxtaposed against Sierran basement rocks to the east. Reports of two wells south of Sacramento, however, show "granite" and "gneiss" at −1,954 m and −2,861 m, respectively, suggesting that the interpreted suture between oceanic and Sierran basements is not marked by the topographic break in the basement surface at the −1,500-m contour. It must be emphasized, however, that these identifications of basement rocks were made some time ago by the operators who drilled the wells, and it is possible that the "granite" may be a leucocratic rock associated with ophiolitic basement, such as plagiogranite, and the "gneiss" may be any dark-colored rock, even part of the ophiolitic basement. It seems reasonably certain, in any case, that the topographic break at the −1,500-m contour is controlled in some measure by a fault, possibly the extension of the Willows fault southeast of Sutter Buttes. It is interesting, and not altogether fruitless, to speculate that the Willows fault southeast of Sutter Buttes coincides with and represents the up-section propogation of the major fault between oceanic crust and the arc-massif basement of the Sierra Nevada. If such is the case, the Willows fault southeast of the Sutter Buttes may represent a structure inherited from the upper-slope discontinuity, a region of structural weakness over the boundary between forearc-basin and arc-massif basements, identified by Karig and Sharman (1975) in modern forearc basins.

From Sutter Buttes north to Chico, a number of wells penetrate basement rocks reported as diorite, gabbro, noritic gabbro, and serpentine. Not surprisingly, this part of the Sacramento Valley is characterized by large, positive gravity and magnetic anomalies that mark the northern part of the inferred Great Valley ophiolitic basement (Cady, 1975). Some thin sections of gabbro and diorite from wells in this area, contained in a collection of thin sections of basement rocks held by the California Academy of Sciences, reveal remarkably fresh coarse- and medium-grained clinopyroxene-plagioclase rocks that show pronounced cumulate textures. These textures, previously unrecognized, provide supporting evidence for the interpretation that the source rocks of the Great Valley anomaly are oceanic crust.

South and east of Sutter Buttes, several wells penetrate rocks reported as granite, granodiorite, metavolcanic rocks, and "gneiss" typical of rocks exposed in the Sierran foothills. The outline of granitic plutonic rocks, shown on plate 1, was determined from reported basement rocks, augmented by our interpretation of residual isostatic gravity data (Roberts and others, 1981). The boundary between the Sierran basement and mafic and ultramafic rocks of probable ophiolitic basement trends about N. 45° E. from Sutter Buttes to Oroville. It is clearly marked by significant changes in the gravity and magnetic patterns of the respective areas. The basement contours do not reflect this inferred lithologic change, and the northeast-trending fault north of Sutter Buttes is contained within the mafic-ultramafic basement terrane.

Sierran crystalline rocks are exposed in several deep canyons that cut through the Pliocene volcanic rocks of the Tuscan Formation east of Chico (Harwood and others, 1981). The mafic-ultramafic basement appears to abut against Sierran basement rocks along a major basement fault beneath the Chico monocline. This tectonic juxtaposition of basement terranes was proposed first by Griscom (1973), and the basement fault he proposed from geophysical data is confirmed by stratigraphic data. The basement fault beneath the Chico monocline shows east-side-up displacement with a minimum stratigraphic throw of 367 m on the basement surface. This fault represents late Cenozoic deformation superposed on a segment of the late Mesozoic boundary between the forearc-basin and arc-massif basements, and it is thus part of the upper-slope discontinuity (Karig and Sharman, 1975).

STRUCTURAL FEATURES IN THE VALLEY FILL

Structure contours drawn on top of the Cretaceous rocks outline a large number of diversely oriented folds and faults distributed throughout the valley. Some of these structures, such as the Corning domes, the Chico monocline, and the Dunnigan Hills anticline, have topographic expression and were recognized in the early ground-water studies of the valley by Kirk Bryan (1923). Most of the other structures do not have obvious surface expression, and they were discovered during exploration and development of the numerous small gas fields in the valley (pl. 1, map A). Although detailed reports have been published for many of the gas fields, few reports have synthesized the data from these studies into detailed structural analyses of the valley as a whole. Noteworthy exceptions to this generalization exist, however, and include the early stratigraphic and structural synthesis by Safonov (1968), the detailed study of the Princeton submarine channel system by Redwine (1972), and the continuing efforts of the California Division of Mines and

Geology to compile available data from the valley into small-scale maps of the entire state (Jennings, 1977).

The extent of many of the faults, particularly the complex pattern of the Willows fault and the relations between that fault system and many folds in the northern valley, has not been reported previously. Analyses of well logs, which are the basis for most reports of individual gas fields, do not provide sufficient data to interpret unequivocally the structure of each field. If recognizable stratigraphic units in the well logs are at different elevations in adjacent wells, it is generally impossible to determine if the units are offset by folding or faulting, or both, without additional data from surface exposures or seismic-reflection profiles. Our interpretation of the structural relations in the valley is based on data from well logs, augmented by detailed mapping of the surficial deposits by Helley, and exceedingly valuable seismic-reflection data obtained from Seisdata Services Inc.

WILLOWS FAULT SYSTEM

The main stem of the Willows fault was discovered in the subsurface rocks of the northern valley when it was penetrated by the Marathon Oil Company (formerly Ohio Oil Company) "Capital Company No. 1" well during development of the Willows-Beehive Bend gas field in the late 1950's (California Division of Oil and Gas, 1960; Alkire, 1962; 1968). From the discovery well, Redwine (1972) traced the Willows fault in the subsurface southeast to Sutter Buttes and suggested that it extended northwest of the discovery well, possibly connecting with the surface fault mapped west of the Orland Buttes (Anderson and Russell, 1939; Jennings and Strand, 1960). On the basis of the distribution of Quaternary units immediately south of Orland Buttes and of two seismic profiles north of the buttes, we have extended the Willows fault into northwestern Tehama County. At Orland Buttes, Upper Cretaceous rocks, the Lovejoy Basalt, and the Tehama Formation, on the up-thrown side of the Willows fault, are juxtaposed against the Tehama Formation on the down-thrown fault block to the west.

Redwine (1972) documented displacement on a 40-km segment of the main stem of the fault from east of Willows to Sutter Buttes and concluded that it dipped 74° or steeper to the east and showed reverse, east-side-up movement that decreased upward toward the surface. He found that the Princeton submarine channel was localized by movement on the fault and that vertical separation in the discovery well varied from about 488 m on top of the Cretaceous rocks to about 477 m on the top of the Eocene Capay Formation.

The pattern of deformation on the Willows fault and its effect on the thickness and facies patterns in the Capay Formation are clearly shown in figure 3. In this approximately east-trending cross section through the Marathon "Capital Company No. 1" well (No. 3, fig. 3), the thalweg of the Princeton channel, which is occupied by marine shale of the Capay, coincides with a syncline in the underlying Upper Cretaceous rocks. The west limb of the complementary anticline in the Upper Cretaceous rocks is broken by east-side-up movement on the Willows fault. The electric logs show that west of the fault the Capay is composed of shale, and east of the fault it is dominantly sandstone that interfingers with shale eastward toward the thalweg of the channel. Folding and faulting clearly postdated the deposition of Upper Cretaceous strata and preceded the deposition of the Capay and occurred between about 60 and 53 m.y. ago. During that time there was some erosion of the Upper Cretaceous rocks, particularly along the channel thalweg. The westward increase in sandstone and a complementary decrease in thickness of the Capay toward the fault suggest that the anticlinal welt of Upper Cretaceous rocks was a shoal area during Capay deposition. Because the shale-rich Capay west of the fault is about the same thickness as the sandstone-rich Capay east of the fault, there appears to have been little, if any, deformation on the Willows fault in this area during deposition of the Capay. The section shows about 475 m of post-Capay offset and possibly small offset on the base of the Tehama, but the amount of post-Pliocene offset is difficult to determine because there is no record for the upper part of well 2 (fig. 3).

CORNING FAULT

Data from a number of sources indicate that the Willows fault is far more extensive and complex than previously thought. The first clue that the Willows fault branched into a multistrand fault system was provided by an analysis of seismicity of the northern valley and Sierran foothills after the Oroville earthquake. Marks and Lindh (1978) located a number of small-magnitude earthquakes along a zone that originated near the Marathon "Capital Company No. 1" well in the Willows-Beehive Bend gas field and extended north about 30 km, rather than following the northwest trend of the Willows fault. These epicenters are shown relative to the trace of the Willows fault in figure 4. The trend of seismic events suggests that a north-trending fault splayed off from the main stem of the Willows fault and passed west of the Corning domes (pl. 1). In the Corning gas fields, analysis of well records by the Sacramento Petroleum Association (1962) showed an anticlinal fold in the area of the Corning domes, with about 121 m of maximum closure on the base of the Tehama Formation in the north dome and a steeply dipping southeast-trending fault located at the north end of south Corning dome, but it did not identify a fault west of them.

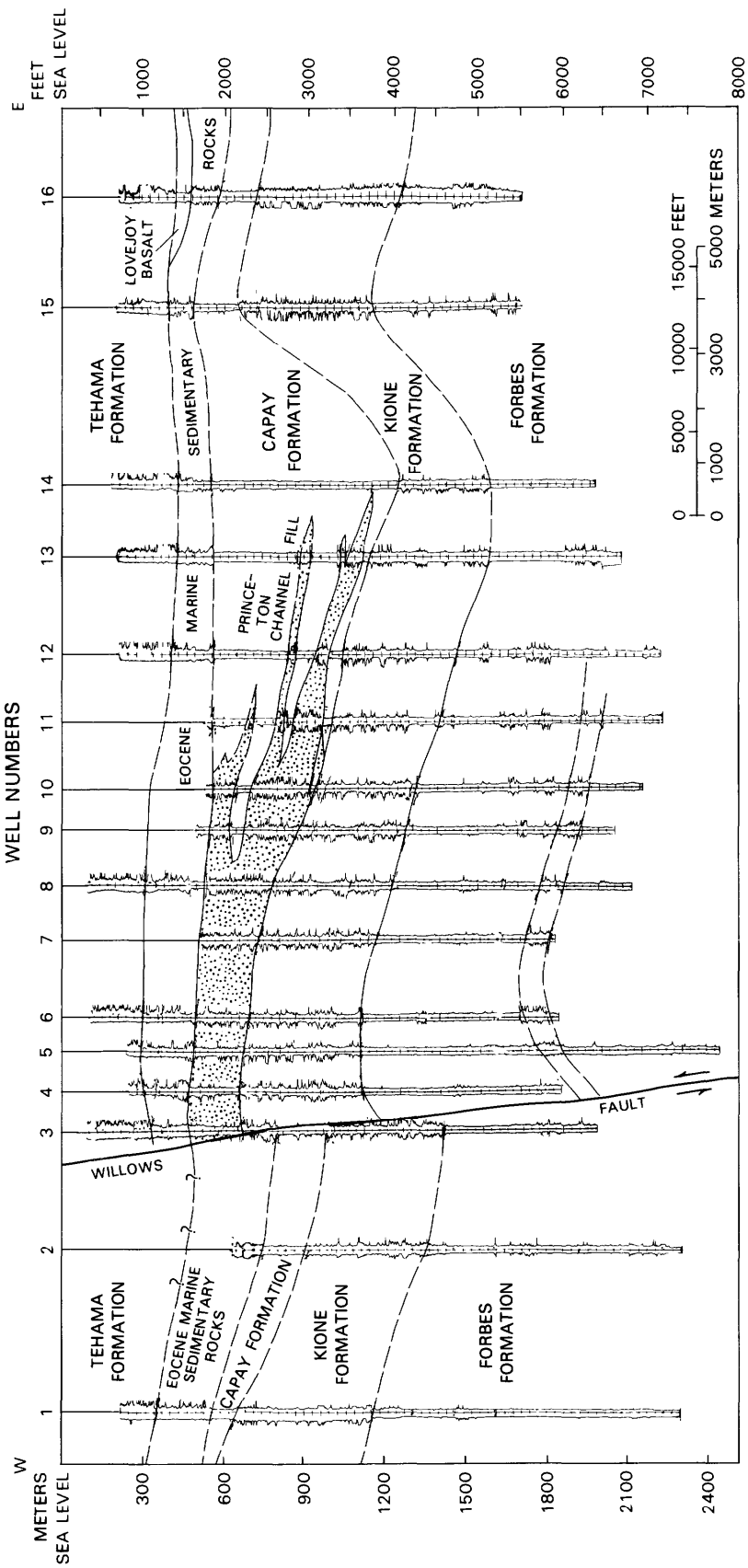


FIGURE 3.—Cross section showing electric logs and stratigraphic and structural relations across Willows-Beehive Bend gas field, Calif. Sandstone in Capay Formation indicated by stipple. Willows fault penetrated in well No. 3. Names of wells shown in appendix. Stratigraphic nomenclature used may not necessarily conform to that adopted by U.S. Geological Survey.

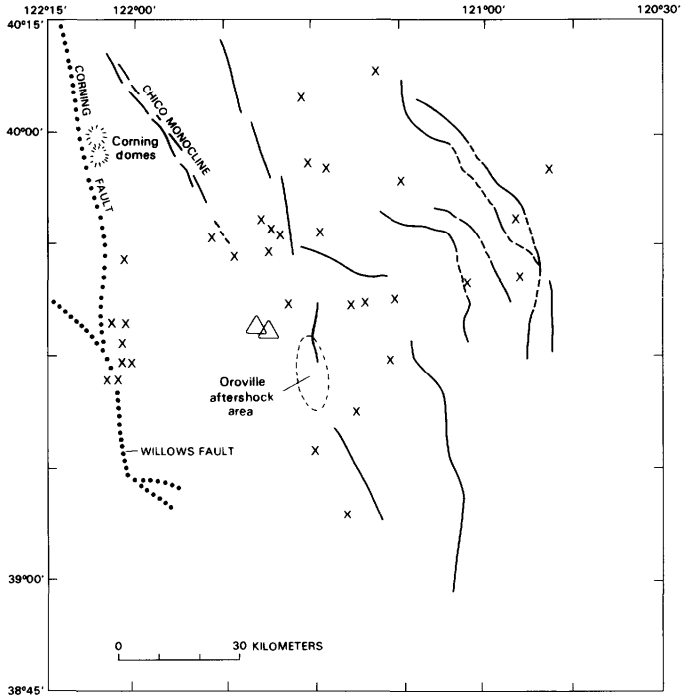


FIGURE 4.—Epicenters (X) of seismic events in area of Oroville, Calif., from June 1975 to August 1976 (modified from Marks and Lindh, 1978). Note north trend of epicenters extending from Willows fault approximately along trace of Corning fault. Unlabeled heavy lines indicate other faults. Triangles show epicenters of two unusually deep (40 km) earthquakes.

Seismic-reflection profiles in the area by Seisdata Services Inc. have identified a major north-trending, steeply east-dipping reverse fault that passes west of the Corning domes and the Greenwood anticline. We call this structure the Corning fault (pl. 1), and part of one of the profiles across it is shown in figure 5. The profile clearly shows that the shallow reflecting horizons in the eastern block are arched beneath the Corning dome by east-side-up drag on the Corning fault. It is also apparent in the profile that the vertical displacement increases with depth, indicating progressive deformation through time, similar to the deformation pattern on the main stem of the Willows fault in the Willows-Beehive Bend gas field (fig. 3). Curiously, however, the amount of vertical displacement of the Upper Cretaceous and younger strata shown on the profile is relatively small compared to the offset of the basement surface suggested by the few deep wells in the area shown on figure 6.

The deepest well east of the Corning fault is the Shell Oil Company "Victor Ranch No. 4" (sec. 7, T. 23 N., R. 2 W.), which bottomed in the Venado Sandstone of Late Cretaceous (Turonian) age at an elevation of −3,713 m (fig. 6). Lithologic information from this well helps interpret the seismic-reflection profile, and its total depth provides a minimum value for the basement elevation 8 km east of the Corning fault. Although local variations in the slope of the basement surface exist, the basement generally dips about 5° SW. between the Chico monocline and the Corning fault. The intersection of the basement surface and the Corning fault ranges in elevation from about −3,900 m in the north to about −4,600 m in the south. This south-southeast plunging line of intersection appears to lie significantly above the basement surface west of the Corning fault.

West of the Corning fault, only one well, the Shell Oil Company "Vilche No. 2" (sec. 5, T. 27 N., R. 4 W.), reached basement, which was serpentinite penetrated at an elevation of −5,978 m (fig. 6). Data from this well are not sufficient to determine the dip of the basement surface west of the Corning fault, but the dip immediately west of the fault may be the same as that just east of the fault, assuming that the basement surface was not chaotically tilted prior to deposition of the Great Valley sequence. If such is the case, the −6,000-m contour can be extrapolated south of the Shell Oil Company "Vilche No. 2" well parallel to the contours east of the Corning fault, as shown on figure 6. This extrapolation gives a vertical separation of about 1,500 m on the basement surface if one assumes no offset on the Red Bluff fault (fig. 6). Because the Red Bluff fault (discussed in a following section of this report) shows down-to-the-south displacement of the valley fill, similar basement offset on the Red Bluff fault would increase the basement separation on the Corning fault. Therefore, 1,500 m of vertical offset on the basement surface across the Corning fault is considered to be a minimum value.

The reason why the basement offset does not appear on the seismic reflection profile is not known. Perhaps the energy input was not sufficient to generate reflections from the deeper basement. Alternatively, the Venado Sandstone, which thickens westward, may have masked reflections from older rocks of the Great Valley sequence and the basement surface west of the Corning fault. Whatever the reason, geologic data strongly suggest that the basement was offset at least 1,500 m on the Corning fault prior to Turonian time and that pre-Turonian rocks of the Great Valley sequence, deposited on the down-dropped block of the fault were unconformably overlapped by the Venado Sandstone. Post-Turonian displacement on the Corning fault is a few hundred meters.

The youngest deposits deformed by the Corning fault are gravels of the Pleistocene Red Bluff Formation, the age of which is between 0.45 and 1.09 m.y. (Harwood and others, 1981).

NORTHWEST EXTENSION OF WILLOWS FAULT

The location of the Willows fault system north and northwest of Orland Buttes is not clearly indicated by direct evidence in either the surface or subsurface rocks.

Wells are sparse in this area of the valley, particularly west of the probable trace of the main stem of the Willows fault. For that reason, the structure contours are very generalized and of little value in locating even major structures.

Our projection of the Willows fault into the Cold Fork, Elder Creek, and Paskenta faults (pl. 1) mapped by Jones and others (1969) is based primarily on the outcrop pattern of the Tehama Formation. North of Elder Creek, the Tehama Formation dips gently east, and the Nomlaki Tuff Member is at the base of the Tehama or is, at most, a few tens of meters above its base. South of Elder Creek, however, the Tehama dips more steeply eastward into the valley, and the Nomlaki is a few hundred meters above the base of the Tehama. This outcrop pattern of the Tehama Formation suggests that the underlying Great Valley sequence was topographically higher and projected farther east into the valley north of the Willows fault prior to deposition of the Pliocene strata. The position of the Nomlaki Tuff Member, relative to the base of the Tehama on opposite sides of the Willows fault, indicates that the Tehama filled a topographic low southwest of the fault

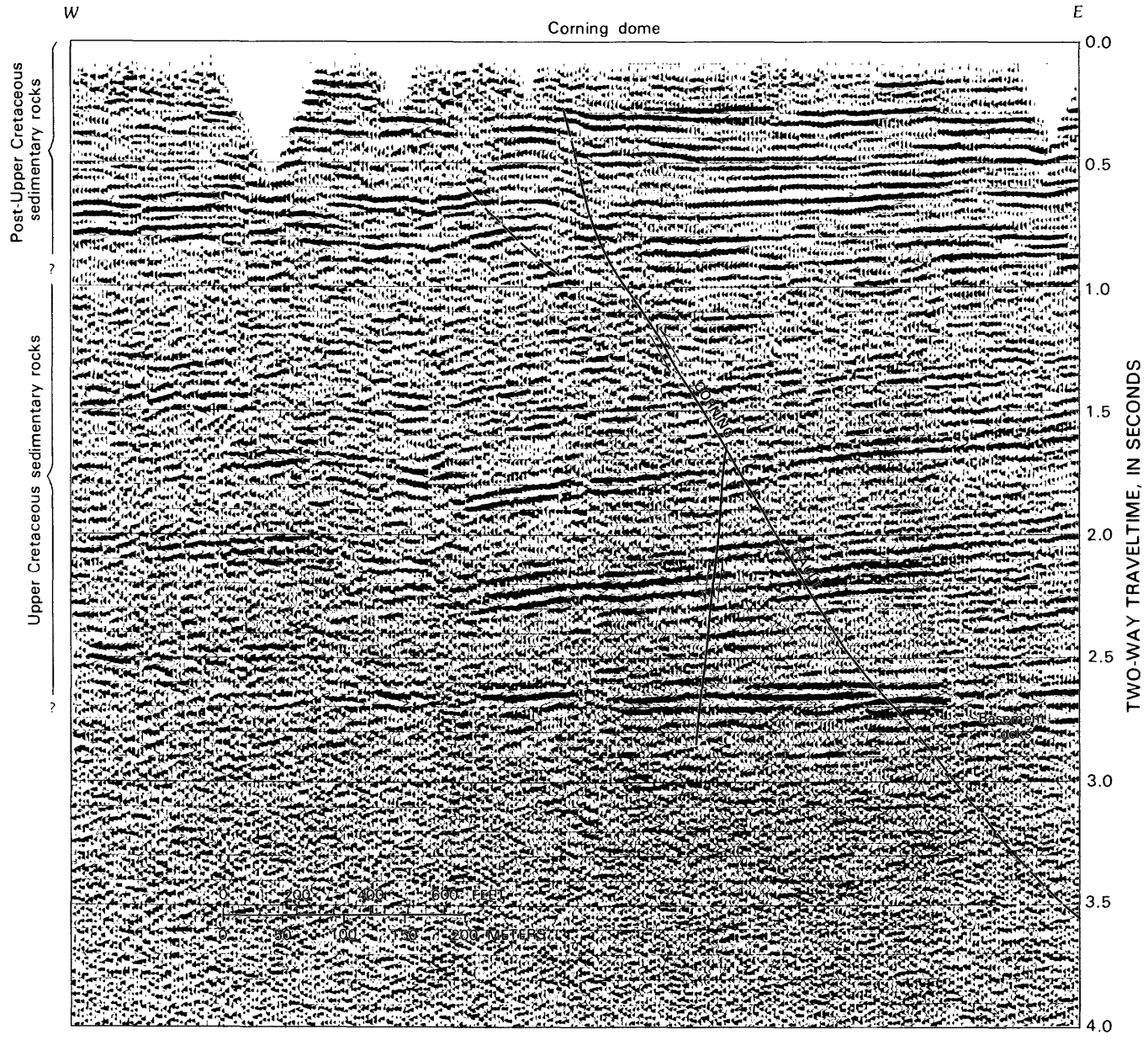


FIGURE 5.—Seismic-reflection profile, from Seisdata Services Inc., showing structural and generalized stratigraphic relations across Corning fault between Corning and Red Bluff, Calif.

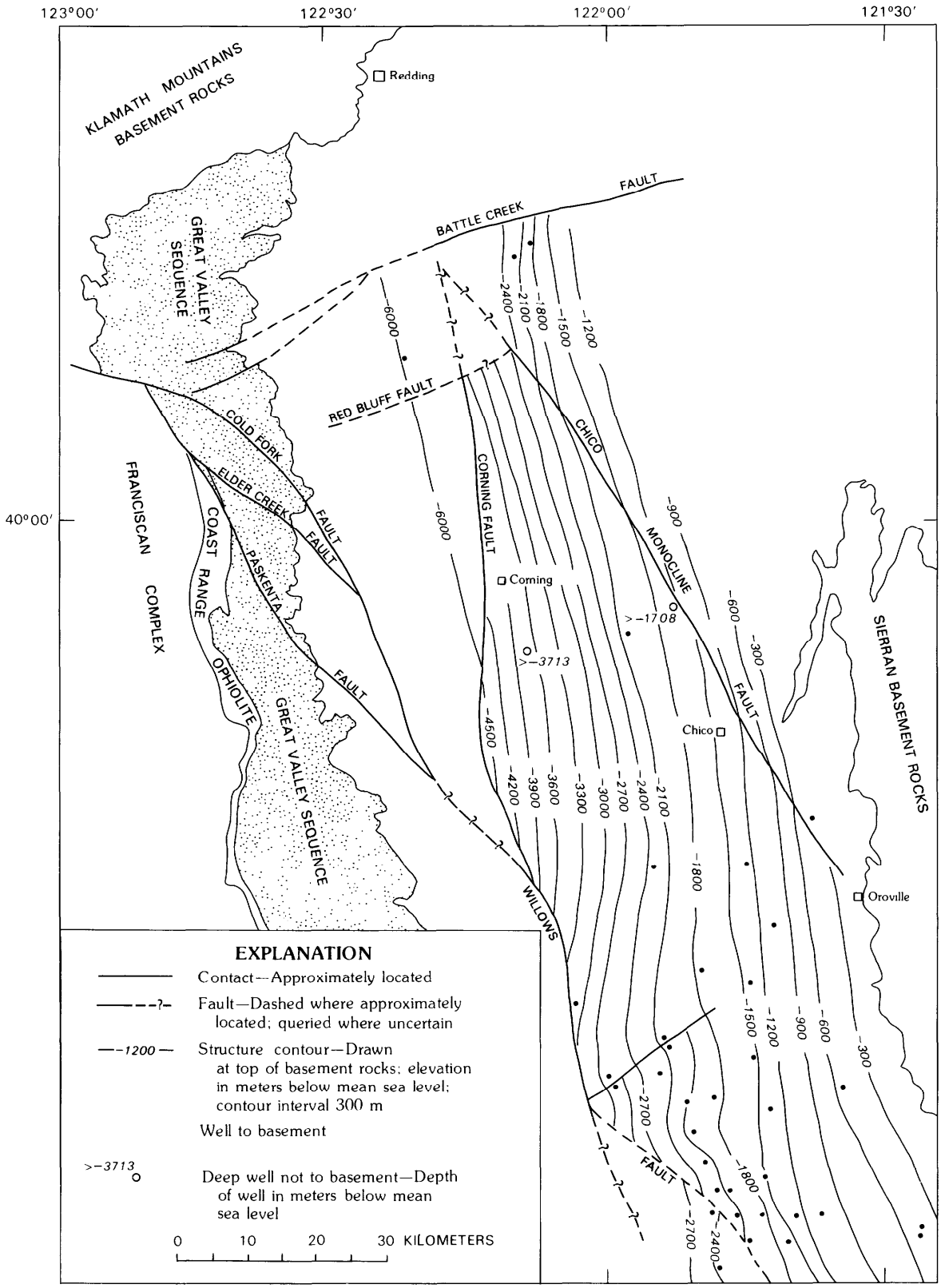


FIGURE 6.—Map of northern Sacramento Valley showing structure contours, drawn on top of basement rocks, used to estimate amount of vertical displacement of basement across Corning fault.

prior to eruption of the Nomlaki about 3.4 m.y. ago. We interpret the topographic low, reflected by the thicker basal part of the Tehama, to be the result of east-side-up movement on the Willows fault, prior to and possibly during, deposition of the lower part of the Tehama Formation. If this interpretation is correct, late Cenozoic movement on the Willows-Elder Creek fault system differs significantly, in style and amount of displacement, from the Cretaceous movement on the Elder Creek-Cold Fork-Paskenta fault system oulined by Jones and Irwin (1971).

Jones and Irwin (1971) inferred at least 96 km of left-lateral displacement of the Lower Cretaceous (Valanginian) strata along the combined Cold Fork-Elder Creek-Paskenta faults. They concluded that this deformation commenced shortly after deposition of the Valanginian strata and continued concurrently with deposition until at least the middle Late Cretaceous. Well-documented vertical displacement of Upper Cretaceous and overlying rocks on the Willows fault in the Willows-Beehive Bend gas field is not incompatible with left-lateral displacement on the Elder Creek fault system to the northwest, but it does indicate that the inferred lateral displacement was accompanied, or postdated by, a major component of east-side-up vertical movement. This vertical movement is consistent with the interpretation that the Elder Creek fault system represents tear faults in the upper plate of the Coast Range thrust (Jones and Irwin, 1971), along which the Klamath Mountains terrane moved upward and westward over the Coast Ranges province (fig. 2).

SOUTHEAST EXTENSION OF WILLOWS FAULT

Location of the Willows fault southeast of Sutter Buttes is not closely constrained by sparse well data along the eastern margin of the valley. No seismic-reflection profiles, that we are aware of, extend far enough east to cross the fault. However, wells in three widely spaced areas do extend far enough east from the deeper parts of the valley to cross the fault, and they provide the most direct evidence for the southeastern extension of the Willows fault. The first area we investigated extends southwest from near Marysville and passes through the Tisdale gas field (pl. 1, map A) just southeast of Sutter Buttes. A cross section (fig. 7) through wells in this area shows that the slope of the basement is significantly steeper east of the Willows fault (between wells 4 and 5, fig. 7), and we infer about 165 m of east-side-up displacement on the basement surface. Shale of the Eocene Capay Formation is recognizable in all of the electric logs in figure 7, and that unit shows about 100 m of displacement between wells 4 and 5. The base of continental deposits (nonmarine sedimentary rocks), which coincides generally with the base of fresh water in the valley, is difficult to identify in all the well logs of this section, but it does not appear to be offset between wells 3 and 5. The dip of the fault is not constrained in this section, and we have shown a steeply east-dipping reverse fault between wells 4 and 5, primarily because the pattern of offset in that area is so similar to that on the Willows fault to the northwest.

About 23 km southeast of the Tisdale gas field, a second line of wells extends from the Sacramento River near Knight's Landing northeastward toward Lincoln. Interest was directed initially to this line of wells because the outline of the Markley canyon, shown by Almgren (1978), is sharply deflected to the south in this area. A section through this line of wells is shown in figure 8. All of the sedimentary rocks in this part of the valley, except those in the Markley canyon, are offset up to the east between wells 3 and 4 (fig. 8). The amount of displacement appears to increase downward in the section from about 30 m at the base of the continental deposits to about 45 m in sandstone and shale sequences in the Upper Cretaceous rocks. Displacement of the basement is inferred to be about 150 m, but the depth to basement west of the Willows fault is not closely constrained by available well data. The most interesting aspect of the section is the marked asymmetry of the Markley canyon fill. Canyon development may have shifted progressively westward, to be localized immediately east of this part of the Willows fault, where the deepest part of the asymmetric canyon fill is located. This pattern of erosion and sedimentation suggests that late Oligocene and early Miocene movement on the Willows fault directly influenced the location and form of the Markley canyon.

The third line of wells we investigated extends from the Sacramento River near Clarksburg to the area east of Florin, where a series of low hills underlain by Pliocene continental deposits of the Laguna Formation rise above the surrounding Pleistocene alluvial deposits. A section through these wells is shown in figure 9. The electric log of the D. D. Feldman "Unit Plan No.1" well (sec. 8, T. 7 N., R. 6 E.); (No. 9, fig. 9) shows an obvious repeat in the Cretaceous rocks just above the basement. We interpret this repeat to represent east-side-up displacement on the Willows fault, which was intersected by the well at an elevation of −1,277 m. If this interpretation is correct, the basement surface is offset about 120 m. A similar offset is shown by Upper Cretaceous rocks.

West of the Willows fault (fig. 9), a steeply east-dipping normal fault, previously unreported, offsets the Capay Formation and older rocks down to the east about 153 m. This normal fault does not appear to offset the base of post-Eocene and younger nonmarine rocks, nor are these rocks offset by the Willows fault to the east. Offset of the basement between wells 5 and 6 (fig. 9) appears to be east side up and suggests early reverse movement on the east-dipping fault.

The location of the Willows fault southeast of Florin is

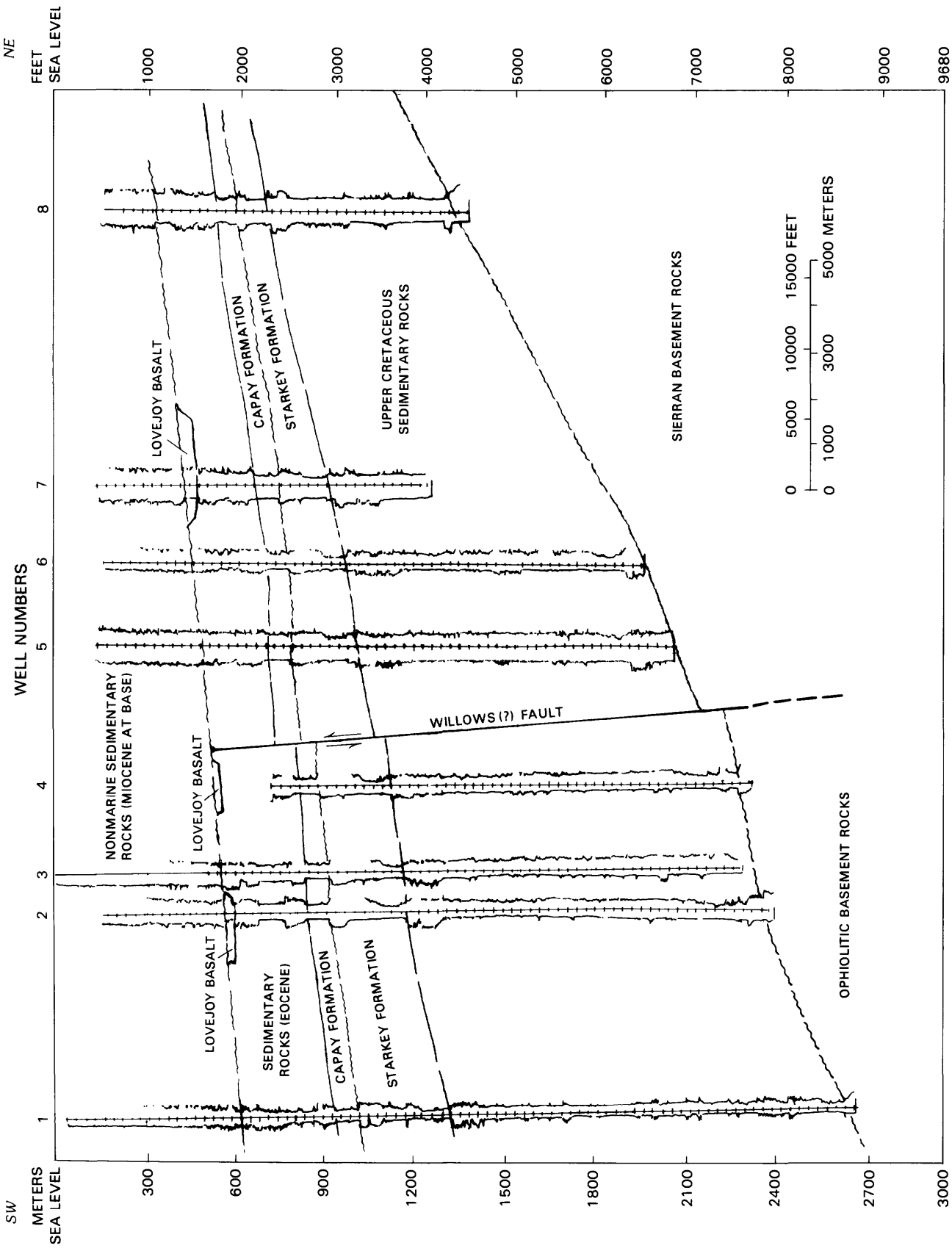


FIGURE 7.—Cross section showing electric logs and stratigraphic and structural relations across possible southeast extension of Willows fault near Tisdale gas field southeast of Sutter Buttes, Calif. Names of wells listed in appendix. Stratigraphic nomenclature used may not necessarily conform to that adopted by U.S. Geological Survey.

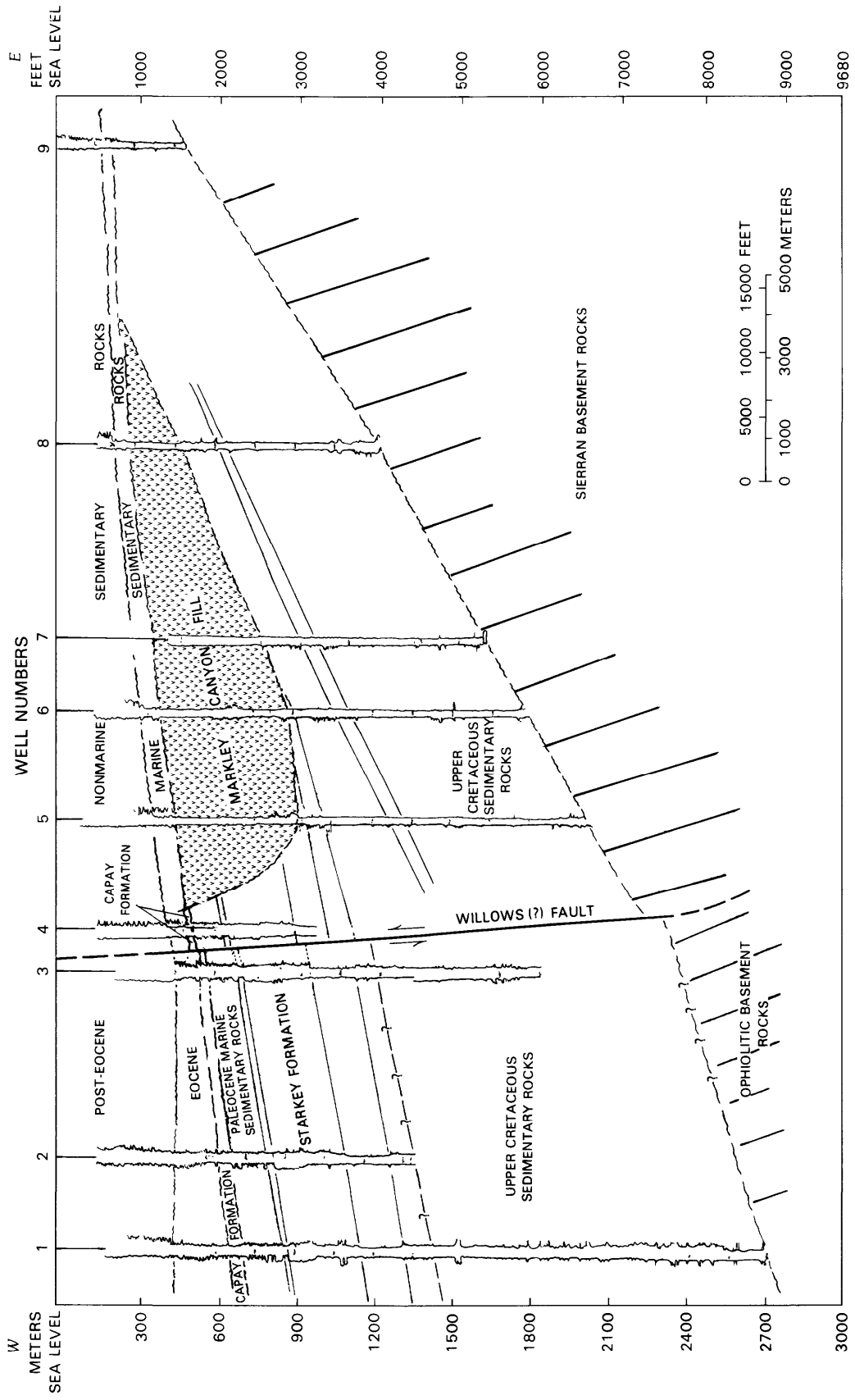


FIGURE 8.—Cross section showing electric logs and stratigraphic and structural relations across possible southeast extension of Willows fault near Catlett-Nicolaus gas fields, Calif. Names of wells listed in appendix. Note asymmetry of Markley canyon fill (patterned) and absence of offset in post-Eocene continental deposits. Stratigraphic nomenclature used may not necessarily conform to that adopted by U.S. Geological Survey.

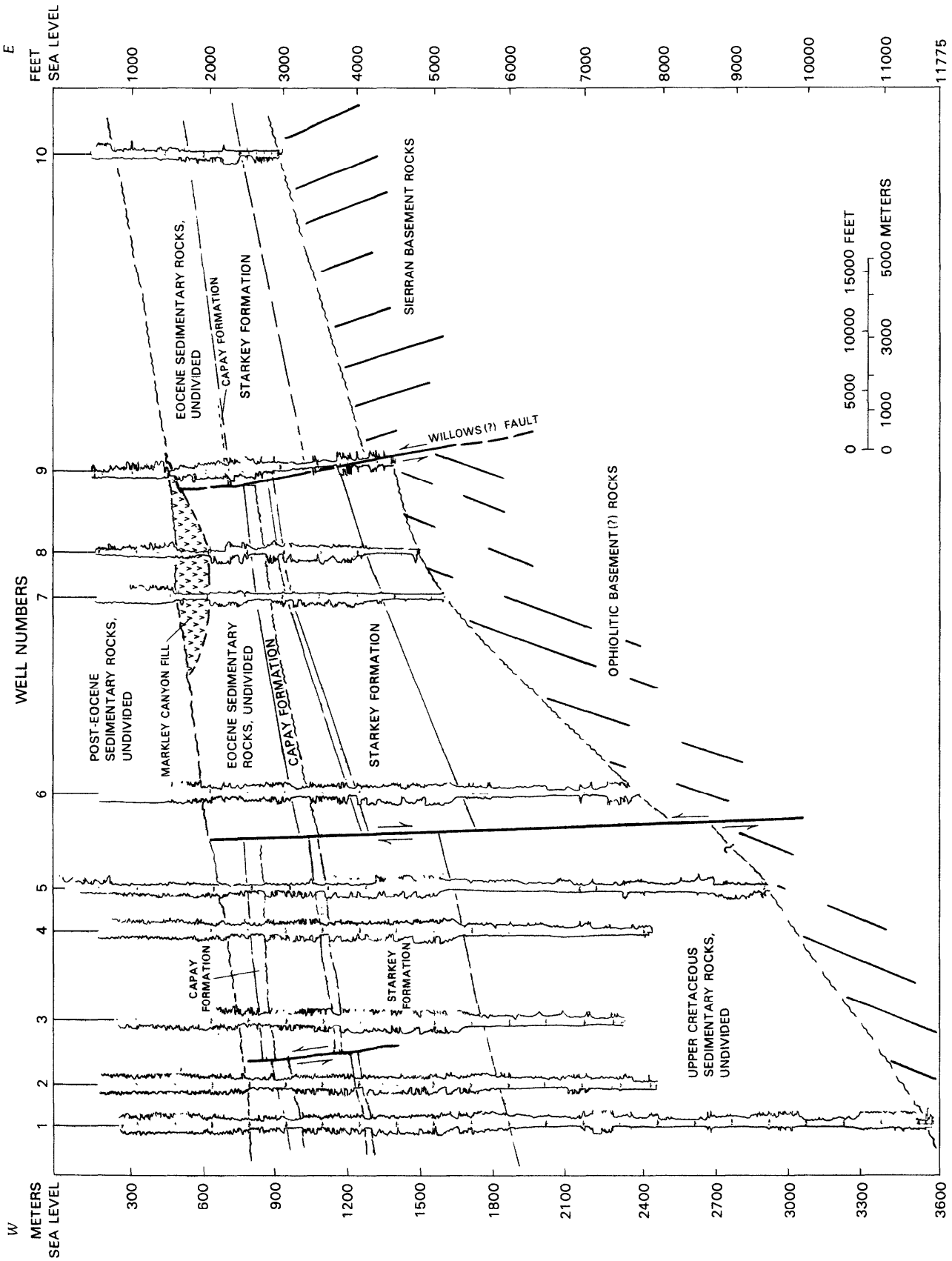


FIGURE 9.—Cross section showing electric logs and stratigraphic and structural relations across possible southeast extension of Willows fault southeast of Florin, Calif. Names of wells listed in appendix. Note repeated electric-log pattern near bottom of well 9 and apparent early east-side-up displacement of basement by unnamed fault between wells 5 and 6, followed by east-side-down offset of Cretaceous and early Tertiary rocks. Stratigraphic nomenclature used may not necessarily conform to that adopted by U.S. Geological

uncertain. A section through several wells east and west of the Lodi gas field, shown in figure 10, indicates a minor deflection in the Capay Formation between wells 6 and 7, but the underlying Cretaceous rocks and the basement surface are not significantly offset in that area. The general east-side-up flexure of the Capay between wells 6 and 7 is the type of deformation that would be expected adjacent to the Willows fault, but the absence of offset in underlying units argues against the existence of the fault. Deformation expressed as fault movement north of Lodi may be expressed as gentle warping to the south.

STRUCTURES NORTHEAST OF THE WILLOWS FAULT

The Willows fault diagonally transects the Sacramento Valley from northwest to southeast and divides the region into two late Cenozoic structural provinces. To the northeast, on the upthrown block of the Willows fault, the present axis of the Sacramento Valley is underlain by the Los Molinos and Glenn synclines (pl. 1). These narrow synclines, coupled with the Corning domes to the west and the Chico monocline to the east, have tightly controlled the course of the Sacramento River and influenced alluvial deposition during the late Quaternary. This tectonic control of alluvial deposition has profoundly influenced land use, particularly in the northeastern part of the valley, where a narrow strip of cultivated land, shown near the top of figure 11, flanks the river and lies directly over the trace of the Los Molinos syncline. South of the constricting influence of the Corning domes and the Chico monocline, late Quaternary alluvial deposits spread laterally across much of the valley over the Glenn syncline, the axial trace of which controls the present course of the Sacramento River as far south as Glenn, Calif. (pl. 1). From Glenn to Colusa, the course of the river lies along the trace of the Willows fault.

From the vicinity of Willows southeast to the Sacramento Delta, the downthrown southwest block of the Willows fault is capped by Holocene basin deposits that flooded over the broad Zamora syncline (pl. 1), burying older deposits, to rest unconformably on Upper Cretaceous rocks north of the Dunnigan Hills. The following part of the report discusses specific structural features on the northeast block of the Willows fault.

SUTTER BUTTES

Sutter Buttes (fig. 11) is a prominent set of hills composed of late Cenozoic volcanic rocks that rise about 635 m above the floor of the Sacramento Valley 15 km northwest of Marysville. According to Williams and Curtis (1977), volcanism and accompanying deformation of the surrounding sedimentary rocks occurred between 2.4 and 1.4 m.y. ago and consisted of two phases. During the early phase of magma injection, Upper Cretaceous and Tertiary rocks were arched into a dome 13 km across, broken by normal and high-angle reverse faults, and rapidly eroded so that the Tertiary rocks were stripped from the core of the dome before the explosive phase of volcanism. Explosive volcanism produced the rampart beds of tuff and tuff breccia that form the peripheral deposits of the buttes (fig. 11).

Extensive drilling for natural gas located an elongate dome in the subsurface about 10 km west of Sutter Buttes. Williams and Curtis (1977) referred to this structure as the buried Colusa buttes, but because it lacks surface expression, we refer to it as the buried Colusa dome (fig. 12). In the buried Colusa dome, several wells (fig. 12) penetrated volcanic rocks similar in composition and age to those in the Sutter Buttes. These data led Williams and Curtis (1977) to conclude that the buried Colusa dome formed solely by forceful magma injection contemporaneous with magmatism at Sutter Buttes. We suggest, however, that magmatism may have been localized by movement on the Willows fault and possibly by movement on the Mesozoic tectonic boundary between ophiolitic and Sierran basement terranes which passes beneath the eastern margin of Sutter Buttes (fig. 12).

The orientation and movement patterns of structures at Sutter Buttes and the buried Colusa dome suggest that deformation occurred in a regional east-west compressive stress field. The distribution of structural features at Sutter Buttes is distinctively asymmetrical. Beds in the Upper Cretaceous rocks on the south and southeast sides of the buttes dip steeply away from the core. Locally, they are overturned. Beds on the north and northwest sides of the buttes generally dip gently away from the core. As shown in figure 12, folds and faults are more abundant on the eastern half of the buttes and the wavelength of folds is tighter there than on the west. In addition to the small normal faults that surround the core of the dome, the eastern half of the dome is cut by a prominent set of steeply inward-dipping, arcuate high-angle reverse faults. This pattern of structural features indicates that the core of Sutter Buttes was thrust eastward as it moved upward.

The northward elongation of the buried Colusa dome strongly suggests that it too was formed in an east-west compressive stress regime. In fact, the amplitude, wavelength, and axial extent of the buried Colusa dome are remarkably similar to folds that occur just east of the Willows fault farther north (pl. 1; fig. 3). Although Redwine (1972) projected the Willows fault southeastward across the buried Colusa dome, our analysis of subsurface data suggests that a fault, possibly the Willows fault or a splay fault related to it, may lie just west of the buried Colusa dome. We conclude that the buried Colusa dome formed partly by east-side-up drag on a high-angle reverse fault along its western margin and partly by magma in-

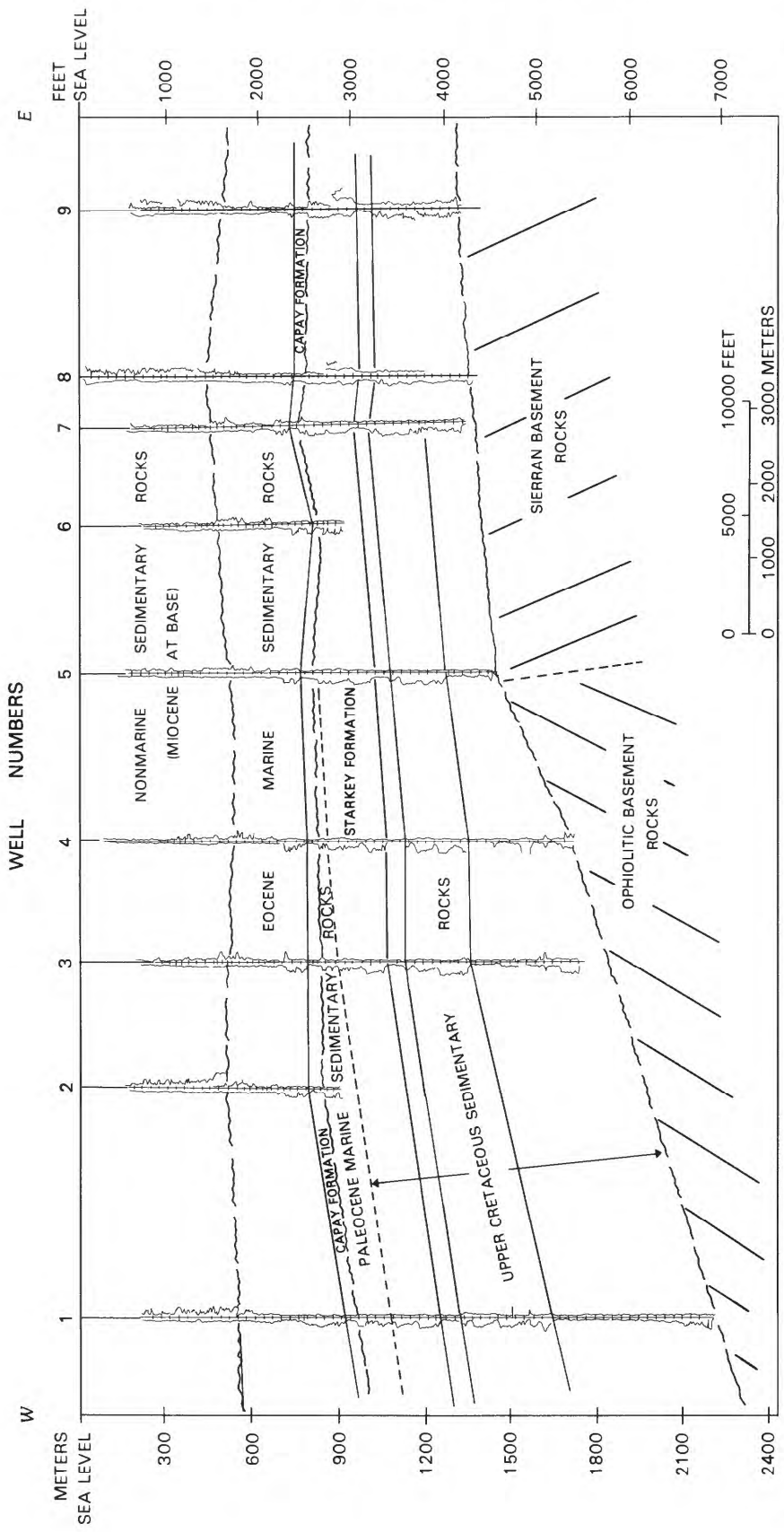


FIGURE 10.—Cross section showing electric logs and stratigraphic and structural relations across possible southeast extension of Willows fault (approximately follows trace of well 5) in area of the Lodi and Galt gas fields, Calif. Names of wells listed in appendix. Stratigraphic nomenclature used may not necessarily conform to that adopted by U.S. Geological Survey.

jection that was localized by movement on that fault.

The pattern of radial normal faults around the core of Sutter Buttes, flanked by reverse faulting to the east and west, assuming that the Willows fault was involved in the tectonism, is the type of deformation found by Withjack and Scheiner (1982) in their modelling experiments of doming in a compressive stress field. Although it is difficult to unequivocally separate magmatic doming from regional compressive deformation in the Sutter Buttes area, supporting evidence for the regional east-west compressive stress field is found in the Chico monocline about 40 km to the north.



FIGURE 11.—U.S. Air Force high-altitude oblique aerial photograph showing northern Sacramento Valley viewed to the north from vicinity of Sutter Buttes (center foreground), a late Pliocene and early Pleistocene volcanic center, approximately 16 km in diameter. Dark core of buttes composed primarily of andesite surrounded by lighter colored volcaniclastic deposits that form peripheral rampart beds of Williams and Curtis (1977). Narrow strip of cultivated land (dark) along Sacramento River (SR) between Corning domes (CD) and Chico monocline (CM) is surface expression of Los Molinos syncline (pl. 1). Oroville dam (OD) located near north end of Cleveland Hills faults where ground rupture occurred during August 1, 1975, Oroville earthquake.

CHICO MONOCLINE

The Chico monocline (fig. 13) is a northwest-trending, southwest-facing flexure that bounds the northeast side of the Sacramento Valley between Chico and Red Bluff. East of the monocline, Pliocene volcanic rocks of the Tuscan Formation dip less than 5° SW., but bedding steepens to 20° or more along the monoclinal flexure where the Tuscan dips beneath Quaternary deposits of the valley. The trace of the monocline is characterized by a complex surface pattern of anastomosing fault strands

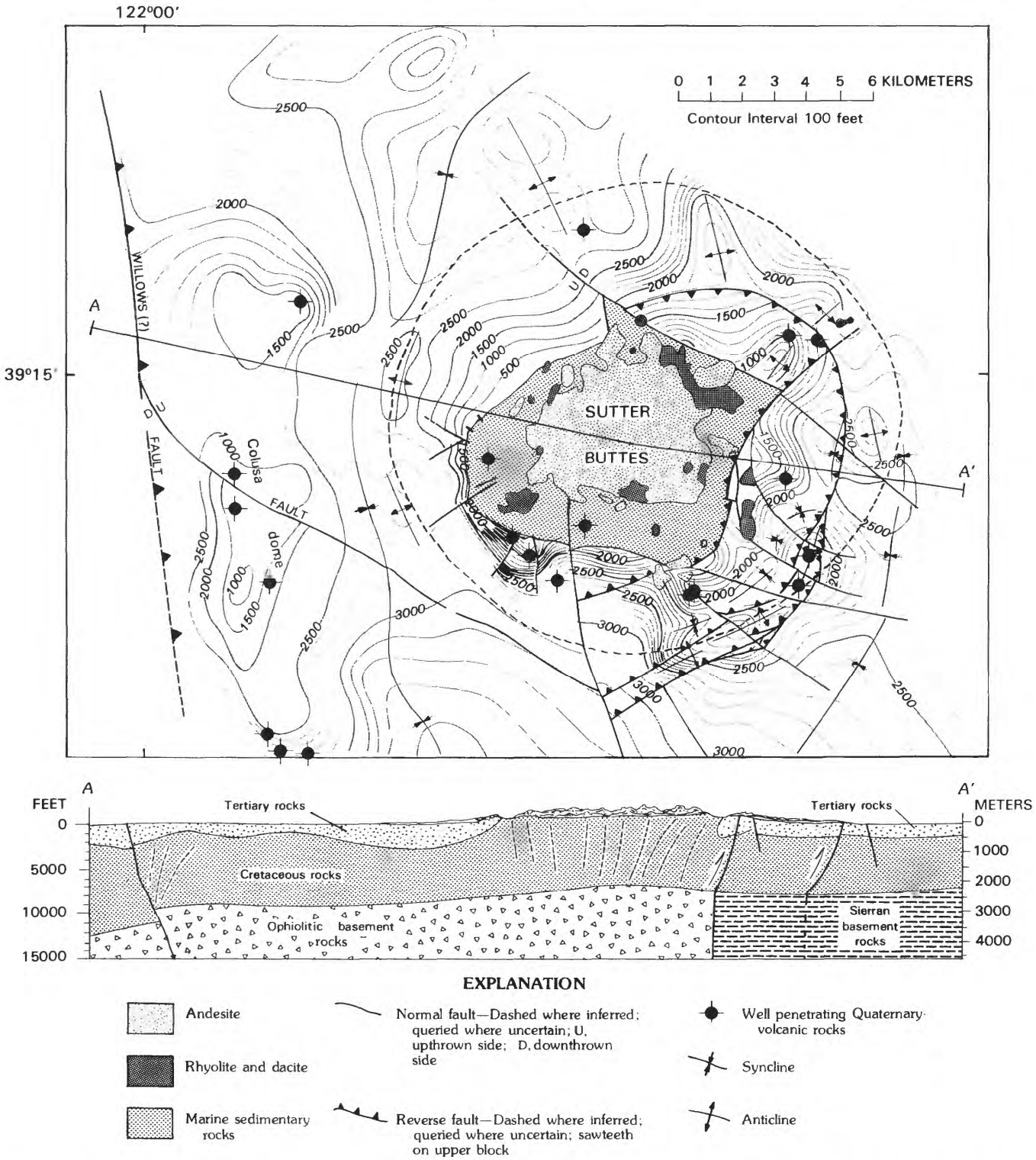


FIGURE 12.—Structure contour map of area around Sutter Buttes, modified from Williams and Curtis (1977, fig. 11) with data from Redwine (1972) and from our examination of electric logs in area of buried Colusa dome. Structure contours in feet; datum is top of the Kione sand of local usage (Williams and Curtis, 1977). Dashed circle on map marks approximate outer limit of rampart beds on valley floor; thin dashed lines on section represent schematic paths of magma injection.



FIGURE 13.—Composite of two U.S. Air Force high-altitude oblique aerial photographs showing pronounced linear trace of Chico monocline (CM, upper right to lower left), broad alluvial fan west of Chico monocline capped by Red Bluff Formation (RB, gray, uncultivated grazing land), and dissected topography of Tuscan Formation (TF) to east. DC, Deer Creek; CD, north Corning dome. Sacramento River (SR) follows trace of Los Molinos syncline (LMS) between north Corning dome and alluvial fan to east.

that show both west- and east-side-down displacements of small magnitude (Harwood and others, 1981).

Structure contours drawn on top of the Cretaceous rocks in the vicinity of the monocline indicate clearly that the Cretaceous strata are flexed and faulted by a major northwest-trending fault at depth beneath the surface trace of the monocline (pl. 1). The best control on the amount of displacement on the master fault beneath the Chico monocline comes from a line of wells that extends generally westward from the Exxon "C. C. Baccala No. 1" well (No. 4, fig. 14), which was drilled just west of the monocline about 18 km northwest of Chico. Although the Baccala well did not reach basement, it bottomed in Upper Cretaceous conglomerate at a depth of −1,700 m and provides a minimum elevation on the basement immediately west of the monocline when used in conjunction with the Pacific Western "Cana No. 1" well (No. 2, fig. 14) that reached serpentine at a depth of −2,100 m about 9 km to the west. Although no wells have been drilled east of the monocline, some control on the elevation and dip of the unconformities at the top and base of the Upper Cretaceous rocks is provided by exposures of these surfaces in several deep canyons to the east. When the trend of the basement surface at these exposures is projected westward, to pass beneath the bottom of the Baccala well, a minimum east-side-up offset of 365 m in the basement rocks is indicated on the fault beneath the monocline (fig. 14). The dip of this major fault cannot be determined directly from surface exposures or subsurface well data, but we show it as a steeply east-dipping reverse fault, because gravity and magnetic data (Griscom, 1973; Cady, 1975; Roberts and others, 1981) indicate that the relatively dense and magnetic basement beneath the northern part of valley extends eastward beneath the Sierran basement exposed east of the monocline. In the Sierran foothills southeast of Oroville, steep east dips are also commonly found in surface exposures of faults that may be the southeastward continuation of the fault beneath the monocline.

From available geophysical evidence, it appears that the fault beneath the monocline is a major tectonic boundary, with a long and complex tectonic history, along which the Sierran basement to the east was juxtaposed against highly magnetic, dense ophiolitic basement to the west (Cady, 1975; Griscom, 1973). These basement terranes were tectonically juxtaposed prior to deposition of the Upper Cretaceous strata. If this interpretation is correct, the fault beneath the Chico monocline may represent a part of the upper-slope discontinuity of Karig and Sharman (1975) that marks the boundary between basement of the late Mesozoic forearc basin to the west and that of the magmatic arc complex to the east. The Chico monocline, in that case, would be a structure inherited from the upper-slope discontinuity, possibly when that major tectonic break was reactivated by late Cenozoic subduction north of the migrating Mendocino triple junction.

The Chico monocline is clearly a late Cenozoic tectonic feature. It formed after deposition of the Ishi Tuff Member of the Tuscan Formation, about 2.6 m.y. ago and prior to the eruption of the olivine basalt of Deer Creek 1.09 m.y. ago (Harwood and others, 1981). Late Cenozoic displacement on the Chico monocline fault has been predominantly east side up, with an apparent component of left-lateral movement that may have contributed to the formation of the Salt Creek, Tuscan Springs and Sevenmile domes at the north end of the monocline and possibly influenced the northeast-trending Inks Creek fold system and Battle Creek fault zone farther northwest.

There is some indication that the Chico monocline fault may be active. The olivine basalt of Deer Creek is offset, but the amount of offset is small. Similarly, a few faults along the monocline show scarps about 1 m in height in the surface of the Tuscan Formation (Harwood and others, 1981). These observations indicate that movement has taken place on the monocline fault system within the past million years. In their study of regional seismicity after the Oroville earthquake, Marks and Lindh (1978)

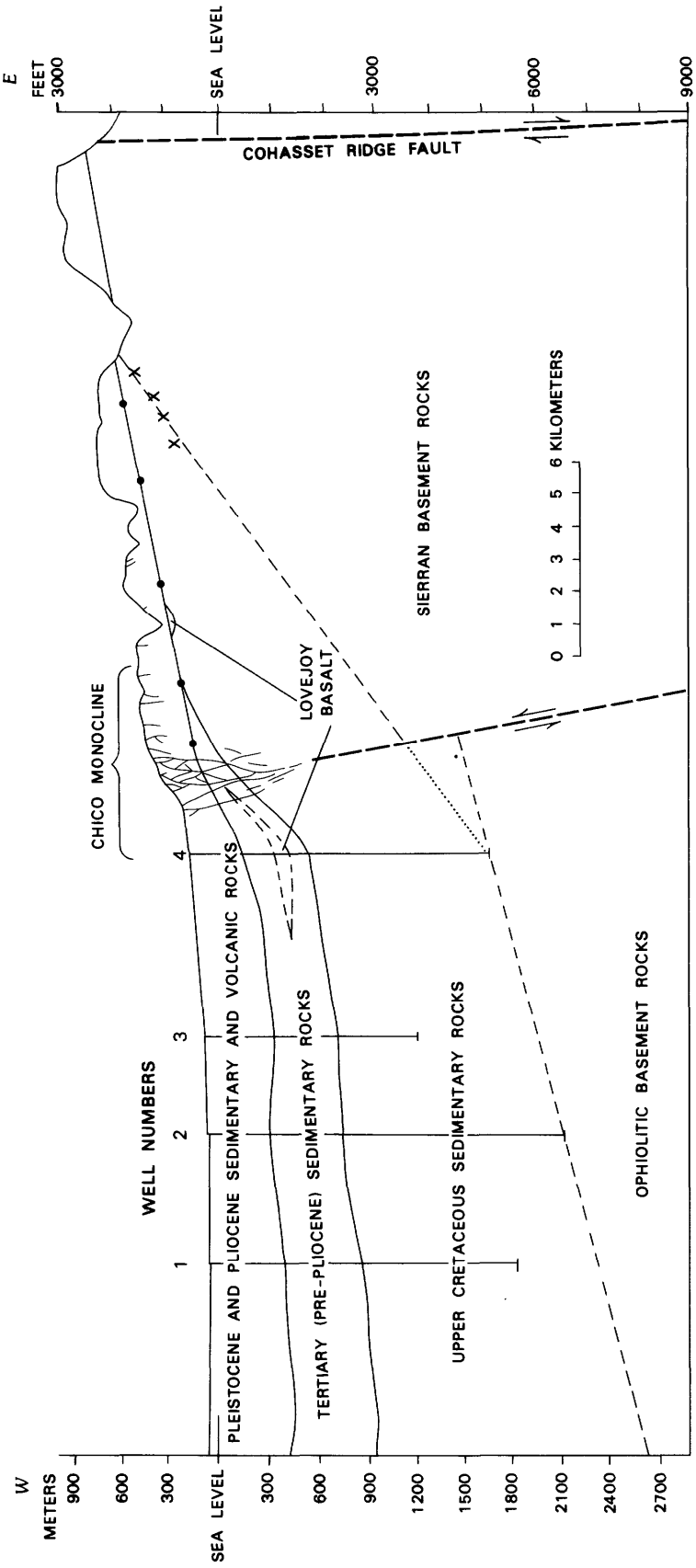


FIGURE 14.—Cross section across Chico monocline about half way between Chico and Red Bluff, Calif., showing offset of basement terranes. Dots indicate unconformity at base of Tuscan Formation, as projected into line of section; x's indicate unconformity at base of Upper Cretaceous rocks, as projected into line of section. Names of wells listed in appendix.

identified two events west of the Oroville aftershock zone at a depth of 40 km, significantly below the main cluster of aftershocks associated with the Oroville earthquake. We interpret those deep events to have occurred on the

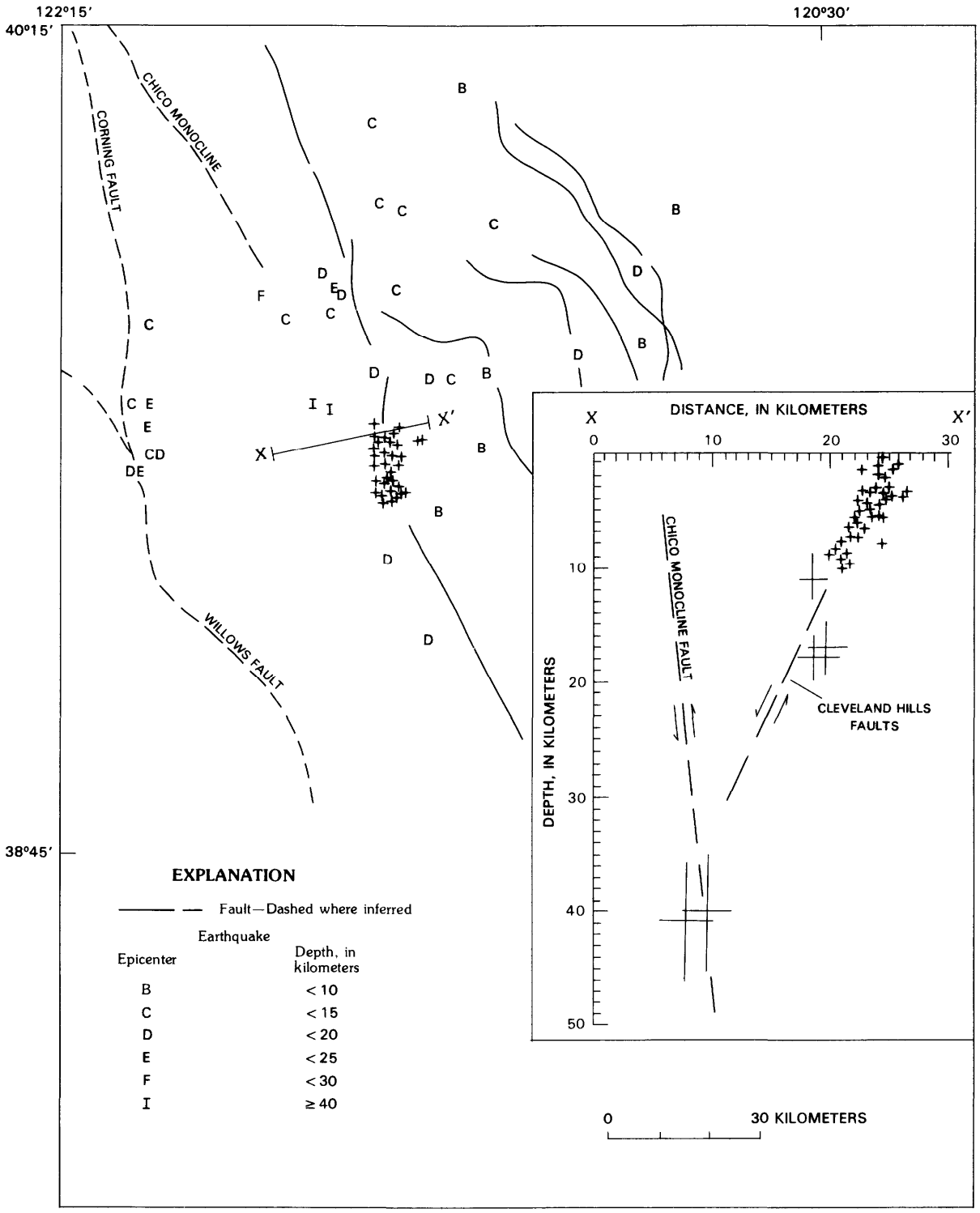


FIGURE 15.—Map and section showing locations of Oroville earthquake aftershocks (crosses on section) in relation to Cleveland Hills faults and Chico monocline (modified from Marks and Lindh, 1978). Earthquakes labeled I on map (largest crosses on section) at a depth of about 40 km are interpreted to have occurred on Chico monocline fault.

basement fault beneath the Chico monocline and not on the Cleveland Hills faults, where most of the aftershock events were located (fig.15). The steeply east-dipping normal fault, shown east of the Chico monocline on figure 15, is one of several short, north- and north-northwest-trending normal faults that extend along the northern foothills of the Sierra Nevada (pl. 1). This normal fault is probably part of the fault system on which the August 1, 1975, Oroville earthquake occurred.

BATTLE CREEK FAULT ZONE

The Battle Creek fault zone strikes east-northeast across the Sacramento Valley between Red Bluff and Redding, nearly at right angles to the trend of the Chico monocline. East of the Sacramento River, the Battle Creek fault zone is marked by a pronounced south-facing escarpment, shown in figure 16, that extends from the river northeastward toward Lassen Peak for a distance of 32 km. Fault strands within this part of the fault zone dip steeply southeast and show predominantly south-side-down, normal fault movement (Harwood and others, 1980; Helley and others, 1981). Vertical displacement on the fault zone increases from about 45 m just east of the Sacramento River to 330 m at Black Butte (fig. 1) and to about 440 m north of Manton. A small component of right-lateral strike-slip movement is suggested by fractures on some of the fault strands, but the exact amount of lateral displacement is not known.

West of the Sacramento River, the valleys of Cottonwood Creek and its south fork are probably controlled in part by the Battle Creek fault system, but modern stream activity and agricultural practices obscure any young traces of the faults east of the South Fork of Cottonwood Creek (pl. 1). At the South Fork of Cottonwood Creek and along Red Bank Creek, late Quaternary terraces show evidence of young faulting (Helley and others, 1981). To the west-southwest, the faults in the terrace deposits merge into previously mapped faults in the Red Bluff and Tehama Formations, and, on strike, they appear to merge with tear faults in the upper plate of the Coast Range thrust mapped by Bailey and Jones (1973).



FIGURE 16.—Photograph of Battle Creek fault scarp (BC) capped by basaltic cinder cone of Black Butte. View to northeast along Highway 36 and across rolling grassy plains underlain by volcanic fanglomerate correlated with the Red Bluff Formation.

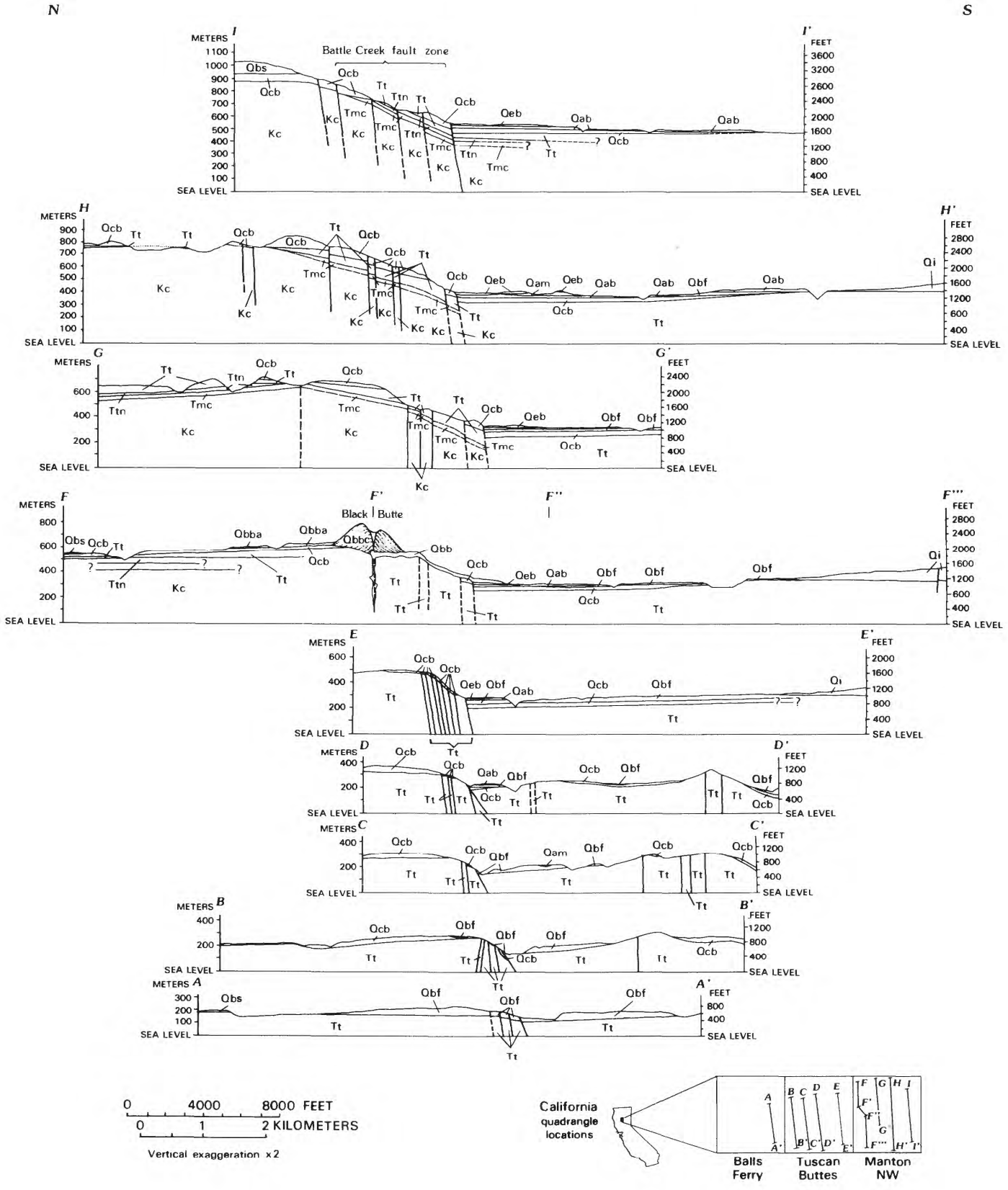
The orientation and distribution of faults in the Battle Creek fault zone east of the Sacramento River are shown in figure 17. Section *A-A′* is located 2.4 km east of the Sacramento River and shows relatively little offset of the fanglomerate that caps the Tuscan Formation. As the fault zone extends eastward, offset on the various Pliocene and Pleistocene units and the height of the fault scarp increases. From near the Sacramento River east to Black Butte (sections *A-A′* through *F-F′*, fig. 17), the fault strands are closely grouped along the fault scarp, but east of Black Butte (sections *G-G′* through *I-I′*, fig. 17) the fault strands are more widely spaced. In map view, the eastern fault strands veer northwestward and appear to die out a short distance north of the escarpment (Harwood and others, 1980).

Several clusters of small-magnitude earthquakes were reported along the eastern third of the Battle Creek fault zone, generally east of Black Butte (Bolt, 1979). Since 1980 the California seismic net of the U.S. Geological Survey has recorded several small-magnitude earthquakes (J. Eaton, oral commun., 1982) that lie approximately along the Battle Creek fault zone and extend west nearly to the Sacramento River.

Coarse volcanic fanglomerate, correlated here with the Red Bluff Formation by soil stratigraphy and geomorphic surface, is offset by the Battle Creek fault zone east of the Sacramento River and dates the major movement as younger than 1.09 m.y. The Rockland ash bed (referred to as the ash of Mount Maidu by Helley and others, 1981) appears to have been partly channeled by the Battle Creek fault scarp, suggesting that the faulting occurred prior to about 0.45 m.y. ago, the age of the Rockland ash bed (Meyer and others, 1980).

INKS CREEK FOLD SYSTEM

A set of northeast-trending folds, referred to as the Inks Creek fold system by Helley and others (1981), deforms the rocks south of the Battle Creek fault zone and structurally controls the major loops in the Sacramento River at Jelly School and the nearby Table Mountain (pl. 1; figs. 1, 18). The axial trace of the major syncline in the fold set passes through Table Mountain and extends northeastward, nearly coincident with Inks Creek. The complementary anticline to the north arches the volcanic fanglomerate, which is correlated with the Red Bluff Formation, and the underlying basalt of Coleman Forebay (Helley and others, 1981), exposing strata of the uppermost part of the Tuscan Formation northeast of Jelly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METERS
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Battle Creek fault zone
Qbs
Qcb
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Vertical exaggeration x2
California quadrangle locations
Balls Ferry
Tuscan Buttes
Manton NW

School. Axial surfaces of the folds are vertical, and fold axes plunge 20°–35° SW. Axial traces of the folds change strike to the northeast so that the anticlinal trace merges with the trend of the Battle Creek fault zone and apparently dies out along the fault to the east-northeast.

West of the Sacramento River, the Inks Creek fold system is expressed as a broad area of uplift known as the Hooker dome (fig. 18). This structure, which has profoundly influenced drainage patterns in the area, particularly along Hooker Creek and Blue Tent Creek (fig. 18), is underlain by the Tehama Formation capped by a few scattered erosional remnants of the Red Bluff Formation.

The Inks Creek fold system is clearly reflected in the structure contours drawn on top of the Cretaceous rocks, which show a closure of about 485 m over the anticline (pl. 1). Although only a few wells in this area reach basement, the elevation of the basement in two wells drilled on the anticline of the Inks Creek fold system is higher than the total depth of some wells to the west that bottomed in Upper Cretaceous rocks. These data indicate that the basement was deformed, along with the cover rocks, during formation of the Inks Creek fold system. They also strongly suggest that the folds shown by the structure contours on plate 1 involve the basement of the valley rather than deformation on a decollement or a series of detachment thrusts in the cover rocks.

The fact that the anticlinal trace of the Inks Creek fold system merges with the Battle Creek fault zone suggests a genetic relation between these major structures. If this interpretation is correct, evidence for the age of the Inks Creek fold system provides data for the age of movement on the Battle Creek fault zone. At Round Mountain, about 3 km southwest of Jelly School, the Rockland ash bed rests unconformably on the eroded western contact of the Red Bluff Formation at an elevation of 160 m. We assume that the ash was deposited in an ancestral channel of the Sacramento River, which apparently formed a large westward bend at that time extending from Bloody Island on the north to the vicinity of Bend on the south (fig. 18). Uplift and erosion of the Red Bluff Formation, which was deposited between 0.45 and 1.09 m.y. ago, had begun

EXPLANATION

Qi	BASALTIC ROCKS OF INSKIP HILL VOLCANIC CENTER (QUATERNARY)--Undifferentiated basalt of Inskip Hill
	BASALTIC ROCKS OF BLACK BUTTE VOLCANIC CENTER (QUATERNARY)--Consist of:
Qbbc	Cinder-cone deposits
Qbba	Cinder-blanket deposits
Qbb	Basalt flow of Black Butte
Qbs	BASALT OF SHINGLETOWN RIDGE (QUATERNARY)
Qeb	BASALT OF EAGLE CANYON (QUATERNARY)
Qab	HYPERSTHENE ANDESITE OF BROKEOFF MOUNTAIN (QUATERNARY)
Qam	ASH OF MOUNT MAIDU (QUATERNARY)--Equivalent to the Rockland ash bed of Sarna-Wojcicki and others (1985)
Qbf	ALLUVIAL FAN DEPOSITS OF BATTLE CREEK (QUATERNARY)
Qcb	BASALT OF COLEMAN FOREBAY (QUATERNARY)
Tt	TUSCAN FORMATION, UNDIVIDED (PLIOCENE)--Locally divided into:
Ttn	Nomlaki Tuff Member
Tmc	MONTGOMERY CREEK FORMATION (EOCENE)
Kc	CHICO FORMATION (UPPER CRETACEOUS)

FIGURE 17.—Geologic cross sections showing statigraphic and structural relations along Battle Creek fault zone. Note eastward increase in height of fault scarp and amount of offset of geologic units from section A-A′ to section I-I′. Geologic units from Helley and others (1981).

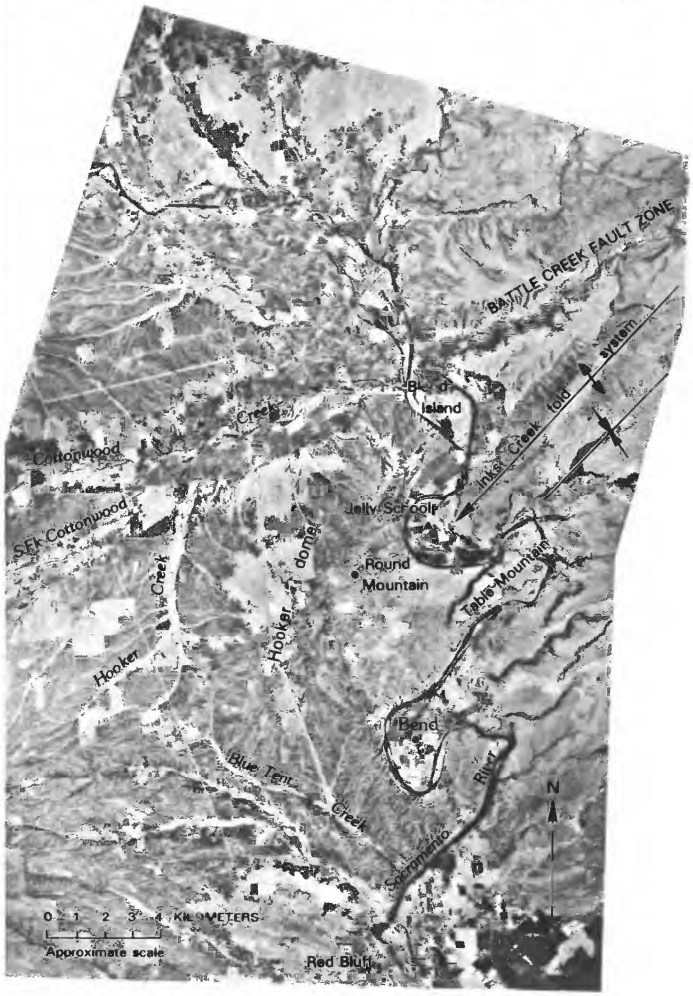


FIGURE 18.—Composite of two U.S. Air Force high-altitude vertical aerial photographs showing topographic expression of Inks Creek fold system (axial traces), Hooker dome, and Battle Creek fault zone.

prior to deposition of the ash. In contrast to the occurrence of the ash at Round Mountain, alluvial deposits of the lower part of the Riverbank Formation are found at an elevation of 120 m in this region, and they flank the present sinuous course of the Sacramento River through the structurally controlled loops of the river at Jelly School and Table Mountain. Clearly, the Sacramento River was forced into its tortuous course around the Inks Creek fold system by early Riverbank time. We conclude, therefore, that the Inks Creek fold system and at least some of the displacement on the Battle Creek fault zone developed in the timespan between 0.45 m.y., the age of the ash, and about 0.4 m.y. ago, the age of the lower part of the Riverbank Formation (Marchand and Allwardt, 1981).

SALT CREEK, TUSCAN SPRINGS, AND SEVENMILE DOMES

Small areas of Upper Cretaceous marine rocks are exposed beneath the Pliocene Tuscan Formation in Salt Creek, at Tuscan Springs, and in Sevenmile Creek between the north end of the Chico monocline and the Inks Creek fold system (pl. 1). In each area, beds in the Tuscan dip outward, away from the Upper Cretaceous rocks, and define three small domes, shown on plate 1 as the Salt Creek, Tuscan Springs, and Sevenmile domes.

The long axes of the domes trend north-northeast and plunge 15°–25° NE. and SW. Cold sulfurous springs are present in the Salt Creek and Tuscan Springs domes, and olivine basalt rests unconformably on steeply northwest-dipping Upper Cretaceous rocks in the core of Sevenmile dome. The olivine basalt was extruded from a north-trending fissure after the Tuscan Formation was domed and erosion had exposed the Upper Cretaceous rocks.

The age of the olivine basalt is unknown, but it probably is a few tens of thousands of years old, at most, and is roughly coeval with similar basalt flows and cinder cones found at Inskip Hill (pl. 1) and Black Butte along the Battle Creek fault zone. The domes probably formed during the same phase of late Quaternary deformation about 0.4–0.45 m.y. ago that produced the Inks Creek fold system and the Battle Creek fault zone, and they are thus younger than the Chico monocline.

RED BLUFF FAULT

The Red Bluff fault is a subsurface structure that extends southwest of Red Bluff for at least 25 km. West of Red Bluff, there is no surface feature associated unequivocally with the fault, and its location on plate 1 is taken from Jennings' (1977) geologic map of California. Apparently Jennings included the fault on that map on the basis of seismic-reflection data obtained from private industry (Oliver and Griscom, 1980). We have not seen that data or any other seismic profiles that might cross the fault. Griscom (1973) inferred the existence of a major northeast-trending fault in the area from magnetic data.

East of Red Bluff, structure contours on top of the Cretaceous rocks outline a major anticline, the broad crest of which lies beneath the Salt Creek, Tuscan Springs, and Sevenmile domes. The axial trace of this anticline roughly coincides with the east-northeast projection of the Red Bluff fault, but there is no indication that the Tuscan Formation is faulted at the surface along the N. 70° E. trend. The southeast limb of the anticline may be faulted at depth, but surface and subsurface data are too sparse to either prove or refute that structural possibility. Between Tuscan Springs and the Humble "Cone Ranch No. 1" well (sec. 20, T. 27 N., R. 2 W.) to the south, the top of the Cretaceous sequence drops about 1,433 m over a distance of less than 8 km. The lower elevation is due to warping and faulting on the Chico monocline fault, as well as to folding and possible faulting along the northeast projection of the Red Bluff fault.

From our reinterpretation of a north-south section along the Sacramento River near Red Bluff given by Redwine (1972, section *F-F'*), the base of the Tehama Formation could be offset, down to the south, by as much as 141 m across the Red Bluff fault just east of Red Bluff. Because of the lack of northeast-trending surface faulting in the Tuscan to the east, however, it seems unlikely that all of that differential elevation is due to fault displacement; much of it may be related to folding over a fault at depth.

FAULTS SOUTH OF INSKIP HILL

The northwest-trending arcuate faults that are shown south of Inskip Hill (pl. 1) are a gross simplification of the faults and fractures found in that area. In detail, the Tuscan Formation is laced with a dense network of short anastomosing faults along which thin lines of shrubs and trees grow (fig. 19). The amount of offset on a single fault is small, generally a few meters or less, and there appears to be no significant cumulative offset in the Tuscan Formation across the fractured area.

The arcuate pattern of faults is concave toward the area of Mineral, to the east, where Wilson (1961) identified a major volcanic center that he called Mount Maidu. It seems reasonably certain that the fracture pattern is related to volcanic-tectonic activity in the Lassen area, but whether it is associated with Mount Maidu or some other volcanic center is uncertain.

STRUCTURES SOUTHWEST OF THE WILLOWS FAULT

With the exception of the buried Colusa dome, the subsurface structure of the valley southeast of the Willows fault to the Sacramento Delta is dominated by the Zamora

syncline. South of buried Colusa dome, the Zamora syncline is asymmetrical and has a broad, gently west-dipping east limb that extends to the Sierran foothills and a steeply dipping west limb that is warped by southeast-plunging folds. North of the buried Colusa dome, the axial trace of the Zamora syncline intersects the Willows fault, and the top of the Upper Cretaceous rocks defines a generally east-dipping homocline.The following sections discuss structural features west of the axial trace of the Zamora syncline.

CAPAY VALLEY-CAPAY HILLS AREA

Cache Creek drains east from Clear Lake and enters the Sacramento Valley west of Woodland, through the tectonically controlled depression of Capay Valley. On the west, Capay Valley is flanked by the eastern slope of the Coast Ranges that contain a remnant of Eocene marine sandstone and shale of the Capay Formation (Redwine, 1972) resting unconformably on Upper Cretaceous marine rocks (Kirby, 1943a). Beds in the Capay and underlying rocks dip 25°-55° E. The Capay Hills, previously known as the Rumsey Hills (Kirby, 1943b), lie immediately east of Capay Valley and are underlain by the same Upper Cretaceous rocks exposed to the west. Here, however, the Cretaceous rocks lie in the core of a faulted southeast-plunging anticline, shown by structure contours on plate 1. They are unconformably overlain by nonmarine sandstone and shale of the Pliocene Tehama Formation. The Eocene Capay Formation is not present in the Capay Hills or in the Capay Valley, where scattered subsurface and surface data indicate that the Tehama rests unconformably on Upper Cretaceous rocks.

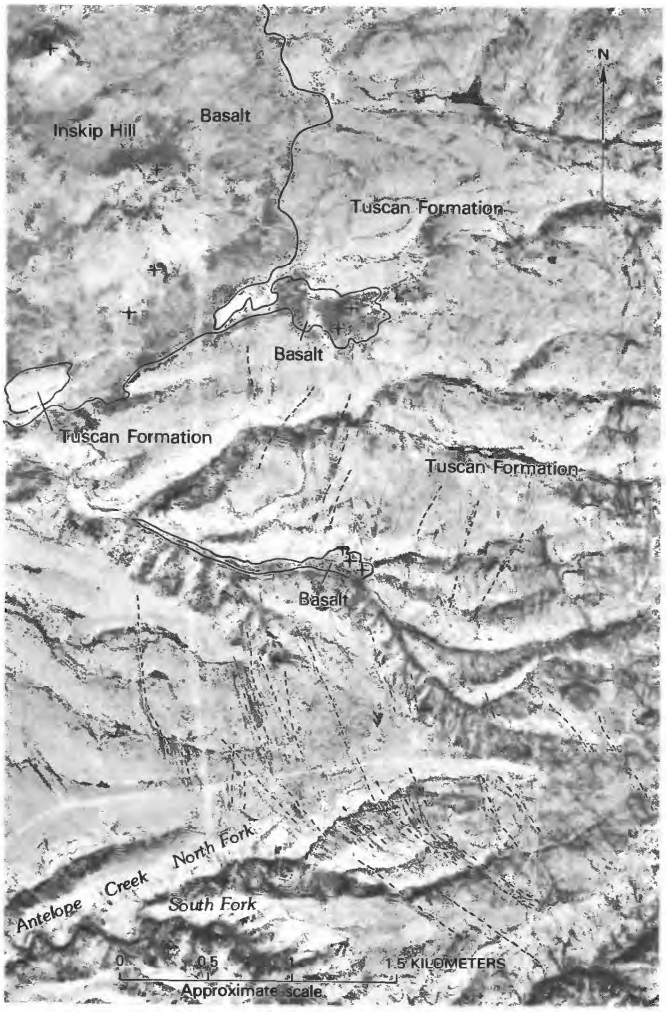


FIGURE 19.—Low-altitude vertical aerial photograph (U.S. Geological Survey) showing arcuate fault pattern (dashes) and cinder cones (crosses) south of Inskip Hill. Gray incised plains are underlain by the Tuscan Formation; thin dark lines are concentrations of brush and trees growing along fault traces.

On the floor of Capay Valley, the Tehama and older rocks have been eroded, and old stream channels have been filled with a variety of Quaternary alluvial deposits. Alluvial deposits of the upper part of the Modesto Formation indicate that Cache Creek entered the Sacramento Valley through a channel cut in the Tehama Formation near the west boundary of Capay Valley in late Wisconsin time. During the past 12,000 years the course of Cache Creek has shifted eastward so that the creek now exits Capay Valley through a sharp gorge cut into the relatively resistant Upper Cretaceous rocks at the southern end of Capay Hills. The shift in the course of Cache Creek and the surface and subsurface data that show faulting in the Tehama Formation provide strong evidence for late Cenozoic tectonism in Capay Valley.

Along the west flank of the Capay Hills, Kirby (1943b) mapped a northwest-trending, east-dipping thrust, the Sweitzer fault, and a lower ancilliary thrust, the Eisner fault; both faults place Upper Cretaceous rocks in contact with the Tehama. Wagner and Saucedo (1984) have reinterpreted the Sweitzer and Eisner faults as west-dipping normal faults. Their interpretation of the Sweitzer fault is supported by subsurface data at the south end of Capay Hills, where the contact between the Forbes and Guinda Formations of Kirby (1943a) is downfaulted about 50 m on the west (fig. 20, wells 3 and 4). Compared to other faults in the area, the Sweitzer fault appears to have played a relatively minor part in the structural evolution of the Capay Valley and Capay Hills.

West of the Sweitzer fault, the contact between the Forbes and Guinda Formations was reported at an elevation of about 219 m beneath the Capay Valley (fig. 20, well 2). That contact is displaced about 610 m up to the west along the northwest-trending, steeply east-dipping East Valley fault (fig. 20). Along the west margin of Capay Valley, the contact between Upper Cretaceous rocks and the Tehama Formation is down faulted about

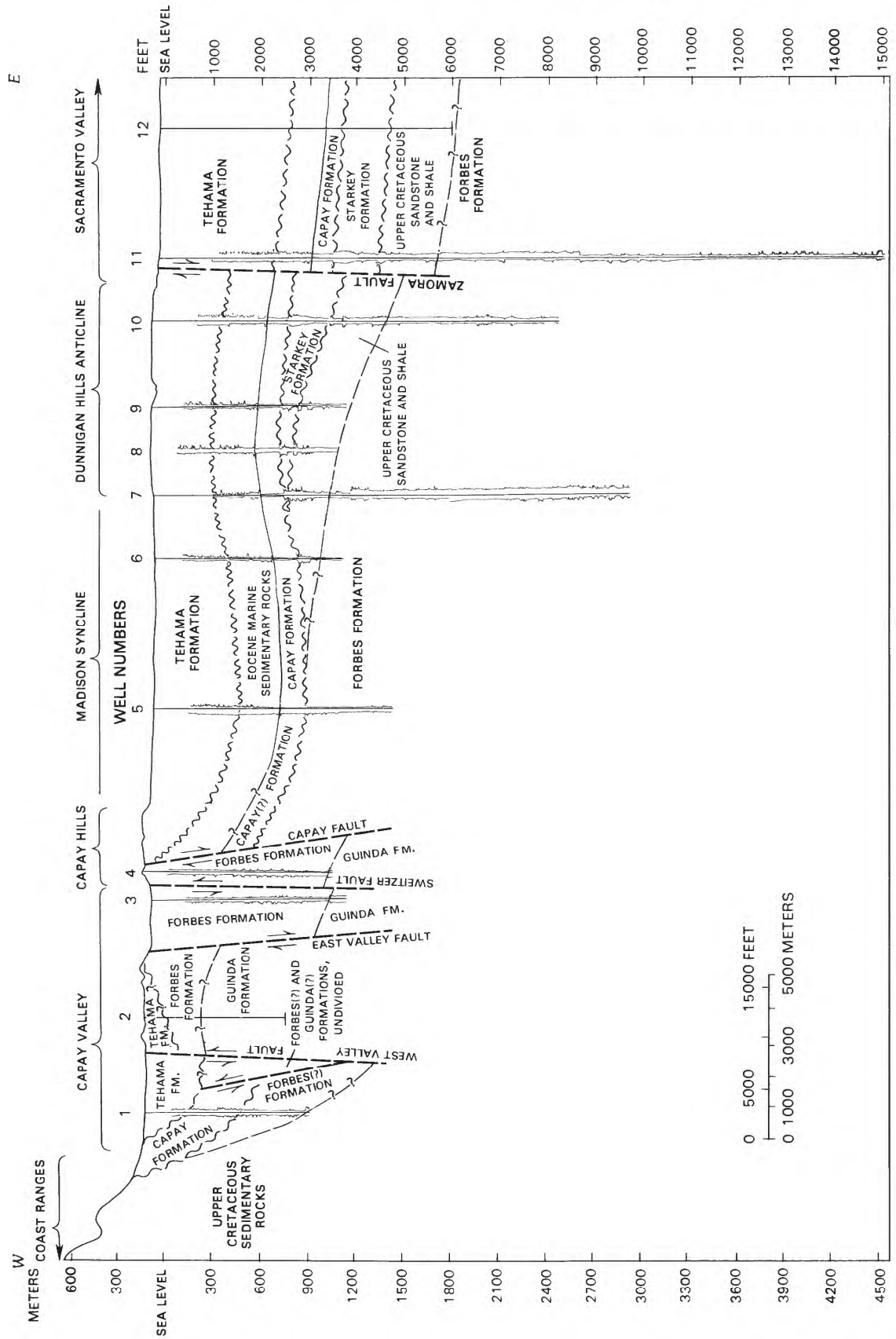


FIGURE 20.—Cross section showing electric logs and stratigraphic and structural relations in Capay Valley, Capay Hills, and Dunnigan Hills. Names of wells listed in appendix. Stratigraphic nomenclature used may not necessarily conform to that adopted by U.S. Geological Survey.

150 m to the west by the near-vertical West Valley fault (fig. 20). At the south end of Capay Valley, Upper Cretaceous rocks are thrust over the Eocene Capay Formation along a thrust or high-angle reverse fault that is exposed to the south along the east flank of the Coast Ranges (pl. 1). The location of this thrust or high-angle reverse fault is unknown east of the West Valley fault.

East of Capay Hills, the Capay Formation unconformably overlies east-dipping Upper Cretaceous rocks beneath the Madison syncline and the Dunnigan Hills anticline (pl. 1; fig. 20). The Capay Formation and overlying Eocene marine rocks are not exposed in the Capay Hills where the Pliocene Tehama Formation rests unconformably on Upper Cretaceous rocks. Because the Capay Formation is present west of Capay Valley, however, we assume that the Capay Formation once extended over the area of the Capay Hills but that it was eroded from the area after west-side-up movement on the Capay fault (fig. 20) and the other high-angle reverse faults to the west under Capay Valley. In this interpretation, the minimum displacement on the Capay fault would be about 700 m. Major west-side-up reverse movement occurred on the Capay fault, the East Valley fault, and the unnamed thrust or high-angle reverse fault to the west in post-Eocene time and before deposition of the Tehama Formation, which contains the 3.4-m.y. old Putah Tuff Member near its base (Sarna-Wojcicki, 1976). West-side-down movement occurred on the West Valley fault subsequent to deposition of the Tehama Formation, and east-side-down, post-Tehama displacement also may have occurred on the East Valley fault and the Capay fault.

DUNNIGAN HILLS ANTICLINE AND THE ZAMORA FAULT

Near Woodland, Bryan (1923) recognized accordant summit elevations capped by Red Bluff gravel on a series of northwest-trending dissected uplands that he called the Hungry Hollow Hills, but which are now known as the Dunnigan Hills. The northeast flank of the upland is bounded by a linear escarpment that Bryan called the Hungry Hollow fault, but which is referred to here as the Zamora fault (pl. 1; fig. 20). He recognized down-to-the-east displacement of at least 121 m at the north end of the fault scarp and offset of about 60 m near Cache Creek to the south (Bryan, 1923, p. 79).

Bryan's early work, combined with the topographic relief in the area, made the Dunnigan Hills a prime target for early seismic-reflection studies that resulted in the discovery of the Dunnigan Hills gas field in 1946 (Rofe, 1962). The gas-producing structure is a doubly plunging, northwest-trending anticline along which various Upper Cretaceous sandstone beds are unconformably capped by the Eocene Capay Formation (fig. 20). This major structure has topographic relief. Red Bluff gravel wraps around the northwest-plunging nose of the fold and occurs in scattered patches along the east flank, on the crest line, and at the southeast-plunging nose of the fold. Oat Creek (pl. 1) and Bird Creek to the southeast (not shown on pl. 1) are antecedent to the fold and change from southeast to northeast courses approximately at its axial trace.

Data from a recent well drilled near Zamora by the U.S. Geological Survey provide new information on the amount of late Cenozoic deformation in the area. A conspicuous volcanic ash bed, penetrated at a depth of −137 m (Page and Bertoldi, 1983), has been correlated tentatively by mineralogy and chemical composition of the glass with the Rockland ash bed by C. E. Meyer and A. M. Sarna-Wojcicki (oral commun., 1982). Because the ash occurs directly above Red Bluff gravels elsewhere in the valley (Harwood and others, 1981; Helley and others, 1981), it is assumed that the ash overlies the Red Bluff in the Zamora well and that there is a minimum of 220 m of vertical displacement of the Red Bluff Formation. This vertical separation is the result of folding on the Dunnigan Hills anticline and displacement on the Zamora fault (fig. 20).

MIDLAND FAULT

The Midland fault is a major subsurface structure that was discovered in the Sacramento Delta during development of the Rio Vista gas field between 1936 and 1943 (Frame, 1944). Through data from extensive drilling, the fault was extended about 25 km north of the Rio Vista field to the Maine Prairie gas field (Arleth, 1968). North of that field, the location of the Midland fault is uncertain. Redwine (1972) proposed that the Sweitzer fault, mapped by Kirby (1943b) in the Capay Hills, was the northwest continuation of the Midland fault. Although Jennings (1977) showed the Midland-Sweitzer fault connection, suitably queried, on his geologic map of California, that interpretation is no longer considered correct (C. Jennings, oral commun., 1981). The location of the Midland fault south of the Rio Vista gas field is uncertain.

In the Rio Vista gas field, the Midland fault is actually a north-trending, steeply west-dipping to vertical fault zone that offsets Paleocene and Eocene rocks down to the west in a series of fault blocks as shown in figure 21. Early in the development of the Rio Vista gas field, it became apparent that movement on the Midland fault had controlled local patterns of Tertiary sedimentation. Frame (1944) noted that the Capay Formation was significantly thicker west of the Midland fault, and he suggested that maximum movement occurred on the fault during or at the close of Capay deposition. Although the Capay Formation shows the greatest amount of syntectonic thickening across the fault, all of the Paleocene and Eocene units show some differential thickening west of the fault (Bur-

roughs and others, 1968). In his detailed analysis of depositional and tectonic cycles in the southern Sacramento Valley, Almgren (1978) demonstrated approximately 610 m of episodic movement on the fault between the early Paleocene and early Oligocene. There is no indication that early Oligocene or younger deposits are offset by the Midland fault; therefore, it appears that the Midland fault was an active structural feature on the early Tertiary continental margin but that it has not been active in the late Cenozoic.

By combining data presented by Burroughs and others (1968) and Almgren (1978), it is possible to calculate approximate displacement rates on the Midland fault during the early Tertiary. Calculation of the displacement rates, shown in figure 22, assumes that displacement occurred on a single fault strand during the time deduced for various units by Almgren (1978) and that initial offset began in the Paleocene. Between 60 and 53 m.y. ago the slip rate was 3.8 cm/1,000 yr. The rate increased to a maximum of 7.2 cm/1,000 yr between 53 and 50 m.y., and it decreased significantly to 0.75 cm/1,000 yr between 49 and 42 m.y.

THORNTON ANTICLINE

The Thornton anticline, or the Thornton arch of Silcox (1968), is an east- to southeast-trending, west-plunging fold that is transected in part by closely spaced northwest-trending faults that generally show west-side-down displacements of less than 20 m. The fold extends from the east-central part of the Sacramento Delta to the vicinity of Lodi and provides structural control for several gas fields along its trace. Silcox (1968) provides the most detailed information on the structural development of the

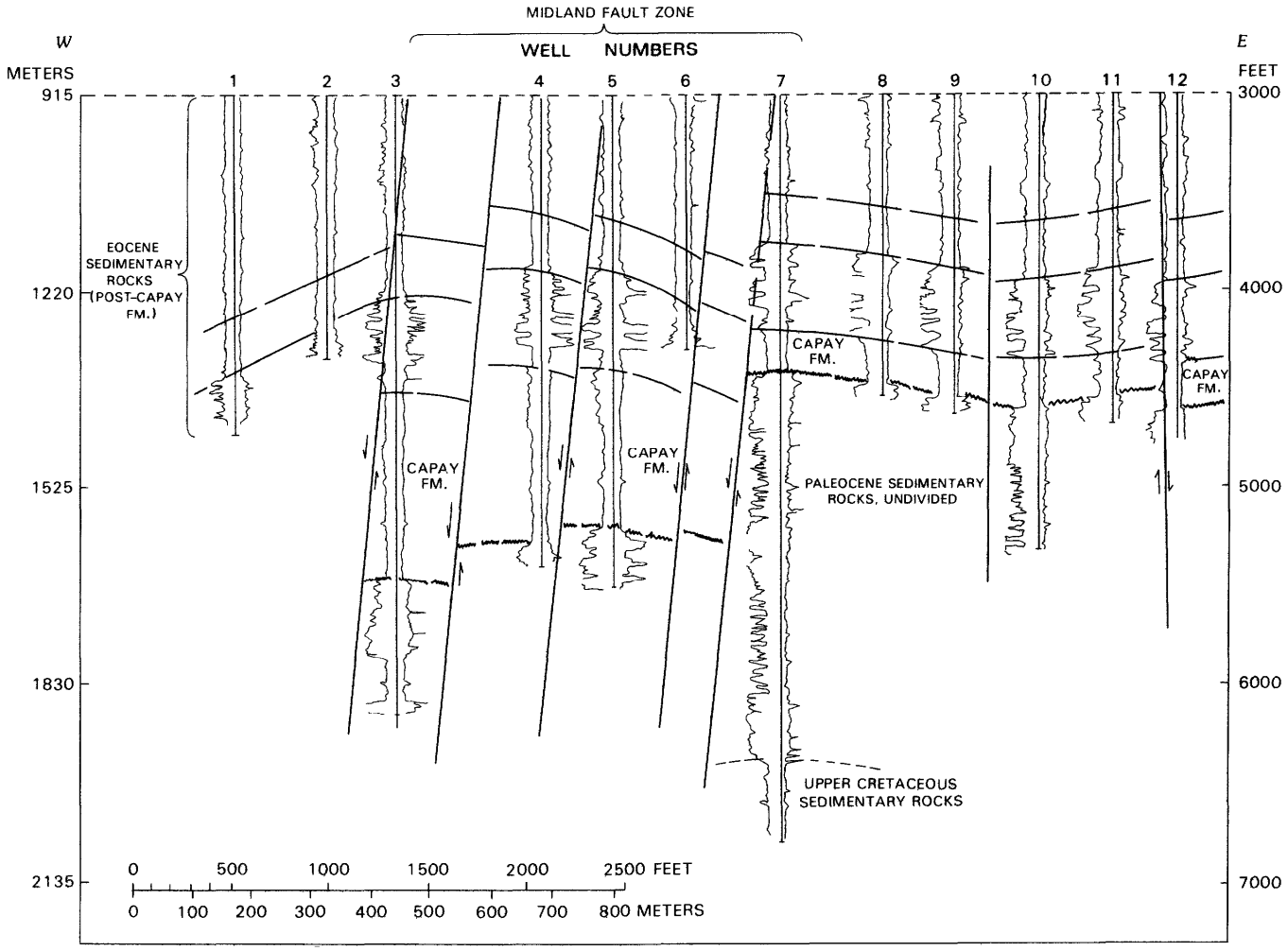


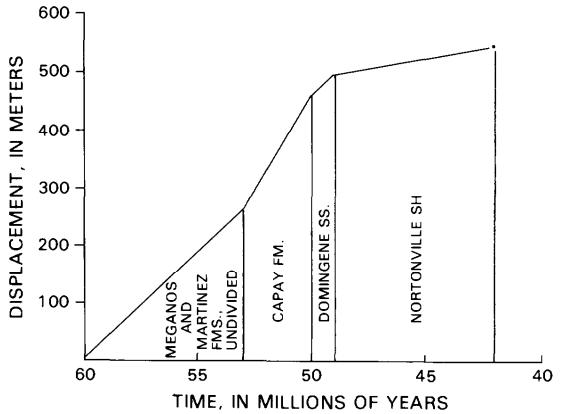
FIGURE 21.—Cross section showing electric logs and stratigraphic and structural relations across Midland fault zone in Rio Vista gas field (modified from Burroughs and others, 1968). Note significant thickening of the Eocene Capay Formation west of easternmost strand of Midland fault zone. Names of wells given by Burroughs and others (1968).

Thornton anticline in his description of the Thornton and Walnut Grove gas fields.

According to Silcox (1968) initial development of the Thornton anticline occurred prior to deposition of the basal Eocene rocks and may have been contemporaneous with Paleocene displacement on the Midland fault to the west. Maximum flexure of the structure apparently occurred in the late Eocene when lower and middle Eocene rocks were eroded and subsequently buried unconformably beneath deposits of the Markley submarine canyon. Miocene continental rocks, which were deposited unconformably on Markley canyon fill, do not show any significant folding over the Thornton anticline, nor are they offset by the northwest-trending faults that cut earlier deposits along the fold. Therefore, the structures are pre-Miocene.

STOCKTON FAULT

The Stockton fault is a northeast-trending, southeast-dipping subsurface fault that extends across the southern part of the Sacramento Valley between Tracy (south of pl. 1) on the west and the vicinity of Milton on the east. The fault lies north of a cross-valley, northeast-trending structural high in the basement, known as the Stockton arch, that apparently was discovered during some of the earliest seismic-reflection profiling done in the valley in the mid-1930's. Wells drilled near the Stockton fault during that time found only minor amounts of gas, and the relations between displacement on the Stockton fault and folding in the Upper Cretaceous marine rocks were not determined until development of the Lathrop gas field during the late 1940's. Teitsworth (1968), in his analysis of the Lathrop gas field, presents the most detailed study of the complex tectonic history of the Stockton fault. His work coupled with our analysis of wells to basement north of the Stockton fault, and Bartow's (1983) analysis of wells south of the fault provide the data for this discussion.



UNIT	DIFFERENTIAL THICKNESS (m)	POSTFORMATION OFFSET (m)	TOTAL OFFSET (m)	TIME (m.y. ago)	RATE (cm/10³ yr)
Nortonville Sh	15	38	53	(49-42)	0.75
Domingene Ss.	26	23	49	(50-49)	4.9
Capay Fm.	215	0	215	(53-50)	7.2
Meganos and Martinez Fms., undivided	260	5	265	(60-53)	3.8

FIGURE 22.—Graph showing amounts and rates of offset on Midland fault zone, assuming all displacement occurred on a single fault strand and that displacement began in the Paleocene. Amount of offset and syntectonic thickening of units taken from figure 21 (modified from Burroughs and others, 1968).

Near the city of Stockton, the −3,000-m basement contour is offset about 5 km in a left-lateral sense and depressed about 300 m down to the south, but the vertical component of movement is not closely controlled in that area. Eastward, near the −2,500-m contour, the basement surface is offset left-laterally about 6 km and depressed nearly 500 m south of the fault. The vertical component of displacement there is reasonably well controlled by wells north and south of the fault. Both the left-lateral and vertical components of displacement decrease eastward along the Stockton fault and appear to die out completely between the −500-m and 0 basement contours. No trace of the Stockton fault has been mapped in the exposed metamorphic rocks of the Sierran foothills between the north end of Gopher Ridge and the Mokelumne River (pl. 1) (Wagner and others, 1981).

Teitsworth's (1968) study of the Lathrop gas field (pl. 1, map A), which is located about 9 km southeast of Stockton, corroborates our analysis of the basement offset on the Stockton fault and adds valuable data about the amount and timing of deformation recorded in the Upper Cretaceous rocks. Teitsworth concluded that the Upper Cretaceous rocks were thicker south of the Stockton fault, indicating south-side-down vertical movement during early phases of deposition, and that they were subsequently offset about 3 km left-laterally during Late Cretaceous time. Deposition of Upper Cretaceous marine shale followed earlier strike-slip displacement on the Stockton fault, and these marine shale units also show left-lateral displacement. Following deposition and strike-slip displacement of the uppermost Upper Cretaceous unit in the area, but prior to deposition of Miocene continental strata that unconformably cap the Upper Cretaceous section, the Stockton fault experienced about 1,000 m of reverse, south-side-up movement (Teitsworth, 1968). During this period of reverse movement, west- and west-northwest-trending anticlines formed in the Upper Cretaceous rocks south of the fault, providing closure that trapped the gas in the Lathrop and East Stockton gas fields (pl. 1, map A). The trend of these folds and the northwest-trending anticlines in the Roberts Island and McDonald Island gas fields (pl. 1, map A) north of the Stockton fault indicate northeast-southwest compression in the area during the period of reverse movement on the Stockton fault. Teitsworth (1968) concluded that reverse

movement probably occurred after the middle Eocene but before deposition of Miocene continental deposits. However, he shows a west-northwest-trending fold in contours drawn on the base of the Miocene rocks south of the Stockton fault, from which we conclude that the northeast-southwest compressive stress operated in the area into the middle Tertiary.

FAULTS IN THE SIERRAN FOOTHILLS

Clark (1960) combined data from a number of sources with his own field observations to produce the first regional structural synthesis of the Sierran foothills. He defined the Foothill fault system as a group of northwest-trending, steeply east-dipping to vertical faults that tectonically separate distinctive belts of Paleozoic and Mesozoic rocks for more than 320 km along strike in the western foothills of the Sierra Nevada. He recognized that the component faults in the system were actually complex fault zones marked by multiple fault strands and intensely sheared, cataclastic, and crumpled rocks, which were associated geographically, in many areas, with major bodies of sheared serpentinite. On the basis of limited paleontologic and radiometric data, he concluded that the major tectonic activity of the Foothill fault system occurred in the Late Jurassic.

Although displacement of Tertiary volcanic units was recognized locally along segments of the Foothill fault system after Clark's study (Bateman and Warhaftig, 1966), few investigations were made into the late Cenozoic deformational history of the fault system before the Oroville earthquake. That seismic event produced ground rupture on the Cleveland Hills faults (Clark and others, 1976) and opened the question of potential late Cenozoic deformation within the whole Foothill fault system.

In their earthquake evaluation studies of the Auburn Dam area, Woodward-Clyde Consultants (1977) made a regional analysis of potential late Cenozoic deformation along many linear features related to the Foothill fault system, and they trenched those linear features that had direct bearing on their Auburn Dam study. That study provided most of the data for our analysis of those strands of the fault system in the border zone between the Sierran foothills and the Sacramento Valley.

COHASSET RIDGE FAULT

Cohasset Ridge is a prominent south- to southwest-trending interfluve located northeast of Chico, between the major drainages of Big Chico Creek and Deer Creek. The ridge is capped by at least two essentially contemporaneous olivine basalt flows that appear to have originated in the Butte Mountain area (about 12 km east of pl. 1), on the southwest slope of a Pliocene volcano named Mount Yana by Lydon (1968). The olivine basalts flowed southwestward in channels eroded in the underlying Tuscan Formation, but subsequent erosion has inverted the topography so that the basalt now stands as the highest unit on the ridge. The olivine basalt of Cohasset Ridge represents the final phase of volcanism that reached the Sacramento Valley from Mount Yana. The upper basalt flow has been dated at 2.41 m.y. (Harwood and others, 1981).

East of Brushy Mountain (pl. 1), the olivine basalt of Cohasset Ridge is abruptly truncated on the east by a steeply east-dipping fault that strikes about N. 40° W., roughly parallel to the Chico monocline fault. Aune (cited in Woodward-Clyde Consultants, 1977) first recognized this fault, which he called the Cohasset Ridge fault, and concluded that the eastern equivalents of the olivine basalt of Cohasset Ridge were downfaulted to the east about 30 m along the normal fault. The Cohasset Ridge fault can be traced north of Deer Creek through an intensely fractured zone in the Tuscan Formation to the vicinity of Mill Creek, where it becomes obscured by a complex pattern of west- and northwest-trending arcuate faults (pl. 1; fig. 19). Although the area south of Deer Creek is heavily forested and the slopes are covered by a veneer of colluvium, the trace of the Cohasset Ridge fault is defined by a prominent topographic linear feature, observed by Rich and Steele (1974), that extends nearly to Magalia, where it apparently is intersected by the Magalia fault.

The Cohasset Ridge fault is a northwest-trending, steeply east-dipping fault that has experienced at least 30 m of east-side-down normal movement in the past 2.41 m.y.

MAGALIA FAULT

About 9 km north of Magalia, (pl. 1), the Cohasset Ridge fault is intersected by the N. 20° W.-trending Magalia fault. Extensive mine workings, which followed Tertiary auriferous gravel deposits at the base of the Tertiary volcanic sequence in the area, provide detailed data on the nature and local extent of the Magalia fault (Gassaway, 1899; Logan, 1930; Woodward-Clyde Consultants, 1977).

Although the Magalia fault is shown as a single fault on the map, detailed mine maps indicate that the fault is actually a complex fault zone consisting of numerous fault strands that have different orientations and amounts of displacement. In the Dix mine at the north end of the mining district, the gold-bearing gravels are offset 28 m down to the east. Southeastward along the trace of the Magalia fault at the Black Diamond mine, the gravel deposits are offset 68 m down to the east. Farther southeast at the Magalia mine, the channel deposits are offset down to the west from 2 to 11 m along three reverse

faults that trend N. 60° W. and dip 58° NE.

From the mining records it appears that the various fault strands in the Magalia fault zone have experienced episodic and different movement through the Tertiary, with both normal east-side-down and reverse east-side-up displacement recorded. The relative ages of this disparate movement pattern along the Magalia fault are unknown, but the youngest movement appears to post-date movement on the Cohasset Ridge fault.

CLEVELAND HILLS FAULTS

The Cleveland Hills faults coincide with surface ruptures that occurred during the Oroville earthquake. During that seismic event, the ground surface failed in a 3.8-km long en echelon pattern of north- and north-northwest-trending normal faults that showed at least 55 mm of horizontal separation across the surface ruptures and as much as 180 mm of west-side-down vertical separation (Clark and others, 1976). Aftershocks of the Oroville earthquake defined a zone of seismic activity, assumed to coincide with the controlling fault, that dipped about 60° W. and trended nearly due north (fig. 15; also Bufe and others, 1976).

Trenches, dug across the zone of surface rupture by the California Department of Water Resources and logged by Akers and McQuilkin (1975), showed a gouge zone about 2 m wide in the bedrock below the surface ruptures that was flanked by 2-4 m of intensely fractured rock transitional into the country rock of foliated greenstone. The gouge zone contains anastomosing shear zones of deformed gouge that provide evidence of repeated earlier faulting along the zone of the ground failure. Earlier deformation in the area is also indicated by 30-60 m of apparent west-side-down offset of an erosion surface of probable Pleistocene age across the Cleveland Hills faults (Aune, 1975).

About 5.7 km northwest of the Cleveland Hills faults (pl. 1), Creely (1965) mapped a north-trending, steeply east-dipping fault that offset the base of Pleistocene or older gravel deposits about 2 m down to the west. Clark and others (1976) reported a second fault in the area that showed minor east-side-down offset of the gravel deposit.

FAULTS SOUTHEAST OF OROVILLE

In their earthquake evaluation of the Auburn Dam area, Woodward-Clyde Consultants (1977) identified a number of prominent linear features in the Sierran foothills southeast of the Cleveland Hills faults. With the exception of the northeast- and north-trending Highway 49 and Hancock Creek lineament zones (pl. 1), the linear features they investigated have northwest trends that coincide closely with the projected trace of the Chico monocline fault. The linear features were trenched extensively and logged in detail (Woodward-Clyde Consultants, 1977), and trench data were integrated with surficial geologic investigations in each area. Evidence of movement in the past 10 m.y. (Woodward-Clyde Consultants' definition of the "late Cenozoic") was detected in the trenches across the northwest-trending linear features, which are shown on plate 1 as the Swains Ravine, Spenceville, and Maidu fault zones and the Dewitt fault.

Deformation in the bedrock exposed in the trenches is remarkably similar to that shown in trenches across the Cleveland Hills faults. In most areas, bedrock beneath the surface lineaments contained one or more zones of slickensided clay-rich gouge a few meters wide or less. The gouge commonly contained anastomosing shear zones composed of polydeformed gouge and thin clay seams that indicated multiple phases of deformation. Rock adjacent to the gouge zones commonly was highly fractured, bleached, or manganese-stained and injected by thin quartz veins. In some trenches, a paleosol rested unconformably on bedrock and was offset locally along the faults marked by the gouge zones. That evidence led Woodward-Clyde Consultants (1977) to conclude that at least some of the faulting had occurred in the past 100,000 years. Based on the evidence presented by Woodward-Clyde Consultants (1977) and our observations in many of the trenches that they excavated during that study, we agree with their conclusions.

REGIONAL STRUCTURAL ANALYSIS

STRUCTURAL DOMAINS IN THE SACRAMENTO VALLEY

As we have shown in preceding sections of this report, late Cenozoic structural features in the valley have diverse orientations and displacement histories. In spite of this diversity, large areas of the valley are characterized by coeval structures that appear to have formed in a similar stress regime. To analyze the late Cenozoic structural evolution of the Sacramento Valley, we have grouped coeval structures that have similar displacement patterns into structural domains (fig. 23).

Delineating the various structural domains obviously depends on correctly identifying and correlating late Cenozoic deposits throughout the valley. Many of the late Cenozoic alluvial deposits are similar in outcrop characteristics, but fortunately they contain or are bracketed by distinctive tephra beds or volcanic flows that allow widespread correlation of alluvial units and provide absolute age control for the alluvial and tectonic histories of the region. In this regard, we have used the following time-stratigraphic units to define the late Cenozoic structural domains of the valley:

Unit	*Age/Age range (m.y.)*	*Reference*
Rockland ash bed	0.4-0.45	Sarna-Wojcicki and others (1985); Meyer and others (1980)
Red Bluff Formation	0.5-1.0	Harwood and others (1981)
Olivine basalt of Deer Creek	1.09	Harwood and others (1981)
Ishi Tuff Member of the Tuscan Formation	2.6	Harwood and others (1981; unpublished data, 1985)
Volcanic rocks of Sutter Buttes	1.4-2.4	Williams and Curtis (1977)
Nomlaki Tuff Member of the Tuscan and Tehama Formations	3.4	Evernden and others (1964)
Putah Tuff Member of the Tehama Formation	3.4	Sarna-Wojcicki (1976)

With the exception of the Dunnigan Hills, the structural domains shown in figure 23 become progressively younger northward through the valley. Late Cenozoic deformation in the Dunnigan Hills domain apparently overlapped that in the Corning domain, but the respective styles of deformation and the inferred stress regimes discussed in a later section differ significantly. This point emphasizes the fact that the structural domains include tectonic features that are homogeneous in time and style of deformation as far as we can determine. To a certain extent, the ages of the structural domains reflect the distribution of the time-stratigraphic units used to identify the major late Cenozoic deformation in a domain. It may be possible to subdivide some domains as more information on the distribution of the younger time-stratigraphic units becomes available. Furthermore, it is important to note that ascribing an age to the late Cenozoic deformation in a domain does not imply that all deformation necessarily began or ended within that time. Many late Cenozoic structural features in the valley formed over earlier structures in the upper Mesozoic or Tertiary rocks, and thus they owe their existence, in part, to tectonic heredity. In some areas, historic low-magnitude earthquakes can be identified with specific structural features such as the Battle Creek fault zone (Bolt, 1979) and Corning fault (Marks and Lindh, 1978), indicating that strain is currently being released on these structures.

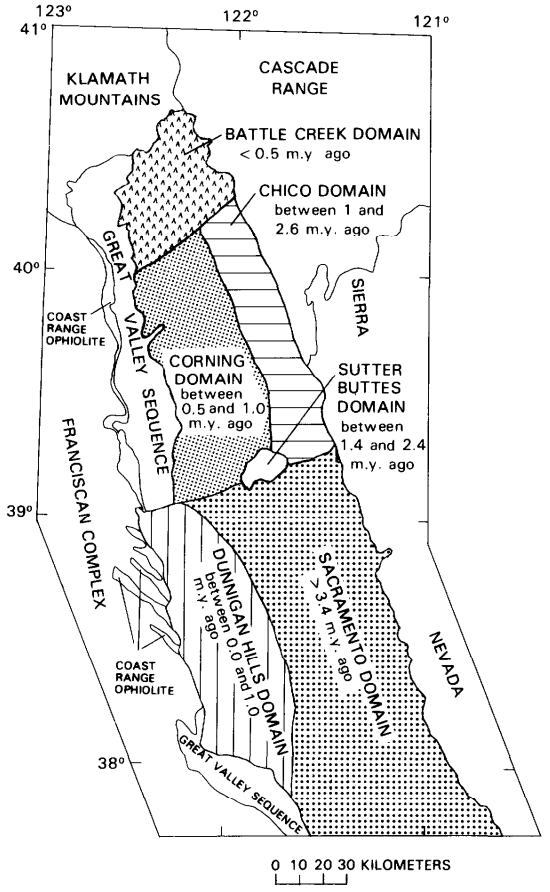


FIGURE 23.—Structural domains in Sacramento Valley. Numbers under domain names give duration or age of deformation that produced late Cenozoic structures in that domain.

SACRAMENTO DOMAIN

The Sacramento domain includes the Stockton fault, the Midland fault, the Thornton anticline, and the possible southeast extension of the Willows fault and other unnamed northwest-trending faults southeast of Sutter Buttes. None of these structures appear to offset or deform late Cenozoic alluvial deposits that are younger than the Nomlaki Tuff Member (figs. 7-10; Silcox, 1968; Teitsworth, 1968).

The minimum age of deformation is difficult to determine. If the Markley submarine canyon was localized, in part, by movement on the southeast extension of the Willows fault, as suggested by figures 8 and 9, then major deformation occurred in the domain in the middle Tertiary and could be as young as early Miocene, which is the upper age of the Markley canyon fill (Almgren, 1978). However, the Pliocene Laguna Formation, which contains the Nomlaki Tuff Member near its base just east of Marysville (Bussaca, 1982), does not appear to be offset in this domain; therefore, we conclude that deformation is older than 3.4 m.y. Upper Cretaceous rocks indicate syndepositional offset on the Stockton fault (Teitsworth, 1968) so the maximum age of deformation is Late Cretaceous.

The Willows fault north of Sutter Buttes (fig. 3) and the faults in Capay Valley (fig. 20) also show protracted deformation, ranging in age from Late Cretaceous to the middle Tertiary, that undoubtedly was contemporaneous with deformation in the Sacramento domain.

SUTTER BUTTES DOMAIN

The complex pattern of folds and faults at Sutter Buttes and the buried Colusa dome was interpreted by Williams

(1929) and Williams and Curtis (1977) to have formed by forceful intrusion of magma between 2.4 and 1.4 m.y. ago. Harwood (1984; this report) suggested that magmatism was localized at Sutter Buttes and the buried Colusa dome by movement on the Willows fault and possibly on the Mesozoic tectonic boundary between oceanic and Sierran basement terranes beneath Sutter Buttes. In this interpretation, deformation in the Sutter Buttes domain occurred through the combined effects of forceful intrusion of magma and east-west compression in a regional stress field.

Deformation in the Sutter Buttes domain may have overlapped in time with deformation in the Chico domain. However, the style of tectonism at Sutter Buttes is unique, and the area must be considered as a separate domain in a regional analysis.

Although Williams and Curtis (1977) suggested that Sutter Buttes formed in roughly half a million years, based on volume and morphology of volcanic deposits, their K/Ar ages for the volcanic complex range from about 1.4 to 2.4 m.y., and we have used that age range as the age of the structural domain.

CHICO DOMAIN

The Chico monocline is the dominant structure in the Chico domain (fig. 23). The monoclinal flexure and the controlling fault at depth (fig. 14) formed after the eruption of the Ishi Tuff Member of the Tuscan Formation, about 2.6 m.y. ago (Harwood, unpub. data, 1984), but before the eruption of the olivine basalt of Deer Creek, about 1.0 m.y. ago (Harwood and others, 1981). Formation of the monocline resulted directly from uplift of the northern Sierra Nevada and rupture along the controlling fault beneath the monocline. On the basis of geophysical evidence (Griscom, 1973; Cady, 1975), it seems reasonably certain that the controlling fault was a major late Mesozoic structure, separating oceanic from magmatic-arc crustal blocks, that was reactivated in the late Cenozoic.

Late Cenozoic tectonic uplift markedly increased erosion in streams antecedent to the monocline from Deer Creek northwest to Salt Creek just east of Red Bluff. Due to their tectonically steepened gradients, these streams deposited coarse, bouldery alluvial fanglomerate composed of volcanic material derived from the Tuscan Formation, extending from the monoclinal arch westward into the valley. The olivine basalt of Deer Creek filled the ancestral channel of Deer Creek east of the monocline and cascaded over the coarse fanglomerate, forming westward-overturned folds at the base of the flow west of the monoclinal flexure.

In Salt Creek and along nearby Hogback Road just east of Red Bluff, the fanglomerate (unit QTog of Harwood and others, 1981) rests unconformably on a partially stripped soil that developed on the Tuscan Formation. The soil indicates a significant period of nondeposition and weathering prior to flexing of the monocline and prior to rapid deposition of the alluvial fanglomerate. A period of erosion also followed deposition of the fanglomerate. The Red Bluff Formation was deposited unconformably on both the Tuscan and fanglomerate in Salt Creek. These stratigraphic relations, coupled with the fact that the Ishi Tuff Member is flexed, eroded, and unconformably overlain by the olivine basalt of Deer Creek along the monocline, establish deformation in the Chico domain between 1.0 and 2.6 m.y. This is clearly before deformation in the Corning domain to the west, where the Red Bluff is significantly folded and faulted.

The orientation of the horizontal compressive stress vector is not closely constrained in the Chico domain. Slickensides on some faults along the monocline flexure have a rake of 35° NW., suggesting some left-lateral oblique slip on the northwest-trending fault system. Whether the slickensides developed at the time the monocline formed or subsequently is unknown, but if they do record strain released during flexing of the monocline, the principal horizontal stress may have been oriented approximately east-west.

CORNING DOMAIN

West of the Chico monocline in an area extending to the Willows fault, late Cenozoic structures range in orientation from northwest to approximately north. The main stem of the Willows fault and the fault along the flank of South Corning dome nearly parallel the trend of the Chico monocline. On the other hand, the Corning fault, the Corning domes, and the Los Molinos and Glenn synclines trend more northerly than the monocline and converge on that structure near Red Bluff. All of these structures, within the Corning domain (fig. 23), deform the Red Bluff Formation and thus postdate the flexing of the Chico monocline. However, the subparallel orientation of structures in the Corning domain northeast of the Willows fault and of those in the Chico domain suggests that all may have formed in a common stress field.

The maximum horizontal compressive stress probably was oriented approximately east-west, normal to the trace of the Corning domes. The Corning fault might represent one shear diagonal of the strain ellipse, and the northwest-trending faults would indicate the other shear diagonal. In this model, strain release would have migrated westward with time, beginning along the Chico monocline and later moving to the Corning domes and Corning fault. Clearly, some offset may have occurred on the Corning fault and the northwest part of the Willows fault during formation of the monocline, and the small amount of offset in the olivine basalt of Deer Creek over the monocline may have occurred during the upwarping of the Red Bluff

Formation over the Corning domes.

The area of the Corning domain southwest of Sutter Buttes and the Willows fault is largely capped by Holocene basin deposits that lap westward onto Upper Cretaceous rocks along the western margin of the valley. These deposits could obscure many structures that might be recorded in the Red Bluff Formation in that area, indicating that the downthrown side of the Willows fault has been a structural basin throughout most of the late Quaternary.

DUNNIGAN HILLS DOMAIN

The Dunnigan Hills domain (fig. 23) includes the Zamora fault, the Dunnigan Hills anticline, the Madison syncline, and the tectonically complex area of Capay Valley and the Capay Hills. The Red Bluff Formation is folded by the Dunnigan Hills anticline and offset by the Zamora fault along the east margin of the Dunnigan Hills (fig. 20). Therefore, the late Cenozoic structures in that area are at least as young as the folds and faults in the vicinity of Corning domes, and they could be younger. Because there is no clear evidence for the minimum age of structures in the domain, we assume that late Cenozoic deformation ranges from 1.0 m.y. to the present.

Although the late Cenozoic deformation may overlap in time with that in the Corning and Battle Creek domains, the orientation and movement pattern of structures are significantly different. The northwest-trending axial surface of the Dunnigan Hills anticline and normal displacement on the northwest-trending Zamora fault suggest that these structures may have formed in a stress field in which the maximum horizontal compressive stress was oriented approximately north-south and the least horizontal compressive stress (maximum extension) was oriented approximately east-west. Because this is the present orientation of the stress field associated with the San Andreas fault in this area (Zoback and Zoback, 1980), late Cenozoic structures in the Dunnigan Hills domain may be related to right-slip wrench tectonism associated with movement on the San Andreas fault system (Allen, 1981).

BATTLE CREEK DOMAIN

The Battle Creek domain (fig. 23) is the youngest structural domain and occurs at the northern end of the valley. It is characterized by northeast-trending folds and faults oriented nearly perpendicular to the north- and northwest-trending structures of other domains to the south.

Late Cenozoic displacement on the northeast-trending, steeply south-dipping faults is invariably down to the south, with a suggestion of minor right-lateral slip on the Battle Creek fault system (Helley and others, 1981). The amount of horizontal separation on the Battle Creek fault is unknown, but it probably is on the order of a few tens of meters to a few hundred meters at the most. The Bear Creek and Red Bluff faults are not exposed well enough to establish or refute the occurrence of late Cenozoic horizontal slip on those structures. The amount of vertical displacement increases eastward along the Battle Creek fault zone, with about half of the vertical separation of units caused by broad anticlinal folding and half by fault displacement (fig. 17). Vertical separation of late Cenozoic units on the Bear Creek and Red Bluff faults is also accomplished partly by folding.

These observations, plus the fact that the Inks Creek fold system appears to be genetically related to folding and faulting on the Battle Creek fault zone, indicate that the structures in the Battle Creek domain formed either by northwest-southeast horizontal compressive stress or by right-lateral shear stress. Strain was released initially by folding, followed by rupture and predominantly normal fault displacement. Initial movement on the Battle Creek fault zone postdated deposition of fanglomerate, which is correlated with the Red Bluff Formation, and the fault scarp restricted movement of the proximal ash-flow part of the Rockland ash bed. Deformation younger than 0.45 m.y. is indicated by distribution of the early Riverbank-age alluvial deposits north of the Battle Creek fault zone and in the tectonically controlled loops of the Sacramento River around the Inks Creek fold system. The late Cenozoic structures in the Battle Creek domain formed in the past half million years.

Little surface evidence is available to document deformation before the late Cenozoic in the Battle Creek domain. A detailed analysis of paleomagnetic directions and lithofacies in the Upper Cretaceous marine rocks and Eocene continental rocks, which locally overlie the Cretaceous rocks, might provide data to resolve this question, but we did not pursue these studies. In the light of recent paleomagnetic studies (Simpson and Cox, 1980; Beck and Plumley, 1980; Magill and Cox, 1981), which suggest a two-phase, clockwise rotation of the Oregon Coast Ranges and possibly of the Klamath Mountains in Eocene and post-Oligocene times, we believe the Battle Creek domain may be a zone of decoupling between the Klamath Mountains and Oregon Coast Ranges provinces to the north and the Sacramento Valley-Sierra Nevada provinces to the south.

VALLEY STRUCTURES RELATED TO REGIONAL STRESS PATTERNS

With the exception of structures in the Dunnigan Hills domain and recent movement on the Cleveland Hills faults, late Cenozoic folds and faults in the Sacramento Valley appear to have formed in an east-west compressive stress regime. The north- and northwest-trending

Willows, Corning, and Chico monocline faults dip steeply east and show reverse displacements. The east-northeast-trending Red Bluff, Battle Creek, and Bear Creek faults dip steeply south and have normal offsets. The axial traces of many folds are parallel to the trends of adjacent faults, and the folding appears to be related to drag on those faults. The amount of lateral displacement on faults in the valley is difficult to determine, but the rake of slickensides and the orientation of ancilliary fractures suggest minor left-lateral movement on the northwest-trending Chico monocline fault and minor right-lateral slip on the east-northeast-trending Battle Creek fault zone. These kinematic patterns are consistent with a regional stress field in which the maximum horizontal component of compressive stress is oriented about N. 75° E. (Harwood, 1984).

The late Cenozoic kinematic pattern and inferred east-west compressive stress regime in the Sacramento Valley appear to be anomalous with respect to contemporary tectonism in adjacent regions. In the California Coast Ranges to the west and in the northern Basin and Range province to the east, north-trending faults generally show normal and right-lateral displacements, east-trending faults show reverse and left-lateral movement, and northwest- and northeast-trending faults show dominantly right-lateral and left-lateral displacement, respectively (Zoback and Zoback, 1980; Hill, 1982). From these kinematic patterns, as well as earthquake focal-plane solutions, and in-situ stress measurements, Zoback and Zoback (1980) and Hill (1982) inferred that the maximum horizontal compressive stress was oriented approximately north-south and the least horizontal compressive stress (maximum extension) was oriented approximately east-west. Hill (1982) related the contemporary stress patterns to movement between the North American and Pacific plates and visualized the western part of the North American plate as a continuous broad zone of deformation following the model first proposed by Atwater (1970).

East-west compressive deformation in the Sacramento Valley suggests that the late Cenozoic stress field was not homogeneous between the continental margin and the northern Basin and Range province. Instead, the Sacramento Valley apparently acted as an independent block where relatively small-scale compressive strain was periodically released in response to large-scale right-lateral transform tectonism in the San Andreas fault zone to the west and major east-west crustal extension in the northern Basin and Range province to the east.

Furthermore, the well-dated deformation patterns in the Sacramento Valley indicate that the compressive strain was not released randomly but, rather, that the late Cenozoic structural features formed in a sequential pattern that is progressively younger to the north. Northward progression of the compressive deformation implies a northward-migrating stress regime or a migrating energy source sufficient to initiate deformation in a regional compressive stress field. The interaction of lithospheric plates along the continental margin appears to provide a reasonable mechanism for generating the sequential compressive strain release observed in the valley.

Successive positions of the Mendocino transform, extrapolated backward in time to 4.0 m.y. at a rate of 5.5 cm/yr (Atwater and Molnar, 1973), are shown relative to the late Cenozoic structural domains in the Sacramento Valley in figure 24. Each domain is characterized by a particular set of late Cenozoic structural features that formed during a definite period of time. The time of deformation in the structural domains is linked to respective positions of the Mendocino transform by corresponding patterns on figure 24. Compressive deformation in the Sacramento domain occurred prior to eruption of the Nomlaki and Putah Tuff Members of the Tehama Formation about 3.4 m.y. ago, but we are unable to correlate movement on specific structures in that domain with relative plate motions shown by successive positions of the Mendocino transform. Beginning with magmatism and deformation in the Sutter Buttes domain about 2.4 m.y. ago, however, reasonable correlation exists between the position of the Mendocino transform and progressive east-west compressive deformation in the Sacramento Valley. This correlation clearly reflects the availability of geologic information that dates deformation in the northern part of the valley, but it may also reflect a greater degree of tectonism in the valley over the past 2.4 m.y. that was related to increased tectonism ahead of the advancing Mendocino triple junction (fig. 24).

According to Silver (1971), an episode of major bending and fracturing occurred in the Juan de Fuca plate (fig. 24) between 2.5 and 0.5 m.y. ago. This deformation apparently increased the north-south compressive stress ahead of the advancing Mendocino triple junction and caused underthrusting of oceanic crust in the Juan de Fuca plate beneath the Mendocino transform. Dickinson and Snyder (1979a) suggested that this type of instability at the Mendocino triple junction would increase the east-west extensional stress in the vicinity of the triple junction and possibly cause eastward migration of right-slip strain release along the San Andreas fault zone. Internal deformation of the Juan de Fuca plate also may have changed the rate and relative motion of the subducted part of that plate relative to the North American plate sufficiently to initiate magmatism at Sutter Buttes and at the Pliocene volcanic centers of Mount Yana and Mount Maidu (fig. 24) (Lydon, 1968) about 2.4 m.y. ago. Subsequent relative movement of the North American plate southwestward from its position above the subducted Juan de Fuca slab, over the eastern projection of the Mendocino transform and onto the area of the slab

window of Dickinson and Snyder (1979b), may have initiated progressive deformation in the Sacramento Valley north of the Sutter Buttes domain.

According to Dickinson and Snyder (1979b), an expanding, triangular-shaped region, which they called the slab window, has developed east of the lengthening San Andreas transform since the rise-trench encounter about 20 m.y. ago. As the slab window expanded, upwelling asthenosphere came into contact with the base of the North American crust producing an expanding region of Neogene extensional tectonism. The northern boundary of the slab window, which is the eastern projection of the Mendocino transform, migrated northward as a consequence of the northward migration of the Mendocino triple junction and relative motion between the North American and Juan de Fuca plates. Successive positions of the northern boundary of the slab window beneath the Sacramento Valley for the past 2.5 m.y. are shown in figure 25.

About 2.5 m.y. ago, the northern boundary of the slab window was located approximately at the latitude of Sutter Buttes (fig. 25*A*). As the North American plate moved southwestward relative to the Juan de Fuca plate, the base of the valley crust near Sutter Buttes moved off the subducted ocean crust of the Juan de Fuca plate and encountered asthenophere in the slab window. This change in thermal regimes at the base of the valley crust possibly reactivated the Willows fault and the ancient tectonic boundary between ophiolitic basement rocks and the Sierran basement rocks, allowing magma to rise and differentiate below Sutter Buttes and the buried Colusa dome. Subsequent southwestward relative movement of the North American plate exposed an increasing area of the Sacramento Valley and northern Sierra Nevada crustal blocks to the higher thermal regime of the slab window. Basaltic volcanism erupted in the Tahoe-Almanor graben (fig. 25*A*) north of Lake Tahoe soon after magmatism began at Sutter Buttes (Dalrymple, 1964). Ac-

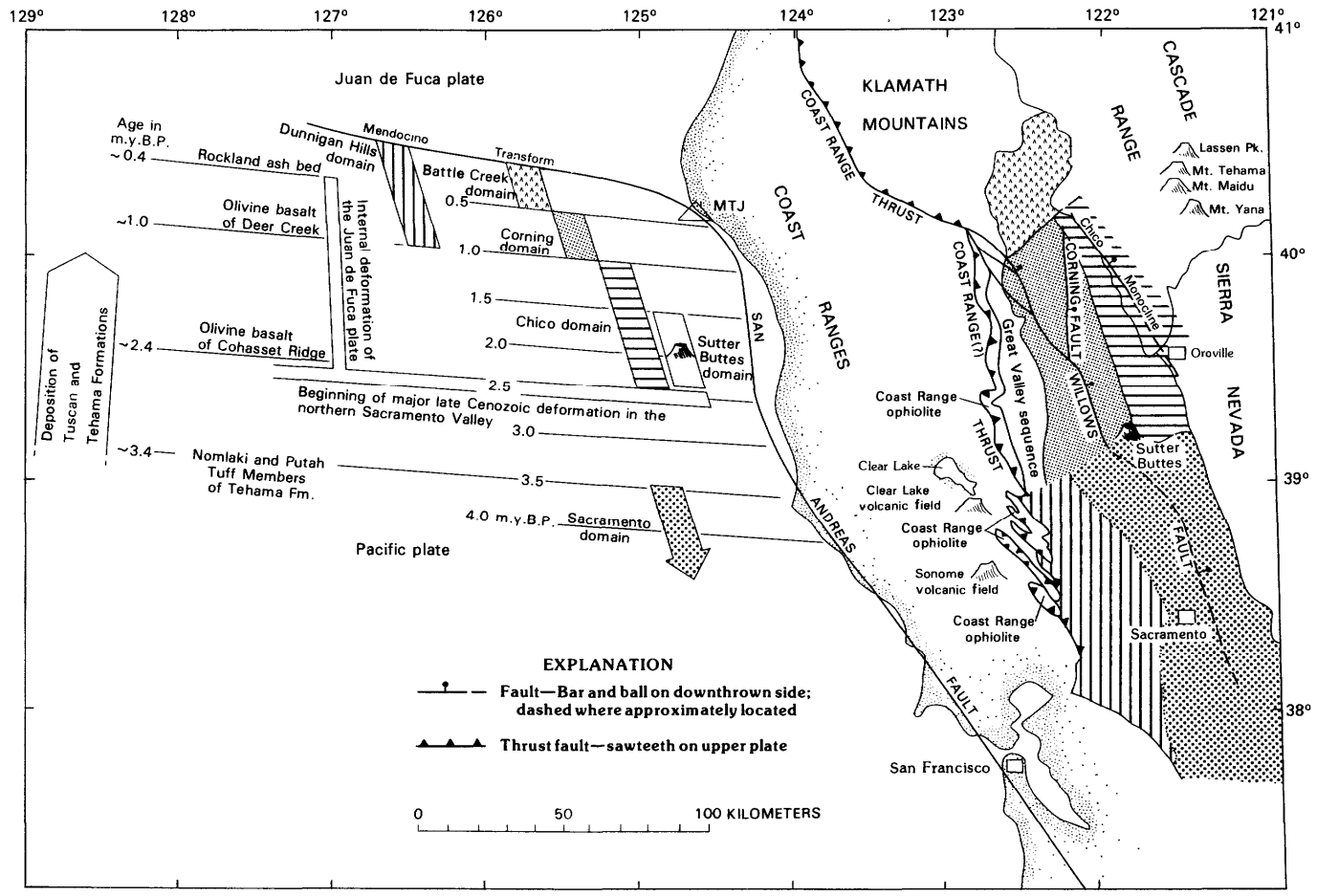
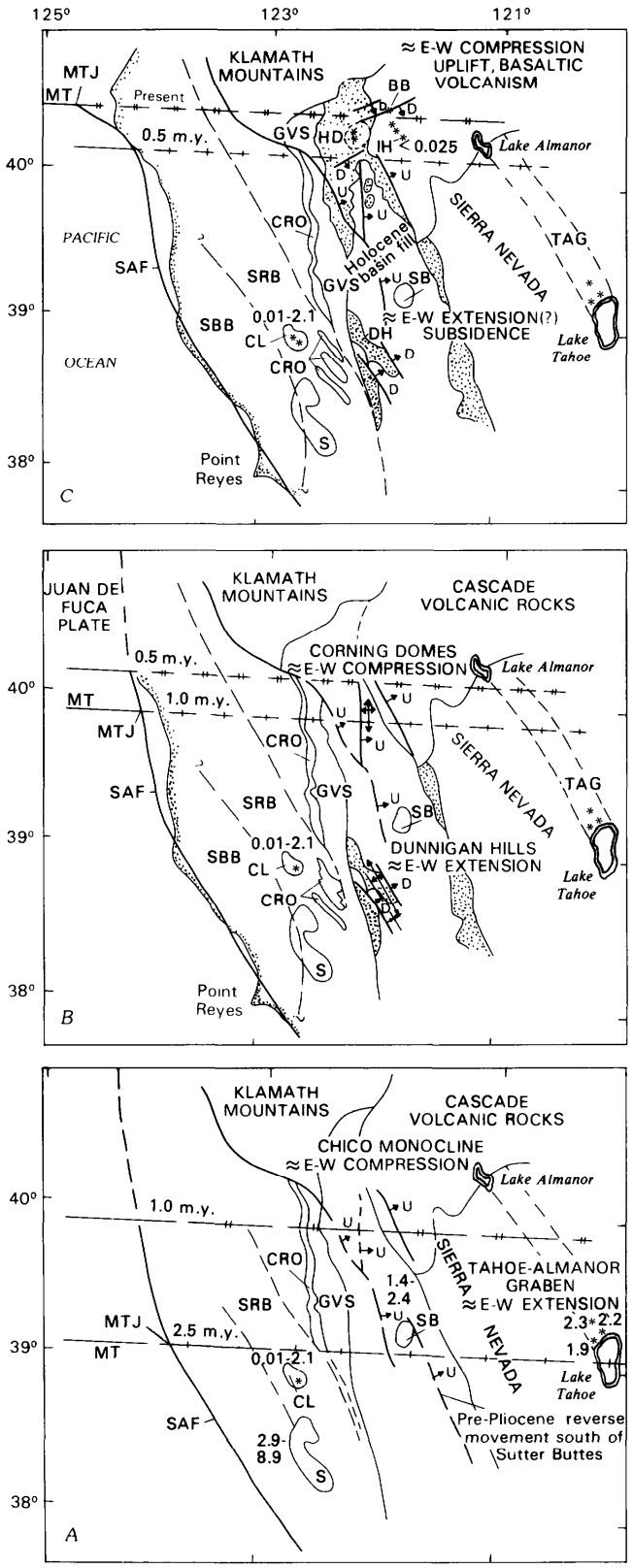


FIGURE 24.—Map of northwestern California relating late Cenozoic structural features and structural domains (patterned) to inferred position of the Mendocino triple junction (MTJ) during time structures formed. Position of Mendocino transform shown in 0.5-m.y. increments during past 4.0 m.y. Dated volcanic units used to bracket age of deformation in Sacramento Valley shown at left.



celerated uplift of the Sierra Nevada, which began about 3.0 m.y. ago in the central part of the range (Huber, 1981; Slemmons and others, 1979), eventually caused rupture between 2.5 and 1.0 m.y. ago along the Mesozoic fault that separates valley and Sierran blocks beneath the Chico monocline. Volcanism at Clear Lake (fig. 25), which began about 2.1 m.y. ago (Donnelly-Nolan and others, 1981), lagged behind passage of the northern boundary of the slab window and has continued nearly to the present.

Between 1.0 and 0.5 m.y. ago (fig. 25*B*), exposure of the base of the valley crust to the slab window may have reactivated the basement fault in the vicinity of the Corning domes, resulting in east-west compressional tectonism. Wrench tectonism and related east-west extension apparently started to affect the southwestern part of the valley after creating a zone of high shear strain in the Santa Rosa block (Fox, 1983), located in the eastern part of the Coast Ranges province. This is the earliest evidence of east-west extensional tectonism found in the valley and suggests a delay time of about 2.5 m.y. between passage of the slab-window boundary and production of recognizable extensional structures.

In the past 0.5 m.y., the northern boundary of the slab window has passed beneath about half of the Battle Creek domain (figs. 24, 25*C*). The morphology of the valley in the Battle Creek domain, therefore, may reflect recent,

EXPLANATION

- Pliocene and Pleistocene alluvium
- * Volcanic center at—
  - BB Black Butte
  - IH Inskip Hill
  - HD Hooker dome
  - CL Clear Lake
  - SB Sutter Buttes
  - S Sonoma volcanic field
- TAG Tahoe-Almanor graben
- MT Mendocino transform
- MTJ Mendocino triple junction
- SAF San Andreas fault
- SBB Sebastopol block
- SRB Santa Rosa block
- CRO Coast Range ophiolite
- GVS Great Valley sequence
- DH Dunnigan Hills
- 1.4-2.4 Numbers indicate age or time of formation of feature, in millions of years. ≈ means approximate
- Contact—Dashed where inferred
- Fault—Dashed where inferred; arrow indicates dip
- D Normal—D, hanging wall
- U Reverse—U, hanging wall
- Doubly plunging anticline
- Syncline

FIGURE 25.—Sketch maps of northwestern California showing inferred positions of northern boundary (barbed dashed lines) of slab window of Dickinson and Snyder (1979b) at about 2.5 and 1.0 m.y. (*A*), 1.0 and 0.5 m.y. (*B*) and 0.5 m.y. and present (*C*).

and possibly on-going, structural changes in the deeper parts of the valley fill and basement caused in part by changes in the thermal regime beneath the thick valley crust. This hypothesis was investigated by Helley and Jaworowski (1983), who used the distribution of the Red Bluff pediment as a surface indicator of deeper valley structures. The elevation of the floor rises abruptly north of Red Bluff, and the dissected uplands expose the Pliocene Tehama Formation that is unconformably capped by remnants of the Red Bluff Formation. Drainage patterns reflect local structures, such as Hooker dome (fig. 18), and major creeks locally follow the dominant northeast structural trends. The gradient of the Sacramento River steepens significantly across the Battle Creek domain, and its incised meanders are structurally controlled. Many of these geomorphic features are preserved, in somewhat more subdued form, around Corning domes and elsewhere in the valley south of Red Bluff (Helley and Jaworowski, 1985).

The northeast-trending Inks Creek fold system and the folding associated with the Battle Creek and Red Bluff faults suggest a northwest-southeast compressive stress system. If such is the case, however, normal displacement on the Bear Creek, Battle Creek, and Red Bluff faults are anomalous. The structural features in the Battle Creek domain may reflect a stress regime in which the maximum horizontal compressive stress (east-west) and the least horizontal compressive stress (north-south) vectors are more nearly equal. This inferred change in the stress pattern may be caused by oblique subduction of the Juan de Fuca plate and the possible buttressing effect of the Klamath Mountains on deformation in the northernmost part of the Sacramento Valley.

CONCLUSIONS

Kinematic patterns of late Cenozoic structural features in the Sacramento Valley differ significantly from those in the Coast Ranges province to the west and the northern Basin and Range province to the east. Certainly for the past 2.5 m.y., and probably much longer, deformation in the valley has occurred in a regional stress field in which the maximum horizontal component of compressive stress was oriented approximately east-west and the minimum component of compressive stress (maximum extension) was oriented approximately north-south. Within this stress regime, strain has been released primarily by reverse movement on north- and northwest-trending high-angle faults and associated folding in the sedimentary rocks of the valley fill. This style of deformation contrasts sharply with the pattern of northwest-trending en echelon folds and pull-apart basins, and east-west oriented thrust faults associated with large-scale right-lateral displacements on the San Andreas fault system (Blake and others, 1978; Graham, 1978; Harding, 1976; McLaughlin, 1981; Page, 1981) and the pattern of pervasive normal faulting, widespread volcanism, and large-scale east-west extension in the Basin and Range province (Christiansen and Lipman, 1972; Lipman and others, 1972; Zoback and others, 1981). During the late Cenozoic, the Sacramento Valley appears to have acted as an independent block on which relatively small-scale compressive deformation was imposed by eastward-directed subduction that was followed by large-scale transform tectonism along the continental margin and major east-west crustal extension in the Basin and Range. Early Tertiary deformation on the Willows fault and in the area of Capay Valley may be related to eastward tectonic wedging of the Franciscan Complex described by Wentworth and others (1984).

Tectonic heredity appears to have played a significant role in late Cenozoic deformation in the Sacramento Valley. Many of the faults that break or drape the upper Cenozoic deposits are located over pre-existing structures within and at the boundaries of basement blocks that were tectonically juxtaposed and broken during the Mesozoic and early Tertiary. The tectonic boundary between ophiolitic and Sierran basement rocks apparently has been reactivated beneath the Chico monocline and the possible southeast extension of the Willows fault. The Corning fault occurs over a Mesozoic fault within the ophiolitic basement terrane.

Within the past 2.5 m.y., at least, late Cenozoic east-west compressive deformation has progressed northward so that structures observed in the Battle Creek domain are a million years younger than those around Sutter Buttes. The northward progress of late Cenozoic deformation correlates with extrapolated positions of the Mendocino transform. Deformation may have been initiated by thermal changes in the valley basement as the North American plate moved relatively southwestward off the subducted oceanic crust of the Juan de Fuca plate and over asthenosphere in the slab window proposed by Dickinson and Snyder (1979b). During this sequential deformation, the relative magnitude of the horizontal compressive stress vectors appears to have changed. The kinematic pattern of structures south of Red Bluff suggests that east-west compression was dominant ($S_{maxEW} >> S_{minNS}$) and resulted in high-angle reverse faulting. However, the horizontal compressive stresses appear to have been more nearly equal ($S_{maxEW} \cong S_{minNS}$) in the Battle Creek domain causing northeast-trending folds and normal displacements on east-northeast-trending faults.

Northwest-trending folds and normal displacement on the Zamora fault suggest that east-west extension may have affected the southwestern part of the valley during the past million years, when east-west compressive deformation was occurring in the Corning domain. Focal-plane solutions constrained by geologic data in the Clear

Lake area indicate that the maximum compressive stress in the Coast Ranges is presently oriented approximately north-south (Bufe and others, 1981). These data, coupled with the observation that right-lateral tectonism is more intense in the Coast Ranges adjacent to the Dunnigan Hills domain than it is to the west or north (Fox, 1983), suggest that late Cenozoic deformation in the Dunnigan Hills domain was related to wrench tectonism on the San Andreas fault system. If such is the case, the beginning of right-lateral wrench tectonism in the valley appears to have lagged behind the northward migration of the Mendocino triple junction by about 2.5 m.y. A similar delay was noted between the migration of the triple junction and the build-up of maximum heat flow in the Coast Ranges by Lachenbruch and Sass (1980).

The well-dated and diverse deformation patterns in the Sacramento Valley indicate that late Cenozoic tectonism evolved through the region in response to major crustal movements outside the valley's physiographic boundaries. East-west compressive tectonism may have been imposed on the valley by eastward subduction of the Juan de Fuca plate, and consequent tectonic wedging of the Franciscan Complex coupled with a major component of westward stress due to east-west extension in the Basin and Range province.

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APPENDIX—*Wells with electric well-log data shown in cross sections*

Well no.	Operator	Well name	Sec.-T.-R.
	Wells on figure 3		
1.	Texaco	Cross No. 1	27-20N.-3W.
2.	Franco Western Oil Co.	Dunlap 36-1	36-20N.-3W.
3.	Marathon Oil Co.	Capital Co. No. 1	30-20N.-2W.
4.	R. W. McBurney	Westpet Sunray McBurney Capitol No. 1	30-20N.-2W.
5.	Mobil Oil Corp.	Capital Co. No. 30-1	30-20N.-2W.
6.	Mobil Oil Corp.	Section 29 Unit No. 4	29-20N.-2W.
7.	R. W. McBurney	Section 29 Unit No. 2	29-20N.-2W.
8.	Mobil Oil Corp.	Section 48 Unit No. 4	21-20N.-2W.
9.	Mobil Oil Corp.	Section 48 Unit No. 1	21-20N.-2W.
10.	Standard Oil Co.	Doheny N. G. Unit No. 1	22-20N.-2W.
11.	Mobil Oil Corp.	Section 46 Unit No. 2	27-20N.-2W.
12.	Bettie A. McBurney	Reserve McBurney Unit S1 No. 1	26-20N.-2W.
13.	Bettie A. McBurney	Section 52 Unit No. 3	25-20N.-2W.
14.	Neaves Pet. Devel. Co.	Neaves Capital 53-1	32-20N.-1W.
15.	Mobil Oil Corp.	Dano Seco No. 1	33-20N.-1W.
16.	Calif. Time Pet. Inc.	Butte Dano Seco No. 4	34-20N.-1W.
	Wells on figure 7		
1.	Occidental	Zumwalt K-2	12-13N.-1E.
2.	Shell	Strat. test well	31-14N.-2E.
3.	G. E. Kadane & Sons	Lamb No. 1	30-14N.-2E.
4.	Atlantic	AMKH et al	28-14N.-2E.
5.	Atlantic	Continental Stent No. 1	15-14N.-2E.
6.	Kenneth L. Sperry	Shannon No. 1	10-14N.-2E.
7.	Exxon	Shannon No. 1	14-14N.-2E.
8.	Pearson Sibert	Tom No. 1	5-14N.-3E.
	Wells on figure 8		
1.	Sun Oil Co.	SMC Cameron Dougherty No. 1	31-12N.-3E.
2.	McCulloch Oil & Gas Corp.	McCulloch-Magoon et al. No. 1	32-12N.-3E.
3.	Davis Oil Co.	Aileen Marty No. 1	35-12N.-3E.
4.	Davis Oil Co.	Van Dyke No. 1	35-12N.-3E.
5.	Decalta Int. Corp.	Osterli No. 3	31-12N.-4E.
6.	Sun Oil Co.	Lenert No. 55-29	29-12N.-4E.
7.	Kenneth L. Sperry	Davis No. 1	21-12N.-4E.
8.	Plateau Oil & Gas Co.	Van Dyke No. 1	24-12N.-4E.
9.	Exxon	Bonnefeld No. 1	10-12N.-5E.

Well no.	Operator	Well name	Sec.-T.-R.
	Wells on figure 9		
1.	Rocky Mtn. Drilling Co.	Murdoch No. 1	27-7N.-4E.
2.	McCulloch Oil & Gas Corp.	Scribner No. 1	27-7N.-4E.
3.	Chevron	Correa No. 1	24-7N.-4E
4.	Neaves Pet. Devel. Co.	Neaves-Standard Oil Sims No. 3	18-7N.-5E.
5.	Chevron	Sims Comm. No. 2	18-7N.-5E.
6.	Calif. Expln. Co.	Sacramento Unit A	16-7N.-5E.
7.	Union Oil Co. of Calif.	Union Dow Attorney General No. 1	13-7N.-5E.
8.	Intex Oil Co.	Unit plan No. 1	19-7N.-6E.
9.	D. D. Feldman	Unit plan No. 1	8-7N.-6E.
10.	Norris Oil Co.	Waegell No. 1	6-7N.-7E.
	Wells on figure 10		
1.	Shell Oil Co.	Shell-Brevelli No. 1	4-4N.-6E.
2.	Amerada Hess Corp.	Comm. 1-2	2-4N.-6E.
3.	Amerada Hess Corp.	Comm. 1-1	1-4N.-6E.
4.	Aminoil USA, Inc.	Comm. 2-1	12-4N.-6E.
5.	Union Oil Co. of Calif.	V-B-G No. 1	7-4N.-7E.
6.	Amerada Hess Corp.	Lodi Comm. 8-1	8-4N.-7E.
7.	Amerada Hess Corp.	Lodi Comm. 9-1	9-4N.-7E.
8.	Shell Oil Co.	Ferrera No. 1-10	10-4N.-7E.
9.	Ben Owens Drilling Co.	Thompson No. 1	11-4N.-7E.
	Wells on figure 14		
1.	Solar Drilling Co.	Solar-McElroy-Crawford No. 1	5-23N.-1W.
2.	Pacific Western	Cana No. 1	11-23N.-1W.
3.	Exxon	G. U. Roney No. 1	1-23N.-1W.
4.	Exxon	C. C. Baccala No. 1	28-24N.-1E.
	Wells on figure 20		
1.	Neaves Pet. Devel. Co.	Neaves-Cobb No. 1	11-10N.-3W.
2.	Empire Oil and Gas Co.	Porterfield No. 1	18-10N.-2W.
3.	Texaco, Inc.	Esparto c.h. No. 2	17-10N.-2W.
4.	Dow Chemical Co.	Duncan No. 1	9-10N.-2W.
5.	Gulf Oil Corp.	A. B. Stevens No. 1	7-10N.-1W.
6.	Atlantic Oil Co.	Irrigated Valley Land No. 1	4-10N.-1W.
7.	A. A. Hopkins, Jr.	Manler No. 62-3	3-10N.-1W.
8.	C. K. M. Oil Co.	Mast No. 1	35-11N.-1W.
9.	Gulf Oil Corp.	L. M. Bemmerley No. 1	36-11N.-1W.
10.	E. B. Towne	Slaven No. 1	30-11N.-1W.
11.	Arco	Reiff No. 1	29-11N.-1W.
12.	Arco	Hermle No. 1	15-11N.-1E.

GPO 785-048/77389

Corin Choppin

From: B&S Wiggin <bwsw@frontier.com>
Sent: Thursday, December 17, 2020 11:05 AM
To: Mary Fahey
Subject: RE: Groundwater list

CAUTION: This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Mary,
One of our concern is on Sand Creek. 50 years ago that Creek spread out very wide & we believe that gave us recharge for our underground water. The county allowed gravel removal & the bank is now about 10 feet lower than it used to be, making the channel very narrow & the water runs very fast. We can't do anything about it because of Fish & game. They will allow some low berms as long as one side has no berm. This isn't much help.
Sharon Wiggin

From: Mary Fahey <mfahey@countyofcolusa.com>
Sent: Thursday, December 17, 2020 7:27 AM
To: Sharon Brett Wiggin <bwsw@frontier.com>
Subject: Groundwater list

Hi Sharon
Got your message. I have put you on the mailing list. Looks like I had an incorrect email for you previously.
If you're interested, you can take a look at the Colusa Groundwater Authority website for information, agendas, minutes, etc.
https://colusagroundwater.org

You will also receive the agendas via email now that I've got your correct email.
Thank you,
Mary

Mary Fahey
Water Resources Division Manager, County of Colusa
Colusa County Water Resources website
Program Manager, Colusa Groundwater Authority
colusagroundwater.org
530.458.0719

From: Ben King <bking@pacgoldag.com>
Sent: Wednesday, December 9, 2020 7:15 PM
To: Ceppos, David M <dceppos@csus.edu>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; Ben King <bking@pacgoldag.com>
Subject: Subsidence Comment

Hi David,

In the interest of time I want to submit my comment about what should be critical infrastructure for the Subsidence Indicator.

As I mentioned in a previous meeting I would suggest that our most critical infrastructure is the transportation infrastructure of I-5 and the residential infrastructure of Arbuckle including the Arbuckle cemetery. The cemetery is very close to the greatest level of subsidence and I -5 crosses adjacent to the area of greatest subsidence.

I believe we have to look at the potential for multi-feet subsidence over decades and we need to look at the subsidence potential in the context of historical events. The most significant natural disaster for the west side of California was the San Francisco earthquake which was recorded at 7.9. My concern is that continued subsidence and the occurrence of a major earthquake on the western side of the Coast Range could cause significant movement in the stream bed gravels and aquifers beneath I-5. Historically the 1906 earthquake was known to affect natural springs that stop flowing around Williams and also caused damage to the Colusa Lake Railroad which ran between Colusa to Sites from Lurline Road West and then northerly toward Sites.

This concern would also impact the Tehama Colusa Canal especially at points where it was built across gulleys in the Colusa foothills – especially since the Tehama Colusa Canal is aging infrastructure.

Thank you

Ben

From: Ben King <bking@pacgoldag.com>
Sent: Wednesday, December 9, 2020 6:31 PM
To: Ceppos, David M <dceppos@csus.edu>
Cc: Ben King <bking@pacgoldag.com>; Mary Fahey <mfahey@countyofcolusa.com>; Ben King <bking@pacgoldag.com>
Subject: Drinking Water Arsenic Contamination

Hi David,

Here is the background information about the arsenic contamination present in the drinking water systems of Grimes, Colusa and Princeton.

The Grimes contamination is documentation in the CA Arsenic Report on Page 21 – Colusa Co. WWD # 1 - 23.9 ug/L

The Colusa contamination resulted in the abandonment of two wells and one SWRCB Compliance Order in 2010 and an abandonment of a well in 2017. These wells are located at the Southern portion of the City of Colusa. The Walnut Ranch attachment refers to the 2010 Compliance Order and the Walnut Ranch Arsenic Remediation attachment.

The Princeton Arsenic level observations are referred in the Princeton Attachment. It is my understanding that the Arsenic level is approximately 18 ug/L.

I should note that groundwater quality around the Sutter Buttes has observed arsenic levels as high as 370 ug/L. This is highlighted in Figure 19 in the Sutter County Groundwater Management Plan Figures attachment. The Sutter County GMP describes the extent of the Sutter Buttes Rampart which is estimated as a 10 to 15 mile radius. This radius would include the groundwater drinking source aquafer.

Thanks for your coordination.

Best Regards,

ARSENIC IN CALIFORNIA DRINKING WATER

Three Years After EPA Notice of Noncompliance to State, Arsenic Levels Still Unsafe in Drinking Water for 55,000 Californians



ENVIRONMENTAL INTEGRITY PROJECT

SEPTEMBER, 2016

ACKNOWLEDGEMENTS

This report was researched and written by Tom Pelton, Courtney Bernhardt, and Eric Schaeffer of the Environmental Integrity Project. The map was created by Kira Burkhart and the graphics by Alana Natke.

THE ENVIRONMENTAL INTEGRITY PROJECT

The Environmental Integrity Project (http://www.environmentalintegrity.org) is a nonpartisan, nonprofit organization established in March of 2002 by former EPA enforcement attorneys to advocate for effective enforcement of environmental laws. EIP has three goals: 1) to provide objective analyses of how the failure to enforce or implement environmental laws increases pollution and affects public health; 2) to hold federal and state agencies, as well as individual corporations, accountable for failing to enforce or comply with environmental laws; and 3) to help local communities obtain the protection of environmental laws.

For questions about this report, please contact EIP Director of Communications
Tom Pelton at (202) 888-2703 or
tpelton@environmentalintegrity.org.

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Arsenic in California Drinking Water

More than three years after the U.S. Environmental Protection Agency found California in noncompliance with the federal Safe Drinking Water Act, 95 community water systems in the state, serving more than 55,000 people, are still providing water with illegal levels of arsenic, according to an examination of state data for the last two years.[1] Arsenic occurs naturally in the soil and groundwater in parts of California and is a known carcinogen that may also damage the developing brains of children and cause other health problems.[2] Many of the people drinking excessive levels of arsenic are poor and/or Latino or African-American, with a cluster in the San Joaquin Valley.[3] Nearly all have been exposed to excessive arsenic levels for at least five years and probably longer.[4]

California requires public water systems to notify their customers when arsenic fails to meet federal health standards. But strangely, the state's language for mailed advisories suggests the water is still safe to drink no matter how high the contimation levels or how long they persist, with the notices telling residents: "You do not need to use an alternative water supply (e.g., bottled water)." [5] That advice conflics with what California tells private well owners (who aren't covered by federal standards) on a state website: "If you suspect that your well may have arsenic, you should not use the water until it is tested, and you take appropriate measures to protect yourself and your family from potential chronic health effects if arsenic is present."[6] Whatever the intention, California's language for people on public water systems is likely to encourage them to drink contaminated water. (For the full text of the California's language, see Appendix A). As the state continues a multi-year effort to solve the contamination problem, it should immediately fix a communications problem so that it clearly warns people not to drink arsenic-tainted tap water.

The highest levels of arsenic in drinking water in California from 2011 through 2015 were in a group home for troubled teenage boys, the Valley Teen Ranch in Madera County. About 50 boys assigned by the courts to the facility have been living in a home with water that has arsenic at concentrations averaging more than 12 times the federal limit (10 parts per billion, or ppb) over these five years, according to state records.[7] "Nobody wants to drink the water because it's brown and nasty,"said Connie R. Clendenan, CEO of the nonprofit organization that runs the group home.[8] "It looks bad."



It is bad. Although California has made substantial progress in addressing

drinking water problems, the state still has 13 school districts, serving a total of 8,822 students, with arsenic in their drinking water that exceeded the federal limit from 2011 to 2015.[9] Twelve mobile home parks in California, serving 889 people, had arsenic in their tap water that averaged up to five times the legal limit. The average annual concentrations of arsenic in the drinking water of 58 residential communities (other than trailer parks) exceeded the legal limit during this time period, as did a military base, three wineries, two food preparation businesses and two campgrounds.

In many of the schools, the group home and military base, administrators say they verbally warn people not to drink tap water. They also provide bottled water as an alternative. But in the residential neighborhoods and trailer parks, it is not clear what warning – if any -- people are receiving. "There is no warning not to drink it. There is no 'non-drink' order out there," said Robert Johnson, President of the Shaver Lake Point 2 Mutual Water Company, which supplies 210 homes in Fresno County with tap water that has seven times the legal limit of arsenic. When asked if these residents should drink bottled water instead of his arsenic-tainted tap water, Johnson said: "It's one of those things, if you want to do it, that's your deal. It's not being recommended. We're not suggesting it. This is per the state of California. We are following their guidance."

The drinking water crisis in Flint, Michigan, was a reminder of how important it is for state governments to issue clear warnings to people with unhealthy tap water. California's mixed message is nearly identical to the one issued by Texas to homeowners with illegal levels of arsenic in their drinking water. Texas also tells consumers with excessive levels of arsenic: "You do not need an alternative water supply."[10] Many other states, however, are more direct in warning people not to drink water with excessive amounts of arsenic, at least for private well owners. Wisconsin, Michigan, Maine, and Washington, for example, simply tell residents not to consume water with more than 10 ppb arsenic (a health standard set by EPA in 2001). Wisconsin advises private well owners: "If your arsenic level is more than 10 ppb, the Wisconsin Department of Health Services recommends that you stop using your water for drinking or food preparation."[11] Florida advises its consumers to avoid water where arsenic contamination persists.[12] The U.S. Department of Health and Human Services makes similar recommendations.[13] If anything, the most recent science suggests that the current 10 ppb arsenic standard is not protective enough and that the IQ of children may be damaged at much lower exposures.[14]

In the wake of a 2013 EPA notice of noncompliance to California over its failure to invest enough money in its drinking water systems, the state has taken several important steps to fix its problems. Over the last three years, the state has more than doubled the amount of funding to build water treatment plants, pipelines, and new wells. The state and counties have filed compliance orders with local utilities to push them to upgrade their systems and are directing small, underfunded water systems to merge with larger utilities. Because of these measures, EPA announced in May 2016 that California was back in compliance with the federal Safe Drinking Water Act.

But in fact, the work is far from done – as witnessed by the 55,985 people in 95 communities across California who still have illegal levels of the carcinogen in their tap water, according to state records.[15] Why the delays? Local officials say that in some cases, bureaucratic

negotiations are holding up projects, which are sometimes stalled because of conflicts between county and state rules. In other cases, local water districts struggle with indecision or a lack of money.

Until these important water system improvements are complete, California and EPA must do a better job of warning consumers to stop drinking water that fails federal health standards. This report recommends:

- California and EPA should revise their regulations and guidance to require that local utilities warn people to stop drinking or cooking with water that fails to meet federal arsenic standards (10 ppb), especially when the contamination persists over several years. The advice should be sensitive to the additional risks posed when children and other sensitive populations drink contaminated water. If there is no reason for consumers to take precautions, there is no reason for Safe Drinking Water Act standards in the first place.

- Public notices mailed to consumers should inform them of options for treating contaminated water at home, e.g., through filtration systems that have proven to be effective. Conversely, the public should be told what doesn't work. For example, boiling water will not reduce arsenic concentrations.

- Federal and state authorities should provide enough money to these 95 California communities to allow them to install water filtration systems or take other steps to eliminate contamination problems. Although the state has already boosted its funding, it still faces a projected $30 billion plus in needed capital improvement projects to help its inadequate systems provide safe drinking water trough 2026.[16]

The big picture is that stepped-up investment in crumbling public infrastructure is sorely needed across the U.S., and it should be regarded as a top priority for both Congress and California lawmakers. But the state also needs to improve its efforts to better inform consumers so people can protect their own health. California does not have to wait for EPA action to strengthen its warnings because the state is already empowered to act independently of EPA.

Public health advisories that are contradictory and confusing – as they are in California -- are as bad as no warnings at all, because they undermine action and weaken public confidence in government.

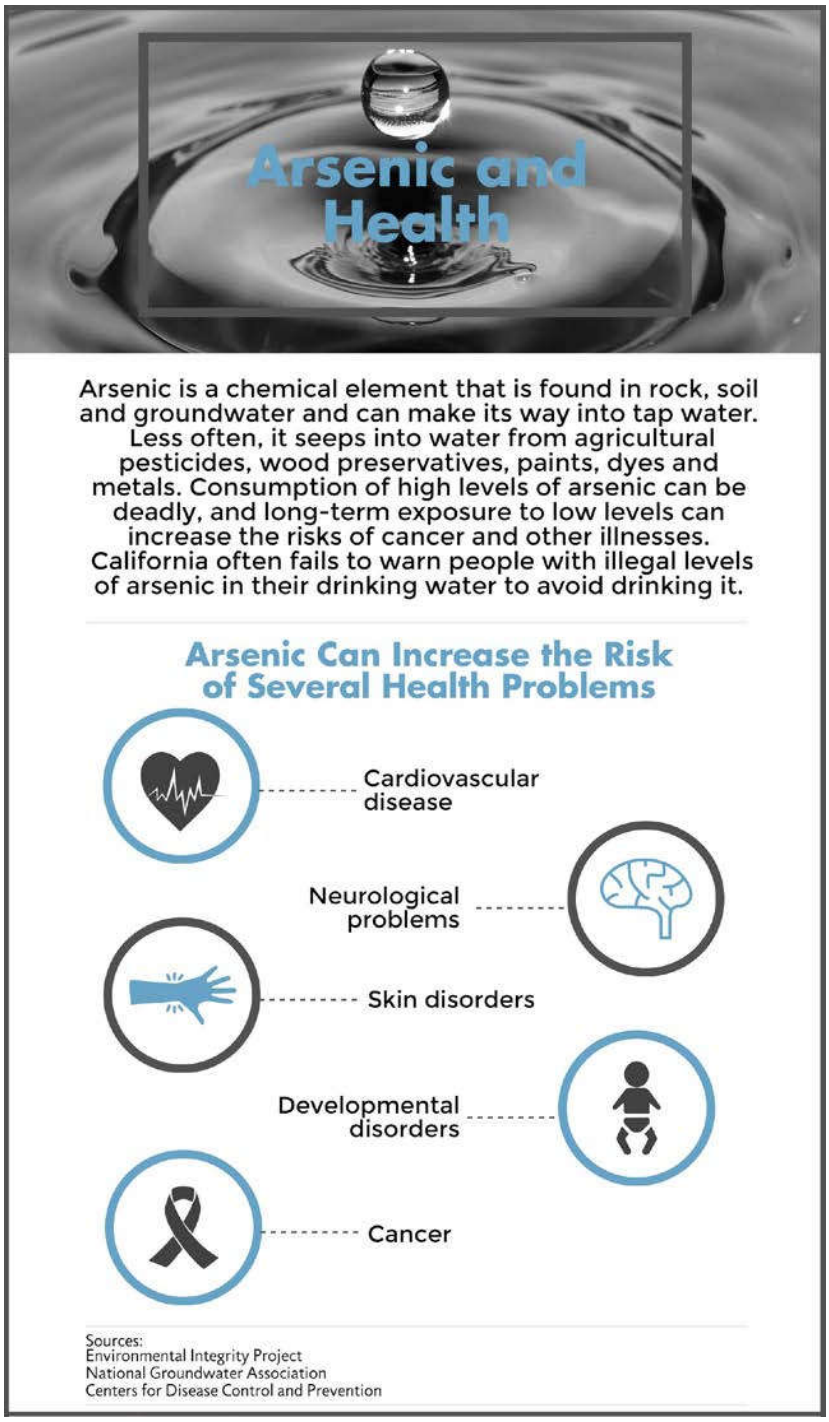
Table 1. Top 20 Arsenic Concentrations in California Public Water Systems

Water System (in Order of Arsenic Levels)	County	Pop. Served	2014-2015 avg (ppb)	2011-2015 avg (ppb)
Lakeview Improvement Association #1	Fresno	160	86.88	86.88*
Fountain Trailer Park Water	Kern	68	85.75	83.90
Hungry Gulch Water System	Kern	33	72.56	70.04
Corral De Tierra Estates WC	Monterey	45	72.50	78.40
Keeler Community Service District	Inyo	50	71.25	75.63
Quail Valley Water District- Eastside System	Kern	60	70.06	69.11
CSA 70 W-4 Pioneertown	San Bernardino	625	64.52	61.55
MD #06 Lake Shore Park	Madera	130	64.25	71.94
Valley Teen Ranch	Madera	50	62.00	120.80
Sierra East Mobile Home Community	Mono	50	54.63	47.03*
Shaver Lake Point #2	Fresno	210	52.31	42.88*
Winterhaven Mobile Estates	Los Angeles	40	52.13	53.35
Olam Spices And Vegetables Inc.	Kings	75	48.38	46.70
The Village Mobile Home Park	Los Angeles	70	45.05	47.04
Callier Water System	San Bernardino	1000	42.13	49.21*
Black Stallion Winery	Napa	25	41.75*	41.75*
Ironwood Camp	San Bernardino	1000	38.38	38.55
Boron CSD	Kern	2500	38.07	37.98
Edgewater Mobile Home Park	Sacramento	40	38.00	37.59
Prunedale MWC	Monterey	252	35.7	32.0

Note: The federal limit for arsenic is 10 ppb. * Average concentrations do not include concentrations from every year. For example, Lakeview Improvement Assn. #1 changed from a non-community water system to a community water system in 2013, and sampling data was only available from 2014 and 2015. Sampling results for Black Stallion Winery were only available for 2015. See Appendix B for annual concentrations in all systems that averaged above 10 ppb.

Health Risks Posed by Arsenic

Arsenic is a chemical element that occurs naturally in geological formations in California and elsewhere, and is also used in a variety of industrial products, including pesticides, paint, and wood preservatives.[17] It is a well-known poison at high doses. At lower doses, researchers have concluded it can cause cancers of the lung, kidney, bladder, skin, and other



organs with prolonged exposure. Any level of exposure, however, carries some risk.[18] According to EPA, the risk of developing cancer after drinking water containing 10 ppb arsenic over a lifetime is 1 in 2,000.[19] This level of risk is almost never 'acceptable' from a regulatory perspective. The agency usually tries to limit lifetime cancer risk to no more than 1 in 10,000, at most. EPA's risk estimate assumes that the cancer risk is linear, meaning if water contains 20 ppb arsenic, those who drink it over a long period of time have a 1 in 1,000 chance of developing cancer. People exposed over shorter periods of time have lower risks, but exposure during childhood may have a greater impact than exposure during adulthood.[20]

Morever, these risk calculations reflected the old thinking. New evidence suggests that the actual cancer risk may be much higher. EPA is currently revising its assessment of cancer risks from arsenic to incorporate more recent science. A 2010 draft of the assessment indicated that the risk of getting cancer from drinking water containing 10 ppb of arsenic is closer to 1 in 136, more than 17 times higher than current assumptions.[21] In addition to causing cancer, arsenic is also a neurotoxin that can harm developing brains at levels at or below the allowable limit.[22] One recent study in Maine, for example, found significant reductions in IQ and other problems in children exposed to arsenic concentrations of 5 to 10 ppb.[23] Specifically, children in homes with more than 5 ppb arsenic in the tap water tested roughly 6 points lower on a full-scale IQ test.[24] While EPA's

Scientific Advisory Board and the most recent studies suggest that the 'safe' level of arsenic is likely much lower than 10 ppb, any concentration higher than 10 is clearly unsafe.

Background on California's Problem

On April 19, 2013, EPA sent a letter to the California Department of Public Health notifying the state that it was out of compliance with the federal Safe Drinking Water Act.[25] The reason was that California's drinking water system was inadequate – providing contaminated water in many poor, rural communities – and the state was not investing enough money to fix the problem. A state investigation that year revealed that 680 community water systems serving 21 million people relied on groundwater that was compromised by one or more contaminants, with the most common being arsenic.[26]

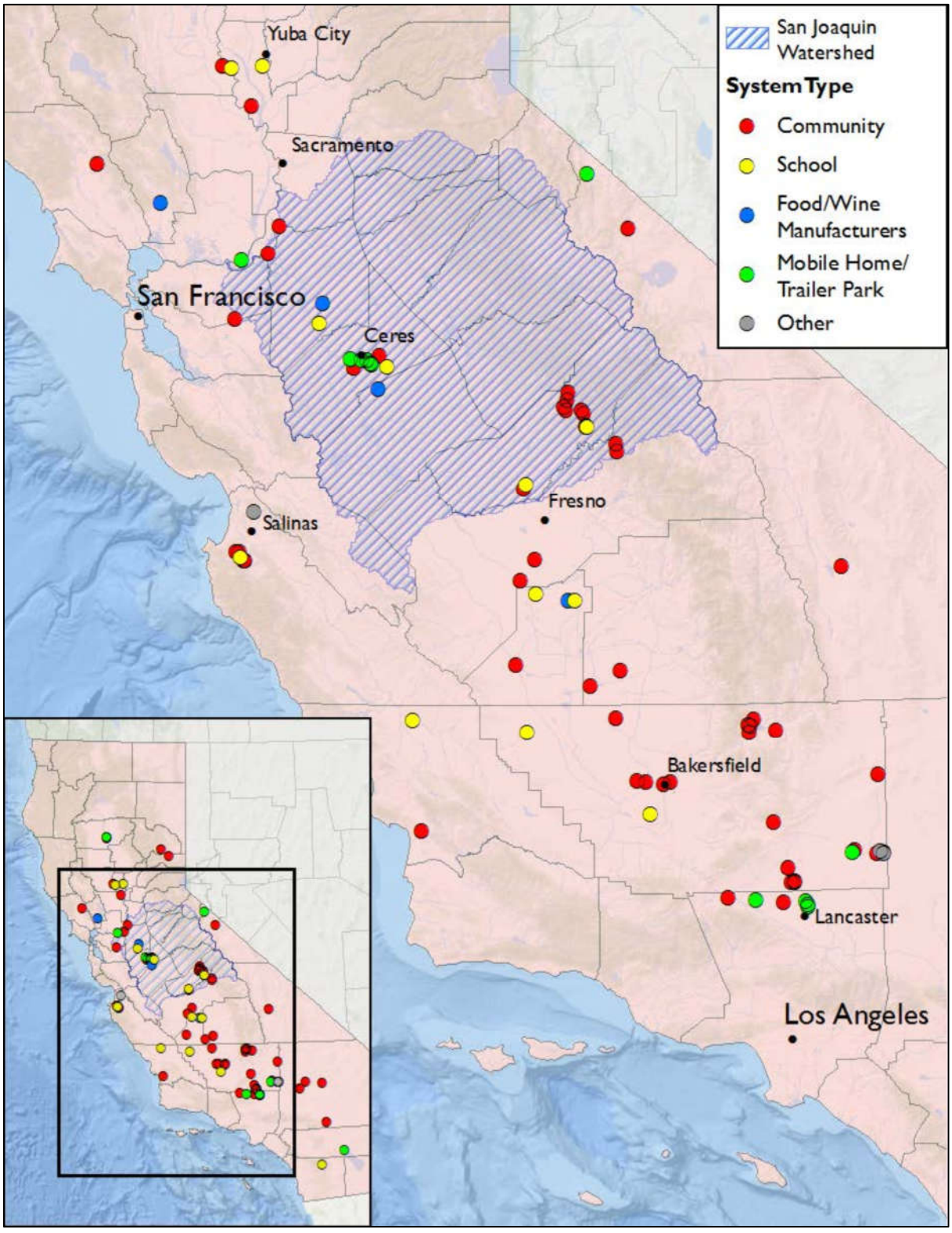
Not all of these 680 water systems provided tap water that had levels of contaminants in excess of federal health standards. In most wealthier and urban communities, the local water utilities treated the groundwater or diluted it with clean water from other wells so that it met the requirements of the federal Safe Drinking Water Act. But in 265 of these communities – often with small populations in rural, isolated areas – the tap water provided to customers had at least one violation of federal standards from 2002 to 2010 for a variety of contaminants, including nitrates from farm fertilizer, according to a 2013 report by the California Department of Health.[27]

In a separate study, researchers at the University of California, Berkeley, examined 464 community water systems serving 1.1 million people in California's San Joaquin Valley, one of the poorest regions in the state, and found that 15 percent of the systems and 14 percent of the people had tap water with arsenic above the federal limit.[28] Of the people exposed, 61 percent were either Latino or African-American. "Community water systems serving higher percentages of people of color had a 260 percent higher chance of having at least one (arsenic) violation," researcher Dr. Carolina L. Balazs and colleagues wrote.[29]

In response to the chronic drinking water problem, Congress had approved $1.5 billion to California over a decade to upgrade its water systems through a program called the Safe Drinking Water State Revolving Fund.[30] Yet because of bureaucratic obstacles and inefficiencies, the state by 2013 had not spent $455 million of those funds – the largest unspent balance of any state. According to EPA's 2013 letter of noncompliance to the California Department of Health, this violated a federal requirement that the state "make *timely* loan or grants using *all available* drinking water funds."[31]

EPA ordered the state to accelerate its efforts to fix public water systems. California Governor Jerry Brown's administration took action in several steps. These included switching control of the state's drinking water program from the Department of Health (where policy focus was dispersed among numerous problems, including drug abuse and AIDS), to the California State Water Resources Control Board (whose only focus is water) under the California Environmental Protection Agency. Since the EPA issued its

Map 1. Public Water Systems with Illegal Levels of Arsenic, 2014-2015



2013 letter of noncompliance, the state has more than doubled the amount of money it is distributing for water system upgrade projects, to an average of $738 million per year, compared to $366 million per year in the period of 2008 to 2012.[32] The unspent balance in the drinking water fund dropped to about $100 million.[33] As a result, EPA in May 2016 decided that California's system was back in compliance.[34]

Recent Analysis of California Records

The problem, however, is still far from fixed. An examination of California's online records by the Environmental Integrity Project (EIP) in May 2016 revealed that there were still 95 community water systems in the state, serving 55,985 people, providing drinking water with levels of arsenic that exceed the federal standard of 10 ppb in 2014 and 2015, according to two-year averages over those years. [35]

Over a longer period of time, 2011 through 2015, state records show 70 systems serving 46,772 residents, that each year have averaged higher than the limit in the Safe Drinking Water Act. These do not include homes on individual private wells, which are not covered by the federal Safe Drinking Water Act.

For a detailed discussion of the methods used to arrive at these numbers, please see Appendix C.

Examples of Drinking Water Contamination

Some of the worst water in community systems in California can be found in the Lakeview Community Association, which serves 160 residents in Shaver Lake (northeast of Fresno, in Fresno County). This community had an average arsenic concentration of nearly nine times the federal limit – 87 ppb – in 2014 and 2015, according to state data.[36]

Four water systems in the unincorporated community of Boron, in San Bernardino County, provided water to about 5,200 residents that had at least three times the safe limit of arsenic in 2014 and 2015.[37] In the city of Keyes in Stanislaus County, 4,891 people have tap water with arsenic concentrations that averaged above the federal limit each year for the last five years. The Pixley Public Utilities District, serving 3,310 residents, had arsenic levels in its drinking water that averaged 50 percent higher than health standards in 2011-2014.

Twelve school districts, serving a combined total of 5,462 students, had arsenic levels that averaged from 30 percent higher to three times the federal limit over the last five years. (See Table 4. Some of these school districts provided explanations, which will be discussed on pages 15 and 16 of this report).

Across California, there were 12 mobile home parks serving 889 people that had average arsenic levels ranging from 20 percent over legal limits to five times the federal standards from 2011 through 2015.[38]

Table 2: Top 10 Mobile Home Parks for Arsenic Contamination

Water System	County	People Served	2014-2015 Avg. (ppb)	2011-2015 Avg. (ppb)
Fountain Trailer Park Water	Kern	68	85.8	83.9
Sierra East Mobile Home Community	Mono	50	54.6	47.0*
Winterhaven Mobile Estates	Los Angeles	40	52.1	53.4
The Village Mobile Home Park	Los Angeles	70	45.1	47.0
Edgewater Mobile Home Park	Sacramento	40	38.0	37.6
Mitchell's Avenue E Mobile Home Park	Los Angeles	26	21.3	21.0
Millstream Mobile Home Park	Tehama	80	20.5	20.0
Country Western Mobile Home Park	Stanislaus	120	20.4	22.2
Saint Anthony Trailer Park	Riverside	300	19.7	21.5
New Orchard Mobile Home Park LLC	Tehama	125	19.6	19.0

Note: federal limit is 10 ppb arsenic. The 2011-2015 average for Sierra East Mobile Home Community reflects fewer than 5 years.

Response from California Officials

The Environmental Integrity Project asked the California State Water Resources Control Board why so many people are still exposed to contaminated drinking water after the state supposedly returned its system to compliance. Officials at the state agency replied in an interview and emails that they had issued orders to nearly all of the local utilities to fix the arsenic problem, but that some local government still need more time to upgrade their systems. In some cases, local utilities are building water filtration systems to remove arsenic, or digging new wells in an effort to extract cleaner water.

"The State Water Board Division of Drinking Water is working with each of these communities to return them to compliance," said Cindy Forbes, Deputy Director of the Division of Drinking Water at the Water Resources Board.[39] "District Office staff are working with these communities to evaluate alternative solutions, including new treatment options, new wells or modification of existing wells, and in some instances consolidation with larger water systems that can provide drinking water that meets all standards. The State Water Board is also helping communities that are struggling financially to reach compliance by offering financial assistance to solutions through low-interest loans and grants."

Public Notification of Drinking Water Violations

As the work continues to upgrade the drinking water systems, however, many citizens of California have not been given warnings to avoid drinking contaminated water.

The background is this: As part of the federal Safe Drinking Water Act, local water utilities are required to periodically test public drinking water systems that serve at least 25 people. When those results show more than 10 ppb arsenic (a standard imposed by EPA in 2001), the utilities must notify residents of the violation in writing by mail "as soon as practical, but within 30 days."[40] In California, however, the warning notices provide a mixed message, stating: "Our water system recently violated a drinking water standard," but also, "you do not need to use an alternative water supply (e.g., bottled water). This is not an emergency…. However, some people who drink water containing arsenic in excess of the (federal limit) over many years may experience skin damage or circulatory system problems, and may have an increased risk to getting cancer."[41] (For the full text of California's notice template for local utilities to use, see Appendix A)

This advisory says two contradictory things: Warning, you have a problem with your water. But don't worry – keep drinking it. If consumers are being told to ignore the federal health standards and keep drinking the contaminated water, there is no reason for the federal Safe Drinking Water standards for arsenic to exist. As stated previously in this report, California is much more clear about warning private well owners to "protect yourself and your family" from arsenic-tainted tap water. And other states – including Wisconsin, Michigan, Maine, and Washington – bluntly advise people not to drink private well water with more than 10 ppb arsenic.

In addition to receiving advisories about violations when they occur, customers also receive annual reports from their local water utilities called "Consumer Confidence Reports." These reports list the levels of more than a dozen different potential contaminants, including bacteria, lead, copper, nitrates and arsenic. When arsenic levels exceed the limit of 10 ppb, these reports provide the numbers and say: "Some people who drink water containing arsenic in excess of the MCL (maximum contaminant level) over many years may experience skin damage or circulatory system problems, and may have an increased risk of getting cancer."[42] But the reports do not tell consumers to stop drinking water with excessive levels of arsenic, and instead hint that it might not be a problem, saying: "Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants."

We asked the California State Water Resources Control Board why the agency doesn't tell people to avoid drinking water with illegal levels of arsenic. In response, Forbes, the deputy director for water, said that the state does provide this kind of blunt and immediate warning for other contaminants that can make consumers sick immediately, such as fecal bacteria. But for arsenic, she said, the threat is more long term. "Arsenic is categorized as a chronic contaminant that poses possible health risks after long-term exposure – 70-plus years of drinking two liters of arsenic-contaminated water a day above the maximum contaminant level," Forbes said. "There are no known acute/immediate health effects that would cause consumers to immediately stop drinking the water."

This answer, however, ignores the fact that many of these California residents have been drinking arsenic-contaminated water for decades. For example, Drs. Carolina Balazs and Isha Ray in 2014 published a study in the American Journal of Public Health in which they interviewed residents with contaminated tap water and found that the current notification requirements are poorly serving people with long-term exposure to pollutants.[43] "A resident from the community of Cutler explained that for years she had received Consumer Confidence Reports indicating that dibromochloropropane levels in the water exceeded the MCL (maximum contaminant level)," Balazs and Ray wrote. "These reports noted that residents should not worry because health impacts were not based on immediate exposure, but rather on lifetime exposure... She had lived in her community for nearly 30 years—so, she asked, should she worry or not? In these situations, water systems simply leave residents to cope with contaminated drinking water as best they can….In these instances, Safe Drinking Water Act regulations ultimately fail the (low-income) household."[44]

California's records identify more than 46,772 people whose tap water has had average levels of arsenic that have exceeded the federal standards for at least five years, from 2011 to 2015. But there is no reason to believe that these people received cleaner water before this. The longer a person drinks water contaminated with excessive levels of arsenic, the higher the increased risk of cancer. In much the same way, smoking a single cigarette is not an immediate health threat, in that it will instantly kill a person. But the longer a person smokes, the worse the health threat. For this reason, California would better protect public health if it told people to stop drinking arsenic-tainted water now, just as health warnings on tobacco required by the U.S. Food and Drug Administration advise, "WARNING: Quitting smoking now greatly reduces serious risks to your health." These advisories do not state, "WARNING: You do not need to change your smoking habits."

Evolution of the Science on Arsenic

One reason for stronger warning language is that scientific research continues to show that arsenic causes health problems – including brain damage in children -- at lower levels than previously thought.

The history of EPA's arsenic rule reflects the continuing evolution of scientific knowledge about the harms that even low levels of the element can cause. Back in 1996, Congress amended the Safe Drinking Water Act and directed EPA to establish new limits for arsenic to replace the old standard of 50 ppb. Based on the best available research, EPA proposed a limit of 5 ppb in 2000. Because arsenic is a carcinogen, some public health experts consider any level above zero to pose some risk. EPA then revised its proposal, based in part on cost considerations, and finalized a new arsenic standard of 10 ppb in 2001.

The EPA Administrator at the time, Christine Todd Whitman, explained that "the 10 ppb protects public health based on the best available science and ensures that the cost of the standard is achievable."[45] The new regulations required that public water systems across the U.S. meet the new standard by January 23, 2006.[46] The law allowed states to grant exemptions until January 23, 2015, for some small community water systems that had trouble complying.[47]

The 2014 Maine study discussed earlier in this report found found significant reductions in IQ in children exposed to arsenic concentrations of 5 to 10 ppb.[48] With this new information, EPA should change its own guidance for notification language so that people – especially parents of young children -- receive a clearer warning not to drink contaminated water. A template for warning language on the federal agency's website for drinking water systems with chemical contaminants such as arsenic advises utilities to tell their customers: "Some people who drink water containing arsenic in excess of the MCL (maxiumum contaminant level) over many years may have an increased risk of getting cancer." But the notices also say: "There is nothing you need to do….If you have specific health concerns, consult your doctor."[49] This is a problem, because many lower-income people do not have doctors with whom they can regularly consult about questions like water quality.

Responses from Local Drinking Water Systems

When asked about their drinking water violations by EIP, some of the utilities in California with illegal levels of arsenic replied that their attempts to fix the problem have been hindered by bureaucratic obstacles at the local level. Others indicated they are taking steps to solve the problem, but simply need more time or money. Not all public systems were contacted by EIP or provided answers.

Table 3. Top 10 Residential Water Systems for Arsenic Contamination (Excluding Mobile Home Parks)

System	County	Population Served	2014-2015 avg (ppb)	2011-2015 avg. (ppb)
Lakeview Improvement Association #1	Fresno	160	86.9	86.9*
Corral De Tierra Estates WC	Monterey	45	72.5	78.4
Keeler Community Service District	Inyo	50	71.3	75.6
Quail Valley Water District-Eastside System	Kern	60	70.1	69.1
MD #06 Lake Shore Park	Madera	130	64.3	71.9
Valley Teen Ranch	Madera	50	62.0	120.8
Shaver Lake Point #2	Fresno	210	52.3	42.9
Boron Community Service District	Kern	2500	38.1	38.0
Monterey Park Tract Comm. Service District	Stanislaus	186	31.9	34.3
North Edwards Water District	Kern	600	31.5	31.6

Note: The federal limit is 10 ppb arsenic. Lakeview had fewer than five years of data available.

At the **Lakeview Improvement Association** in Fresno County, 160 people have been receiving drinking water with more than eight times the legal limit of arsenic on average for

at least the last five years, according to state data. State records show that on May 16, 2016, the California Water Resources Control Board issued a citation to the association's water system, imposing a fine of $1,000 for its failure to follow the directives of two earlier compliance orders, in 2014 and 2015. "The water system continues to violate the arsenic maximum contaminant level (MCL) and does not appear to be making progress toward the compliance deadline," says the most recent letter from the state. "Additionally, the water system has failed to routinely conduct the public notification of the arsenic MCL violation, as required."

Philip Dutton, an engineer for surrounding Fresno County, said that the Lakeview Association's plan, as expressed verbally, is to test some in-home water filtration systems and see how well they perform.[50] "They've got a few of these (filtration systems) installed in homes, but they are sampling from different technologies to try and identify what is going to be the best long-term alternative," Dutton said. The California State Water Resources Control Board's website already lists which types of filtration technologies work well to remove arsenic.[51]

In **Kettleman City**, in Kings County, 1,450 residents have had tap water with excessive levels of arsenic for decades. The average from 2011 to 2015 was 20 percent above the legal limit, according to state data. "I have a daughter, a little one, who's still brushing her teeth with contaminated water, taking a bath in contaminated water," said Maricela Mares-Alatorre, a city resident, during a recent public hearing of the state water board.[52] The Kettleman City Community Services District has promised local residents that it will build a $9 million water treatment plant, but the project has been repeatedly delayed – with a target to open in the fall of 2016 recently pushed back to 2018.[53]

At the **Corral De Tierra Estates** subdivision in Monterey County, 45 people have been exposed to drinking water with arsenic levels almost eight times the legal limit from at least 2011 through 2016, state records indicate. This small water system has received 10 violations notices from the state for excessive levels of arsenic over the last decade, with the most recent in the first quarter of 2016, when it had 77 ppb of the contaminant (compared to the 10 ppb limit).

The manager of Monterey County's drinking water program, Cheryl Sandoval, said Corral De Tierra Estates is among at least five privately-owned water systems that have been issued corrective orders by the county because they are in violation of the arsenic standard. Solving the problem is taking longer than expected, Sandoval said, and some of the local water utilities are still debating the best path forward. "Dealing with the problem is very complicated," Sandoval said.[54] "They haven't made a lot of progress toward compliance, but they are going to have to." One challenge is that a water treatment plant for even a small system can cost hundreds of thousands of dollars and cause new waste disposal problems, because the plants produce concentrated arsenic sludge that must be handled carefully as a hazardous material. Corral De Tierra Estates and other subdivisions want to try in-home water treatment systems as a systemic solution, but county rules don't allow that, Sandoval said. However, debate over this in-home option continues, because new state regulations may open the door for in-home filtration as a systemic solution in the future.

Meanwhile, as the bureaucratic discussions continue, residents are receiving confusing advice about whether they should drink the water pouring from their taps with illegal levels of arsenic. One recent report from Corral de Tierra Estates to local water consumers, displayed on the state website and sent to homeowners in July 2014, advised people that arsenic levels were eight times above the legal limit.[55] But that fact was buried in the middle of a dense report with lots of numbers that also gave the impression that the exceedance was not a problem. The report told homeowners: "The presence of contaminants does not necessarily indicate that the water poses a health risk."[56]

At the **Quail Valley Water District-Eastside System** in Kern County, 60 residents have been receiving drinking water with seven times the legal limit of arsenic over the last five years, state records show. In April 2015, the state issued a compliance order to the local utility and mandated that it fix the problem by April 2018.

Randy Hardenbrook, Director of the Quail Valley Water District, said the problem should be solved within the next two years because a $5.8 million grant from the state is allowing the district to build a new pipeline. The pipe will be about 8.5 miles long and will connect a part of the system with arsenic-tainted water to a well that has good water.[57] In the interim, local residents receive quarterly letters with data on the arsenic exceedances but are not being provided with bottled water. More importantly, they are not being told to refrain from consuming the contaminated water. "We're not telling them not to drink it," Hardenbrook said, "but we are telling them there are long-term health effects."[58]

At the **Shaver Lake Point #2** subdivision in Fresno County, 210 people have been receiving tap water with more than four times legal levels of arsenic for at least the last five years, according to state data. In January 2015, the state wrote to the water system's administrators and ordered them to come into compliance with the federal and state arsenic limits by December 31, 2016.

With only four months left until the deadline, the arsenic levels remain illegally high and Robert Johnson, President of the Shaver Lake Point Mutual Water Company, said he is still thinking about what to do about the problem.[59] "Currently, it's being researched. We have engineers involved. We have water experts involved, and we are trying to figure it out," Johnson said. He added that building a water filtration system could cost as much as $250,000, so the subdivision is considering trying to blend water from its arsenic-tainted wells with cleaner water from different wells.

Meanwhile, nobody in the community is being warned to avoid the contaminated water. "There is no warning not to drink it. There is no 'non-drink' order out there," said Johnson.[60] When asked if his customers should drink bottled water as a precaution instead of the arsenic-tainted tap water, Johnson said: "It's one of those things, if you want to do it, that's your deal. It's not being recommended. We're not suggesting it. This is per the state of California."

Group Home for Troubled Children

The **Valley Teen Ranch**, a Christian residential treatment group home for 32 court-referred abused and neglected boys in Madera County, has arsenic in its tap water that averaged more than 12 times the federal limit from 2011 through 2015, according to state records.[61] "We've been out of compliance, but no children have gotten sick, no adults have gotten sick," said Connie R. Clendenan, CEO of the nonprofit organization that runs the group home. "Nobody wants to drink the water here because it's brown and nasty."[62]

About five years ago, the state approved a $5 million grant to help the group home solve the problem by linking its small water system to a larger one run by the county. But the work has not started yet. Because of ongoing negotiations at the county level, the fix could still be three years or more away, Clendanan said. Meanwhile, children are being given bottled water and are verbally warned not to drink tap water, although there are no warning signs posted above sinks.

"I want to get out of the water business. I'm in the kid business," Clendenan said. Of the continuing delays in fixing the problem with contaminated water, she said: "Nobody's mad. But it's government, and it takes a lot of time. It's just the stupid county."

Table 4. Schools with Excessive Arsenic in Drinking Water

System	County	Population Served	2014-2015 avg. (ppb)	2011-2015 avg. (ppb)
Kit Carson Elem. School	Kings	510	34.7	34.7*
Washington School WS	Monterey	250	26.1	27.7
MUSD-Nile Garden School	San Joaquin	804	20.9	22.8
Liberty High School	Madera	1340	17.9	20.5*
Island Union School	Kings	300	11.9	18.8
Winship Elementary School	Sutter	38	16.4	17.3*
Lakeside School	Kern	800	16.3	16.9
Barry Elementary School	Sutter	650	15.2	15.3
Pleasant Valley Elementary	San Luis Obispo	100	13.8	14.1
Gratton School	Stanislaus	110	13.5	13.5
North Fork Union School	Madera	350	12.9	12.4
Warner Unified School District	San Diego	250	10.9	11.4
Central Union Elementary	Kings	320	10.1	13.5

*Note: federal limit is10 ppb arsenic. *Indicates systems with monitoring gaps (less than five years available data)*

Arsenic in School Drinking Water

At the **Washington School in Salinas,** California, the tap water serving about 250 students has had almost three times the federal limit of arsenic for the last five years, 28 ppb on average over this time period, compared to the limit of 10 ppb.[63] School Principal Whitney Meyer said that the local school district has been discussing the problem for several years but does not yet have a solution. Meanwhile, students are given bottled water, she said.

"We remind them over and over that they cannot drink the water," Meyer said.[64] "Many of the students live out in this area and their homes are similarly impacted (with arsenic), so they also hear the message at home. We have drinking stations with clean water in every classroom, teaching space, and hallway. The fountains have all been shut down."

At the **Barry Elementary School in Yuba City**, California, the arsenic levels have averaged 50 percent above the federal limit for arsenic over the last five years. Because of the violations, the state issued a compliance order to the school in May 2015. Tom Butcher, Director of Maintenance and Facilities for the school system, said that the school has not yet solved the problem, but is giving bottled water to students as officials try to figure out a solution.[65] Adminstrators of the water system are discussing a consolidation with a larger neighboring system that has better water. "The (state) Water Board indicates a best case scenario of a consolidation in approximately 1.5 years," Butcher said. "Until the consolidation is completed (the school district) will continue to provide bottled drinking water."

At the **Kit Carson Elementary School**, in Hanford, Ca., arsenic levels in drinking water averaged more than three times the legal limit in 2011 through 2014, according to state records. In January 2015, the school solved the problem by connecting its pipes to the water system of the surrounding city,[66] whose arsenic levels are below the federal limits.

At the **Lakeside School in Bakersfield,** California, the arsenic levels in the drinking water averaged more than 70 percent above the federal limit for arsenic over the last five years, 17 ppb compared to the limit of 10 ppb. Ty Bryson, District Superintendent, said that the school notified all families by sending home notice letters with the students and by posting warnings in the office. "We provide bottled drinking water for students and staff," Bryson said. "We drilled an alternate well, but that also had unacceptable levels of contaminant. We are now pursuing an alternative source of drinking water by connecting to a local municipal water source via pipeline."

At the **Gratton School in Denair,** California, the drinking water system has had arsenic levels that averaged 40 percent above the federal limit for arsenic over the last five years, state records indicate. The school's superintendent, Shannon Sanford, said that students have been provided bottled water for the last two years. "Students were initially warned (not to drink the water) and signs were used until fountains were disabled," Sanford said. More recently, the school drilled a new well that will be used for the 2016-2017 school year that should solve the problem.

At the **Island Union School in Lemoore,** California, arsenic levels in the drinking water were nearly twice the federal limit from 2011 to 2015, averaging 18.8 ppb compared to

federal limit of 10 ppb, according to state records. Superintendent Charlotte Hines said the school dug a new well in 2015, and provided students and warnings and bottled water in the interim. "We know that bottled water is only a temporary solution," Hines said. "And in an effort to find a permanent solution, the school requested -- and was awarded -- state funding to drill a new well that would meet all primary drinking water standards."[67]

Military Base with Contaminated Water

At the **U.S. Army Base Fort Irwin** in San Bernardino County, 16,000 soldiers live in facilities that have had arsenic in some tap water at levels 50 percent higher than the federal limit from 2011 through 2015, state records indicate. For the last three years, the Army Corps of Engineers has been building a new $100 million water treatment plant at the base to solve the problem. The plant is now undergoing testing and is scheduled to go online in October 2016, base officials indicate.

"The new plant will treat all Fort Irwin water to comply with Safe Drinking Water act Standards for ALL pollutants of concern including …arsenic," said Muhammad A. Bari, Director Public Works at Fort Irwin.[68]

In the interim, soldiers have been provided with bottled water and warned which faucets to avoid, according to base managers.

Vineyards with High Arsenic Levels

In San Joaquin County, the **Delicato Family Vineyards** had arsenic levels in the tap water that averaged 18 ppb from 2011 through 2014, which was 80 percent higher than the federal limits, state records indicate. Kylie Barnett, a spokeswoman for the company, said that the vineyards worked with county officials in 2014 to build a new drinking water system, including by digging two new wells, which brought the arsenic levels down below the federal standard in 2015 and 2016.[69] "The drinking water is not used in production of our wine," Barnett noted. Before the repair, people working at the vineyards and visiting were provided bottled water, she said.

In Napa County, the **Larkmead Vineyards** had drinking water with six times more arsenic than allowed from 2011 through 2013, according to state records. No results were listed for 2014 or 2015, and it is unclear if the drinking water system, which serves 25 people, is used for workers or guests. (Wine making does not generally use tap water.) Emails sent to managers of the vineyard asking about the water were not returned. The researchers of this report also received no response from the **Black Stallion Winery** in Napa County, whose tap water had four times legal limits of arsenic from 2011 through 2015, according to state records.

Conclusion

California is making progress toward solving its drinking water contamination problem. The state has reorganized its drinking water agency, and increased its financial assistance to local utilities to build water treatment systems, dig new wells, and take other steps to resolve the issue. The work, however, is expected to take many more years. In the meantime, tens of thousands of people continue to be exposed to drinking water with illegal levels of arsenic, a carcinogen that could damage the developing brains of children and cause other health problems. And yet, the warnings that some of these residents receive from the government are contradictory and confusing.

Both California and the federal government need to do more to protect consumers, especially the young. This report recommends:

1) California and EPA should both revise the language for written notifications of violations of arsenic standards, so that people are clearly advised to stop drinking contaminated water. If the violations are in schools or group homes, warning signs should also be posted over all sinks and drinking fountains. The state should help provide bottled water as an interim solution.

2) Consumers should be provided more information through the mail about what works and what does not work to remove arsenic from tap water. Residents need to know, for example, that boiling water will not help, but that certain filtration systems can remove the carcinogen. In some cases, residents may need technical help from the state in understanding how to use filtration systems properly.

3) Both Congress and the state government should increase investments in upgrades to California's drinking water systems. This is not only an environmental justice issue, but also a sensible strategy to boost the local economy through the hiring of engineers, construction workers and others to improve local infrastructure.

Counter arguments made by California officials – that the state is already taking action, and that arsenic is not an immediate threat to public health – do not hold water. Although the state has issued enforcement orders to local utilities, some local officials clearly still need more prodding and money to upgrade their water systems. A growing amount of scientific research suggests that arsenic increases the risk of cancer and other diseases and may do so at a lower level than expressed in current federal regulations. Years more of exposure to arsenic-tainted water will only raise the risk of cancer or neurological damage for California residents.

The state and federal governments should advise people to stop drinking contaminated water immediately, just as public health experts urge smokers to change their habits sooner rather than later because it will increase their odds of survival.

With public health warnings, simple and direct is better than bureaucratic and complex, because safe is better than sorry when people's lives and minds are at risk.

APPENDIX A: California's Language for Public Notices about Arsenic Violations

IMPORTANT INFORMATION ABOUT YOUR DRINKING WATER

Este informe contiene información muy importante sobre su agua potable.
Tradúzcalo o hable con alguien que lo entienda bien.

[System] Has Levels of Arsenic Above the Drinking Water Standard

Our water system recently violated a drinking water standard. Although this is not an emergency, as our customers, you have a right to know what you should do, what happened, and what we are doing to correct this situation.

We routinely monitor for the presence of drinking water contaminants. Water sample results received on [date] showed arsenic levels of [level and units]. This is above the standard, or maximum contaminant level (MCL), of 0.010 milligrams per liter.

What should I do?

- **You do not need to use an alternative water supply (e.g., bottled water).**
- This is not an emergency. If it had been, you would have been notified immediately. However, *some people who drink water containing arsenic in excess of the MCL over many years may experience skin damage or circulatory system problems, and may have an increased risk to getting cancer.*
- If you have other health issues concerning the consumption of this water, you may wish to consult your doctor.

What happened? What is being done?

[Describe corrective action]. We anticipate resolving the problem within [estimated time frame].

For more information, please contact [name of contact] at [phone number] or [mailing address].

Please share this information with all the other people who drink this water, especially those who may not have received this notice directly (for example, people in apartments,

nursing homes, schools, and businesses). You can do this by posting this public notice in a public place or distributing copies by hand or mail.

Secondary Notification Requirements

Upon receipt of notification from a person operating a public water system, the following notification must be given within 10 days [Health and Safety Code Section 116450(g)]:

- SCHOOLS: Must notify school employees, students, and parents (if the students are minors).
- RESIDENTIAL RENTAL PROPERTY OWNERS OR MANAGERS (including nursing homes and care facilities): Must notify tenants.
- BUSINESS PROPERTY OWNERS, MANAGERS, OR OPERATORS: Must notify employees of businesses located on the property.

This notice is being sent to you by [system].

State Water System ID#: _____. Date distributed: _____.

APPENDIX B: Listing of All California Public Drinking Water Systems with Arsenic Levels that Averaged Over the Federal Limit over the Last Five Years

System Name	County	Pop. Served	2014-2015 Avg (ppb)	2011-2015 Avg (ppb)	
Lakeview Improvement Association #1	Fresno	160	86.9	86.9	^
Fountain Trailer Park Water	Kern	68	85.8	83.9	*
Hungry Gulch Water System	Kern	33	72.6	70.0	*
Corral De Tierra Estates WC	Monterey	45	72.5	78.4	*
Keeler Community Service District	Inyo	50	71.3	75.6	*
Quail Valley Water District-Eastside System	Kern	60	70.1	69.1	*
CSA 70 W-4 Pioneertown	San Bernardino	625	64.5	61.6	*
MD #06 Lake Shore Park	Madera	130	64.3	71.9	*
Valley Teen Ranch	Madera	50	62.0	120.8	*
Sierra East Mobile Home Community	Mono	50	54.6	47.0	^
Shaver Lake Point #2	Fresno	210	52.3	42.9	^
Winterhaven Mobile Estates	Los Angeles	40	52.1	53.4	*
Olam Spices And Vegetables Inc.	Kings	75	48.4	46.7	*

System Name	County	Pop. Served	2014-2015 Avg (ppb)	2011-2015 Avg (ppb)	
The Village Mobile Home Park	Los Angeles	70	45.1	47.0	*
Callier Water System	San Bernardino	1000	42.1	49.2	^
Black Stallion Winery	Napa	25	41.8	41.8	^
Ironwood Camp	San Bernardino	1000	38.4	38.6	*
Boron CSD	Kern	2500	38.1	38.0	*
Edgewater Mobile Home Park	Sacramento	40	38.0	37.6	*
Prunedale MWC	Monterey	252	35.7	32.0	
Kit Carson Elem. School	Kings	510	34.7	34.7	^
Darr Water Co.	San Bernardino	1000	34.3	36.0	*
Monterey Park Tract Community Service District	Stanislaus	186	31.9	34.3	*
North Edwards WD	Kern	600	31.5	31.6	*
Desert Lake Community Service District	Kern	700	31.0	32.5	*
Locke Water Works Co [SWS]	Sacramento	80	29.5	29.1	*
Lucky 18 On Rosamond, LLC.	Kern	73	28.0	24.3	*
Washington School WS	Monterey	250	26.1	27.7	*
Rancho Marina	Sacramento	250	24.0	30.1	*
Colusa Co. WWD #1 - Grimes	Colusa	500	23.9	24.7	*
Bridgeport PUD	Mono	850	23.3	24.0	*
Country Hills Estates	San Luis Obispo	60	23.0	26.8	^
Doubletree Ranch Water System	Contra Costa	49	21.6	22.4	*
Mitchell's Avenue E Mobile Home Park	Los Angeles	26	21.3	21.0	*
Vista Del Toro WS	Monterey	87	21.0	20.4	*
MUSD-Nile Garden School	San Joaquin	804	20.9	22.8	*
Country Villa Apts.	Stanislaus	30	20.8	21.1	*
Millstream Mobile Home Park	Tehama	80	20.5	20.0	*
Country Western Mobile Home Park	Stanislaus	120	20.4	22.2	*
Saint Anthony Trailer Park	Riverside	300	19.7	21.5	*
New Orchard Mobile Home Park LLC	Tehama	125	19.6	19.0	*
MD #24 Teaford Meadow Lakes	Madera	150	19.0	12.5	
William Fisher Memorial Water Company	Kern	53	19.0	18.4	*
Ceres West Mobile Home Park	Stanislaus	161	18.9	18.0	*
Boulder Canyon Water Association	Kern	28	18.4	17.9	*
Lakeview Ranchos Mutual Water Company	Kern	120	18.1	22.4	*
Liberty High School	Madera	1340	17.9	20.5	^
Sutter Co. WWD #1 (Robbins)	Sutter	350	17.9	18.1	*
MD #42 Still Meadow	Madera	100	17.7	17.7	^
Maher Mutual Water Company	Kern	150	17.7	20.8	*
Cedar Valley Mutual Water Co.	Madera	137	17.6	18.6	^
First Mutual Water System	Kern	35	17.5	15.1	*
Sierra Co. W.W.D #1 Calpine	Sierra	225	17.0	14.1	*
Bar-Len MWC	San Bernardino	124	16.6	16.2	*

System Name	County	Pop. Served	2014-2015 Avg (ppb)	2011-2015 Avg (ppb)	
Winship Elementary School	Sutter	38	16.4	17.3	^
Lakeside School	Kern	800	16.3	16.9	*
Lanare Community Services Dist	Fresno	660	16.2	17.3	*
Delicato Vineyards	San Joaquin	25	15.6	18.3	^
Fourth Street Water System	Kern	56	15.6	14.0	*
Barry Elementary School	Sutter	650	15.2	15.3	*
Rand Communities Water District	Kern	450	15.1	15.3	*
US Army Fort Irwin	San Bernardino	16000	14.9	15.4	*
Pond Mutual Water Company	Kern	48	14.7	14.4	^
Alpaugh Community Services District	Tulare	1026	14.5	17.8	
Lands Of Promise Mutual Water Associatio	Kern	190	14.4	15.0	*
Pixley Public Util Dist	Tulare	3310	14.4	15.0	*
Caruthers Comm Serv District	Fresno	2497	14.3	15.4	*
Nord Road Water Association	Kern	32	14.2	15.0	*
Lancaster Park Mobile Home Park	Los Angeles	53	14.2	15.0	*
Mesa Del Toro MWC	Monterey	90	14.2	13.1	*
Green Run Mobile Estates	Stanislaus	100	14.0	15.1	*
Pleasant Valley Elementary	San Luis Obispo	100	13.8	14.1	*
Loch Haven Mutual Water Company	Sonoma	50	13.8	13.1	*
Gratton School	Stanislaus	110	13.5	13.5	*
Hillview Water Co-Raymond	Madera	290	13.4	17.8	
Mettler Valley Mutual	Los Angeles	100	13.0	13.1	*
Mobile Plaza Park	Stanislaus	125	13.0	12.7	*
Hilmar Cheese Company	Merced	1000	13.0	13.3	
North Fork Union School	Madera	350	12.9	12.4	*
Yosemite Forks Est Mutual	Madera	110	12.8	11.6	
MD #08 North Fork Water System	Madera	264	12.8	13.9	^
Keyes Community Services Dist.	Stanislaus	4891	12.3	12.8	*
Countryside Mobile Home Park	Stanislaus	60	12.1	12.5	*
Land Project Mutual Water Co.	Los Angeles	1500	12.1	13.5	*
El Adobe POA, Inc.	Kern	200	12.1	12.1	*
Island Union School	Kings	300	11.9	18.8	
Plumas Eureka CSD	Plumas	325	11.6	11.4	*
Kettleman City CSD	Kings	1450	11.4	12.0	*
Laguna Seca WC	Monterey	162	11.1	11.7	*
Los Molinos Comm. Services Dist.	Tehama	1500	11.1	9.0	
R.S. Mutual Water Company	Kern	67	11.0	11.1	*
Oasis Property Owners Association	Kern	100	10.9	10.8	^
Warner Unified School District	San Diego	250	10.9	11.4	^
MD #07 Marina View Heights	Madera	200	10.5	9.3	
Central Union Elementary	Kings	320	10.1	13.5	^

Note: Click on the hyperlink in the name of the system to view the state records for each water system.

** Indicates a system that has had annual concentrations averaging over the federal limit (10 ppb) each year 2011-2015*

^ Indicates that the 2011-2015 average includes years for which data was not available.

APPENDIX C:

Methods

This report is based on public data available from the California Environmental Protection Agency's State Water Resources Control Board (SWRCB) as of May 2016. We downloaded the SWRCB's Water Quality Analyses Database Files for 2011-2016 and identified public water systems that had arsenic concentrations that exceeded the 10 ppb Maximum Contaminant Level, targeting the systems with frequent exceedances between 2011 and 2015. The SWRCB database contained results for each water source used by a drinking water system, such as wells, treated or blended water, and standby wells that are only allowed to be used for a few days during a year. SWRCB warns users of its database that results in the database may not reflect the quality of water that systems actually served their customers.

Calculating average arsenic concentrations

- We calculated the average arsenic concentration from each individual water source at each water system using the sampling results available in SWRCB's database as of May 2016. Some sampling results from the end of 2015 may not have been available in the database at the time we downloaded the data in May.

- We reviewed each water system's source descriptions to determine which sources represented water served to consumers and whether the source should be included in the system-wide average arsenic concentration. For example, if the database showed that a system had two groundwater wells and a 'treated' source, we assumed that consumers would be served the treated source if results for that treated source were available each year. If the database listed a treated source in 2011, for example, but contained no data from that source for the following years, we excluded that source from the average because it was not clear if the system continued treating water for arsenic. If a system listed a source as inactive or as a 'standby' option, we excluded that source from the analysis because we could not determine when or if the water was used. We compared the selected sources with available Consumer Confidence Reports available through California's Drinking Water Watch system and narrative information in public SWRCB enforcement action documents to verify, to the extent possible, that the sources we selected represented water that was provided to consumers. If no information was available for a particular system, we relied on the

assumptions described above (i.e. inactive and standby sources were not used, treated sources were used instead of untreated sources when concentrations were available for each year). We did not include purchased water sources.

- After identifying individual sources, we calculated the system's annual average arsenic concentration using the annual average concentrations from each source. The average concentrations during the two-year period between 2014 and 2015 and the five year period between 2011 and 2015 are time-weighted average concentrations (i.e. we averaged the annual average concentrations from each year). This method is similar to how the California EPA's Office of Environmental Health Hazard Assessment calculated average concentrations at drinking water systems for use in it's 2014 CalEnviroScreen 2.0 tool, except we focused on annual average concentrations from 2011-2015, rather than a single average concentration from 2005-2013.

- We excluded entire systems from the analysis if a) they were inactive, b) the available data and source descriptions did not allow us to confidently assume that customers received the sampled water at their taps, and c) the average concentration over the most recent two years (2014-2015) fell below the MCL.

Mapping Public Water Systems

To map water system locations, we found the centroids of public water system boundaries from the California Environmental Health Tracking Program's Water Systems Geographic Reporting Tool, or Water Boundary Tool (WBT). For systems without boundaries in the WBT, we determined coordinates from the addresses in the SWRCB Water Quality Analysis database files and the California Drinking Water Watch system.

Notes

[1] Based on averages for 2014-2015. Numbers in this report from the California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed May, 2016.
[2] U.S. EPA (1998), Integrated Risk Information System, Inorganic Arsenic, available at http://www.epa.gov/iris/subst/0278.htm.
[3] Carolina L. Balazs, Rachel Morello-Frosch, Alan E. Hubbard and Isha Ray, "Environmental justice implications of arsenic contamination in California's San Joaquin Valley: a cross-sectional, cluster-design examining exposure and compliance in community drinking water systems," Environmental Health, 2012. Link: https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-11-84
[4] California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed May. Records show 51,306 residents receiving drinking water from 2011-2015 with annual averages of more than 10 ppb.

[5] California Code of Regulations Title 22, Chapter 15, Section 64463.4(b)] reglations require notifications for arsenic exceedances. The California State Water Resources Board template for the language in notifications to be sent out by local water utilities is available on state agency's website at: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Notices.shtml.

[6] California State Water Resources Control Board website, link: http://www.waterboards.ca.gov/drinking_water/certlic/device/watertreatmentdevices.shtml
[7] Ibid.
[8] Telephone interview with Connie R. Clendenan, CEO of the Valley Teen Ranch nonprofit organization, on August 1, 2016.
[9] Ibid.
[10] Texas Commission on Environmental Quality Notice of Drinking Water Arsenic Violation. Available at https://www.tceq.texas.gov/assets/public/permitting/watersupply/pdw/notices/chemical/arsenic.pdf
[11] Wisconsin Department of Natural Resources, Arsenic, Available at: http://dnr.wi.gov/topic/groundwater/arsenic/, accessed 3/7/2016.
[12] Florida Department of health, Brueau of Environmental Health, "Chemicals in Private Drinking Water Wells Fact Sheet- Arsenic," Available at: http://www.floridahealth.gov/environmental-health/drinking-water/_documents/arsenic-fs.pdf. Accessed 3/7/2016.
[13] See e.g. U.S. Department of Health and Human Services, (2004), "Health Consultation: Arsenic in Private Drinking Water Wells, Cornville, Yavapai County, Arizona," available at: http://www.atsdr.cdc.gov/HAC/pha/ArsenicInPrivate061504-AZ/ArsenicInPrivateHC061504.pdf, accessed 3/8/2016.
[14] Wasserman et al. (2014), A Cross-Sectional Study of Well Water Arsenic and Child IQ in Maine Schoolchildren, Environ Health 13:23-32.
[15] Based on averages for 2014-2015. Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016.
[16] Letter from Jared Blumenfeld, Director of EPA's Region 9 office, to California Department of Public Health Director Dr. Ron Chapman, April 19, 2013. Link: https://www3.epa.gov/region9/water/grants/pdf/CDPHNoticeofNonCompliance.pdf
[17] U.S. Centers for Disease Control, fact sheet on arsenic. Available at http://www.cdc.gov/biomonitoring/pdf/Arsenic_FactSheet.pdf
[18] U.S. EPA (1998), Integrated Risk Information System, Inorganic Arsenic, available at http://www.epa.gov/iris/subst/0278.htm.

[19] The EPA describes arsenic's cancer-causing potency with a 'slope factor' (because it describes the slope of the dose-response curve). The current EPA slope factor for arsenic is 1.5 per mg/kg-d. This number represents the risk that can be expected from consuming one milligram of arsenic per kilogram of body weight per day. The EPA also translates the slope factor into a 'drinking water unit risk' of 5×10^{-5} per µg/L. For carcinogens, the formal MCL Goal is always zero. Zero is an unattainable goal, so in most cases the EPA will reduce exposure to carcinogens to a level of 'acceptable risk,' something between 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000).[19] One way of looking at this range is to assume that risks less than 1 in 1,000,000 are always 'acceptable,' while risks greater than 1 in 10,000 never are. The risks of drinking arsenic at the MCL of 10 µg /L are much higher than 1 in 10,000.

[20] See, e.g., National Research Council, Critical Aspects of EPA's IRIS Assessment of Inorganic Arsenic – Interim Report, 82 – 83 (2013). For health endpoints like childhood IQ, the critical window of exposure is obviously much less, encompassing in utero development and childhood.

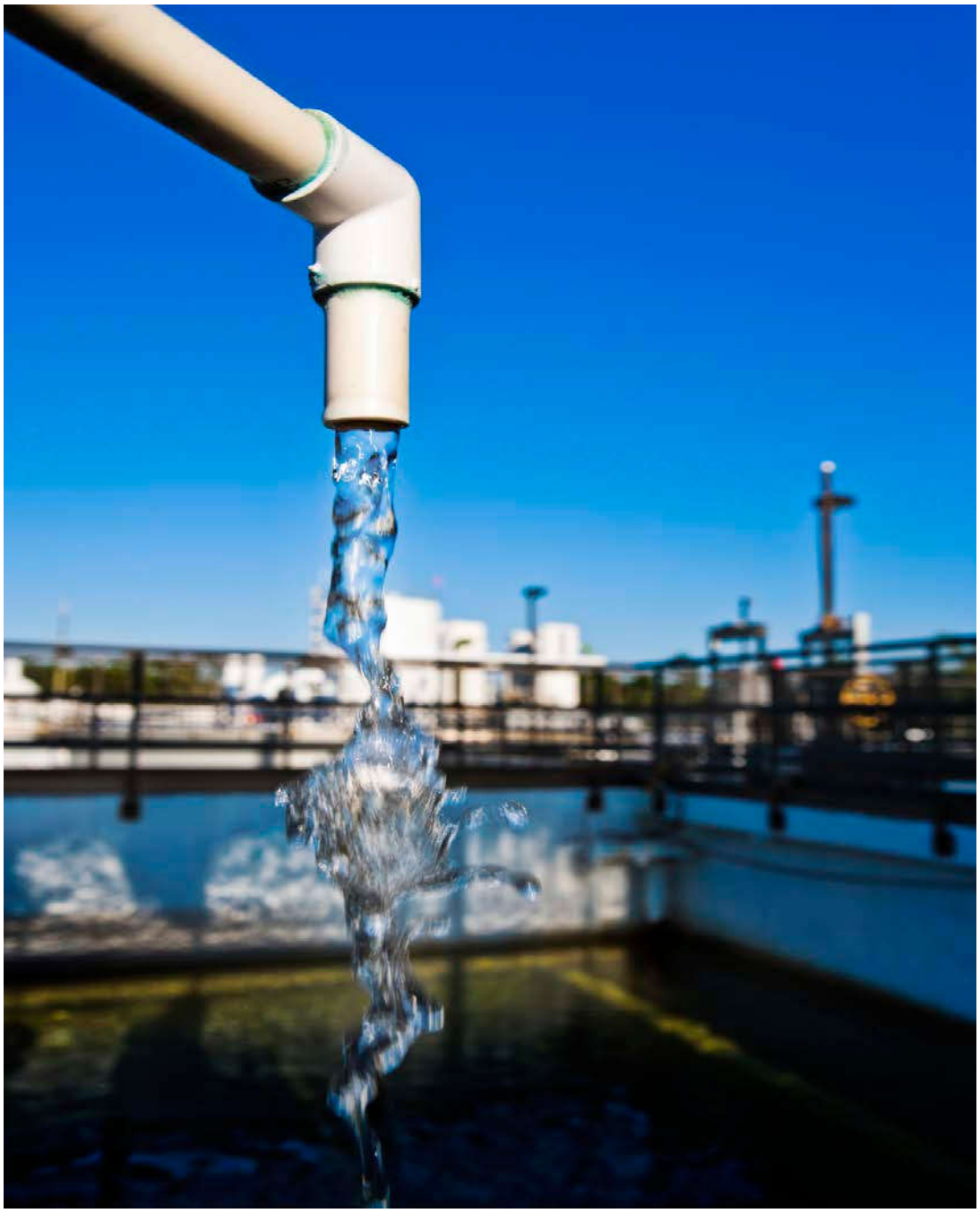
[21] EPA web page, "Drinking Water Arsenic Rule History," available at: https://www.epa.gov/dwreginfo/drinking-water-arsenic-rule-history.
[22] ATSDR (2007), Toxicological Profile for Arsenic; Grandjean and Landrigan (2014), Neurobehavioural Effects of Developmental Toxicity, *Lancet Neurol* 13:330-338.

[23] Wasserman et al. (2014), A Cross-Sectional Study of Well Water Arsenic and Child IQ in Maine Schoolchildren, *Environ Health* 13:23-32.

[24] Ibid.

[25] Ibid.
[26] California Water Resources Board report to the California legislature, "Communities that Rely on a Contaminated Groundwater Source for Drinking Water," January 2013. Link: http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/docs/ab2222.pdf
[27] California Water Resources Board report to the California legislature, "Communities that Rely on a Contaminated Groundwater Source for Drinking Water," January 2013. Link: http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/docs/ab2222.pdf
[28] Carolina L. Balazs and colleagues, "Environmental Justice Implications of Arsenic Contamination In California's San Joaquin Valley: a Cross-Sectional, Cluster-Design Examining Exposure and Compliance in Community Drinking Water Systems," Environmental Health, November 14, 2012. Link: https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-11-84
[29] Ibid.
[30] Letter from Jared Blumenfeld, Director of EPA's Region 9 office, to California Department of Public Health Director Dr. Ron Chapman, April 19, 2013. Link: https://www3.epa.gov/region9/water/grants/pdf/CDPHNoticeofNonCompliance.pdf
[31] Ibid.
[32] California Water Boards press release, "State Water Board, Drinking Water Revolving Fund Return to Safe Drinking Water Act Compliance," May 26, 2016. Link: http://www.waterboards.ca.gov/press_room/press_releases/2016/pr052616_cap_release.pdf
[33] Ibid.
[34] Ibid.
[35] Based on averages for 2014-2015. Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016.
[36] Ibid.
[37] Ibid.
[38] Ibid.
[39] Email from Andrew DiLuccia, Public Information Officer for the California State Water Resources Control Board, containing quote from Cindy Forbes, Deputy Director of the Division of Drinking Water, on August 8, 2016. Telephone interview with Forbes on August 4, 2016.
[40] California State Water Resources Board, template for public notification of Arsenic MCL Exceedance, Link: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Notices.shtml
[41] Ibid.
[42] Example of Consumer Confidence Report for a California system can be found on the state website: https://sdwis.waterboards.ca.gov/PDWW/JSP/WaterSystemDetail.jsp?tinwsys_is_number=370&tinwsys_st_code=CA&wsnumber=CA1000071#
[43] Carolina L. Balazs and Isha Ray, "The Drinking Water Disparities Framework: On the Origins and Persistence of Inequities in Exposure," American Journal of Public Health, April 2014, Vol 104, No. 4. Link: http://www.ncbi.nlm.nih.gov/pubmed/24524500.
[44] Ibid.
[45] Ibid.
[46] Ibid.
[47] 40 CFR 142.20(a)(2)
[48] Wasserman et al. (2014), A Cross-Sectional Study of Well Water Arsenic and Child IQ in Maine Schoolchildren, Environ Health 13:23-32.
[49] U.S. EPA public notification template on EPA website: https://www.epa.gov/dwreginfo/public-notification-templates-community-and-non-transient-non-community-water-systems
[50] Telephone interview on August 25, 2016 with Philip Dutton, engineer for Fresno County.
[51] California State Water Resources Control Board website, http://www.waterboards.ca.gov/drinking_water/certlic/device/watertreatmentdevices.shtml
[52] KFSN-TV, ABC-30 in Fresno, report "Kettleman City Residents Get Answers to Questions about Construction of Water Treatment Plant," August 31, 2016. Link: http://abc30.com/society/kettleman-city-residents-get-answers-to-questions-about-construction-of-water-treatment-plant/1493726/
[53] Ibid.

[54] Telephone interview on August 26, 2016, with Cheryl Sandoval, Supervising Environmental Health Specialist and Manager of Monterey County's drinking water program.
[55] Corral de Tierra Water Company 2013 Consumer Confidence Report, dated July 11, 2014.
[56] Ibid.
[57] Telephone interview on August 26, 2016, with Randy Hardenbrook, Director of the Quail Valley Water District.
[58] Ibid.
[59] Telephone interview on August 25, 2016, with Robert Johnson, President of the Shaver Lake Point 2 Mutual Water Company.
[60] Ibid.
[61] Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016.
[62] Telephone interview with Connie R. Clendenan, CEO of the Valley Teen Ranch nonprofit organization, on August 1, 2016.
[63] Numbers from California State Water Control Resources Board online database, "Drinking Water Watch," https://sdwis.waterboards.ca.gov/PDWW/ Records accessed July 28, 2016
[64] Email from Whitney Meyer, Principal of the Washington School in Salinas, California, on August 1, 2016.
[65] Email from Robert Shemwell, Assistant Superintendent of Business Services of the Yuba City Unified School District, containing quote from Tom Butcher,Director of Maintenance and Facilities, on August 12, 2016.
[66] Email on August 24, 2016, from Liliana Stransky of the Kings County Department of Public Health.
[67] Email from Superintendent Charlotte Hines of the Island Union School in Lemoore, California, August 4, 2016.
[68] Email from Kenneth Drylie, Public Affairs Specialist at Fort Irwin, containing quotes from Muhammad A. Bari, Director Public Works at the forst, on August 11, 2016.
[69] Email from Kylie Barnett, Director Public Relations at Delicato Family Vineyards, August 10, 2016.



ENVIRONMENTAL INTEGRITY PROJECT

1000 Vermont Avenue, NW
Suite 1100
Washington, DC 20005
202-296-8800
www.environmentalintegrity.org

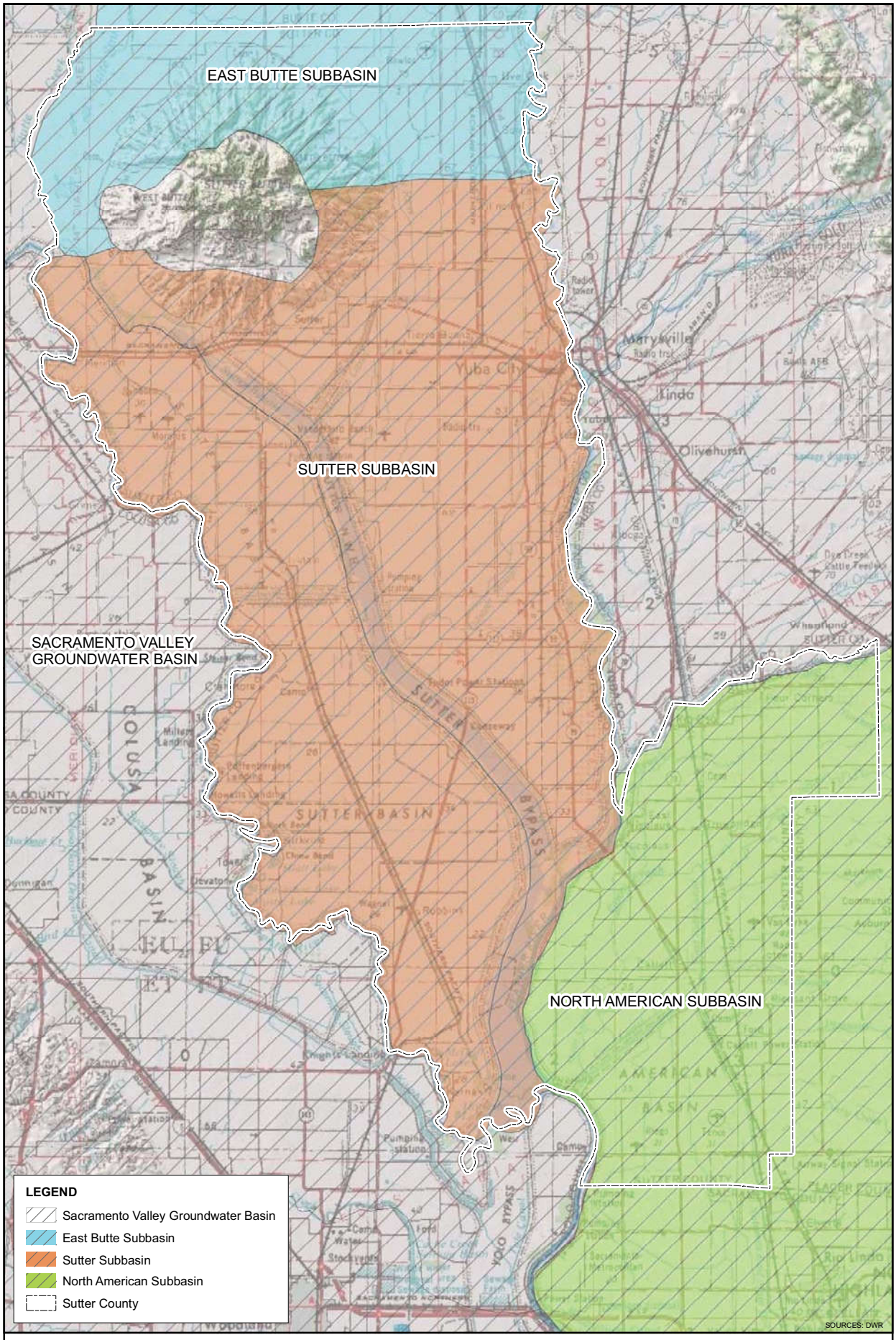


FIGURE 1
GROUNDWATER BASIN AND SUBBASINS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS
3301 C Street, Bldg. 100-B Tel: 916.341.7760
Sacramento, CA 95816 Fax: 916.341.7767

J:\Jobs\8337_SutterCounty\GIS\Tasks\20120201 Final Draft Figure Comments\Figure 1 Groundwater Subbasins.mxd 2/7/2012 12:50:01 PM bdemucha

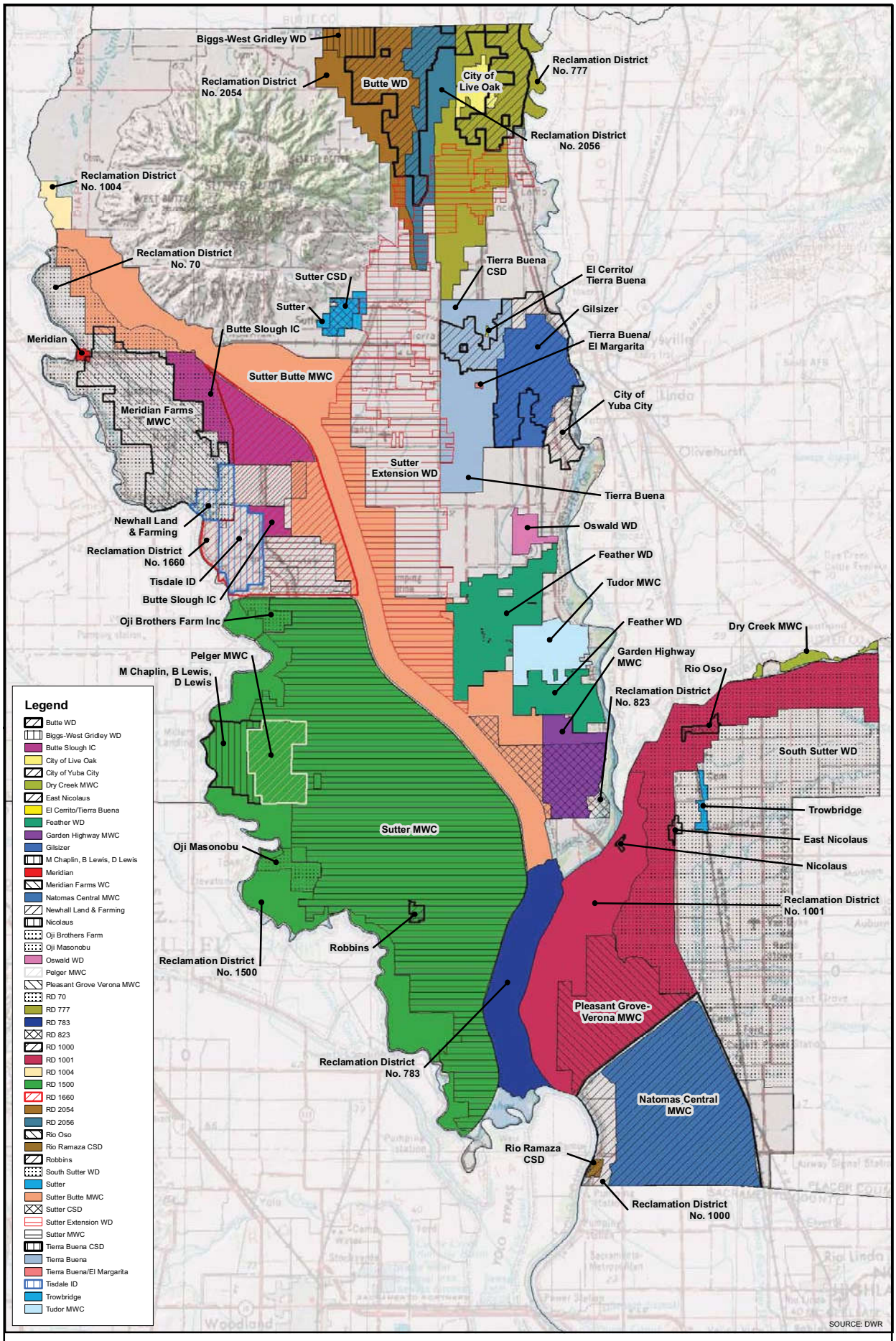


FIGURE 2
WATER DISTRICTS, PURVEYORS, AND WATER COMPANIES
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS
3301 C Street, Bldg. 100-B Tel: 916.341.7760
Sacramento, CA 95816 Fax: 916.341.7767

J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 2 Water_District_Poster.mxd 2/7/2012 12:39:44 PM bdemucha

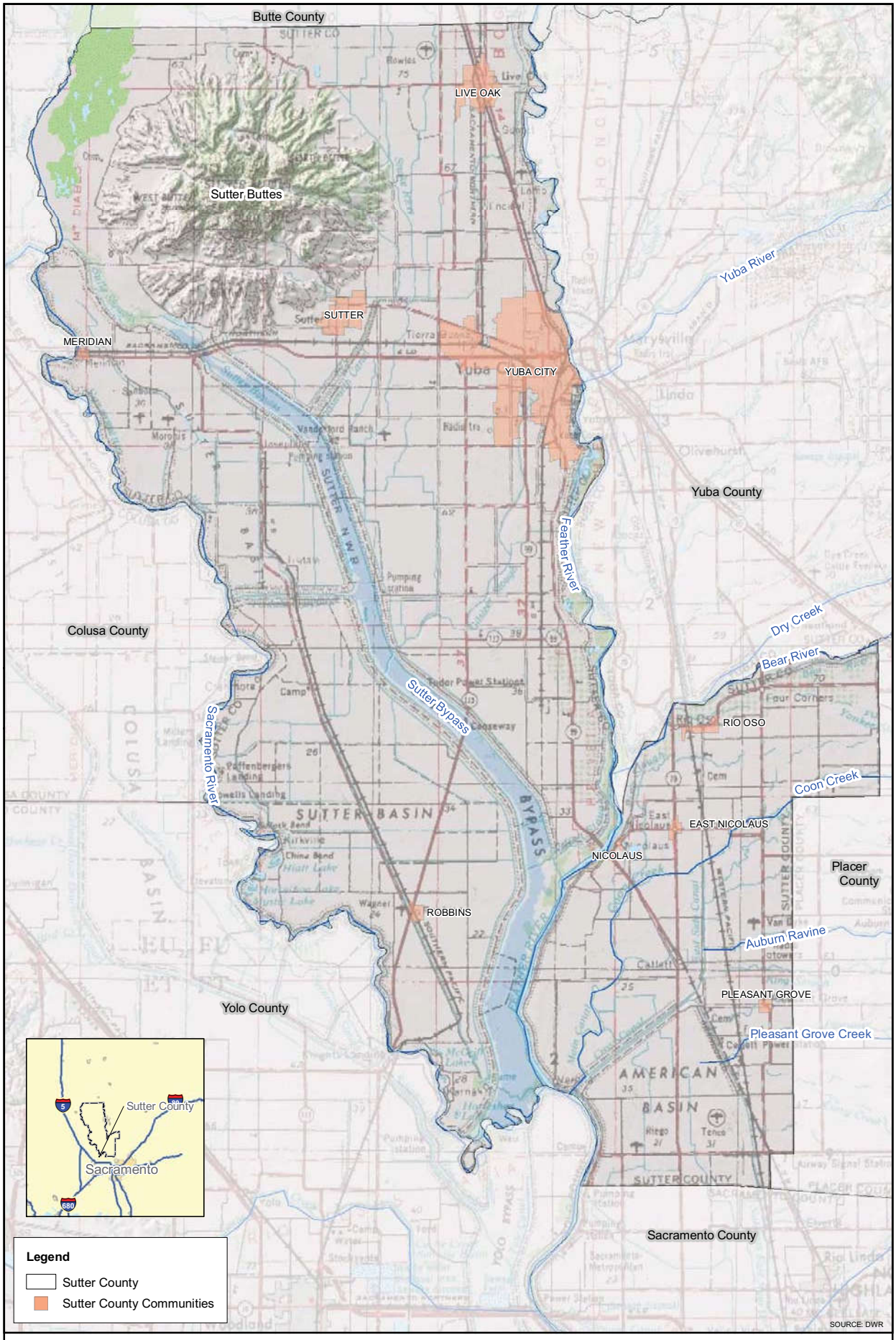


FIGURE 5
PHYSICAL FEATURES
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS
3301 C Street, Bldg. 100-B Tel: 916.341.7760
Sacramento, CA 95816 Fax: 916.341.7767

J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 5 Sutter County Physical Features.mxd 2/7/2012 12:47:54 PM bdemucha

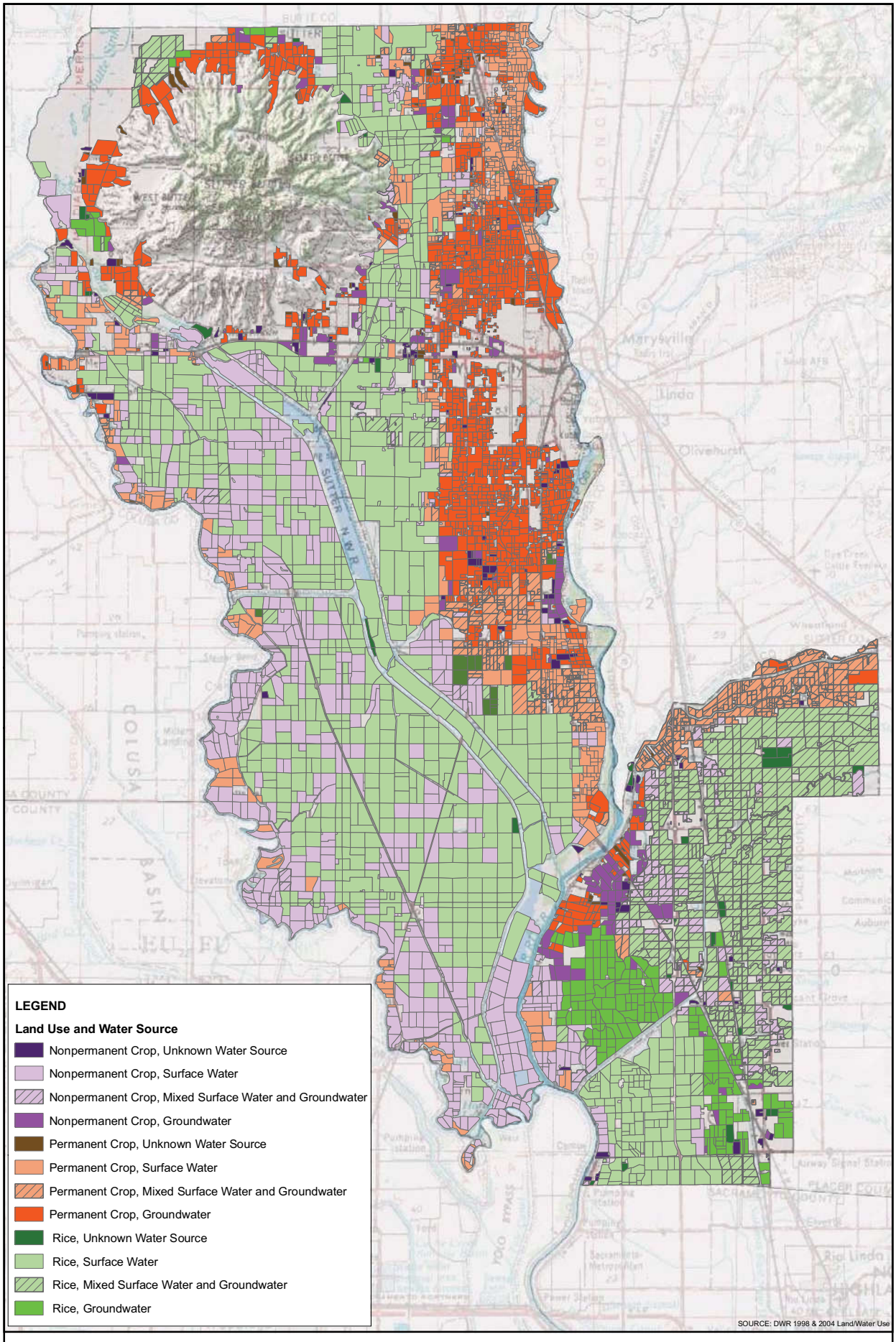


FIGURE 6
WATER SOURCES FOR IRRIGATED CROPS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

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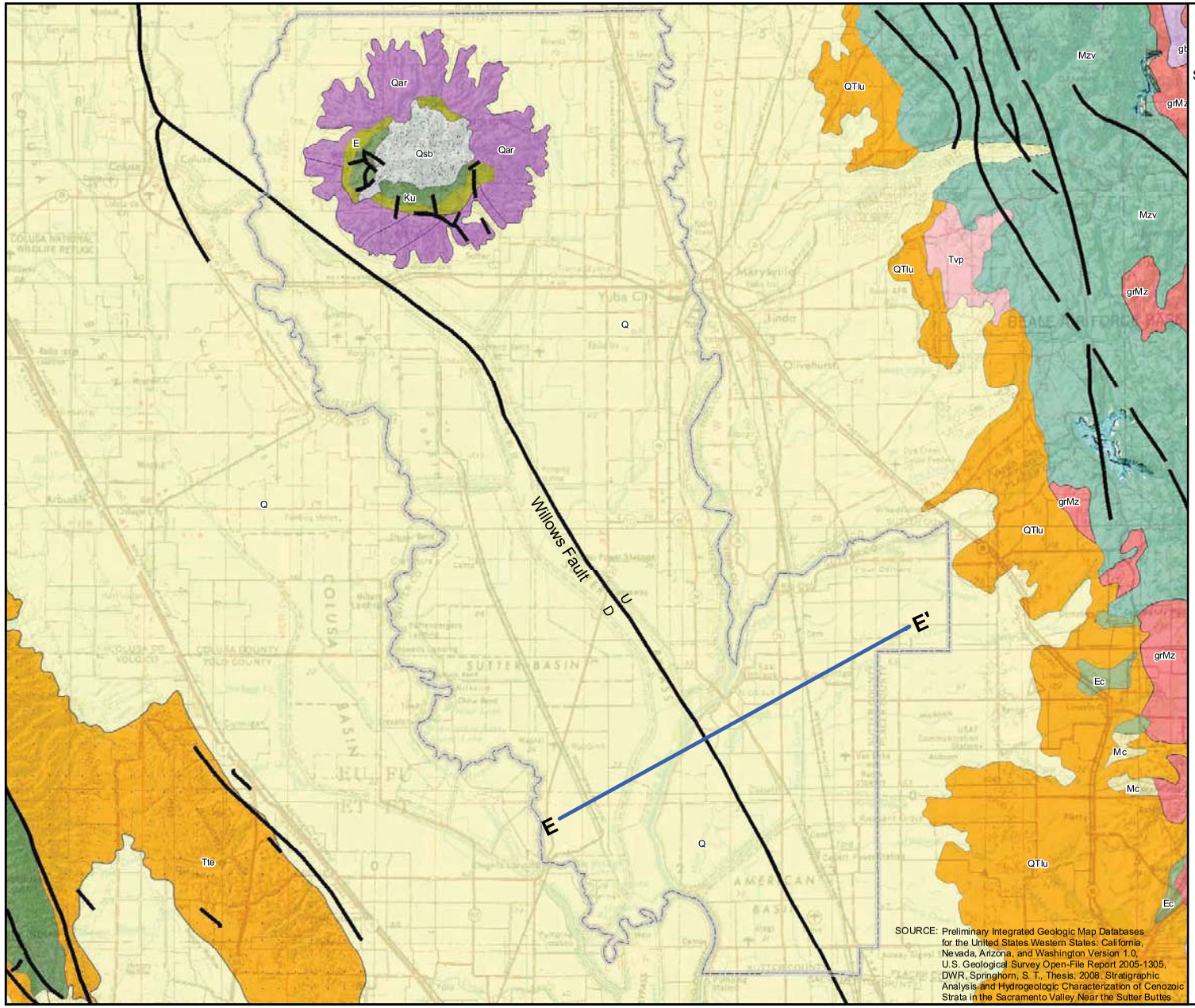
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 6 Water_Source_IRR_Crops_.mxd 2/7/2012 12:52:19 PM bdemucha

FIGURE 7
SIMPLIFIED SURFACE GEOLOGY AND FAULTS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012



NORTH

0 2 4
MILES

LEGEND

- Q - Recent Deposits
  - Qb - Basin Deposits
  - Qm - Modesto Formation
  - Qr - Riverbank Formation
- Qsb - Sutter Buttes Igneous Rocks
- Qar - Sutter Buttes Andesitic Rampart
- QTlu - Laguna Formation
- Tte - Tehama Formation
- Tvp - Andesite, Rhyolite
- Mc - Sandstone, Conglomerate
- Ec - Conglomerate, Sandstone
- E - Mudstone, Sandstone
- Ku - Sandstone, Mudstone
- J - Mudstone, Sandstone, & Slate
- um - Serpentinite
- Mzv - Volcanic, Metavolcanic
- gb - Gabbro, Diorite
- grMz - Granodiorite
- Fault
- Fault Displacement - U, upthrown side; D, downthrown side
- Counties
- Simplified Conceptual Geologic Cross Section Line (See Figure 8)

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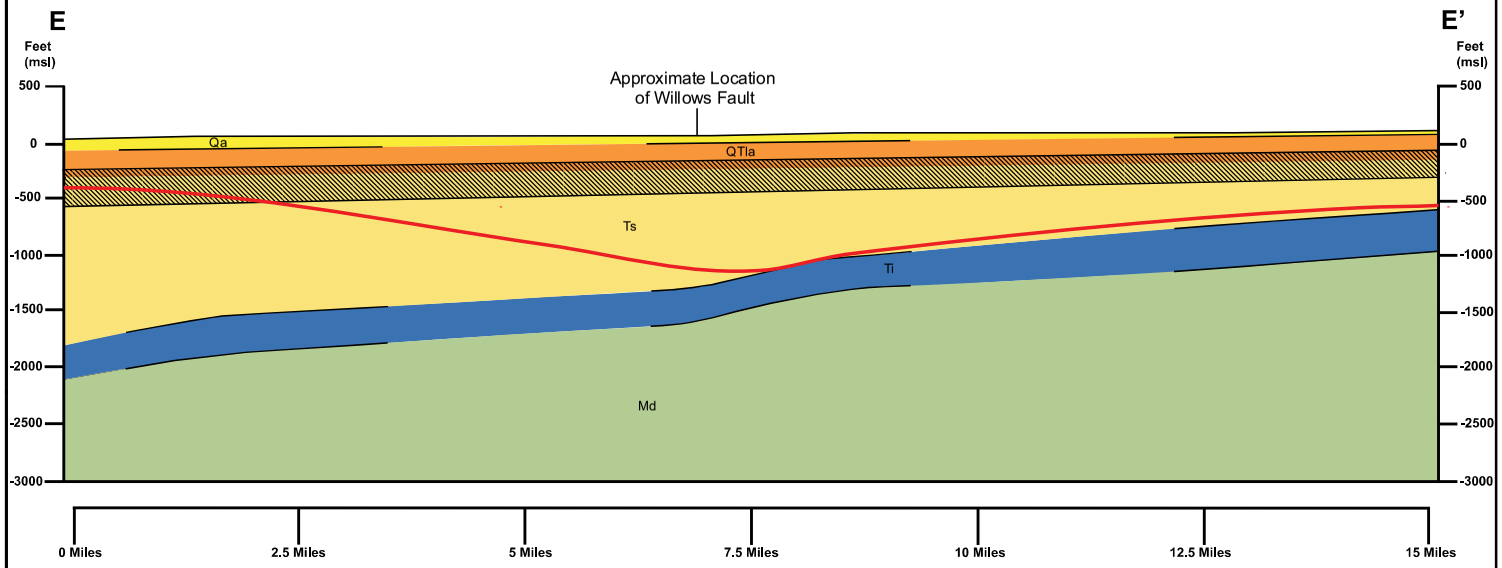
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 7 Simplified Surface Geology and Faults.mxd 2/7/2012 12:54:14 PM bdemucha

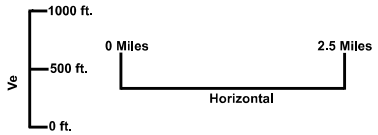
FIGURE 8
SIMPLIFIED CONCEPTUAL GEOLOGIC CROSS SECTION
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012



Explanation

- Qa — Alluvial Deposits
- QTla — Laguna Formation
- Laguna and Sutter Formation Transition (approximate depth)
- Ts — Sutter Formation (map unit, Williams and Curtis, 1977; Helley and Harwood, 1985)
  - Tt — Tuscan Formation (map unit, Helley and Harwood, 1985)
  - Tm — Mehrten Formation (map unit, Helley and Harwood, 1985)
- Ti — Ione Formation (map unit, Helley and Harwood, 1985)
- Md — Marine Deposits
- Inferred Geologic Contact
- Approximate Base of Fresh Water. Line represent depths at which Specific Conductance levels exceed approximately 3,000 umhos/cm

Cross Section Scale



SOURCES: DOGGR; DWR; Springhorn, S. T., Thesis, 2008, Stratigraphic Analysis and Hydrogeologic Characterization of Cenozoic Strata in the Sacramento Valley Near the Sutter Buttes; Berkstresser, C.F. Jr. 1973. Base of Fresh Ground-Water -- Approximately 3,000 micromhos in the Sacramento Valley and Sacramento-San Joaquin Delta, California. U.S. Geological Survey Water-Resource Inv. 40-73; Helley, E. J. and Harwood, D. S., 1985, Geologic Map of Late Cenozoic Deposits of the Sacramento Valley and Northern Sierran Foothills, California.

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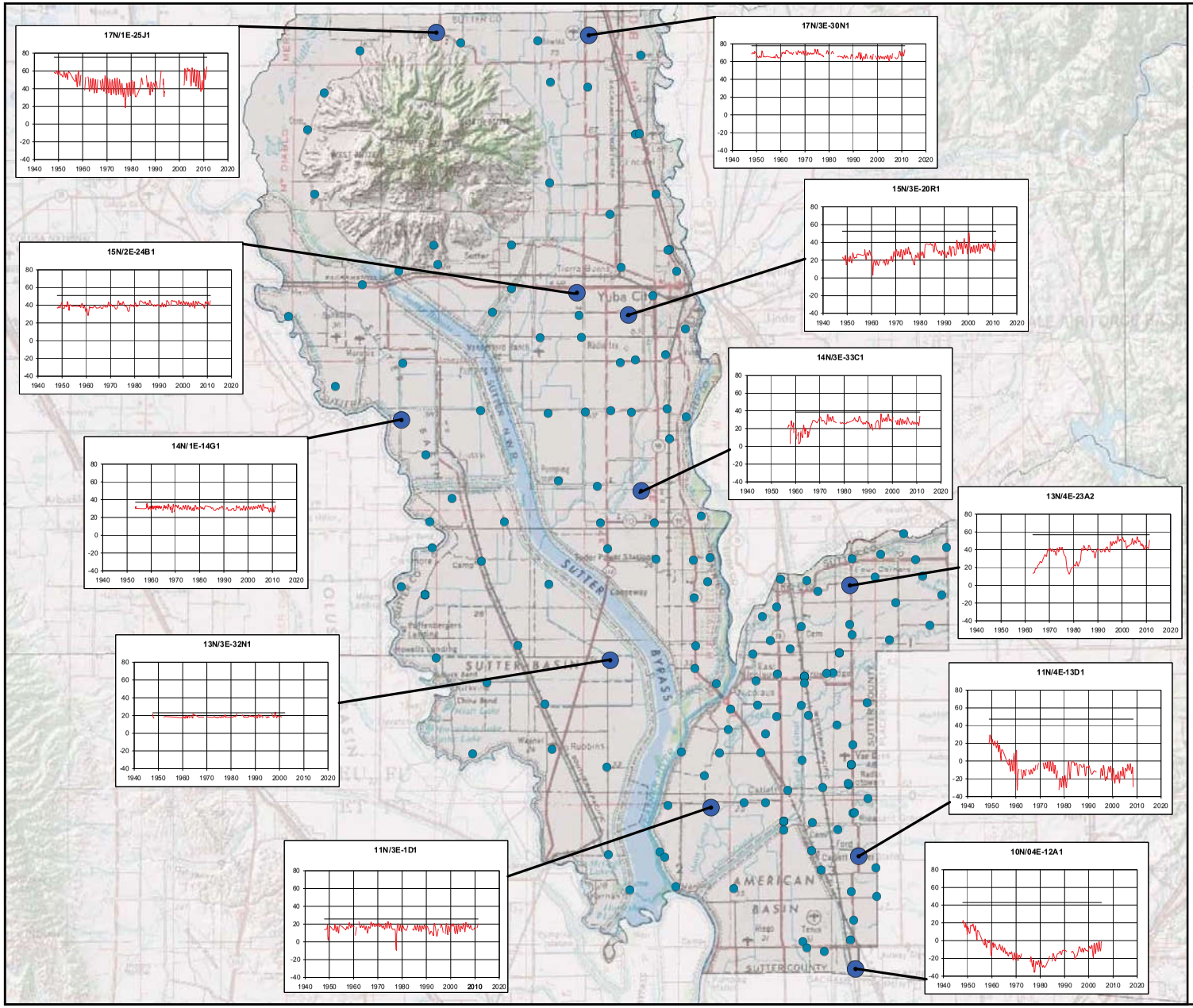


FIGURE 9
HISTORIC GROUNDWATER ELEVATIONS IN SUTTER COUNTY
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH

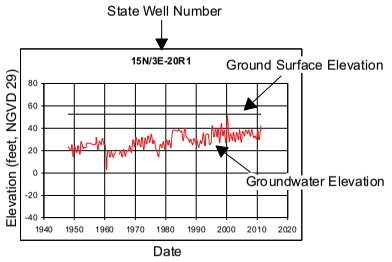
0 2 4
MILES

Legend

- Well with Hydrograph Shown
- Well with Water Level Measurement since 2004

Note: This figure represents wells with historic water level and current measurements either submitted to or obtained by the California Department of Water Resources and may not represent current monitoring activities. Groundwater elevations are in feet above mean sea level.

SOURCE: DWR



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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 9 Historic Groundwater Elevations in Sutter County .mxd 2/7/2012 12:59:56 PM bdemucha

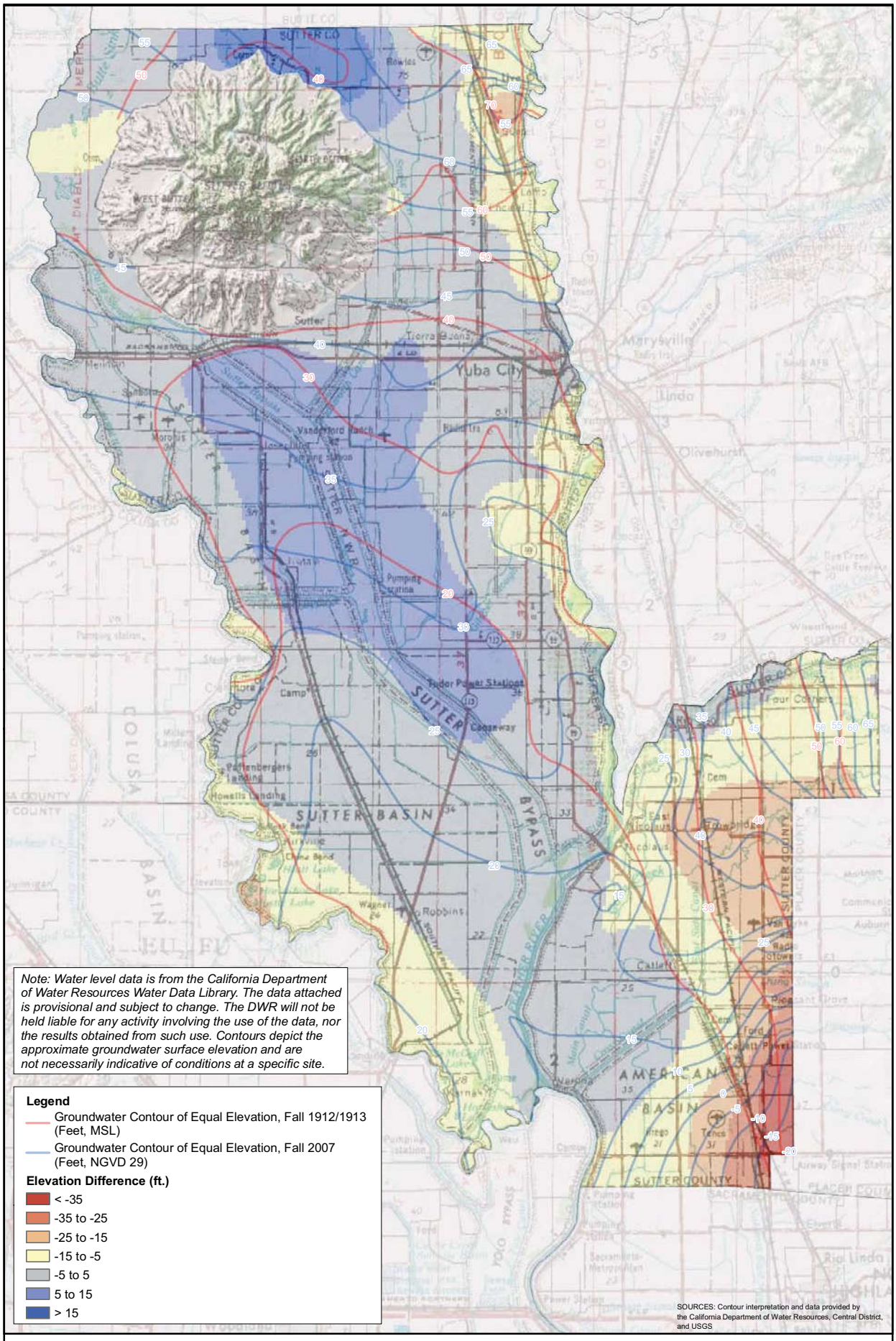

FIGURE 10
GROUNDWATER LEVEL CHANGE MAP
FALL 2007 AND FALL 1912/1913
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120201 Final Draft Figure Comments\Figure 10 Groundwater_elevation_change_map.mxd 2/7/2012 5:35:33 PM bdemucha

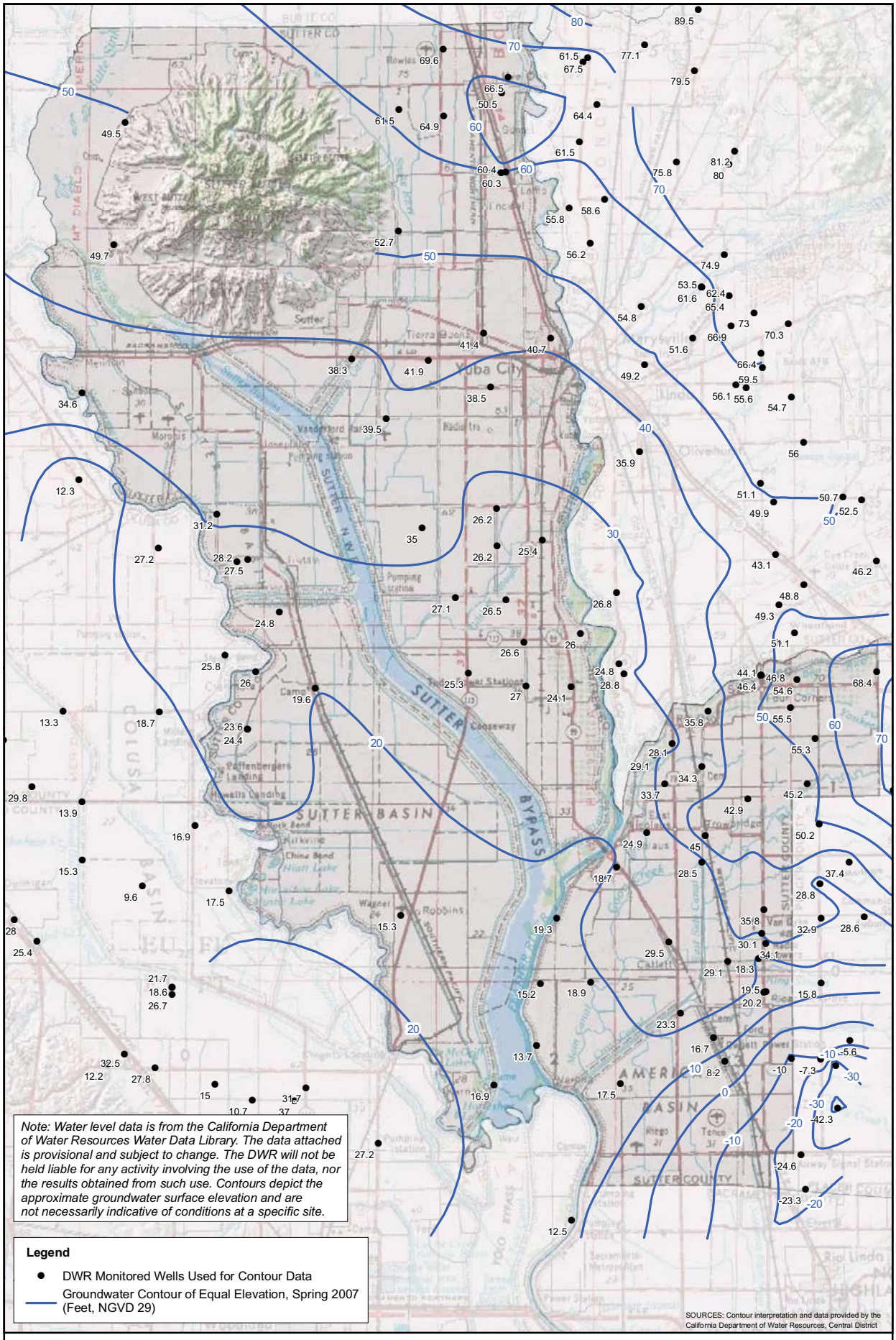

FIGURE 11
GROUNDWATER ELEVATION CONTOUR MAP
SPRING, 2007
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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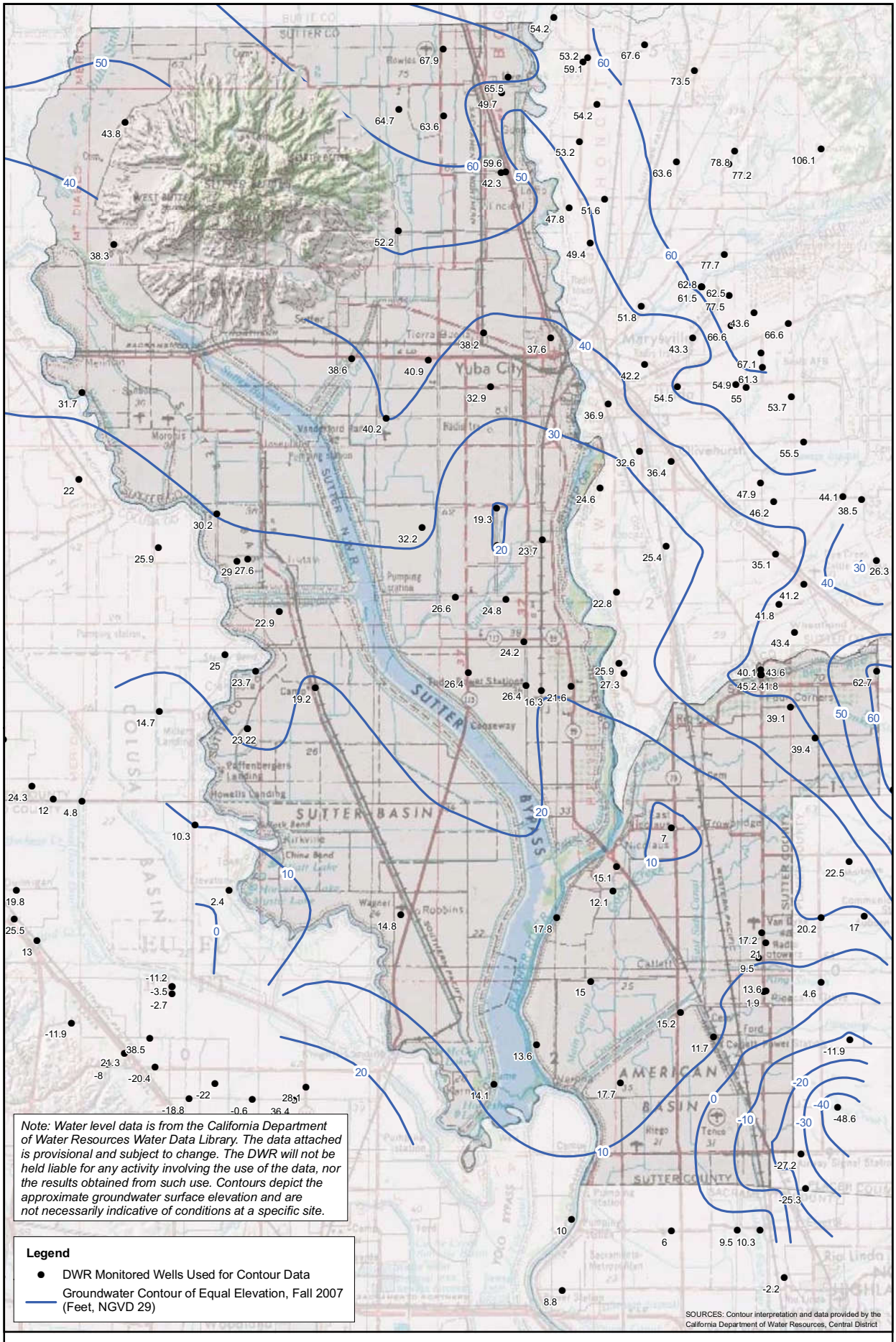

FIGURE 12
GROUNDWATER ELEVATION CONTOUR MAP
FALL, 2007
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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NORTH
0 1.5 3
MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 12 Groundwater Elevation Contour Map Fall 2007.mxd 2/7/2012 6:07:59 PM bdemucha

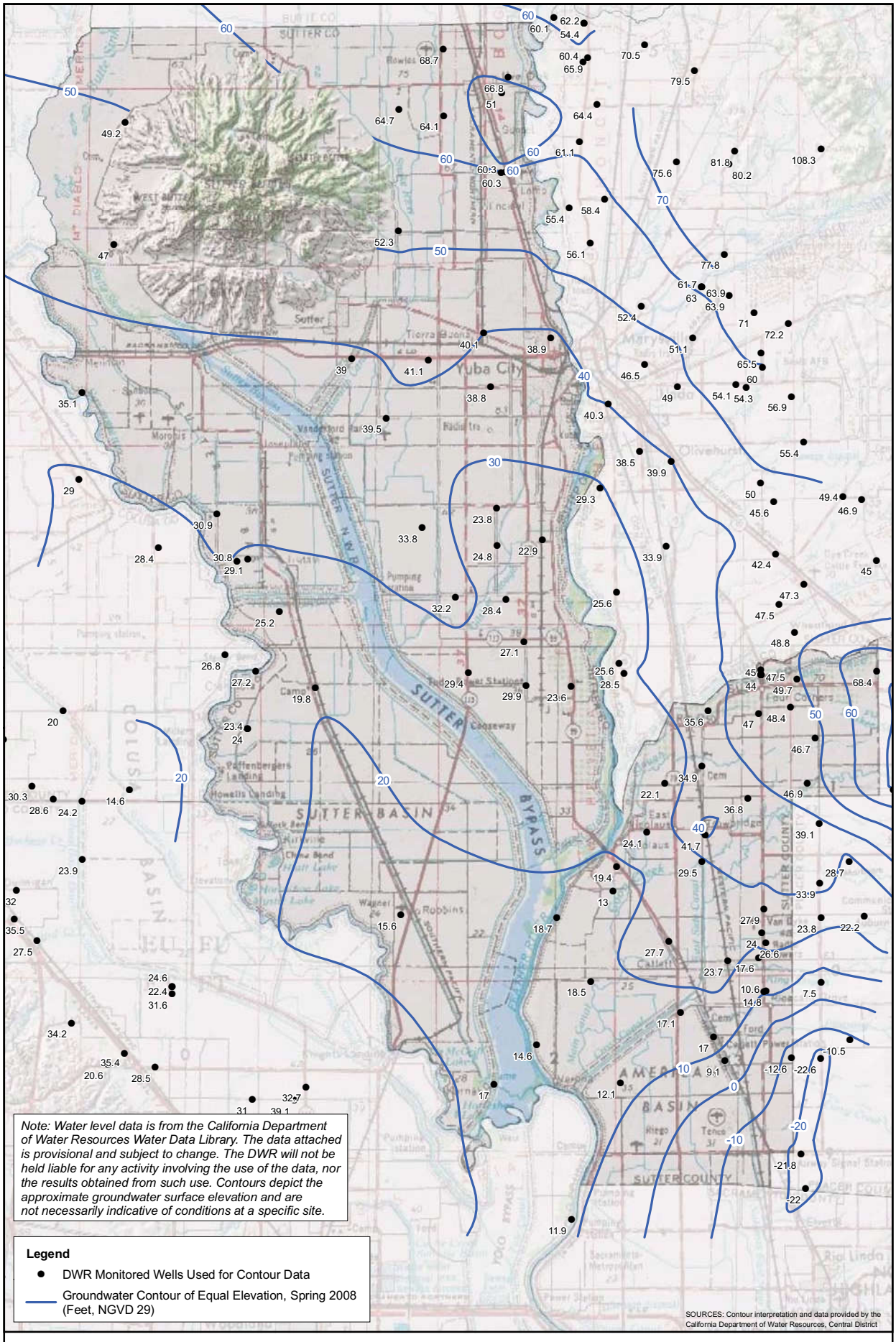

FIGURE 13
GROUNDWATER ELEVATION CONTOUR MAP
SPRING, 2008
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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NORTH
0 1.5 3
MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 13 Groundwater Elevation Contour Map Spring 2008.mxd 2/7/2012 6:20:59 PM bdemucha

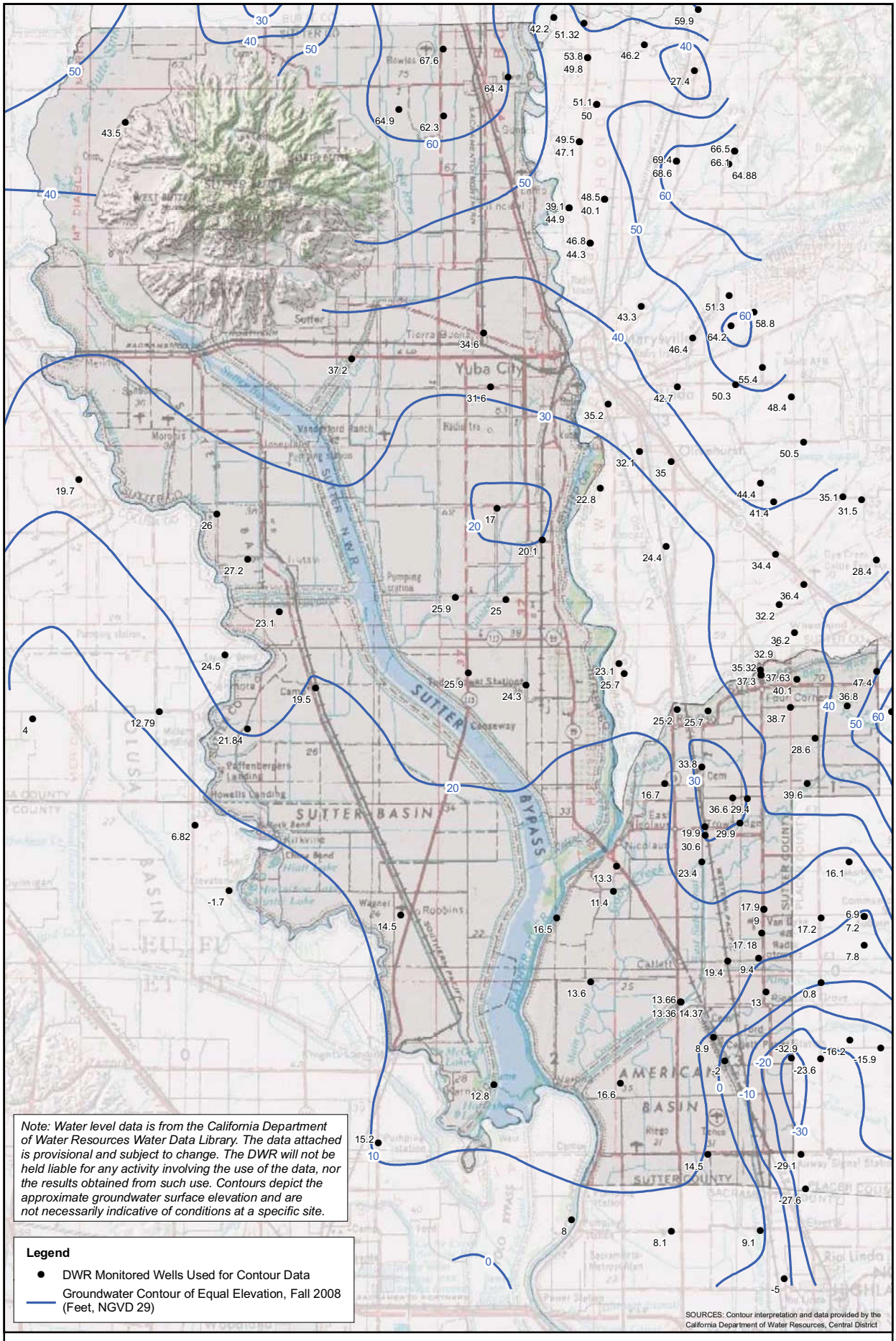

FIGURE 14
GROUNDWATER ELEVATION CONTOUR MAP
FALL, 2008
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

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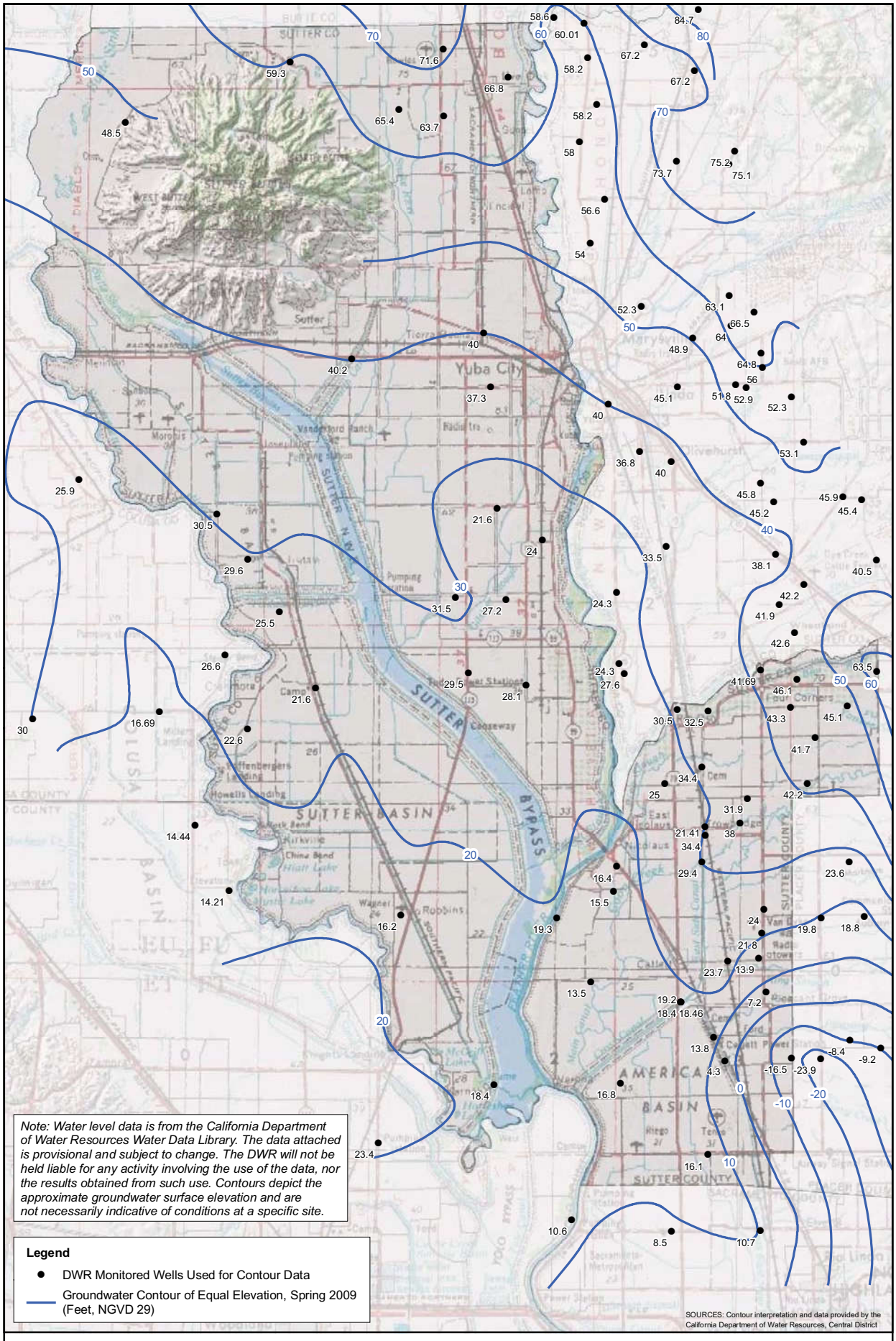
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 14 Groundwater Elevation Contour Map Fall 2008.mxd 2/8/2012 9:20:28 AM bdemucha



Note: Water level data is from the California Department of Water Resources Water Data Library. The data attached is provisional and subject to change. The DWR will not be held liable for any activity involving the use of the data, nor the results obtained from such use. Contours depict the approximate groundwater surface elevation and are not necessarily indicative of conditions at a specific site.

Legend

- DWR Monitored Wells Used for Contour Data
- Groundwater Contour of Equal Elevation, Spring 2009 (Feet, NGVD 29)

SOURCES: Contour interpretation and data provided by the California Department of Water Resources, Central District

FIGURE 15
GROUNDWATER ELEVATION CONTOUR MAP
SPRING, 2009
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
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NORTH
0 1.5 3
MILES

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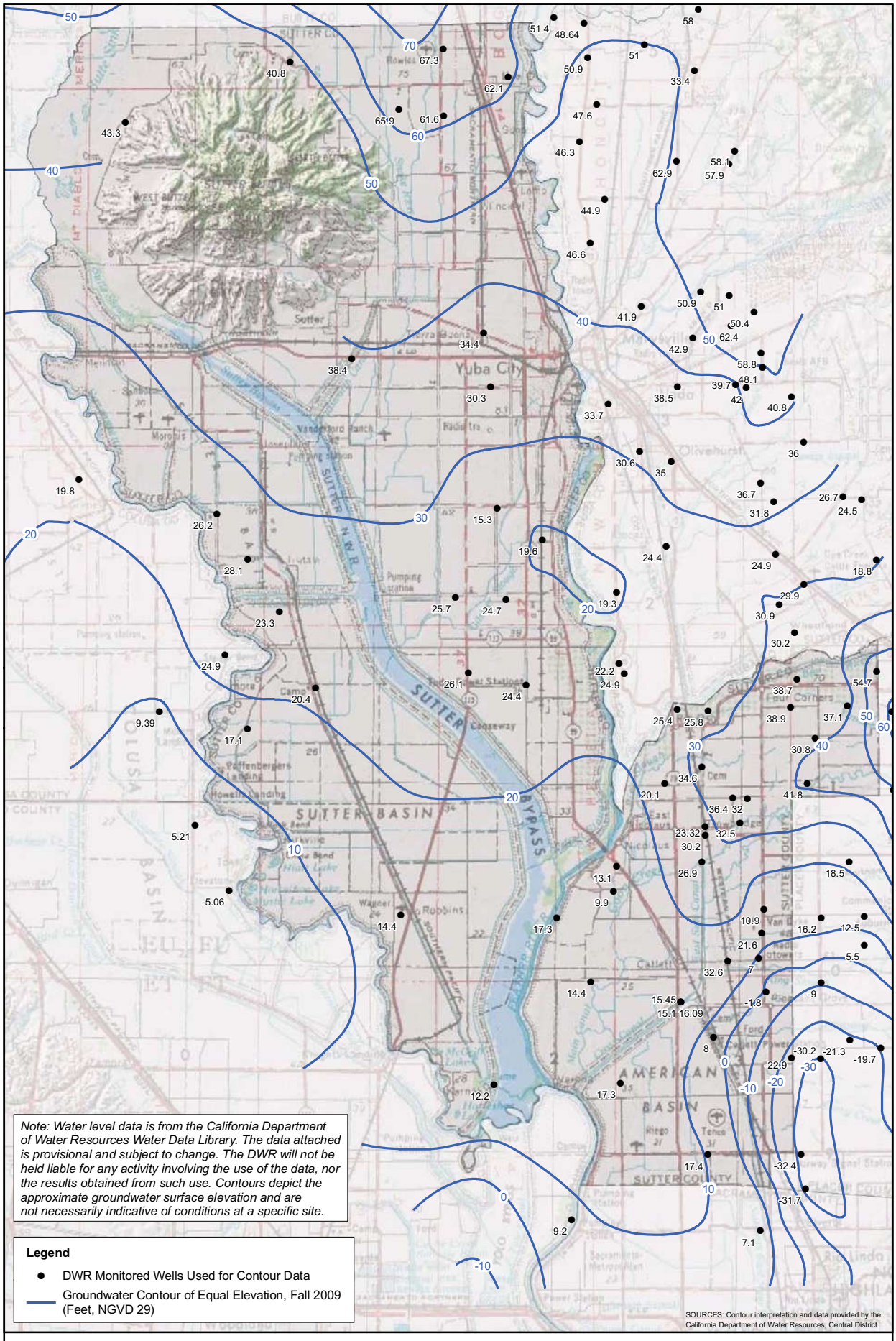

FIGURE 16
GROUNDWATER ELEVATION CONTOUR MAP
FALL, 2009
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

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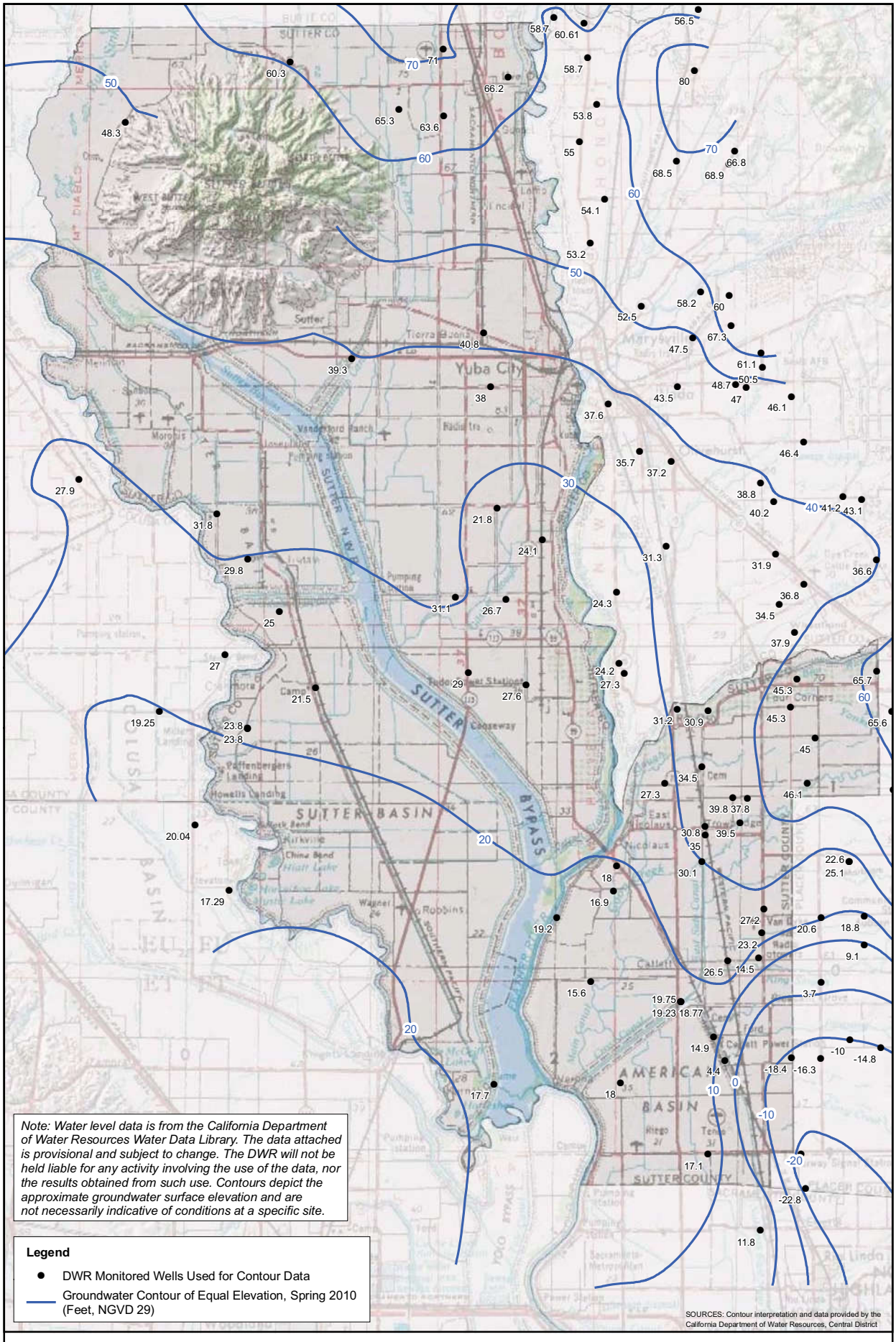
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 16 Groundwater Elevation Contour Map Fall 2009.mxd 2/8/2012 9:44:53 AM bdemucha



Note: Water level data is from the California Department of Water Resources Water Data Library. The data attached is provisional and subject to change. The DWR will not be held liable for any activity involving the use of the data, nor the results obtained from such use. Contours depict the approximate groundwater surface elevation and are not necessarily indicative of conditions at a specific site.

Legend

- DWR Monitored Wells Used for Contour Data
- Groundwater Contour of Equal Elevation, Spring 2010 (Feet, NGVD 29)

SOURCES: Contour interpretation and data provided by the California Department of Water Resources, Central District

FIGURE 17
GROUNDWATER ELEVATION CONTOUR MAP
SPRING, 2010
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

SUTTER COUNTY CALIFORNIA

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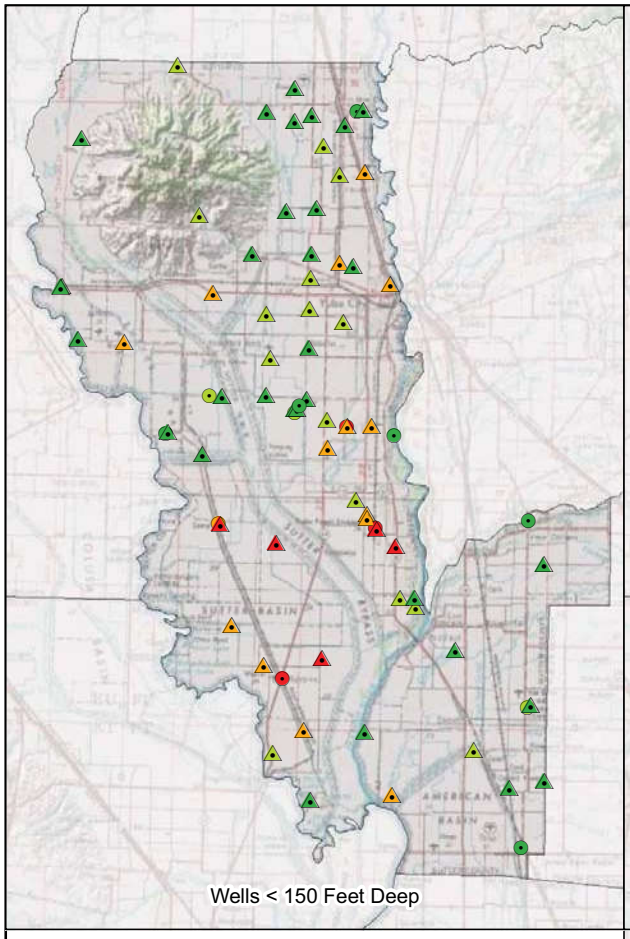
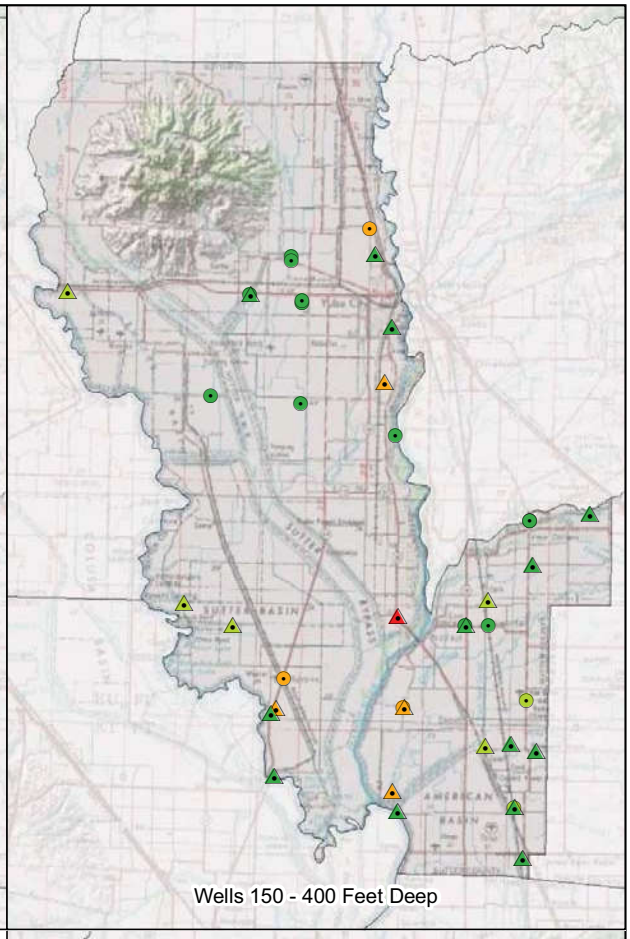




EC in DWR Wells (µmhos/cm)

- < 600
- 600 - 900
- 900 - 1600
- > 1600

EC in USGS Wells (µmhos/cm)

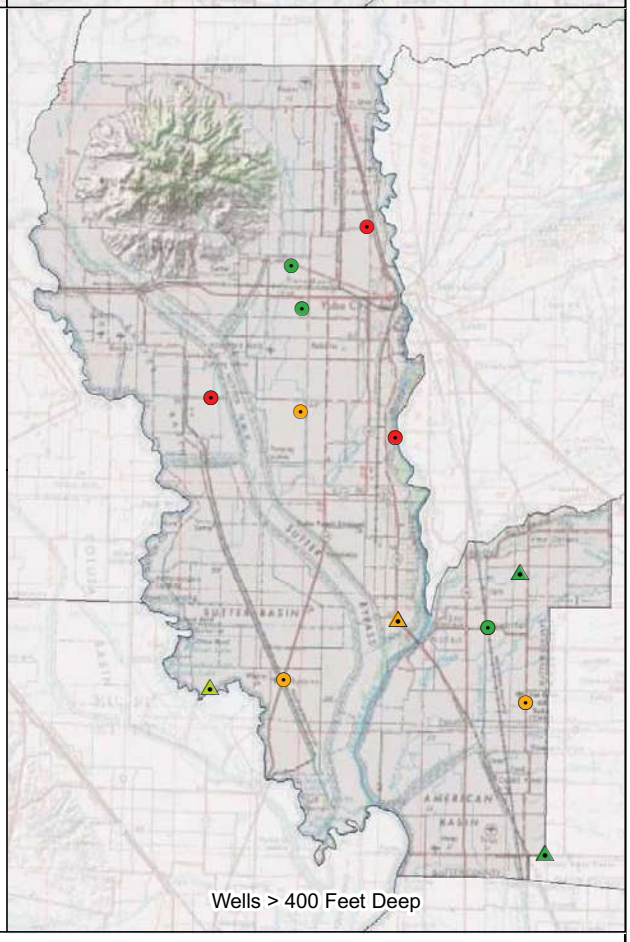
- < 600
- 600 - 900
- 900 - 1600
- > 1600

Note:
"EC" is an abbreviation for specific conductance, which is related to the salt content of a water sample.

For public drinking water systems, the secondary (aesthetic) maximum contaminant levels for EC are 900 micromhos/centimeter (µmhos/cm) (recommended), 1600 µmhos/cm (upper), and 2200 µmhos/cm (short-term).

For irrigation, crop yields decrease above a threshold EC value, which is crop-dependent. Crop yield potential decreases above these threshold levels:

Almonds - 1000 µmhos/cm
Beans - 700 µmhos/cm
Rice - 2000 µmhos/cm
Squash - 2100-3100 µmhos/cm
Tomatoes - 1700 µmhos/cm
Wheat - 4000 µmhos/cm



SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA

FIGURE 18
SPECIFIC CONDUCTANCE BY WELL DEPTH
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 3 6
MILES

SUTTER COUNTY CALIFORNIA

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 18 EC_Well Depth.mxd 2/8/2012 10:00:29 AM bdemucha

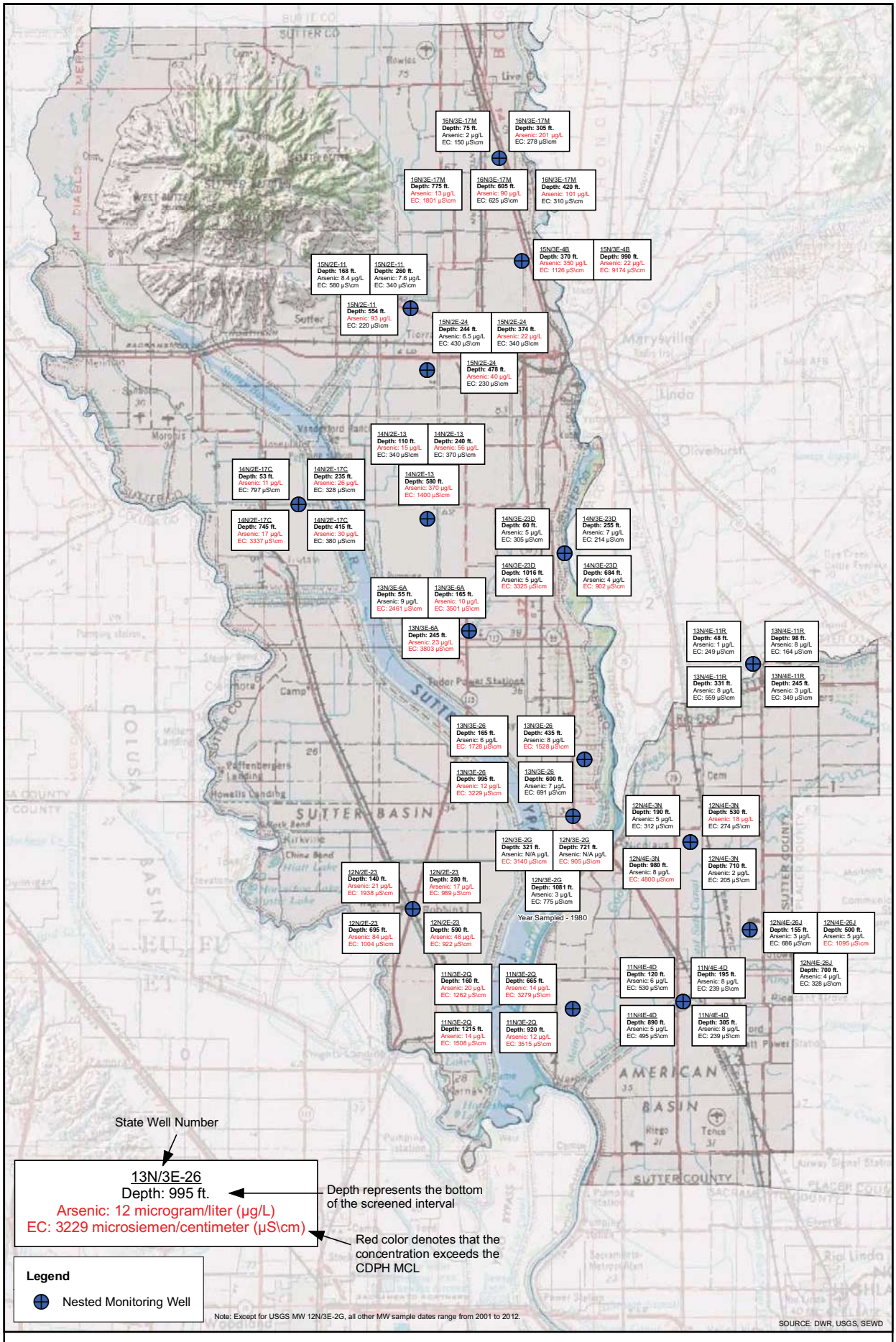

FIGURE 19
DEPTH SPECIFIC ARSENIC AND SPECIFIC CONDUCTANCE CONCENTRATIONS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

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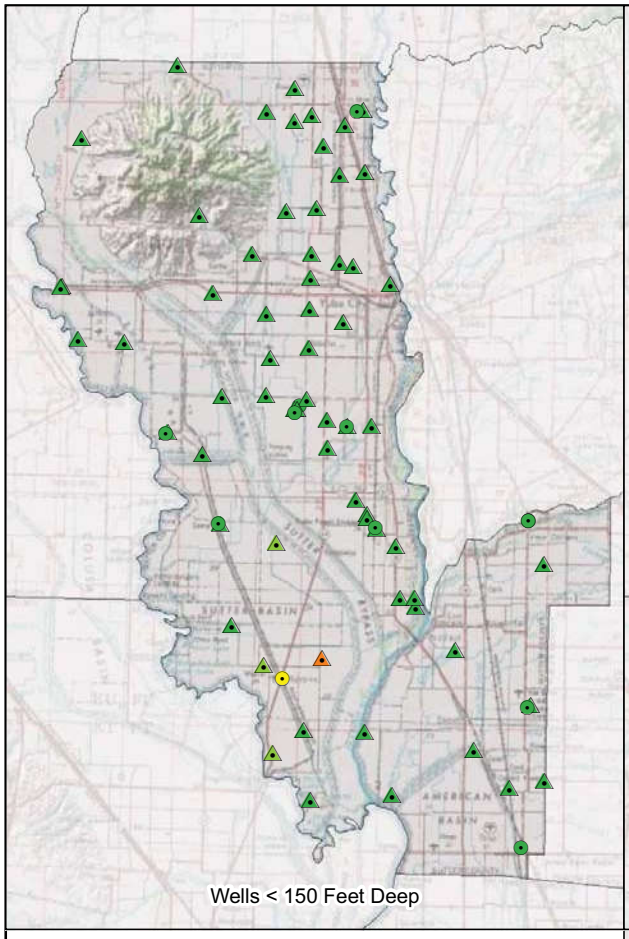
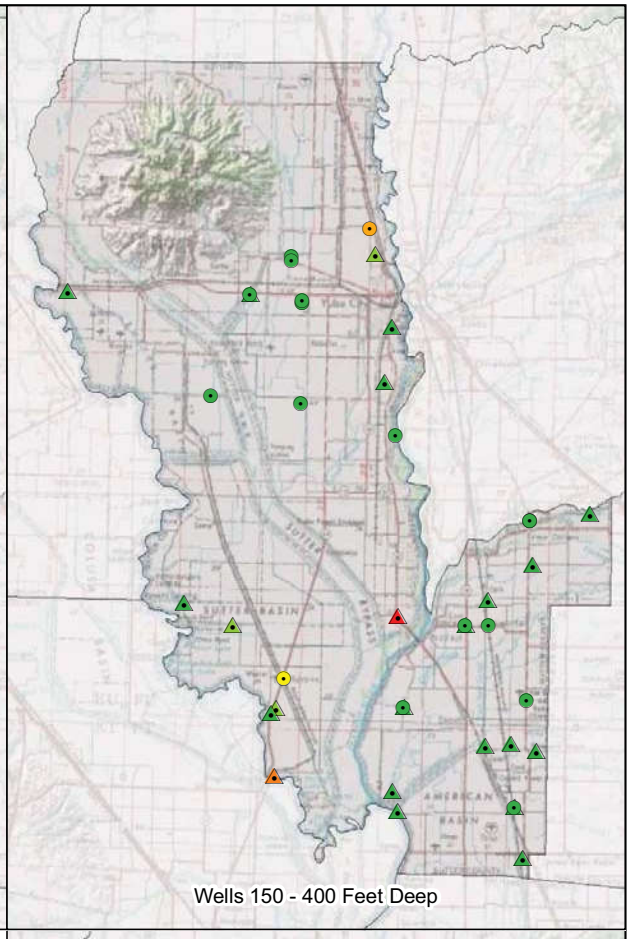
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120201 Final Draft Figure Comments\Figure 19 Depth Specific Arsenic and Specific Conductance.mxd 2/8/2012 11:34:41 AM bdemucha



Wells < 150 Feet Deep



Wells 150 - 400 Feet Deep

Boron in DWR Wells (µg/L)

- < 500
- 500 - 750
- 750 - 1000
- 1000 - 2000
- > 2000

Boron in USGS Wells (µg/L)

- < 500
- 500 - 750
- 750 - 1000
- 1000 - 2000
- > 2000

Note:
Boron is naturally occurring and leaches from aquifer materials into groundwater.

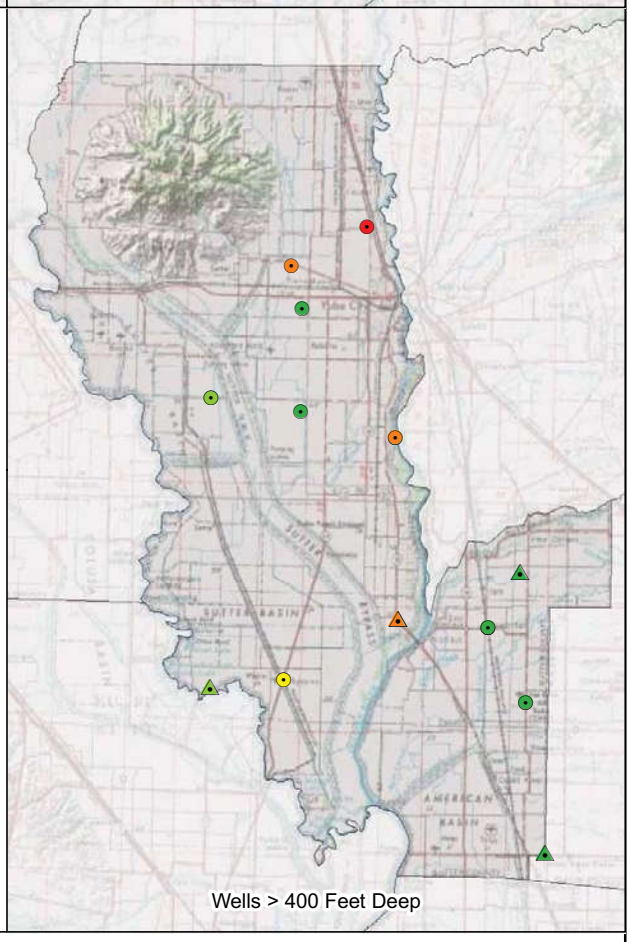
For public drinking water systems, there is a notification level for boron of 1000 micrograms/liter (µg/L).

For irrigation, boron is necessary for crop growth but becomes toxic to the point that yields may decrease above these threshold levels:

Beans - 750 - 1000 µg/L
Grapes - 500 - 750 µg/L
Squash - 2000 - 4000 µg/L
Tomatoes - 4000 - 6000 µg/L
Walnuts - 500 - 750 µg/L
Wheat - 750 - 1000 µg/L

Many other trees are vulnerable to boron toxicity above 500 - 750 µg/L.

SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA



Wells > 400 Feet Deep

FIGURE 20
BORON BY WELL DEPTHS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH

0 3 6
MILES

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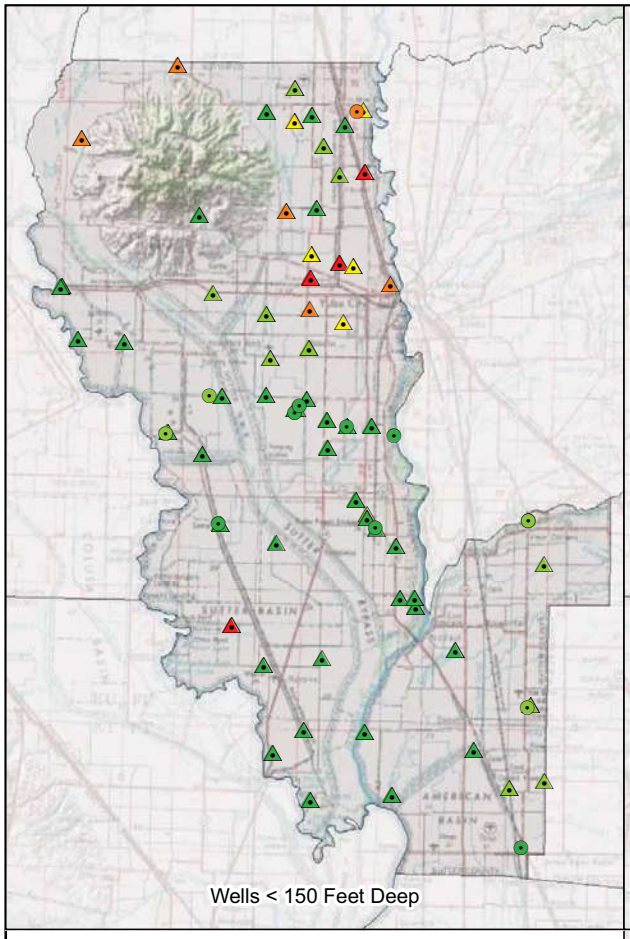
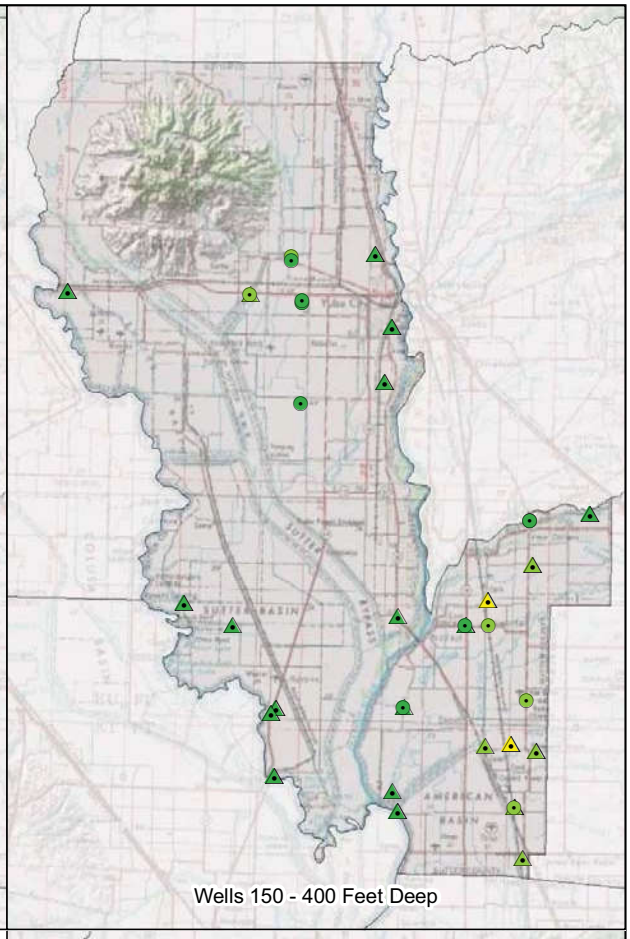




Nitrate in DWR Wells (mg/L)

- < 5
- 5 - 15
- 15 - 30
- 30 - 45
- > 45

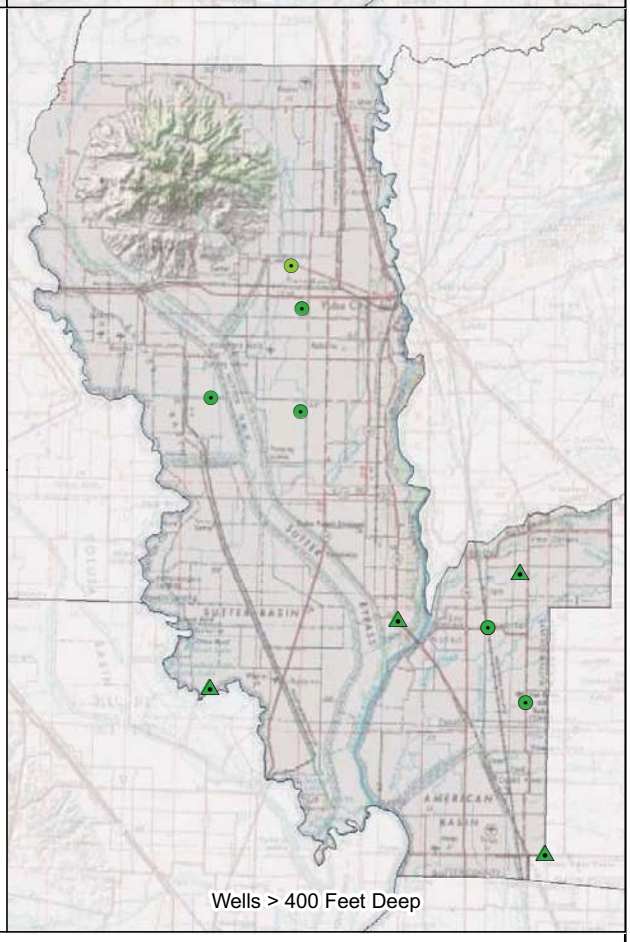
Nitrate in USGS Wells (mg/L)

- < 15
- 5 - 15
- 15 - 30
- 30 - 45
- > 45

Note:
Nitrate is generally introduced into groundwater by septic systems, fertilizers, or confined animal operations.

For public drinking water systems, the primary (health-based) maximum contaminant level for nitrate as NO3 is 45 milligrams/liter (mg/L).

At concentrations exceeding the maximum contaminant level, nitrate can interfere with the blood's ability to carry oxygen. This effect can be especially pronounced in infants, where it is known as "blue baby syndrome".



SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA

FIGURE 21
NITRATE BY WELL DEPTH
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 3 6
MILES

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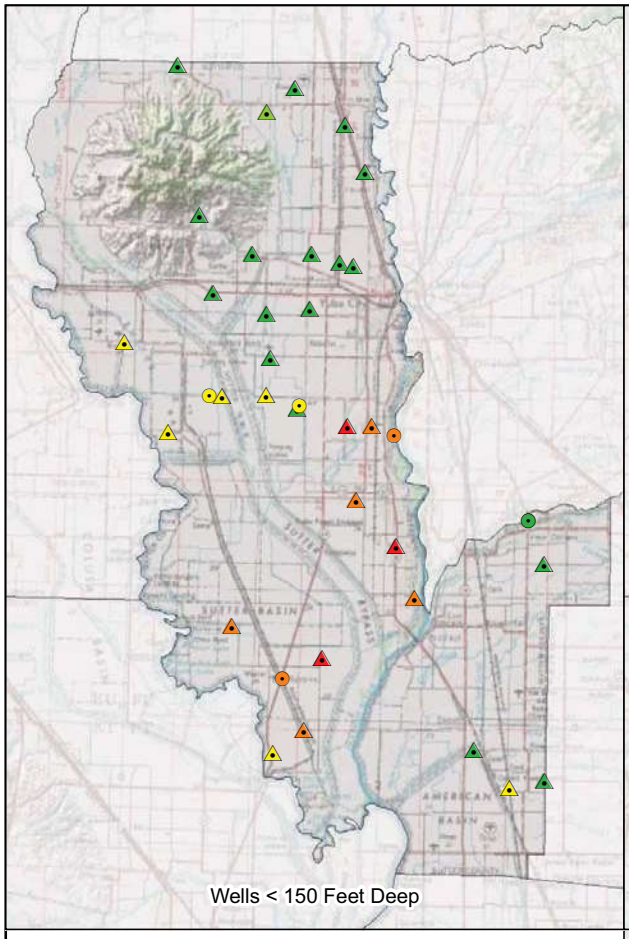
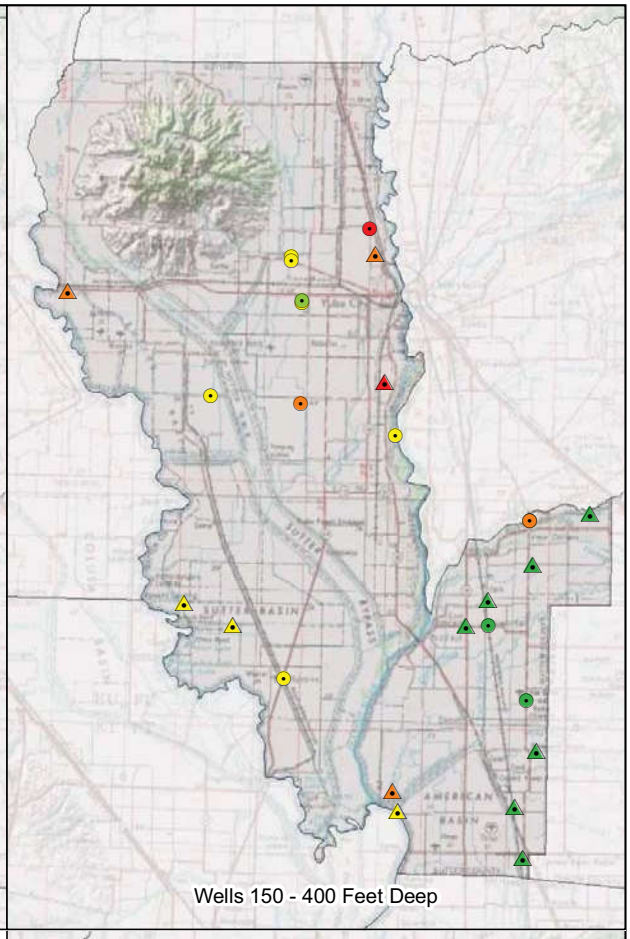
J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 21 Nitrates_Well Depth.mxd 2/8/2012 2:10:46 PM bdemucha





Manganese in DWR Wells (µg/L)

- < 25
- 25 - 50
- 50 - 150
- 150 - 500
- > 500

Manganese in USGS Wells (µg/L)

- < 25
- 25 - 50
- 50 - 150
- 150 - 500
- > 500

Note:
Manganese is naturally occurring and leaches from aquifer materials into groundwater.

For public drinking water systems, the secondary (aesthetic) maximum contaminant level for manganese is 50 micrograms/liter (µg/L). There is also a notification level for manganese of 500 µg/L. Notification levels are health-based advisory levels for chemicals that do not have primary maximum contaminant levels.

Manganese can cause staining of plumbing and fixtures, and can contribute a metallic odor to water. At very high concentrations (above the notification level) manganese may cause neurologic problems.

Analysis for manganese is very sensitive to turbidity of samples - turbid samples will often have artificially high results for manganese.

SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA

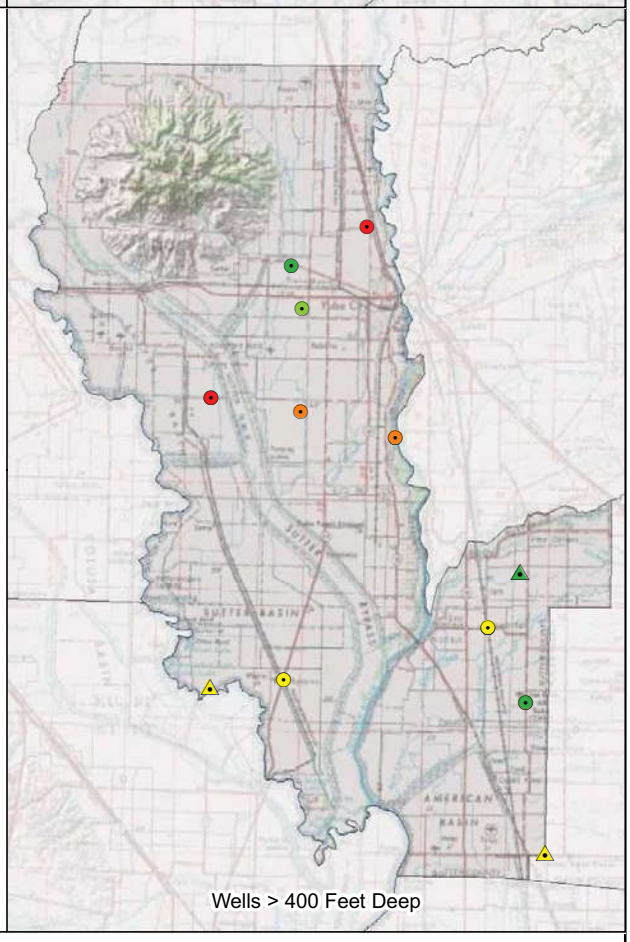


FIGURE 22
MANGANESE BY WELL DEPTHS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 3 6
MILES

SUTTER COUNTY CALIFORNIA

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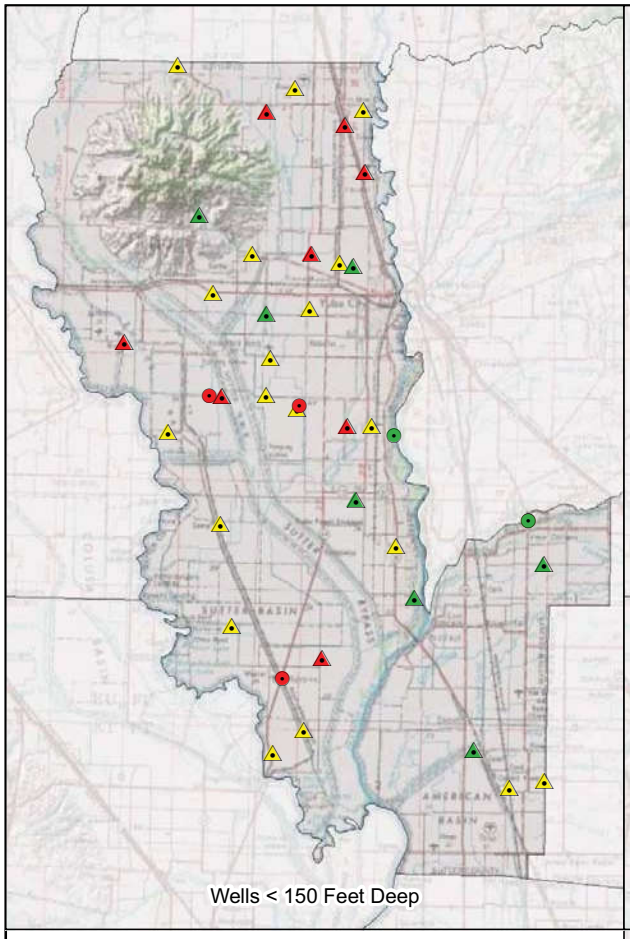
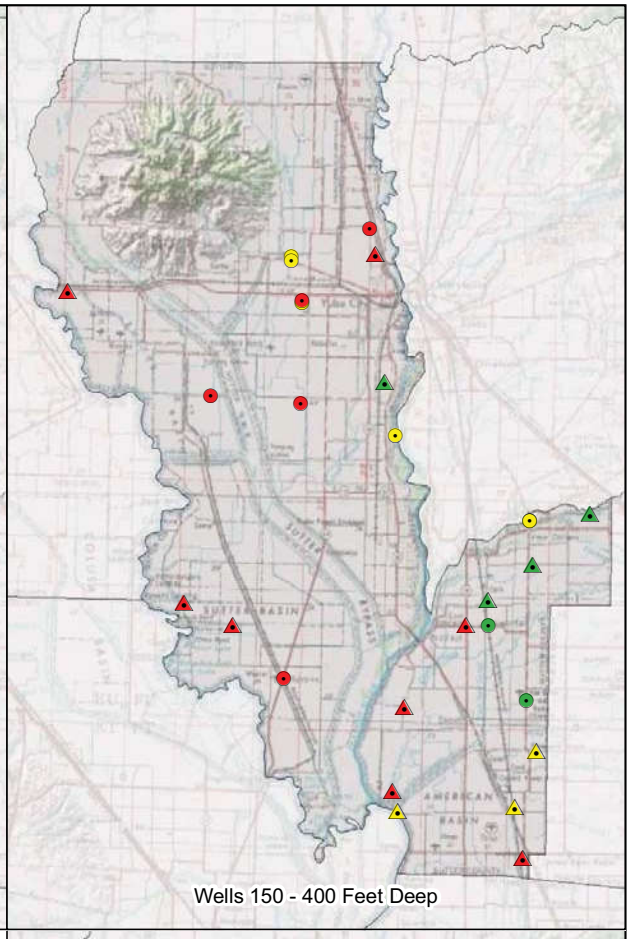
3301 C Street, Bldg. 100-B Tel: 916.341.7760
Sacramento, CA 95816 Fax: 916.341.7767





Arsenic in DWR Wells (µg/L)

- < 5
- 5 - 10
- > 10

Arsenic in USGS Wells (µg/L)

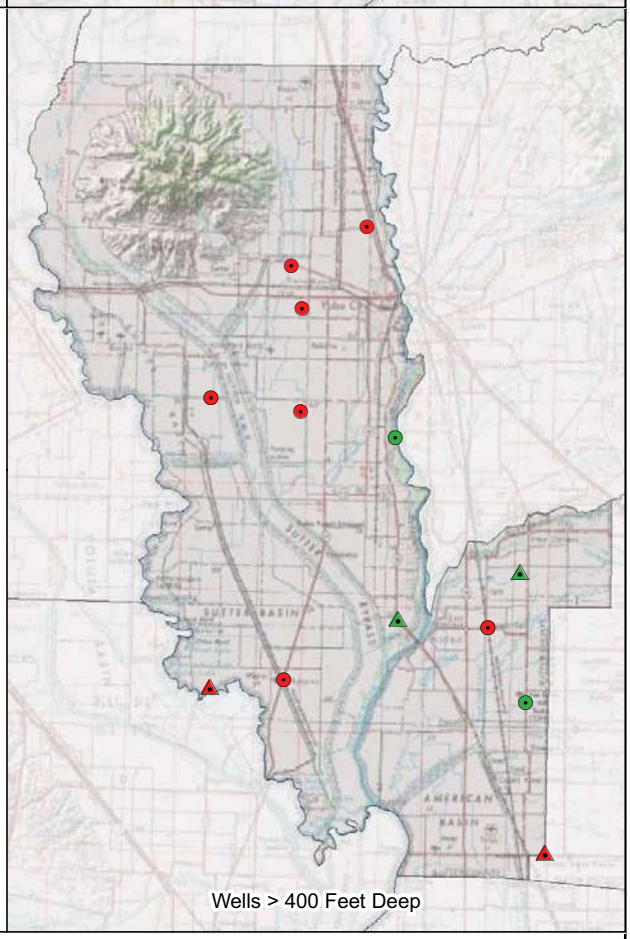
- < 5
- 5 - 10
- > 10

Note:
Arsenic is naturally occurring and leaches from aquifer materials into groundwater.

For public drinking water systems, the primary maximum contaminant level for arsenic is 10 micrograms/liter (µg/L).

Exposure to arsenic can cause both short and long term health effects. Long term exposure to arsenic has been linked to cancer of the bladder, lungs, skin, kidneys, nasal passages, liver and prostate. Short term exposure to high doses of arsenic can cause other adverse health effects.

Analysis for arsenic is very sensitive to turbidity of samples - turbid samples will often have artificially high results for arsenic.



SOURCES: USGS, DWR, SEWD, DHS, FAO, EPA

FIGURE 23
ARSENIC BY WELL DEPTHS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH

0 3 6
MILES

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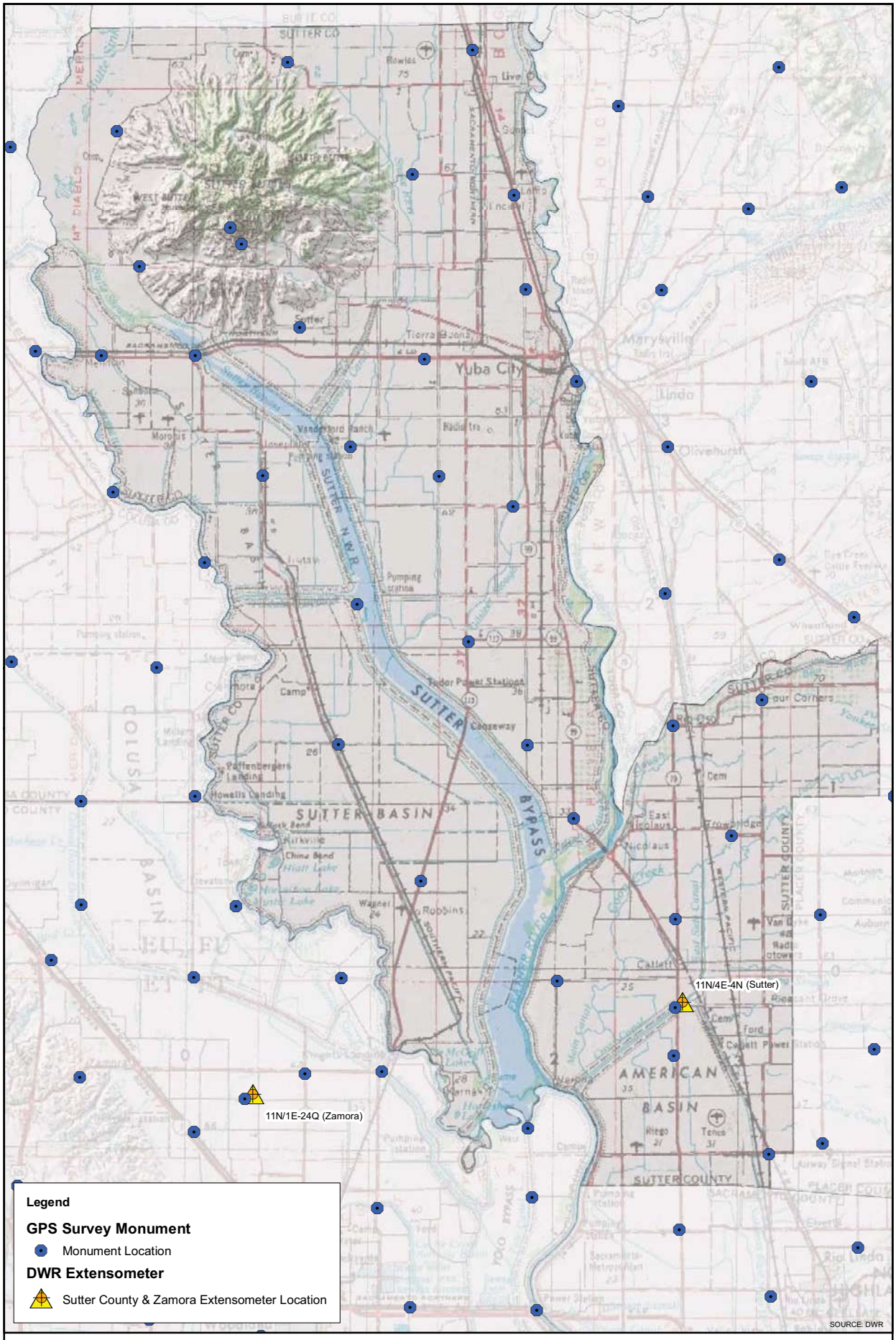

FIGURE 24
LAND SUBSIDENCE NETWORK
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 24 Land Subsidence Network.mxd 2/8/2012 2:43:42 PM bdemucha

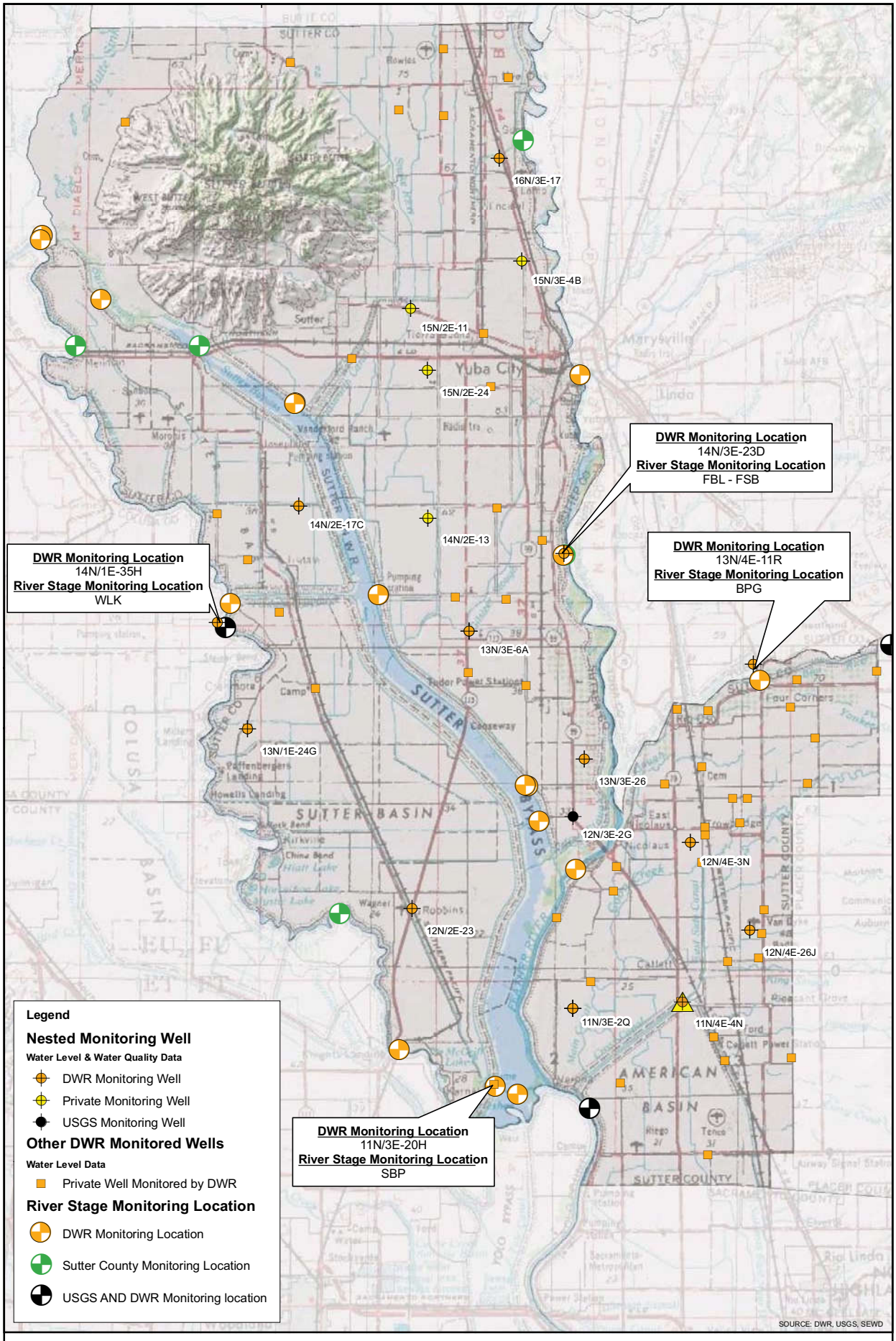

FIGURE 25
GROUNDWATER AND RIVER STAGE MONITORING LOCATIONS
SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN
FEBRUARY 2012

NORTH
0 1.5 3
MILES

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J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 25 Groundwater and River Stage Monitoring Locations.mxd 2/8/2012 2:46:51 PM bdemucha

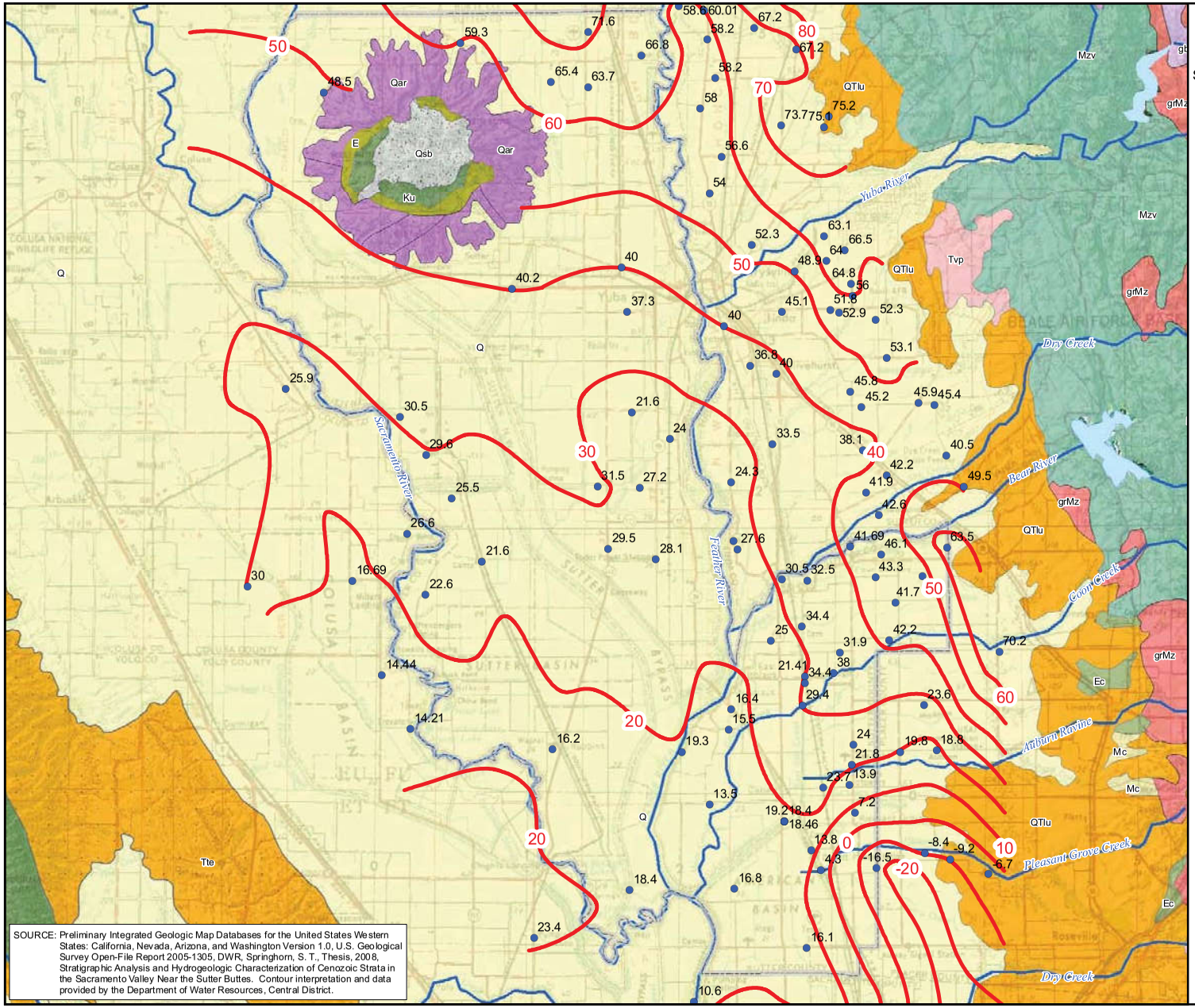

FIGURE 26

RECHARGE AND GROUNDWATER ELEVATION CONTOUR MAP SPRING, 2009

SUTTER COUNTY GROUNDWATER MANAGEMENT PLAN

FEBRUARY 2012

NORTH

0 2 4

MILES

- Q - Recent Deposits
  - Qb - Basin Deposits
  - Qm - Modesto Formation
  - Qr - Riverbank Formation
- Qsb - Sutter Buttes Igneous Rocks
- Qar - Sutter Buttes Andesitic Rampart
- QTlu - Laguna Formation
- Tte - Tehama Formation
- Tvp - Andesite, Rhyolite
- Mc - Sandstone, Conglomerate
- Ec - Conglomerate, Sandstone
- E - Mudstone, Sandstone
- Ku - Sandstone, Mudstone
- J - Mudstone, Sandstone, & Slate
- um - Serpentinite
- Mzv - Volcanic, Metavolcanic
- gb - Gabbro, Diorite
- grMz - Granodiorite
- Sutter County
- DWR Monitored Wells Used for Contours
- Groundwater Contour of Equal Elevation (Feet, NGVD 29)

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Sacramento, CA 95816 Fax: 916.341.7767

J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 26 Recharge and Groundwater Elevation Contour Map Spring, 2009.mxd 2/8/2012 3:11:15 PM bdemucha

Figure 27
Sutter County
Well Construction By Year

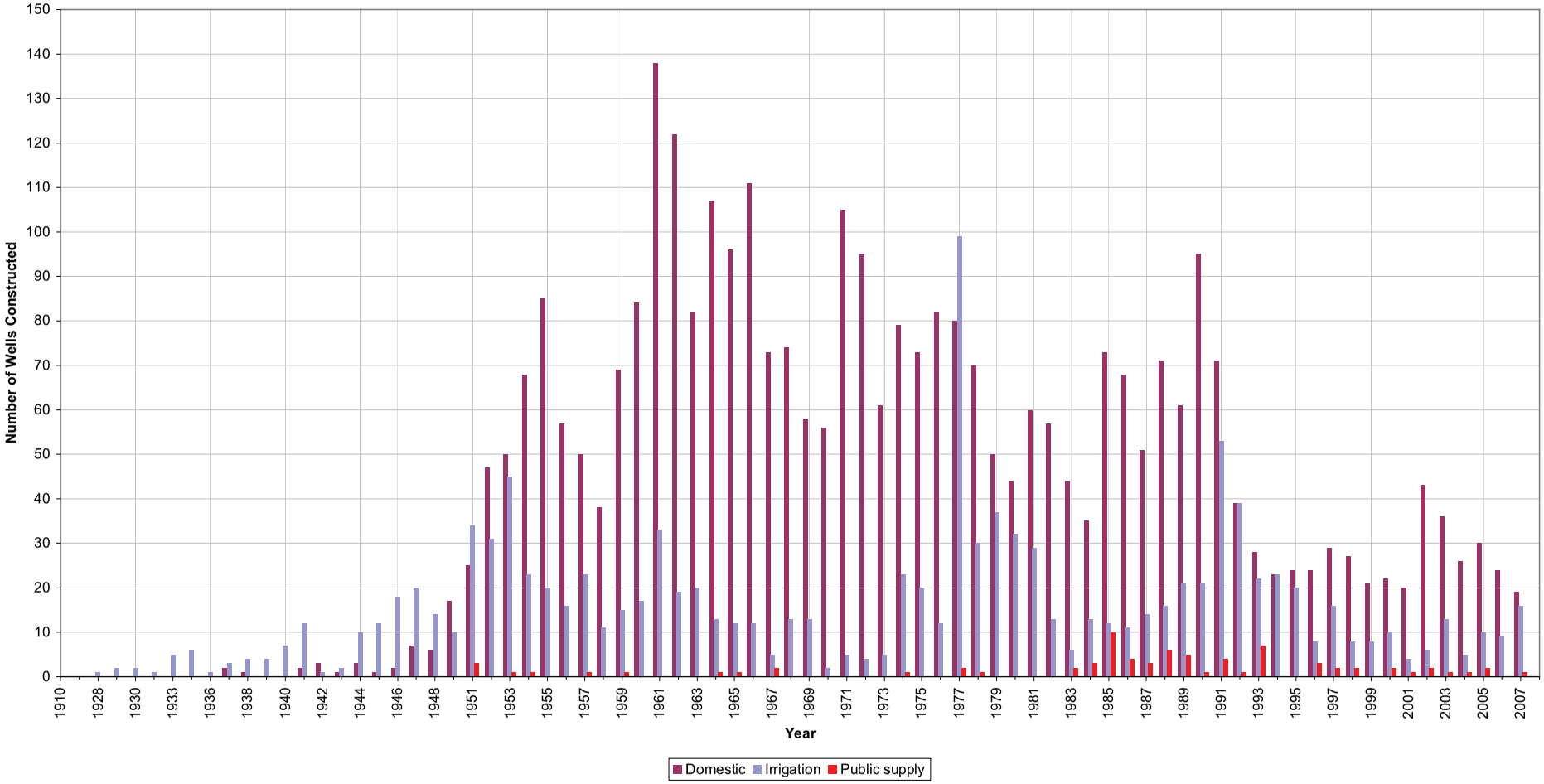
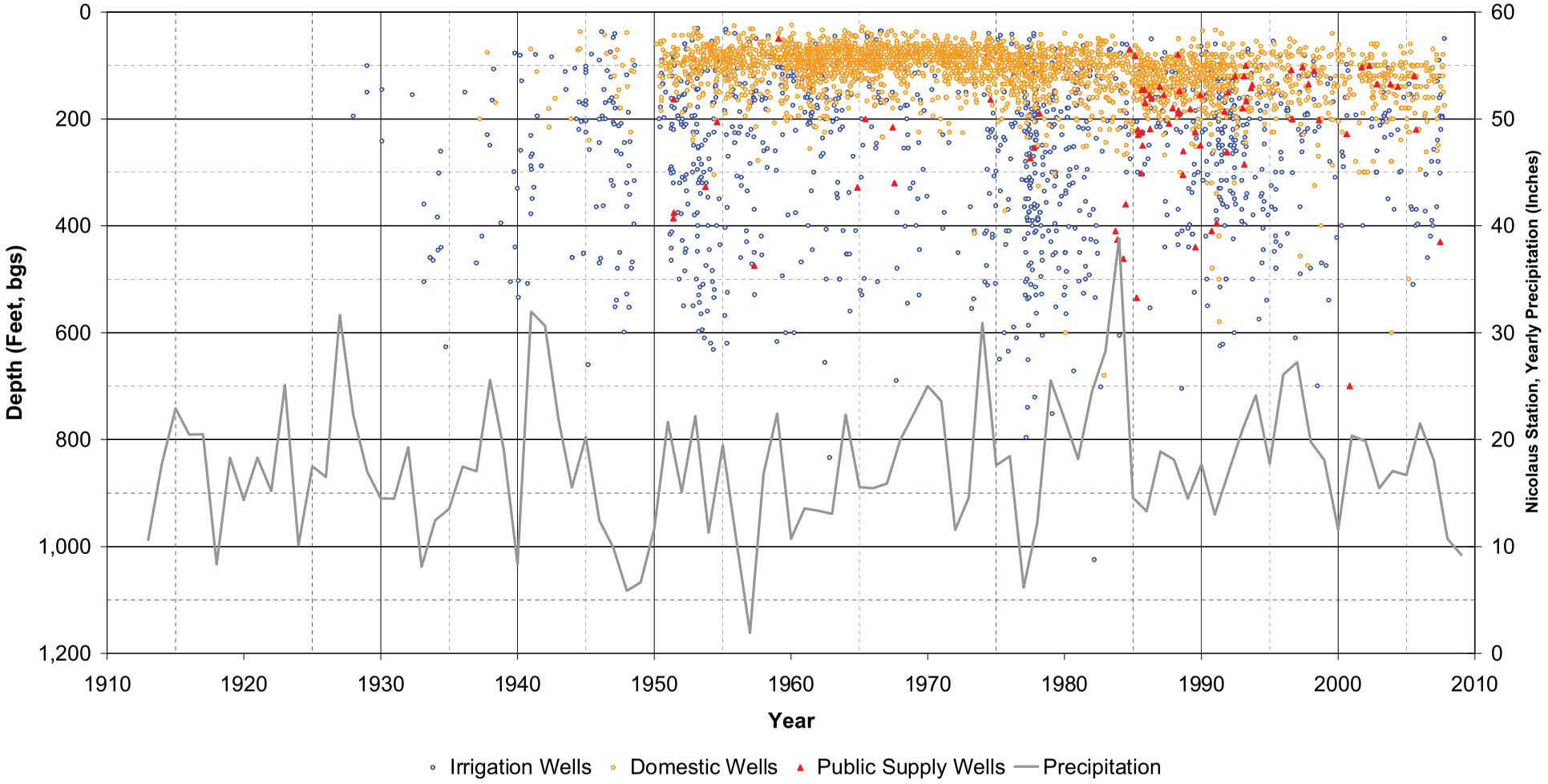


Figure 28
Sutter County
Historic Well Construction by Depth and Annual Precipitation



Toxic Water: A series about the worsening pollution in American waters and regulators' response

Examine whether contaminants in your water supply met two standards: the legal limits established by the Safe Drinking Water Act, and th typically stricter health guidelines. The data was collected by an advocacy organization, the Environmental Working Group, who shared it with The Times.

Browse All States
Understanding the Data
Related Story
Join the Discussion
All Stories in the Series: Toxic Waters »

View State...

Princeton Water District

Chart
Key
1 or more tests taken in the month
1 or more positive detections
1 or more tests above health limit
1 or more tests above legal limit

Princeton, California. Serves 408 people.

1 contaminant above legal limits

In some states a small percentage of tests were performed before water was treated, and some contaminants were subsequently removed or diluted. As a result, some reported levels of contamination may be higher than were present at the tap. Results shown are based on individual samples and may not indicate a violation of the Safe Drinking Water Act, which often occurs only after prolonged tests show concentrations above a legal limit.

					Number of Tests					
Contaminant	Average result	Maximum result	Health limit	Legal limit	Total #	Positive result	Above health	Above legal	Monthly Testing History Chart key at top of page	E.P.A. regulated
Arsenic (total)	12.50 ppb	17	2	10	1	1	1	1		Yes

Units: ppb: parts per billion, pCi/L: picocuries per liter, ppm: parts per million, mrem/yr: millirems per year, MFL: million fibers per litre

Additional Resources

View E.W.G.'s Report for This System »

Note: The Times' analysis may differ from the Environmental Working Group (Learn More)

View E.P.A. Violations »

Source: The Environmental Working Group (**About this data**)

System operators should contact The Times to report inaccuracies or comments.

Charles Duhigg, Matthew Ericson, Tyson Evans, Brian Hamman, Derek Willis

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DEL ORO WATER COMPANY

DELIVERING NATURE'S PRECIOUS RESOURCE



November 3, 2015

Advice Letter No. 424

TO THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Del Oro Water Company, Inc. on behalf of its Walnut Ranch District (District) hereby transmits for filing the following Advice Letter No. 424 to recover costs associated with both the District's reimbursement of City of Colusa fees incurred in contract negotiations for the Emergency Transmission Intertie Project as well as District costs incurred with the Colusa Industrial Park Intertie Project. Changes in the respective District tariff schedule are attached hereto:

Cal. P.U.C. Sheet No.	Title of Sheet	Schedule No.	Canceling Cal. P.U.C. Sheet No.
-W	Schedule No. WR-2 (cont.) Residential Flat Rate Service	WR-2	1701-W
-W	Table of Contents		-W
-W			-W

Purpose

DOWC hereby submits this filing and the attached calculations **[Exhibit A]** in support of its claim for reimbursement of the costs associated with both the Emergency Transmission Intertie Project with the City of Colusa as well as those incurred with the Colusa Industrial Park Intertie Project. All costs have been tracked in DOWC's Preliminary Statement Paragraph S "Del Oro Water Company Extraordinary Events Emergency Water and/or Supplemental Water Memorandum Account (EEEW/SWMA)" **[Exhibit B]**. This account tracks costs which are incurred from time-to-time in purchasing water from outside agencies and/or interconnecting to outside agencies (either temporarily or permanently) in order to facilitate delivery of water for any of DOWC's districts. The EEEW/SWMA for the District has tracked all costs **[Exhibit C]** totaling $93,845.29 specifically relating to contract negotiations with the City regarding the Emergency Transmission Intertie Project as well as the legal and engineering costs of the proposed Colusa Industrial Park Intertie Project.

Background

CITY OF COLUSA/DOWC WALNUT RANCH EMERGENCY TRANSMISSION INTERTIE PROJECT

On August 18, 2008 Del Oro Water Company (DOWC), on behalf of its Walnut Ranch District, contacted Mr. Rob Hickey, then City Manager for the City of Colusa, and requested the City Council consider a permanent intertie to their system as an alternative to the Colusa Industrial Park Intertie Project which was suspended while the customers and the City explored the City purchasing the District's assets. DOWC thought an intertie with the City would provide its customers with potable water at the most reasonable cost. The City's ultimate position was that an intertie could only be used on an emergency basis and not considered a permanent solution to the water issues within the District.

As part of the agreement executed on February 3, 2009 with the City **[Exhibit D]**, DOWC agreed to pay all City costs in bringing the emergency contract to fruition. A recent internal audit has found the costs totaling $8,184.11 were not addressed for reimbursement to the District in discussions with the City. These costs are included in the total requested reimbursement.

THE COLUSA/DOWC INDUSTRIAL PARK INTERTIE PROJECT

In 2005, the District began working on an intertie project with the Colusa Industrial Park knowing the water issues within the District required an alternative source. Efforts were also required as a response to The State Water Resources Control Board's (formerly The State Department of Public Health) Compliance Order No. 01-21-10 on July 15, 2010 ordering the District to achieve compliance with the maximum contaminant level for Arsenic, which the District's water supply exceeded. Tremendous efforts and cooperation between the parties resulted in the Colusa Industrial Park Intertie Project **[Exhibit E]**, approved by CPUC Res. W-4761, dated May 7, 2009 **[Exhibit F]**, but which was stalled due to customers' desire to annex to the City of Colusa. In that regard, the District suspended work on the project and the project was classified in CPUC Res.W-4873 **[Exhibit G]** as "... currently suspended Industrial Park Intertie Project...". Point being made that the project was not disapproved but reimbursement was on hold pending the customers' and City's efforts to have the City of Colusa acquire the District.

Now comes forth the City of Colusa, as of October 29, 2015, with an officially tendered 'sole tentative offer' on fair market value as well as their recognition of the Purchase Water Surcharge (Advice Letter No. 366-A). However, we believe we have a disconnect regarding the recovery process for costs incurred in bringing the Colusa Industrial Park Intertie Project to a shovel ready status, and DOWC's entitlement to reimbursement for legal and associated appraisal costs to date.

Therefore, The District proposes to collect the $93,845.29 reflecting both the Emergency Transmission Intertie Project and the Colusa Industrial Park Intertie costs in a surcharge of $20.58 per customer per month for sixty (60) months or until the full amount is collected.

Requested Effective Date

DOWC is submitting the attached as a Tier 3 filing and requests that it become effective at the earliest date as the Commission's decision is critical in negotiating with the City of Colusa.

Notice and Service

All customers and interested parties will be notified of the request for reimbursement of costs associated with the Colusa Industrial Park Intertie Project for Commission consideration and approval and its rate impact by way of direct mail on Tuesday, November 3, 2015 **[Exhibit H]**.

File a PROTEST:

A protest is a document stating that you object to the utility receiving all or some part of its request. If you wish to file a protest, you must state the facts constituting the grounds for the protest, how the advice letter affects you, and the reasons why you believe the whole advice letter, or part of it, is not justified.

If the protest requests an evidentiary hearing (an evidentiary hearing is a legal proceeding held before an administrative law judge at the Commission to obtain evidence), your protest must state the facts you would present at the evidentiary hearing to support your request for a complete or a partial denial of the advice letter. The filing of a protest does not ensure that an evidentiary hearing will be held. The decision whether or not to hold an evidentiary hearing will be based on the contents of the protest.

File a RESPONSE:

A response is a document that does not object to the request sought in the application, but nevertheless, presents information you believe would be useful to the Commission in acting on the application.

Whether you wish to file a PROTEST or send a RESPONSE you must:

- Send a copy of your document to the utility.
- A protest must be emailed or mailed (email preferred) within (20) days of the date you received this notice.

The utility must respond to your protest or response within five (5) days. All protests or responses to this filing should be sent to:

California Public Utilities Commission,
Water Division
505 Van Ness Avenue
San Francisco, California 94102
E-Mail : water_division@cpuc.ca.gov

and

Director of Community Relations
Drawer 5172
Chico, CA 95927
(530) 717-2509 / Fax: (530) 894-7645
E-Mail: communityrelations@delorowater.com

If you have not received a reply to your protest within ten (10) business days, contact Del Oro Water Company at 1-530-717-2509.

This filing will not cause withdrawal of service nor conflict with any other schedule or rule.

A copy of Del Oro Water Company's filing may be inspected in its business office: 426 Broadway, Suite 301, Chico, California 95928 or by visiting the website at www.delorowater.com. Further information may be obtained from the utility at its business office or from the Commission at the above address.

Del Oro Water Company, Inc.

Janice Hanna

JANICE HANNA
Director, Corporate Accounting

Attachments

Del Oro Water Company- Walnut Ranch District Consolidation

Updated on: February 9, 2018

County: Colusa
Population: 182
Challenges: Drinking water standard violation for Arsenic
Consolidation date: April 6, 2017

The Del Oro Water Company - Walnut Ranch District served a population of 182 customers. The water system had one well which exceeded the maximum contaminant level for arsenic and physically collapsed, leaving the Walnut Ranch Subdivision to rely on an emergency intertie with the City of Colusa (City).



Figure 1. Old Well and Associated Equipment

A consolidation project was funded by a $500,000 State Revolving Fund planning grant which included the following- an engineering report, CEQA/NEPA[1] documentation, annexation agreements, and plans and specifications for needed distribution upgrades.

The City acquired the assets of Del Oro Water Company - Walnut Ranch District in April 2017. The consolidating system is now moving forward to replace distribution pipelines under a construction project with the State Water Resources Control Board's Division of Financial Assistance.

Even with the City's water rates and a temporary assessment on the customers for required upgrades, the customers are paying $20 less per month under the consolidation compared to when the system was operating alone. The figure shows the well and sand separation, and pressure tank equipment that is no longer required to be operated and maintained by the subdivision adding the reduction of their monthly bills.

[1] California Environmental Quality Act (CEQA)/ National Environmental Policy Act (NEPA)

From:	Karen Biane
To:	Mary Fahey
Subject:	Sub-watershed public comments
Date:	Thursday, December 17, 2020 2:56:52 PM
Attachments:	Colusa subwatershed comments.docx

CAUTION: This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Dear Ms. Fahey:

My name is Karen Biane. My family is a "stakeholder" in the Glenn County subwatershed basin. I have had the opportunity to attend the online December 9, 2020 Colusa Glenn Subbasin SGMA, and December 14, Butte SGMA meetings. I found both sets of meetings to be worth attending. At the conclusion of the meetings, public input was encouraged, which is why I am writing.

My background is in the financial services industry, and international bank management training. That background is what has compelled me to write. I have attached a memo outlining my commentary on specific areas about the presentations and plans.

I am aware of the incredible complexity and challenges the planning and implementation of the program will involve. The ideas presented are designed to potentially improve the communications to, and understanding by, the water community.

I will look forward to the December 22, 2020 meeting. Please feel free to contact me with any questions. My email is: knbiane@gmail.com, home phone: 916-791-1912.

Respectfully submitted,

Karen Biane
knbiane@gmail.com

From: Ben King <bking@pacgoldag.com>
Sent: Tuesday, February 2, 2021 3:06 PM
To: Ceppos, David M <dceppos@csus.edu>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; Ben King <bking@pacgoldag.com>
Subject: Determination of the Location of the Willows Fault Near the City of Colusa

Hi David,

Can you forward this email to Mr. Clark and Mr. Loy

I believe that it is important to have the correct location of the Willows Fault regarding the proximity of the Fault to the City of Colusa. As you will see in the attached Figure 7 from the Sutter County GMP it looks like a wishbone like structure near the City with one fork trending south east away from the City on the east side of the Sacramento River and another fork on the west side of the River nearer to the City trending more in a north south direction.

The HCM identifies the north south fork as an "unnamed Anticline" and cites several sources including the (USGS Paper 1359) Harwood and Helley report as supplemented by the California Department of Natural Resources. The Sutter GMP cites a USGS Geologic Map dated from 2005 which possibly may be more precise? Harwood and Helley have a figure (as attached) which is hard to decipher as to its location to the City or the River but seems to indicate that the fork begins at the 39.15 latitude which would be south of the Colusa Airport but north of Meridian.

The reason I think it is important to get the best information on this fork in the Willows Fault is the potential for the movement of arsenic contamination along the Willows Fault from the desorption of arsenic from the metal and iron oxides in the volcanic rock of the Sutter Buttes. So far the public water supply for the City does not seem to be contaminated but the location of this fork may be problematic for the future risk profile.

There is also the potential for the movement of the anoxic seawater from the Buttes formation via the Willows Fault but that is less of the concern because it relates more to potential degradation in potability rather than arsenic toxicity.

Thank you for your time and consideration of this matter.

Best Regards,

Ben

CHICO MONOCLINE

The Chico monocline (fig. 13) is a northwest-trending, southwest-facing flexure that bounds the northeast side of the Sacramento Valley between Chico and Red Bluff. East of the monocline, Pliocene volcanic rocks of the Tuscan Formation dip less than 5° SW., but bedding steepens to 20° or more along the monoclinal flexure where the Tuscan dips beneath Quaternary deposits of the valley. The trace of the monocline is characterized by a complex surface pattern of anastomosing fault strands

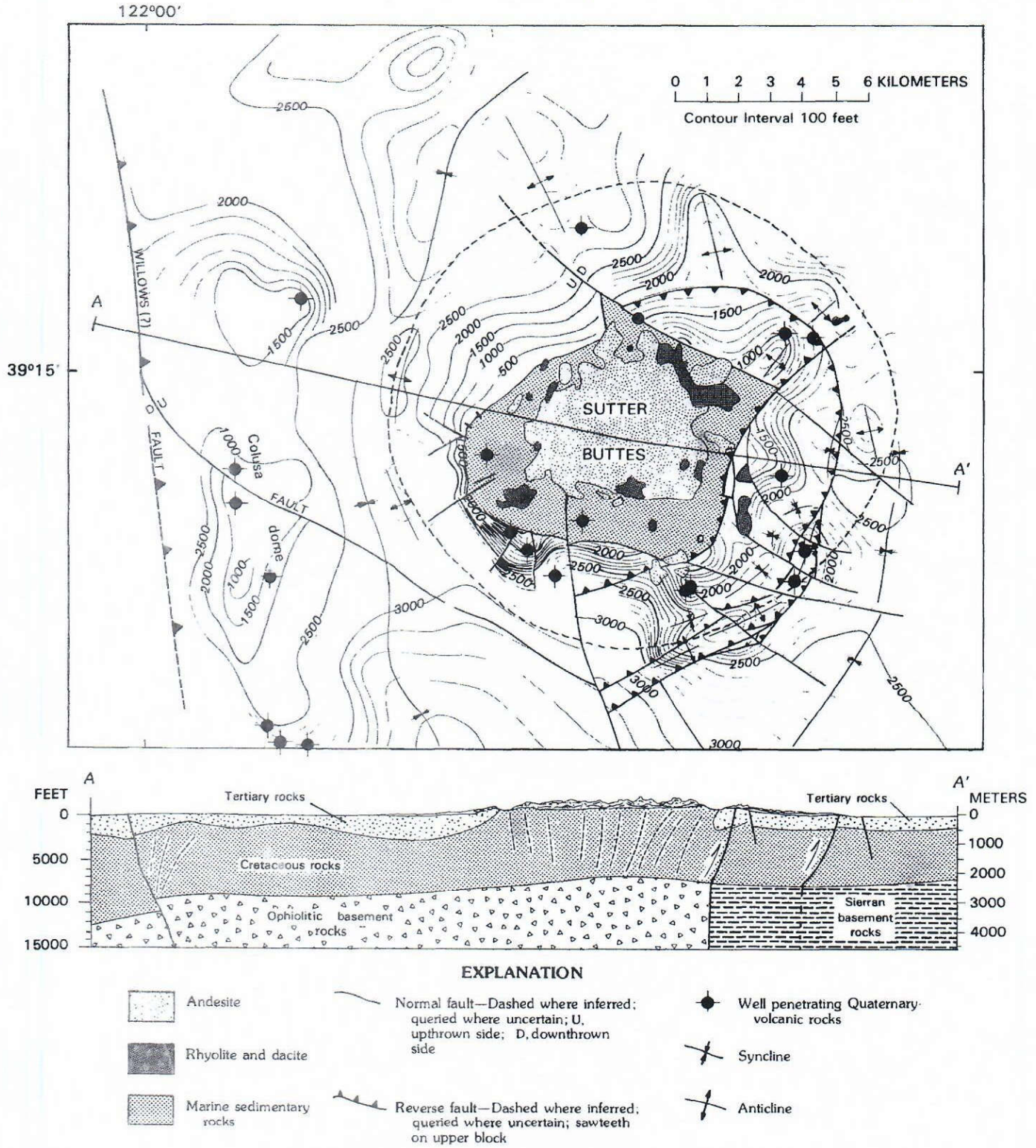


FIGURE 12.—Structure contour map of area around Sutter Buttes, modified from Williams and Curtis (1977, fig. 11) with data from Redwine (1972) and from our examination of electric logs in area of buried Colusa dome. Structure contours in feet; datum is top of the Kione sand of local usage (Williams and Curtis, 1977). Dashed circle on map marks approximate outer limit of rampart beds on valley floor; thin dashed lines on section represent schematic paths of magma injection.

Unit	*Age/Age range (m.y.)*	*Reference*
Rockland ash bed	0.4-0.45	Sarna-Wojcicki and others (1985); Meyer and others (1980)
Red Bluff Formation	0.5-1.0	Harwood and others (1981)
Olivine basalt of Deer Creek	1.09	Harwood and others (1981)
Ishi Tuff Member of the Tuscan Formation	2.6	Harwood and others (1981; unpublished data, 1985)
Volcanic rocks of Sutter Buttes	1.4-2.4	Williams and Curtis (1977)
Nomlaki Tuff Member of the Tuscan and Tehama Formations	3.4	Evernden and others (1964)
Putah Tuff Member of the Tehama Formation	3.4	Sarna-Wojcicki (1976)

With the exception of the Dunnigan Hills, the structural domains shown in figure 23 become progressively younger northward through the valley. Late Cenozoic deformation in the Dunnigan Hills domain apparently overlapped that in the Corning domain, but the respective styles of deformation and the inferred stress regimes discussed in a later section differ significantly. This point emphasizes the fact that the structural domains include tectonic features that are homogeneous in time and style of deformation as far as we can determine. To a certain extent, the ages of the structural domains reflect the distribution of the time-stratigraphic units used to identify the major late Cenozoic deformation in a domain. It may be possible to subdivide some domains as more information on the distribution of the younger time-stratigraphic units becomes available. Furthermore, it is important to note that ascribing an age to the late Cenozoic deformation in a domain does not imply that all deformation necessarily began or ended within that time. Many late Cenozoic structural features in the valley formed over earlier structures in the upper Mesozoic or Tertiary rocks, and thus they owe their existence, in part, to tectonic heredity. In some areas, historic low-magnitude earthquakes can be identified with specific structural features such as the Battle Creek fault zone (Bolt, 1979) and Corning fault (Marks and Lindh, 1978), indicating that strain is currently being released on these structures.

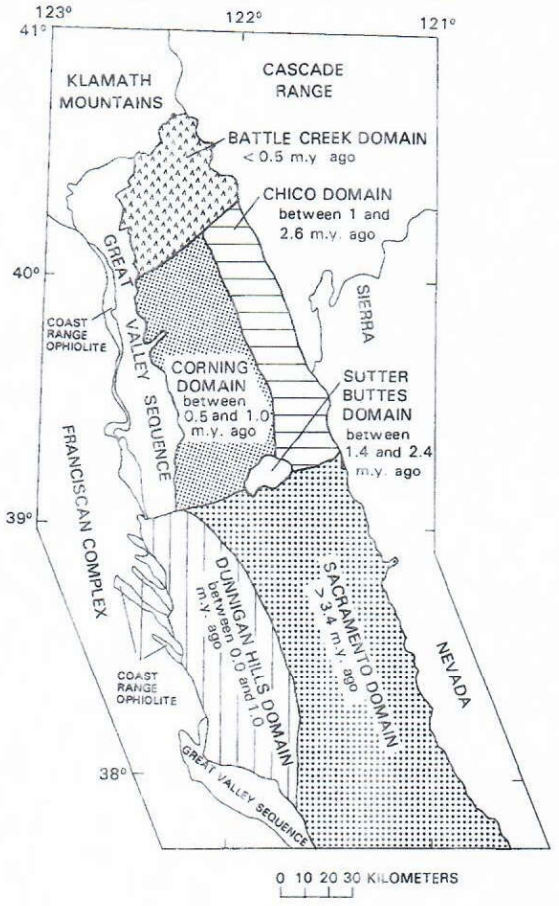


FIGURE 23.—Structural domains in Sacramento Valley. Numbers under domain names give duration or age of deformation that produced late Cenozoic structures in that domain.

SACRAMENTO DOMAIN

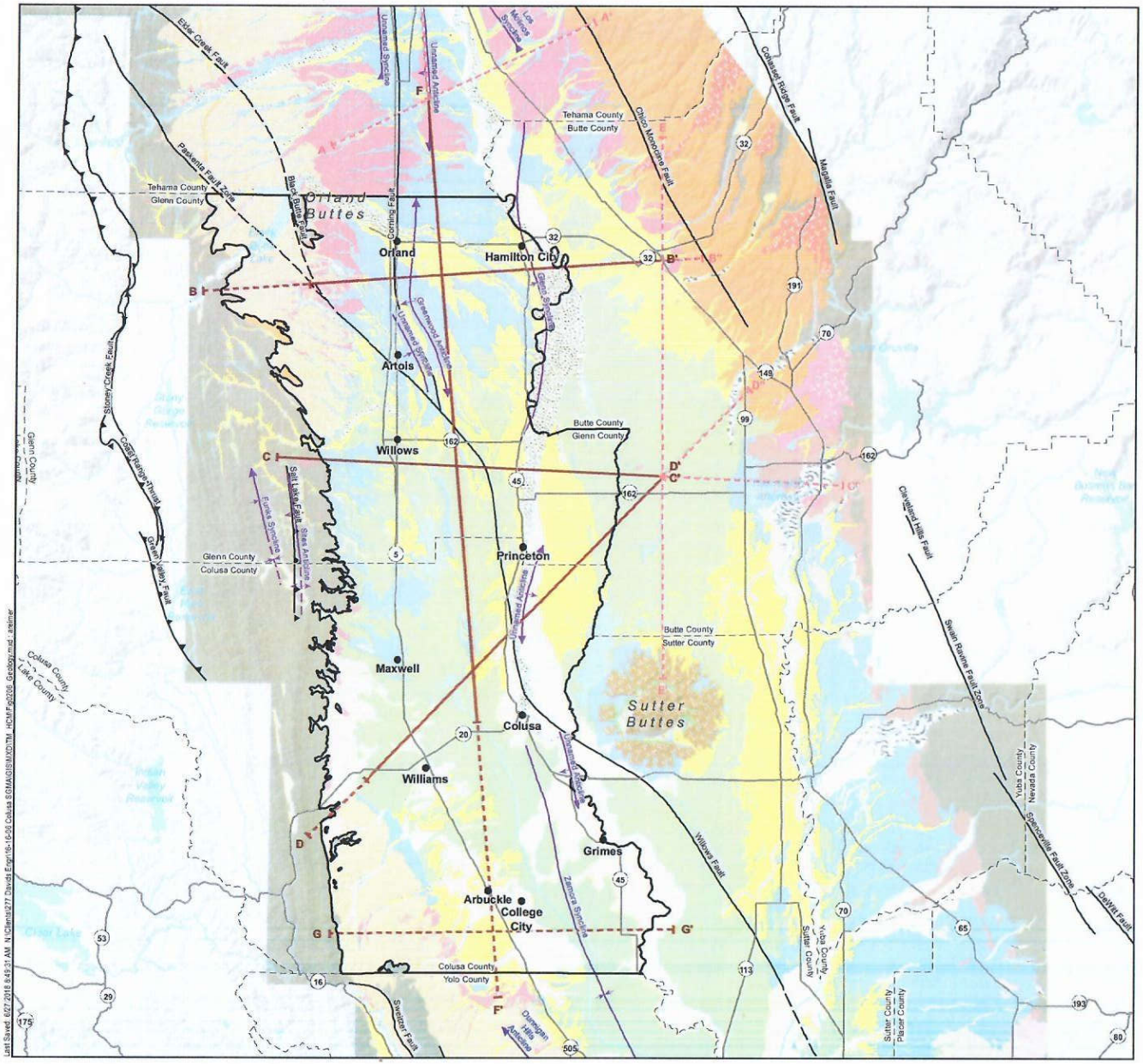
The Sacramento domain includes the Stockton fault, the Midland fault, the Thornton anticline, and the possible southeast extension of the Willows fault and other unnamed northwest-trending faults southeast of Sutter Buttes. None of these structures appear to offset or deform late Cenozoic alluvial deposits that are younger than the Nomlaki Tuff Member (figs. 7-10; Silcox, 1968; Teitsworth, 1968).

The minimum age of deformation is difficult to determine. If the Markley submarine canyon was localized, in part, by movement on the southeast extension of the Willows fault, as suggested by figures 8 and 9, then major deformation occurred in the domain in the middle Tertiary and could be as young as early Miocene, which is the upper age of the Markley canyon fill (Almgren, 1978). However, the Pliocene Laguna Formation, which contains the Nomlaki Tuff Member near its base just east of Marysville (Bussaca, 1982), does not appear to be offset in this domain; therefore, we conclude that deformation is older than 3.4 m.y. Upper Cretaceous rocks indicate syndepositional offset on the Stockton fault (Teitsworth, 1968) so the maximum age of deformation is Late Cretaceous.

The Willows fault north of Sutter Buttes (fig. 3) and the faults in Capay Valley (fig. 20) also show protracted deformation, ranging in age from Late Cretaceous to the middle Tertiary, that undoubtedly was contemporaneous with deformation in the Sacramento domain.

SUTTER BUTTES DOMAIN

The complex pattern of folds and faults at Sutter Buttes and the buried Colusa dome was interpreted by Williams



Symbology

- Northern Sacramento Valley Geology Cross Section Used for Preliminary Hydrogeologic Conceptual Model
- Section Extension or New Cross Section
- Northern Sacramento Valley Geology Cross Section Not Used for Preliminary Hydrogeologic Conceptual Model
- Study Area

0 4 8
Scale in Miles

Geologic Structures

- Anticline
- Syncline
- Plunging Anticline
- Plunging Syncline
- Doubly Plunging Anticline
- Double Plunging Syncline
- Fault
- Thrust Fault

Geologic Units

- Stream Channel Deposits (Holocene)
- Alluvial Deposits (Holocene)
- Basin Deposits (Holocene)
- Landslides (Quaternary)
- Modesto Formation (Pleistocene)
- Riverbank Formation (Pleistocene)
- Red Bluff Formation (Pleistocene)
- Turlock Lake Formation (Pleistocene)
- Older Gravel Deposits (Pleistocene - Pliocene)
- Rockland Ash Bed (Pleistocene)
- Volcanic Rocks and Lacustrine Deposits of Sutter Buttes (Pleistocene - Pliocene)
- Basaltic Rocks (Pleistocene - Pliocene)
- Tehama Formation (Pliocene)
- Nomlaki Tuff Member (Pliocene)
- Putah Tuff Member (Pliocene)
- Tuscan Formation (Pliocene)
- Laguna Formation (Pliocene)
- Sutter Formation of Williams and Curtis (1977) (Pliocene - Oligocene)
- Channel Deposits (Pliocene - Miocene)
- Mehrten Formation (Pliocene - Miocene)
- Lovejoy Basalt (Miocene)
- Ione Formation (Eocene)
- Sedimentary Rocks in Sutter Buttes Area (Eocene)
- Metamorphic, Igneous, and Sedimentary Rocks (pre-Paleogene)
- Tailings

Source:
1. California Department of Water Resources, 2014, Geology of the Northern Sacramento Valley: prepared by the California Department of Water Resoures Northern Region Office, Groundwater and Geologic Investigations Section, updated September 2014.
2. Helley, E.J. and Harwood, D.S., 1985, Geologic Map of the Late Cenozoic Deposits of the Sacramento Valley and Northern Sierran Foothills, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1790, scale 1:62,500, GIS geodatabase.
3. Jennings, C.W. and Strand, R.G., 1960, Geologic Map of California, Olaf P. Jenkins Edition, Ukiah Sheet: Department of Natural Resources Division of Mines and Geology, third printing 1992, scale 1:250,000.
4. Koenig, J.B., 1963, Geologic Map of California, Olaf P. Jenkins Edition, Santa Rosa Sheet: California Department of Natural Resources Division of Mines and Geology, scale 1:250,000.

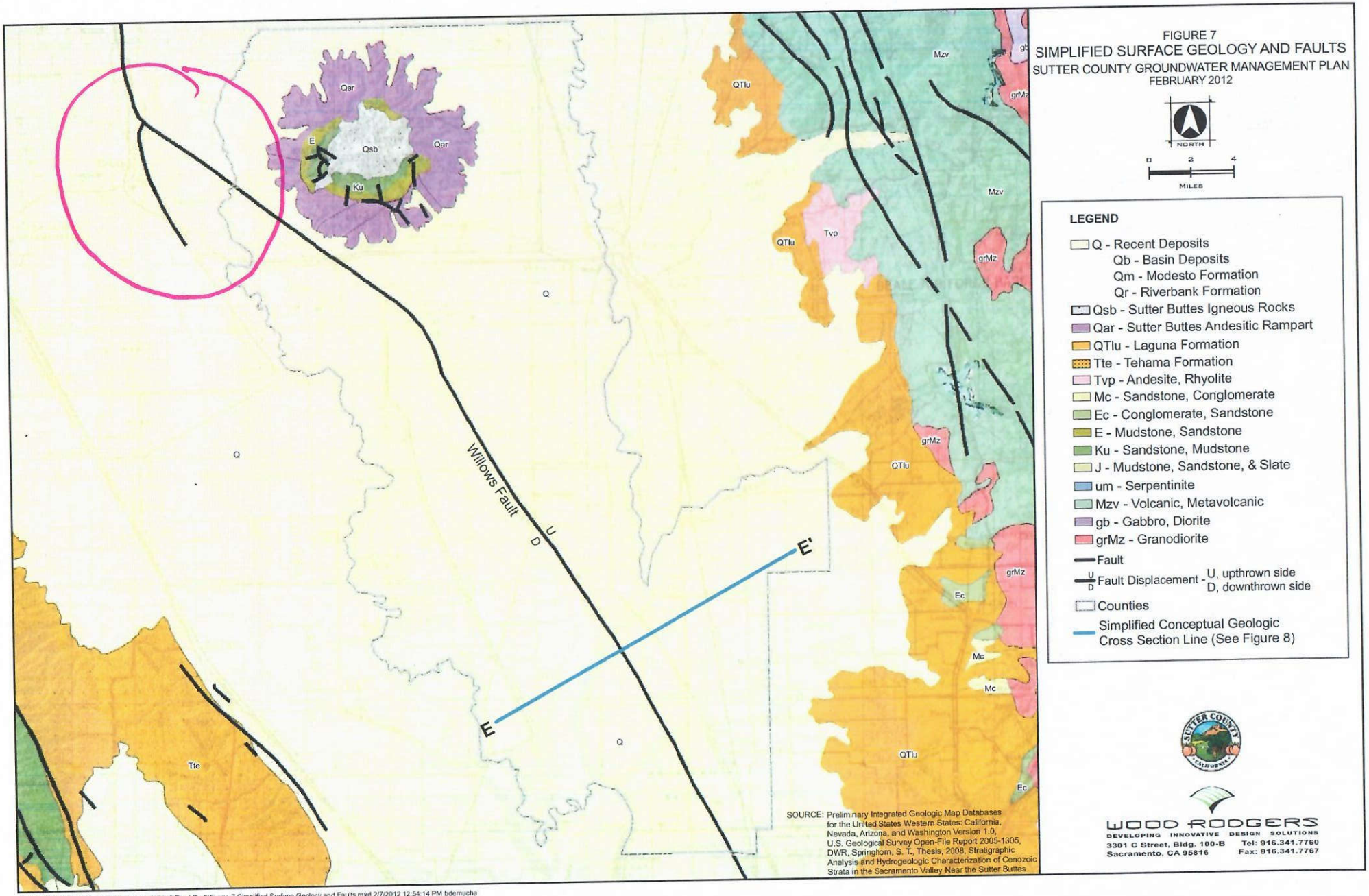
Horizontal Datum: North American Datum of 1983, California State Plane Zone II, feet.

Notes:
1. The Helley and Harwood mapping is used where available and is supplemented with geologic mapping from the California Department of Natural Resources Division of Mines and Geology sheets to cover the entire study.
2. Geologic structures are dashed where approximated.

Figure 2-6

Geologic Map

Counties of Colusa and Glenn
Hydrogeologic Conceptual Model



J:\Jobs\8337_SutterCounty\GIS\Tasks\20120116 Final Draft\Figure 7 Simplified Surface Geology and Faults.mxd 2/7/2012 12:54:14 PM bdemucha

From: Ben King <bking@pacgoldag.com>
Sent: Monday, February 8, 2021 4:54 PM
To: Ceppos, David M <dceppos@csus.edu>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; Ben King <bking@pacgoldag.com>
Subject: California Geological Survey - Willows Fault Location Near City of Colusa

Hi David,

Can you send this follow up email regarding the location of the Willows Fault and its location near the City of Colusa to Mr. Loy and Mr. Clark.

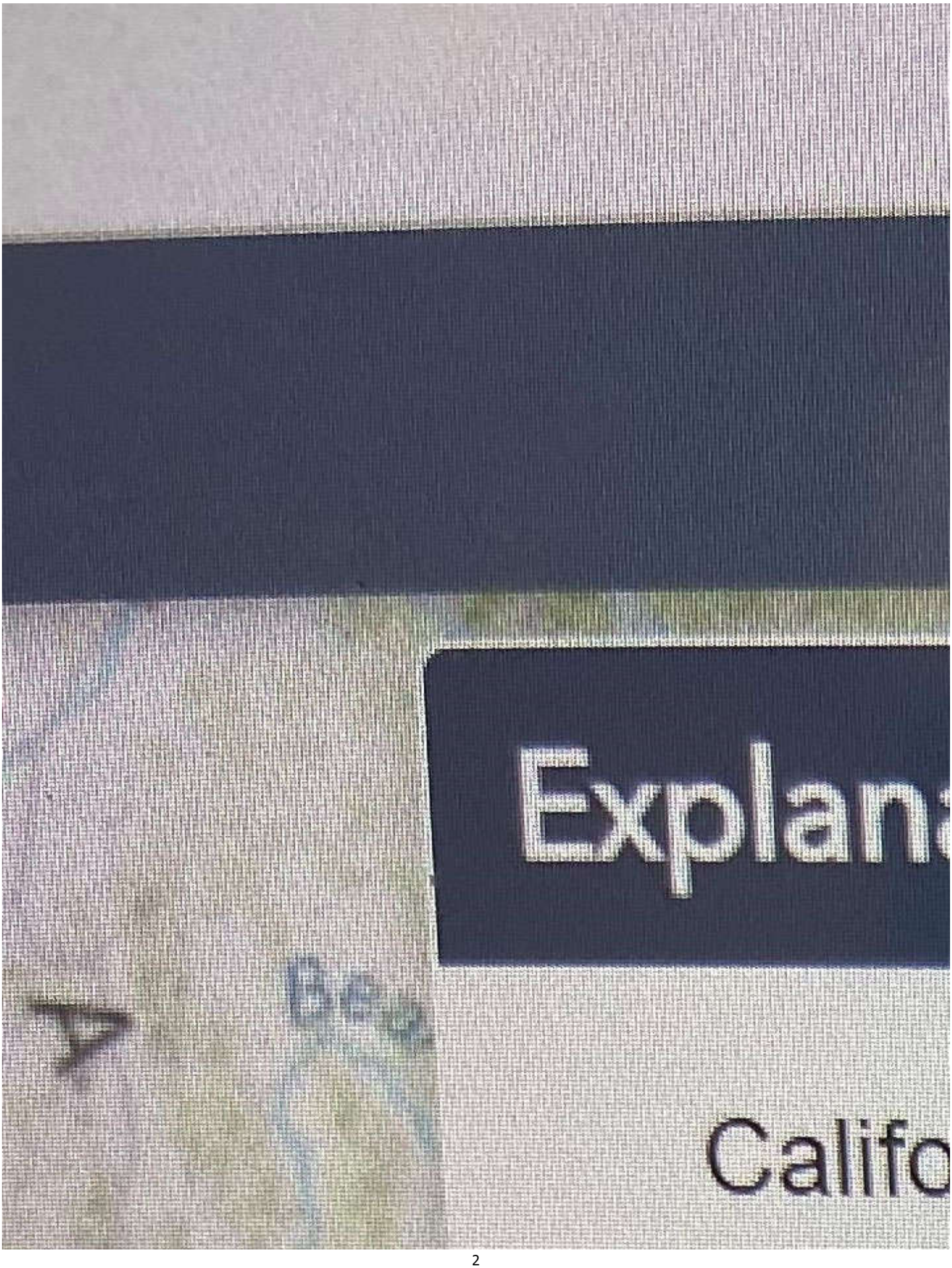
The link for the California Geological Survey is below. The location of the Willows Fault appears to have a fork north of the Colusa State Park and ironically appears to run under the Colusa County Courthouse. I have included three photos from the link.

https://maps.conservation.ca.gov/cgs/fam/app/

I believe this is a different location than set out in the Geologic Figure in the HCM. It seems to be very close to the City of Princeton and the Colusa Rancheria. It actually runs through Colusa and towards Grimes and Meridian along Hwy 20. As I mentioned before I wanted to raise the issue of the Fault as the mechanism whereby the arsenic and seawater contamination from the Sutter Buttes may be translocating.

Thank you for your time and consideration

Ben King


Explan
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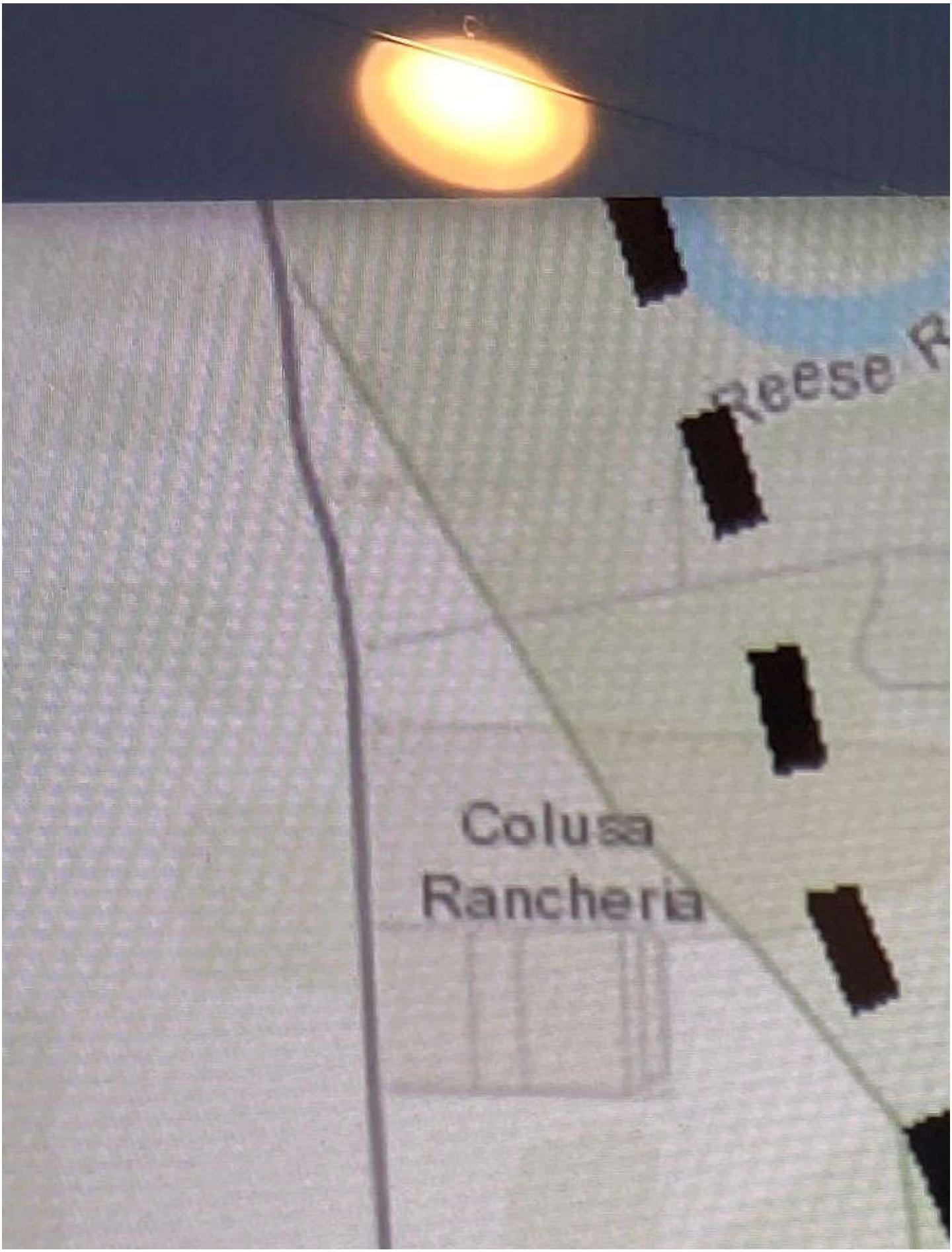
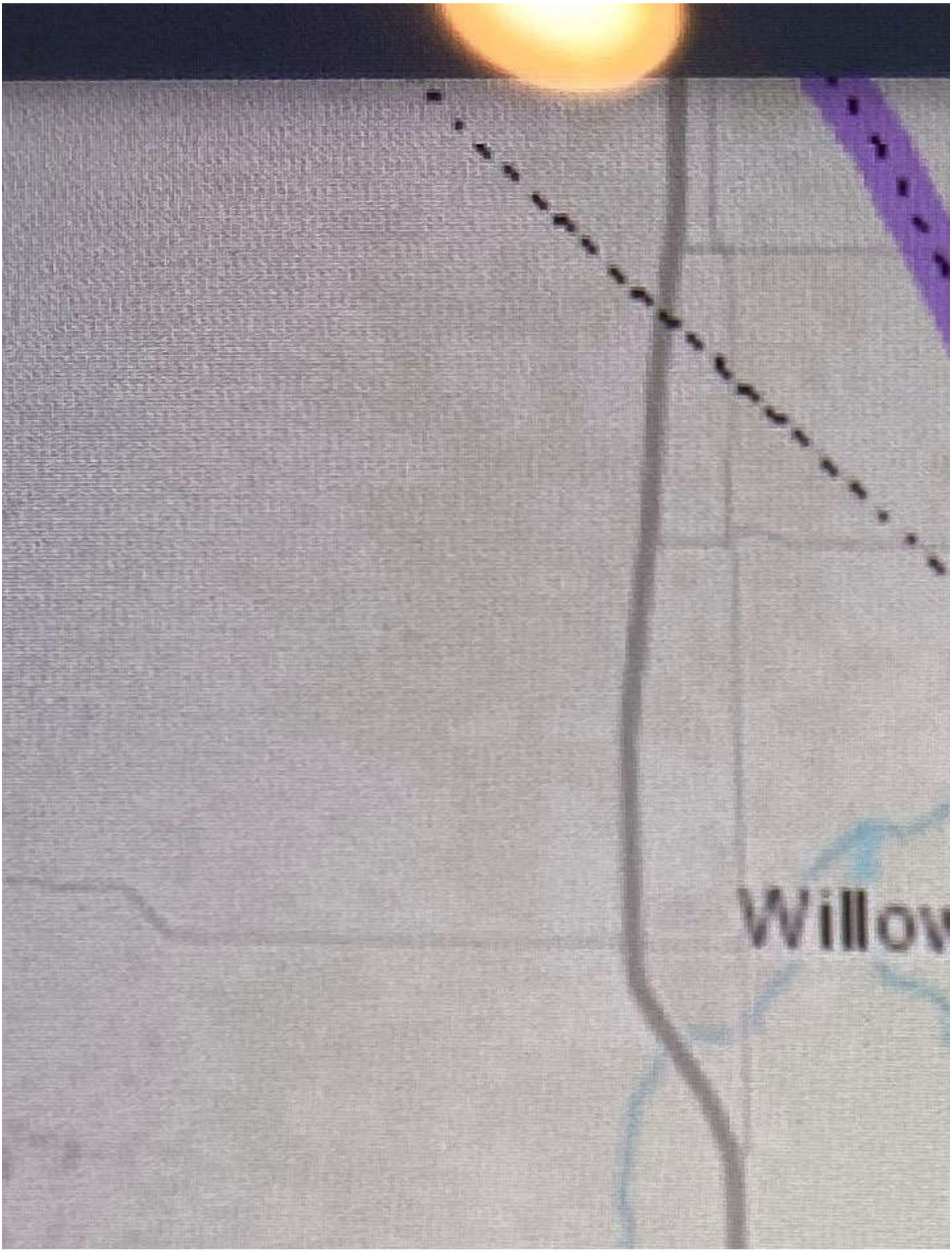

Reese R
Colusa
Rancheria


Willow

From: Byron Clark
Sent: Friday, January 22, 2021 11:03 AM
To: Matt Jones <Matt@tnpfarms.com>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; 'Lisa Hunter' <LHunter@countyofglenn.net>
Subject: RE: Follow Up Regarding Colusa Subbasin GSP Questions

Hi Matt,

I wanted to follow up from our discussion in December and provide a map and kmz of the water budget subareas used to develop the model and associated water budgets for the basin (see link below). As discussed, these do not represent management areas but rather subareas within the basin based on water supplier boundaries, county boundaries, and other considerations.

I agree regarding management areas being a tough discussion. The SGMA regulations do not provide a lot of detail regarding the use of management areas, and they have been used differently in many basins. Also, I completely agree the basin is interconnected.

Regarding recharge and banking, I wanted to reiterate that we fully anticipate considering in-lieu and direct recharge projects as part of GSP development and implementation. There seem to be substantial opportunities for the use of additional surface water, particularly in wet years which we are exploring.

Finally, the link includes maps of physical characteristics of the subbasin and jurisdictional boundaries that were presented to the TACs on January 8 that may be helpful.

https://app.box.com/s/eidbnyyqii3ay2rk87etlcse4jzuzcct

Regards,

Byron

Byron Clark, P.E. | Supervising Engineer | Davids Engineering, Inc.
1772 Picasso Avenue, Suite A, Davis, CA 95618 | office 530.757.6107 x106

From: Matt Jones <Matt@tnpfarms.com>
Sent: Wednesday, January 13, 2021 10:59 AM
To: Byron Clark <byron@davidsengineering.com>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; 'Lisa Hunter' <LHunter@countyofglenn.net>
Subject: RE: Follow Up Regarding Colusa Subbasin GSP Questions

Wanted to follow up regarding “management areas”. It is a tough discussion and should include laying out the facts regarding areas of concern. I vague statement regarding an area does not do anybody justice and leads to speculation and possibly inaccurate conclusions. The attached maps paint a clearer picture of “areas” of concern, but more importantly it emphasizes how our basin is interconnected and impacts of “areas” not within the “management areas”?

I would also like to follow up regarding recharge and banking. I am trying to get an understanding of how it will play a roll in the GSP or if it will be addressed within the GSP.

Regards;

From: Byron Clark <byron@davidsengineering.com>
Sent: Tuesday, December 15, 2020 12:19 PM
To: Matt Jones <Matt@tnpfarms.com>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; 'Lisa Hunter' <LHunter@countyofglenn.net>
Subject: Follow Up Regarding Colusa Subbasin GSP Questions

Hi Matt,

Thank you for your questions below regarding the water budget development for the Colusa GSP. Would you be available for a call to make sure I understand your questions to make sure I respond in a supportive manner?

Thank you,

Byron

Byron Clark, P.E. | Supervising Engineer | Davids Engineering, Inc.
1772 Picasso Avenue, Suite A, Davis, CA 95618 | office 530.757.6107 x106

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From: Matt Jones <Matt@tnpfarms.com>
Date: December 10, 2020 at 3:59:35 PM PST
To: Mary Fahey <mfahey@countyofcolusa.com>
Subject: GSP

Good meeting and information today.
You are all doing a great job!
I know there is still a long way to go.

I have 2 points of clarification or questions;

1) The 38 subbasins. How can we access the interactive mapping for these?
    a. How were they determined etc.
        i. Forgive me, I have missed several of the latest meetings.
2) Recharge was touched upon. I did not see or hear discussion regarding banking of In-Leu or recharged water within the basin.
    a. I am sure it would be a minimal amount but may think about using within the water budget?
        i. Is banking being addressed in the GSP?

Thanks;

Mathew E. Jones
T&P Farms / T&P Farms Huller & Sheller
Regulatory Operations Manager
O: (530) 476-3137
C: (530) 712-1227

From: Ben King [mailto:bking@pacgoldag.com]
Sent: Saturday, February 27, 2021 2:58 PM
To: Mary Fahey <mfahey@countyofcolusa.com>
Cc: Ben King <bking@pacgoldag.com>
Subject: February 17 CGA Presentatin

Hi Mary,

I wanted to point out that there are two different versions of the Presentation for the 2/17/21 on the CGA Website

If I look at the Meetings Link:

https://colusagroundwater.org/mdocs-posts/2021_02_17-cga-board-special-meeting-presentation/

There is a version without maps

If I look at the Presentations link:

https://colusagroundwater.org/mdocs-posts/2021_02_17-cga-board-special-meeting-presentation-ma/

The Presentation includes maps under Areas of Interests. The link in the Agenda also includes this version. Perhaps this was part of the Agenda Materials that was updated at the Meeting?

Best Regards,

Ben

From: Ben King <bking@pacgoldag.com>
Sent: Sunday, February 28, 2021 4:58 PM
To: Ceppos, David M <dceppos@csus.edu>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; Davison, Brandon@DWR <Brandon.Davison@water.ca.gov>; Ben King <bking@pacgoldag.com>; dkalfsbeeksmith@countyofcolusa.org
Subject: Groundwater Arsenic Contamination Issues Raised by Springhorn Follow Up

HI Dave,

I was finally able to get access to Stephen Springhorn's paper on the Sutter Buttes Rampart. I want to make sure that Mr. Clark and Mr. Loy are aware of his recommendations and concerns as they draft the Basin Setting for the Colusa Basin especially in light of the work highlighted in a recent USGS Paper on arsenic contamination.

Stephen Springhorn had two relevant points concerning arsenic contamination:

> (I)Under **Future Work** – ".. additional data collection regarding " Elevated arsenic concentrations in groundwater related to the Sutter Buttes Rampart material".
> (II) In 6.1 – " Data analyses suggest there is a connection between elevated arsenic concentrations in groundwater and the presence of the Sutter Buttes Rampart volcaniclastic material .."

In the USGS Paper 1358 " Water Quality in Basin-Fill Aquifers of the Southwestern United States: Arizona, California, Colorado, Nevada, New Mexico and Utah, 1993-2009. The causal connection between volcaniclastic material and arsenic contamination of groundwater is established for water with pH greater than 8 and under anoxic conditions.

> See Page 54 " The interaction of metal oxides, particularly iron oxide, is one of the most important processes by which groundwater can be enriched or depleted in arsenic…..**If the PH is greater than 8, arsenic tends to desorb from the iron oxides and dissolves into the groundwater. Under anoxic conditions, iron oxides dissolve and release iron and arsenic into the groundwater regardless of pH"**

In the area of the Sutter Buttes Rampart, potentially via the Willows Fault and south of the Sutter Buttes we experience either very high pH observations or connate anoxic seawater. See the attached table included in the Sutter-Yuba Investigations report showing TDS levels as high as 10,000 in the Sutter Basin as of 1949. Additionally, see the attached table in the Curtin Paper which includes 137 well observations in his 1971 Paper. There are several observations of TDS above 5000 from Township 13 N southward and surprisingly in several shall wells also.

> Regarding the Willows Fault and potential for translocation of connate water leading to arsenic contamination as far north as Princeton - the USGS report mentions a situation in the Rio Grande where " The highest concentrations of arsenic in groundwater in the Middle Rio Grande Basin are associated with volcanic rocks in the northern part of the basin and **with fault zones through which deep, mineralized groundwater rises**."

When the work done in 1949 in the Sutter-Yuba Investigations is matched with the work done by George Curtin for his 1971 Paper is analyzed in context of the work done by Springhorn, the existence of the saline and anoxic seawater is clear. The analysis done in the 2014 USGS Paper confirms the casual relationship between both high pH and anoxic conditions. This time series and geographic specific well observations is compelling by magnitude and consistency regarding the casual relationships of the Sutter Buttes geology and the arsenic contamination.

In addition to the Paper referenced I am also attaching the EPA Violation Reports for the Grimes and Princeton water systems and a USGS Paper done on the geological history of the Sutter Buttes Volcano.

Thanks again for your time and consideration

Ben King

HYDROGEOLOGY OF THE SUTTER BASIN, SACRAMENTO VALLEY, CALIFORNIA

by

George Curtin

A Thesis Submitted to the Faculty of the

DEPARTMENT OF GEOSCIENCES

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN GEOLOGY

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 7 1

Well Number	Depth ft.	Chemical constituents equivalents per million			percent reactance value			parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
10N/1E-15H2	176	1.95 33.6	2.14 36.9	1.71 29.5	4.24 71.7	0.54 9.1	1.13 19.1	1.5	270	204
10N/2E-17J3	243	2.05 34.8	2.14 36.3	1.71 29.0	4.24 74.3	0.40 7.0	1.07 18.7	1.5	278	207
11N/1E-4R1	-	1.30 11.1	4.59 39.2	5.82 49.7	9.43 77.8	1.39 11.5	1.30 10.7	4.2	695	295
11N/1E-16P1	172	1.85 32.2	2.06 35.9	1.83 31.9	4.74 80.2	0.23 3.9	0.93 15.8	1.3	304	195
11N/2E-14F4	330	1.35 24.9	1.73 31.9	2.35 43.3	4.78 86.3	0.20 3.6	0.56 10.1	0.7	277	153
11N/2E-32G1	-	1.45 13.1	5.85 52.9	3.75 33.9	7.26 68.7	1.00 9.5	2.31 9.5	3.3	604	366
11N/3E-3N2	112	0.75 39.5	0.25 13.2	0.90 47.4	1.73 91.0	0.08 4.2	0.02 5.3	0.1	131	50
11N/3E-14N2	-	3.59 28.8	3.40 27.2	5.49 44.0	4.30 34.1	0.18 1.4	8.10 64.0	0.3	705	351
11N/3E-14R1	236	1.20 10.0	0.30 2.5	10.51 87.5	4.83 40.0	0.06 0.9	7.17 59.1	0.2	718	75
11N/3E-24D1	145	2.18 30.8	2.88 40.4	2.05 28.8	6.92 93.4	0.15 2.3	0.31 4.3	0.2	365	253
11N/3E-36L1	140	0.37 9.5	0.23 5.9	3.33 84.7	3.20 82.5	0.20 5.2	0.48 12.4	0.3	246	30
11N/4E-3P2	305	2.30 40.6	2.38 42.0	0.99 17.5	4.49 82.1	0.11 2.0	0.87 15.9	0.0	295	234

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
11N/4E-9D1	-	1.40 42.2	1.32 39.7	0.60 18.1	2.60 76.3	0.50 14.7	0.31 9.0	0.1	184	138
11N/4E-14D2	204	0.83 26.1	0.99 31.1	1.36 42.8	2.16 77.7	0.08 2.9	0.54 19.4	0.2	152	91
11N/4E-19E2	-	1.35 31.4	1.41 32.8	1.54 35.8	3.00 69.3	0.31 7.2	1.02 23.5	0.1	262	138
12N/1W-21A1	405	1.50 32.7	2.30 50.3	0.78 17.0	4.20 97.5	0.00 0.0	0.11 2.5	0.0	214	189
12N/2E-2J1	100	30.37 28.2	35.30 33.4	39.90 37.8	4.10 4.0	0.05 0.0	99.45 96.0	0.6	5610	205
12N/2E-9B2	-	1.35 20.6	0.03 4.0	5.17 79.0	3.89 65.2	0.33 5.5	1.75 29.3	0.5	402	69
12N/2E-11N1	-	1.55 12.5	1.15 9.3	9.70 78.2	4.30 36.0	0.00 0.0	7.61 64.0	0.9	728	135
12N/2E-14B1	-	7.58 18.3	9.21 22.2	24.65 59.5	3.12 7.9	0.00 0.0	38.63 92.1	0.8	2790	841
12N/2E-16R1	-	2.25 21.5	0.72 6.9	7.46 71.6	7.13 70.0	0.35 3.5	2.68 26.5	0.6	577	148
12N/2E-18SW	1500	19.83 19.2	7.22 7.0	76.12 73.8	2.71 2.5	0.08 0.1	99.98 97.4	10.8	5870	166
12N/2E-23Q1	-	1.15 12.1	0.55 5.8	7.82 82.1	4.50 48.4	0.01 0.0	4.79 51.6	0.7	571	85

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
12N/2E-24G1	446	0.70 7.6	0.72 7.9	7.61 84.5	4.00 47.4	0.35 4.1	4.09 48.5	0.1	670	-
12N/2E-24L1	1565	19.81 19.3	7.23 7.2	75.21 73.5	2.70 2.6	0.08 0.1	100.03 97.3	10.8	5940	-
12N/2E-24L2	146	19.81 36.5	9.29 17.1	25.23 46.4	3.47 8.1	0.02 0.0	39.48 91.9	1.1	2452	-
12N/2E-26A1	-	1.40 13.3	0.72 6.8	8.41 79.9	4.64 44.8	0.00 0.0	5.72 55.2	0.6	608	107
12N/2E-35SW	44	4.09 15.3	5.84 21.7	16.88 63.0	4.20 15.4	0.01 0.0	23.41 84.6	0.4	1628	-
12N/3E-13F1	285	0.85 20.3	0.47 11.2	2.87 68.5	2.91 69.8	0.02 0.5	1.24 29.7	0.2	266	66
12N/3E-16H2	-	2.15 19.0	4.45 39.3	4.73 41.7	5.28 47.1	2.21 19.7	3.71 32.2	0.0	620	330
12N/3E-23G1	120	6.47 36.6	4.72 26.7	6.49 36.7	2.82 15.9	0.23 1.3	14.72 82.8	0.4	1060	561
12N/3E-25A1	155	2.05 41.3	1.45 29.2	1.46 29.4	4.02 79.2	0.25 5.0	0.76 15.1	0.1	286	175
12N/25C2	97	3.79 50.1	2.20 29.1	1.58 20.9	4.13 54.9	0.75 10.0	2.65 35.2	0.1	435	252
12N/3E-26R1	-	2.99 42.2	1.64 23.1	2.46 34.7	3.52 48.6	0.17 2.4	3.55 49.0	0.1	423	234

Well Number	Depth ft.	Chemical constituents equivalents per million			percent reactance value			parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
12N/3E-30H1	232	4.64 13.9	2.96 8.9	25.71 77.2	3.18 9.7	0.19 0.6	29.34 89.7	1.5	1970	380
12N/4E-4N2	89	1.45 36.2	1.75 43.6	0.81 20.22	2.72 68.3	0.19 4.8	1.07 26.9	0.0	257	160
12N/4E-6G1	82	2.50 26.2	4.30 45.0	2.76 28.8	6.20 69.0	2.17 24.1	0.62 6.9	0.2	491	340
12N/4E-7R1	100	0.95 32.3	1.35 45.9	0.64 21.8	2.63 92.9	0.02 0.7	0.18 6.4	0.0	181	115
12N/4E-32J1	-	4.39 42.8	4.19 40.8	1.68 16.4	4.25 41.6	2.08 20.4	3.89 38.1	0.0	682	427
13N/1W-15R2	-	1.80 33.3	1.23 22.8	2.37 43.9	4.03 75.9	0.21 4.0	1.07 20.5	0.5	287	153
13N/1W-36Q2	36	1.75 38.6	1.15 24.9	1.72 36.5	3.31 74.3	0.15 3.4	0.99 22.3	0.3	276	145
13N/1E-22J1	-	2.84 52.4	1.48 27.3	1.10 20.3	3.71 69.6	0.17 3.2	1.44 27.0	0.1	327	216
13N/1E-36Q1	-	1.75 37.9	1.15 24.9	1.72 37.2	3.31 74.4	0.15 3.4	0.99 22.2	0.3	276	145
13N/2E-23B1	72	17.41 28.0	21.18 38.7	20.87 33.3	3.54 5.6	0.00 0.0	59.80 94.4	0.4	5970	2080
13N/3E-2C4	190	3.64 36.8	3.67 37.1	2.58 26.1	5.94 61.2	0.98 10.1	2.79 28.7	0.2	486	-

Well Number	Depth ft.	Chemical constituents equivalents per million / percent reactance value						parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
13N/3E-14G1	-	5.56 21.5	14.18 54.9	6.08 23.6	2.98 11.2	3.39 12.9	20.01 75.9	0.1	1994	987
13N/3E-15B1	95	6.99 31.5	9.01 40.6	6.20 27.9	2.75 12.5	0.06 0.3	19.18 87.2	0.1	1400	800
13N/3E-15C2	90	8.53 37.6	10.85 44.0	5.29 21.4	4.18 16.8	0.06 0.2	20.68 83.0	0.1	1580	970
13N/3E-23C1	105	13.40 41.9	13.00 40.6	5.60 17.5	5.92 18.7	0.10 0.3	25.60 80.8	0.2	1884	1320
13N/3E-23H1	-	5.10 30.7	7.70 46.4	3.80 22.9	3.43 20.7	0.46 2.8	12.65 76.5	0.1	900	640
13N/3E-24D1	-	7.80 26.2	11.80 39.6	10.21 34.2	1.46 4.8	0.23 0.8	28.50 94.4	0.5	2140	980
13N/4E-3D1	130	1.30 22.2	3.30 56.3	1.26 21.5	3.93 68.0	0.19 3.3	1.66 28.7	0.0	320	230
13N/4E-17J1	200	2.45 39.5	2.75 44.3	1.01 16.3	3.33 56.7	2.00 34.1	0.54 9.2	0.02	387	260
13N/4E-21A1	-	3.59 36.3	5.26 53.2	1.04 10.6	4.31 42.9	5.45 54.3	0.28 2.8	0.0	565	445
13N/4E-27M1	196	0.70 29.4	1.02 42.9	0.66 27.7	1.92 84.2	0.02 0.9	0.34 14.9	0.0	163	86
13N/4E-32N1	84	0.95 23.4	1.43 35.2	1.68 41.4	2.41 83.1	0.12 4.1	0.37 12.8	0.0	200	119

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value CA	MG	NA+K	HCO3+CO3	SO4	CL	parts per million B.	TDS	TH
13N/4E-33J2	154	1.95 35.7	2.55 46.6	0.97 17.7	4.56 85.6	0.09 1.7	0.68 12.8	0.0	312	-
14N/1W-2D1	-	2.84 31.8	2.47 27.6	3.63 40.6	3.67 40.6	1.64 18.2	3.72 41.2	0.2	493	268
14N/1W-12A1	-	1.05 17.6	0.09 1.5	4.83 80.9	4.41 74.7	0.02 0.3	1.47 24.9	0.5	319	57
14N/1E-1A1	-	3.24 45.5	2.63 36.9	1.25 17.6	6.05 88.1	0.37 5.4	0.45 6.6	0.0	344	294
14N/1E-24N1	125	1.60 34.0	1.73 36.0	1.42 30.0	3.99 86.0	0.441 10.0	0.19 4.0	0.1	248	166
14N/2E-13L1	79	1.20 29.6	1.81 44.7	1.04 25.7	3.90 96.3	0.06 1.5	0.09 2.2	0.0	205	150
14N/2E-17E1	330	1.25 25.9	1.25 25.9	2.32 48.2	3.93 83.6	0.33 7.0	0.48 9.4	0.1	298	196
14N/2E-30R1	188	1.90 27.8	1.58 23.1	3.37 49.1	5.22 77.5	0.21 3.1	1.30 19.4	0.1	386	174
14N/3E-4E5	160	2.20 26.0	4.12 48.7	2.14 25.3	5.61 71.0	1.44 18.2	0.85 10.8	0.0	455	316
14N/3E-5A3	106	4.39 34.5	5.18 40.8	3.14 24.7	8.30 66.4	2.08 16.6	2.12 17.0	0.1	670	481
14N/3E-5D2	150	1.50 29.8	2.10 41.7	1.44 28.6	4.54 91.9	0.17 3.4	0.23 4.7	0.0	266	180

Well Number	Depth ft.	Chemical constituents			equivalents per million percent reactance value			parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
14N/3E-6A1	100	2.50 32.9	3.29 43.4	1.80 27.7	6.54 89.3	0.58 7.9	0.20 2.7	0.0	363	180
14N/3E-7H1	105	1.90 23.9	4.18 52.6	1.86 23.4	6.06 77.5	0.58 7.4	1.18 15.1	0.0	401	304
14N/3E-9K1	230	2.99 33.2	3.57 39.6	2.45 27.2	3.65 41.5	0.19 2.2	4.96 56.3	0.1	628	328
14N/3E-13D1	650	1.00 37.6	0.68 25.6	0.98 36.8	2.01 76.4	0.00 0.0	0.62 23.6	0.2	198	84
14N/3E-14E2	90	1.10 44.7	1.07 43.5	0.29 11.8	2.25 91.8	0.10 4.1	0.10 4.1	0.0	118	104
14N/3E-16B2	99	4.09 29.3	7.15 51.1	2.74 19.6	4.18 29.8	1.60 11.4	8.23 58.7	0.1	895	564
14N/3E-18A2	125	2.69 35.1	3.29 42.9	1.69 22.0	6.39 81.2	0.58 7.4	0.90 11.4	0.1	396	301
14N/3E-20H3	105	2.59 34.4	3.19 42.3	1.74 23.1	5.35 73.5	0.58 8.0	1.35 18.5	0.1	385	289
14N/3E-23M2	83	0.90 37.2	1.16 47.9	0.36 14.9	2.41 97.6	0.02 0.8	0.04 1.6	0.0	385	289
14N/3E-24M1	-	1.75 34.3	2.06 40.3	1.30 25.4	3.56 71.8	0.69 13.9	0.71 14.3	0.1	280	191
14N/3E-24P1	-	1.15 41.7	0.53 19.2	1.08 39.1	1.95 72.8	0.00 0.0	0.73 27.2	0.2	184	84

Well Number	Depth ft.	Chemical constituents			equivalents per million percent reactance value			parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
14N/3E-25D3	85	1.10 41.4	0.90 33.8	0.66 24.8	2.11 79.6	0.06 2.3	0.48 18.1	0.0	159	102
14N/3E-26D4	110	0.77 32.9	0.05 2.1	1.52 65.0	1.61 95.3	0.05 3.0	0.03 1.8	0.2	136	11
14N/3E-27K1	180	2.89 24.8	3.91 33.6	4.84 41.6	5.60 49.1	0.31 2.7	5.50 48.2	0.2	665	340
14N/3E-28E1	-	1.25 22.2	2.46 43.6	1.93 34.2	3.52 62.4	0.24 4.3	1.88 33.3	0.2	286	185
14N/3E-29Q1	-	5.12 26.9	6.52 34.2	7.40 38.9	2.92 15.6	0.10 0.5	15.67 83.8	0.4	1000	581
14N/3E-31B1	63	1.30 20.5	2.86 45.2	2.17 34.3	5.51 88.9	0.21 3.4	0.48 7.7	0.0	317	208
14N/3E-32F1	-	5.63 26.4	7.08 33.2	8.60 40.4	3.42 16.1	0.05 0.2	17.76 83.7	0.3	1135	635
14N/3E-33A1	-	3.99 30.3	6.04 45.9	3.13 23.8	2.60 19.7	0.05 0.4	10.54 79.9	0.1	682	501
14N/3E-33C1	-	3.04 21.0	7.76 53.7	3.64 25.2	3.06 21.0	0.13 0.9	11.37 78.1	0.2	806	540
14N/3E-34F1	84	3.49 28.1	4.31 34.7	4.63 37.3	4.96 40.5	0.00 0.0	7.28 59.5	0.1	750	390
14N/3E-34J1	-	1.80 18.9	5.80 60.8	1.94 20.3	3.62 38.3	1.29 13.6	4.55 48.1	0.1	481	380

Well Number	Depth ft.	Chemical constituents equivalents per million			percent reactance value			parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
14N/4E-6H1	112	1.00 44.4	0.58 25.8	0.67 29.8	1.86 81.6	0.07 3.1	0.35 15.4	0.0	116	79
14N/4E-7M1	83	2.25 35.3	2.87 45.0	1.26 19.7	3.51 56.3	2.19 35.1	0.54 8.7	0.0	528	395
14N/4E-9J1	100	1.64 33.3	2.06 41.8	1.23 25.0	3.54 73.1	0.15 3.1	1.15 23.8	0.0	242	165
14N/4E-22H1	400	0.70 31.3	0.64 28.6	0.90 40.2	1.52 70.4	0.02 0.9	0.62 28.7	0.0	191	67
14N/4E-27N1	510	0.80 36.0	0.50 22.5	0.92 41.4	1.92 86.9	0.06 2.7	0.23 10.4	0.0 0.0	148	65
15N/1E-16R1	-	1.90 27.5	3.78 54.7	1.23 17.8	5.84 85.8	0.35 5.1	0.62 9.1	0.1	355	283
15N/1E-35H1	108	2.20 35.1	2.96 47.2	1.11 17.7	5.22 85.6	0.20 3.3	0.28 4.6	0.0	225	-
15N/1E-35R1	-	3.84 47.4	3.53 43.6	0.73 9.0	5.28 66.1	0.62 7.8	2.09 26.2	0.0	466	370
15N/2E-1R1	49	2.10 36.5	2.55 44.3	1.01 17.5	4.69 88.2	0.46 8.7	0.17 3.2	0.0	310	231
15N/2E-22D1	306	1.05 36.0	0.99 33.9	0.83 28.4	2.54 89.4	0.10 3.5	0.10 7.0	0.0	184	100
15N/2E-26D2	-	3.24 40.9	2.79 35.2	1.90 24.0	5.23 74.2	0.44 6.2	1.38 19.6	0.1	447	304

Well Number	Depth ft.	Chemical constituents equivalents per million / percent reactance value						parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
15N/3E-4C2	147	3.04 34.2	4.52 50.9	1.32 14.9	5.72 69.3	1.77 21.5	0.76 9.2	0.1	558	379
15N/3E-9C2	200	2.20 34.9	2.28 36.2	1.82 28.9	5.52 88.0	0.44 7.0	0.31 4.9	0.1	350	224
15N/3E-11H4	60	0.94 39.2	1.13 47.1	0.33 13.7	2.17 90.0	0.11 4.6	0.13 5.4	0.0	127	103
15N/3E-13F1	350	1.80 50.9	0.92 26.0	0.82 23.1	2.68 77.5	0.50 14.5	0.28 8.0	0.0	239	136
15N/3E-13J2	300	1.10 44.2	0.54 21.7	0.85 34.1	1.90 74.2	0.01 0.4	0.65 25.4	0.0	201	82
15N/3E-14N1	350	0.70 24.4	0.72 25.1	1.45 50.5	2.34 81.3	0.00 0.0	0.54 18.8	0.3	182	71
15N/3E-15C1	170	1.15 28.3	0.65 16.0	2.27 55.8	3.59 87.4	0.01 0.2	0.51 12.4	0.3	257	90
15N/3E-15E2	188	1.64 24.4	1.92 28.6	3.15 46.9	4.96 76.0	0.27 4.1	1.30 19.9	0.4	329	178
15N/3E-15H4	133	3.49 41.8	3.95 47.3	0.91 10.9	6.65 81.4	0.20 2.5	1.32 16.1	0.0	483	373
15N/3E-15J2	160	0.55 9.1	4.35 71.7	1.17 19.3	3.99 75.9	0.71 13.5	0.56 10.7	0.0	354	245
15N/3E-15Q1	-	0.70 16.8	0.86 20.6	2.61 62.6	3.61 84.6	0.04 0.9	0.62 14.5	0.3	262	-

Well Number	Depth ft.	Chemical constituents equivalents per million percent reactance value						parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
15N/3E-19M1	75	0.94 30.2	1.39 44.7	0.78 25.1	2.79 92.1	0.09 3.0	0.15 5.0	0.1	150	117
15N/3E-21C1	185	1.30 23.6	2.86 51.9	1.35 24.5	4.47 81.1	0.25 4.5	0.79 14.3	0.0	328	208
15N/3E-22N1	115	3.49 34.4	4.75 46.8	1.90 18.6	7.42 74.6	0.75 7.5	1.78 18.0	0.0	529	412
15N/3E-23C1	118	0.75 46.3	0.65 40.1	0.22 13.6	1.41 92.2	0.05 3.3	0.07 4.6	0.0	99	70
15N/3E-23D1	125	2.25 38.3	3.30 51.5	0.60 10.2	5.19 90.1	0.29 5.0	0.28 4.9	0.0	325	264
15N/3E-24F1	130	2.84 42.8	2.59 39.0	1.21 18.2	4.71 69.4	0.58 8.5	1.50 22.1	0.1	334	261
15N/3E-26C1	163	1.35 30.0	1.71 38.0	1.44 32.0	4.03 90.2	0.10 2.2	0.34 7.6	0.0	262	153
15N/3E-26M1	250	1.45 32.6	1.23 27.6	1.77 39.8	3.97 89.4	0.10 2.3	0.37 8.3	0.2	241	134
15N/3E-27C1	80	3.89 32.2	6.02 49.8	2.17 18.0	8.85 77.2	0.92 8.0	1.69 14.8	0.2	557	496
15N/3E-27L1	150	2.15 31.6	3.05 51.3	1.59 17.0	4.93 86.1	0.33 6.3	1.41 7.6	0.0	370	260
15N/3E-29G1	90	3.09 34.3	4.27 47.4	1.65 18.3	7.20 85.7	0.75 8.9	0.45 5.4	0.0	488	367

Well Number	Depth ft.	Chemical constituents equivalents per million / percent reactance value						parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
15N/3E-29G2	110	2.84 31.6	4.61 51.3	1.53 17.0	7.35 86.1	0.54 6.3	0.65 7.6	0.0	487	373
15N/3E-30D1	65	2.64 37.9	3.44 49.4	0.89 12.8	6.10 94.0	0.23 3.5	0.16 2.5	0.0	384	304
15N/3E-34N2	80	3.80 22.9	10.38 62.5	2.43 14.6	7.02 42.8	2.02 12.3	7.36 44.9	0.1	831	709
15N/4E-8D1	333	1.87 43.8	1.82 42.6	0.58 13.6	3.04 73.3	0.90 21.7	0.21 5.1	0.1	220	184
15N/4E-16P1	450	1.15 41.8	1.07 39.0	0.53 19.2	2.21 81.6	0.42 15.5	0.08 2.9	0.0	184	111
15N/4E-20J2	271	1.60 36.9	2.14 49.3	0.60 13.8	3.13 73.0	0.98 22.8	0.18 4.2	0.0	271	187
15N/4E-29H1	145	1.35 36.2	1.75 46.9	0.63 16.9	2.96 80.2	0.54 14.6	0.19 5.2	0.0	187	155
15N/4E-31A1	157	1.05 39.5	1.07 40.2	0.54 20.3	2.32 89.9	0.02 0.8	0.24 9.3	0.0	172	105
16N/1W-29J1	-	1.30 31.3	1.48 35.7	1.37 33.0	3.82 94.1	0.00 0.0	0.24 5.9	0.1	199	139
16N/3E-14G1	63	4.34 46.7	4.22 45.4	0.73 7.9	6.78 76.9	1.19 13.5	0.85 9.6	0.0	472	428
16N/3E-16B1	46	0.84 46.9	0.80 44.7	0.15 8.4	1.49 87.1	0.12 7.0	0.10 5.9	0.0	90	82

Well Number	Depth ft.	Chemical constituents equivalents per million			percent reactance value			parts per million		
		CA	MG	NA+K	HCO3+CO3	SO4	CL	B.	TDS	TH
16N/3E-23B1	160	1.13 40.1	1.08 38.3	0.61 21.6	2.38 90.5	0.10 3.8	0.15 5.7	0.0	160	110
16N/3E-26Q1	416	1.40 46.1	0.80 26.3	0.84 27.6	2.40 81.6	0.17 5.8	0.37 12.6	0.1	218	110
16N/3E-31C1	72	1.32 30.8	2.04 47.7	0.92 21.5	3.92 92.7	0.16 3.8	0.15 3.5	0.0	318	168
16N/3E-36E1	85	2.16 37.1	2.84 48.7	0.83 14.2	5.04 92.5	0.02 0.4	0.39 7.2	0.0	280	250

PWS ID	PWS Name	EPA Region	Primacy Agency	PWS Type	Primacy Type	Primary Source	Activity Status
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active

PWS ID	PWS Name	EPA Region	Primacy Agency	PWS Type	Primacy Type	Primary Source	Activity Status
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active
CA0600008	COLUSA CO. WWD #1 - GRIMES	Region 9	California	Community water system	State	Ground water	Active

Deactivation Date	Population Served Count	Rule Name	Violation Code	Violation Type
-	381	Arsenic	2	Maximum Contaminant Level Violation, Average
-	381	Arsenic	2	Maximum Contaminant Level Violation, Average
-	381	Arsenic	2	Maximum Contaminant Level Violation, Average
-	381	Lead and Copper Rule	52	Follow-up Or Routine LCR Tap M/R
-	381	Arsenic	2	Maximum Contaminant Level Violation, Average
-	381	Arsenic	2	Maximum Contaminant Level Violation, Average
-	381	Nitrates	3	Monitoring, Regular
-	381	Arsenic	2	Maximum Contaminant Level Violation, Average
-	381	Arsenic	2	Maximum Contaminant Level Violation, Average
-	381	Arsenic	2	Maximum Contaminant Level Violation, Average
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-	381	Lead and Copper Rule	52	Follow-up Or Routine LCR Tap M/R
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Deactivation Date	Population Served Count	Rule Name	Violation Code	Violation Type
-	381	Arsenic	2	Maximum Contaminant Level Violation, Average
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-	381	Arsenic	2	Maximum Contaminant Level Violation, Average
-	381	Arsenic	2	Maximum Contaminant Level Violation, Average
-	381	Radionuclides	3	Monitoring, Regular
-	381	Radionuclides	3	Monitoring, Regular

Violation Category Code	Is Health Based	Contaminant Name	Compliance Period Begin Date	Compliance Period End Date
MCL	Y	Arsenic	1-Apr-18	30-Jun-18
MCL	Y	Arsenic	1-Jan-18	31-Mar-18
MCL	Y	Arsenic	1-Oct-17	31-Dec-17
MR	N	Lead and Copper Rule	1-Oct-17	-
MCL	Y	Arsenic	1-Jul-17	30-Sep-17
MCL	Y	Arsenic	1-Apr-17	30-Jun-17
MR	N	Nitrate	1-Jan-17	31-Dec-17
MCL	Y	Arsenic	1-Jan-17	31-Mar-17
MCL	Y	Arsenic	1-Oct-16	31-Dec-16
MCL	Y	Arsenic	1-Jul-16	30-Sep-16
MCL	Y	Arsenic	1-Apr-16	30-Jun-16
MCL	Y	Arsenic	1-Jan-16	31-Mar-16
MCL	Y	Arsenic	1-Oct-15	31-Dec-15
MR	N	Lead and Copper Rule	1-Oct-15	-
MCL	Y	Arsenic	1-Apr-15	30-Jun-15
MCL	Y	Arsenic	1-Jan-15	31-Mar-15
MCL	Y	Arsenic	1-Oct-14	31-Dec-14
MCL	Y	Arsenic	1-Jul-14	30-Sep-14
MCL	Y	Arsenic	1-Jan-14	31-Mar-14
MCL	Y	Arsenic	1-Oct-13	31-Dec-13
MCL	Y	Arsenic	1-Jul-13	30-Sep-13
MCL	Y	Arsenic	1-Apr-13	30-Jun-13
MCL	Y	Arsenic	1-Jan-13	31-Mar-13
MCL	Y	Arsenic	1-Oct-12	31-Dec-12
MCL	Y	Arsenic	1-Jul-12	30-Sep-12
MCL	Y	Arsenic	1-Apr-12	30-Jun-12
MCL	Y	Arsenic	1-Jan-12	31-Mar-12
MCL	Y	Arsenic	1-Oct-11	31-Dec-11
MCL	Y	Arsenic	1-Jul-11	30-Sep-11
MCL	Y	Arsenic	1-Apr-11	30-Jun-11
MCL	Y	Arsenic	1-Jan-11	31-Mar-11
MCL	Y	Arsenic	1-Oct-10	31-Dec-10
MCL	Y	Arsenic	1-Jul-10	30-Sep-10
MCL	Y	Arsenic	1-Apr-10	30-Jun-10

Violation Category Code	Is Health Based	Contaminant Name	Compliance Period Begin Date	Compliance Period End Date
MCL	Y	Arsenic	1-Jan-10	31-Mar-10
MCL	Y	Arsenic	1-Oct-09	31-Dec-09
MCL	Y	Arsenic	1-Jul-09	30-Sep-09
MCL	Y	Arsenic	1-Apr-09	30-Jun-09
MR	N	Gross Alpha, Excl. Radon and U	1-Oct-81	30-Sep-82
MR	N	Gross Alpha, Excl. Radon and U	30-Oct-80	29-Oct-81

Compliance Status	RTC Date	Enforcement Action Type Code	Enforcement Action Description	Is Major Violation
Known	-	SFL	State Administrative/Compliance Order without penalty issued	-
Known	-	SFL	State Administrative/Compliance Order without penalty issued	-
Known	-	SFL	State Administrative/Compliance Order without penalty issued	-
Open	-	SFL	State Administrative/Compliance Order without penalty issued	-
Known	-	SFL	State Administrative/Compliance Order without penalty issued	-
Known	-	SFL	State Administrative/Compliance Order without penalty issued	-
Returned to Compliance	12-Feb-19	SOX	State Compliance achieved	Y
Known	-	SFL	State Administrative/Compliance Order without penalty issued	-
Known	-	SFL	State Administrative/Compliance Order without penalty issued	-
Known	-	SFL	State Administrative/Compliance Order without penalty issued	-
Known	-	SFL	State Administrative/Compliance Order without penalty issued	-
Known	-	SFL	State Administrative/Compliance Order without penalty issued	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	17-Jul-19	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	27-Feb-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	27-Feb-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-
Returned to Compliance	27-Feb-18	SOX	State Compliance achieved	-
Returned to Compliance	27-Feb-18	SOX	State Compliance achieved	-
Returned to Compliance	27-Feb-18	SOX	State Compliance achieved	-

Compliance Status	RTC Date	Enforcement Action Type Code	Enforcement Action Description	Is Major Violation
Returned to Compliance	27-Feb-18	SOX	State Compliance achieved	-
Returned to Compliance	27-Feb-18	SOX	State Compliance achieved	-
Returned to Compliance	27-Feb-18	SOX	State Compliance achieved	-
Returned to Compliance	27-Feb-18	SOX	State Compliance achieved	-
Known	-	-	-	Y
Known	-	-	-	Y

Severity Indicator Count	Public Notification Tier	Violation First Reported Date
-	2	23-Aug-18
-	2	23-Aug-18
-	2	23-Aug-18
-	3	17-May-18
-	2	23-Aug-18
-	2	23-Aug-18
-	3	23-Aug-18
-	2	23-Aug-18
-	2	23-Aug-18
-	2	23-Aug-18
-	2	23-Aug-18
-	2	23-Aug-18
-	2	22-Feb-16
-	3	17-May-18
-	2	2-Sep-15
-	2	22-Feb-16
-	2	16-Feb-15
-	2	16-Feb-15
-	2	16-Feb-15
-	2	16-Feb-15
-	2	16-Feb-15
-	2	16-Feb-15
-	2	16-Feb-15
-	2	26-Jun-13
-	2	22-Feb-16
-	2	22-Feb-16
-	2	22-Feb-16
-	2	26-Jun-13
-	2	22-Feb-16
-	2	22-Feb-16
-	2	22-Feb-16
-	2	26-Jun-13
-	2	26-Jun-13

Severity Indicator Count	Public Notification Tier	Violation First Reported Date
-	2	26-Jun-13
-	2	4-Jun-10
-	2	30-Nov-09
-	2	30-Nov-09
-	3	30-Sep-82
-	3	30-Sep-81

PWS ID	PWS Name	EPA Region	Primacy Agency	PWS Type	Primacy Type	Primary Source	Activity Status
CA0600013	COLUSA CO. WWD #2 - PRINCETON	Region 9	California	Community water system	State	Ground water	Active
CA0600013	COLUSA CO. WWD #2 - PRINCETON	Region 9	California	Community water system	State	Ground water	Active
CA0600013	COLUSA CO. WWD #2 - PRINCETON	Region 9	California	Community water system	State	Ground water	Active
CA0600013	COLUSA CO. WWD #2 - PRINCETON	Region 9	California	Community water system	State	Ground water	Active
CA0600013	COLUSA CO. WWD #2 - PRINCETON	Region 9	California	Community water system	State	Ground water	Active
CA0600013	COLUSA CO. WWD #2 - PRINCETON	Region 9	California	Community water system	State	Ground water	Active
CA0600013	COLUSA CO. WWD #2 - PRINCETON	Region 9	California	Community water system	State	Ground water	Active
CA0600013	COLUSA CO. WWD #2 - PRINCETON	Region 9	California	Community water system	State	Ground water	Active
CA0600013	COLUSA CO. WWD #2 - PRINCETON	Region 9	California	Community water system	State	Ground water	Active
CA0600013	COLUSA CO. WWD #2 - PRINCETON	Region 9	California	Community water system	State	Ground water	Active
CA0600013	COLUSA CO. WWD #2 - PRINCETON	Region 9	California	Community water system	State	Ground water	Active

Deactivation Date	Population Served Count	Rule Name	Violation Code	Violation Type
-	356	Consumer Confidence Rule	71	Consumer Confidence Report Complete Failure to Report
-	356	Arsenic	2	Maximum Contaminant Level Violation, Average
-	356	Arsenic	2	Maximum Contaminant Level Violation, Average
-	356	Arsenic	2	Maximum Contaminant Level Violation, Average
-	356	Arsenic	2	Maximum Contaminant Level Violation, Average
-	356	Arsenic	2	Maximum Contaminant Level Violation, Average
-	356	Arsenic	2	Maximum Contaminant Level Violation, Average
-	356	Lead and Copper Rule	52	Follow-up Or Routine LCR Tap M/R
-	356	Lead and Copper Rule	51	Initial Tap Sampling for Pb and Cu
-	356	Radionuclides	3	Monitoring, Regular
-	356	Radionuclides	3	Monitoring, Regular

Violation Category Code	Is Health Based	Contaminant Name	Compliance Period Begin Date	Compliance Period End Date
Other	N	Consumer Confidence Rule	1-Jul-16	-
MCL	Y	Arsenic	1-Jul-10	30-Sep-10
MCL	Y	Arsenic	1-Apr-10	30-Jun-10
MCL	Y	Arsenic	1-Jan-10	31-Mar-10
MCL	Y	Arsenic	1-Oct-09	31-Dec-09
MCL	Y	Arsenic	1-Jul-09	30-Sep-09
MCL	Y	Arsenic	1-Apr-09	30-Jun-09
MR	N	Lead and Copper Rule	1-Oct-05	-
MR	N	Lead and Copper Rule	1-Jul-93	-
MR	N	Gross Alpha, Excl. Radon and U	1-Oct-81	30-Sep-82
MR	N	Gross Alpha, Excl. Radon and U	30-Oct-80	29-Oct-81

Compliance Status	RTC Date	Enforcement Action Type Code	Enforcement Action Description	Is Major Violation	Severity Indicator Count
Returned to Compliance	6-Feb-17	SOX	State Compliance achieved	-	-
Returned to Compliance	27-Jan-11	SOX	State Compliance achieved	-	-
Returned to Compliance	27-Jan-11	SOX	State Compliance achieved	-	-
Returned to Compliance	27-Jan-11	SOX	State Compliance achieved	-	-
Returned to Compliance	27-Jan-11	SOX	State Compliance achieved	-	-
Returned to Compliance	27-Jan-11	SOX	State Compliance achieved	-	-
Returned to Compliance	27-Jan-11	SOX	State Compliance achieved	-	-
Returned to Compliance	1-Mar-18	SOX	State Compliance achieved	-	-
Returned to Compliance	30-Sep-05	EOX	Federal Compliance achieved	-	-
Known	-	-	-	Y	-
Known	-	-	-	Y	-

Public Notification Tier	Violation First Reported Date
3	14-Feb-17
2	26-Jun-13
2	26-Jun-13
2	26-Jun-13
2	4-Jun-10
2	30-Nov-09
2	30-Nov-09
3	6-Sep-13
3	12-Dec-95
3	30-Sep-82
3	30-Sep-81

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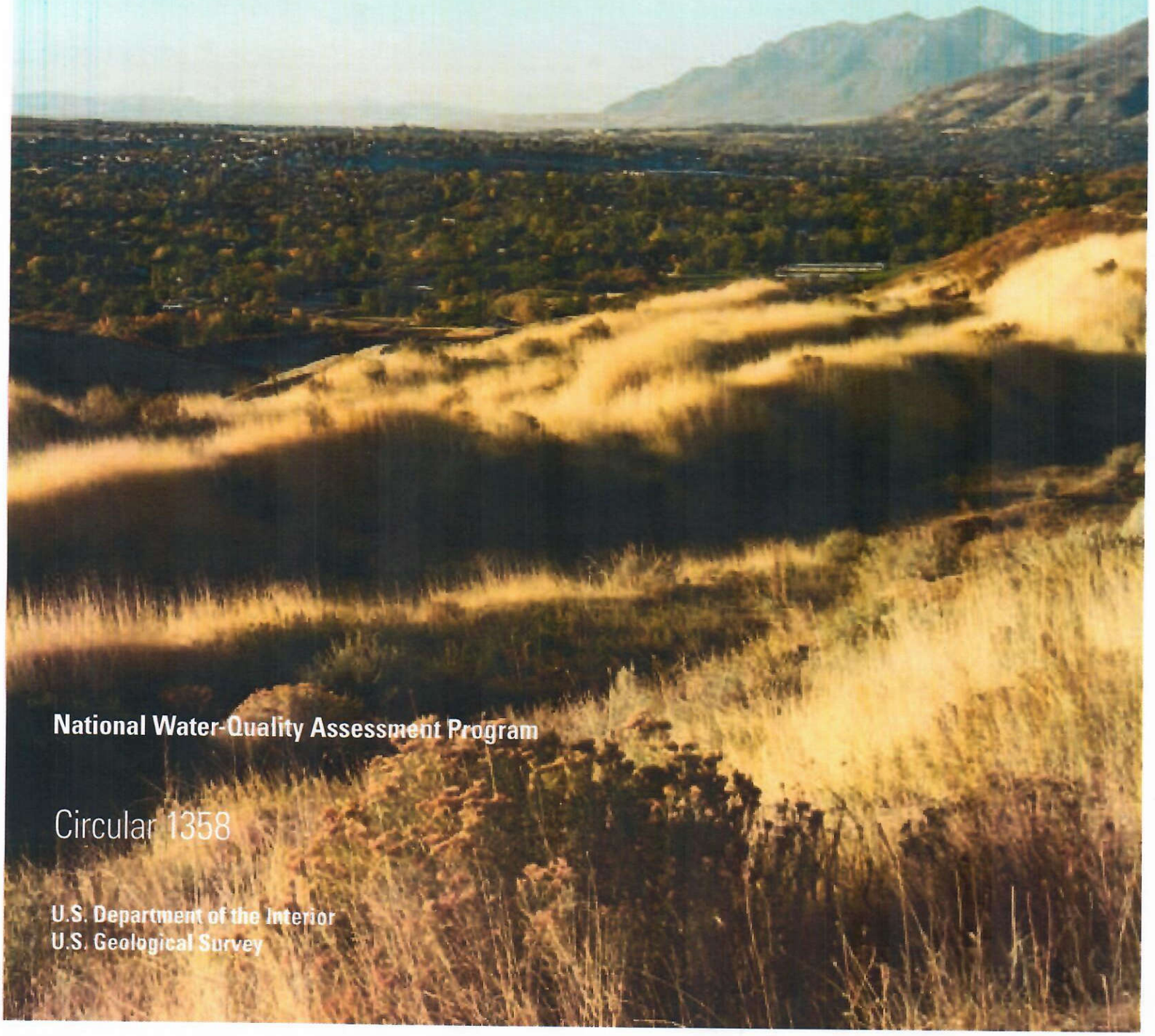
The Quality of Our Nation's Waters

Water Quality in Basin-Fill Aquifers of the Southwestern United States: Arizona, California, Colorado, Nevada, New Mexico, and Utah, 1993–2009



National Water-Quality Assessment Program

Circular 1358

U.S. Department of the Interior
U.S. Geological Survey

The Quality of Our Nation's Waters

Water Quality in Basin-Fill Aquifers of the Southwestern United States: Arizona, California, Colorado, Nevada, New Mexico, and Utah, 1993–2009

By Susan A. Thiros, Angela P. Paul, Laura M. Bexfield, and David W. Anning

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U.S. Department of the Interior
SALLY JEWELL, Secretary

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Chapter 6: *Understanding Where and Why Contaminants Occur in Southwest Basin-Fill Aquifers*

Arsenic, uranium, nitrate, dissolved solids, VOCs, and pesticides—these are the contaminants that are most likely to limit the use of groundwater now or in the future. Where do they occur, and what sources or processes control their concentrations? Answering these questions for selected basin-fill aquifers can help to identify areas across the Southwest that might be especially vulnerable to contamination and to estimate concentrations in areas where no data are available.

This chapter describes the sources of and factors that affect arsenic, uranium, nitrate, dissolved solids, VOCs, and pesticides in Southwest basin-fill aquifers, with focus on the intermediate to deeper parts of the aquifers that supply water for drinking and irrigation purposes.

The heavily irrigated Coachella Valley in southern California extends to the Salton Sea, a topographically low area that naturally accumulates minerals in groundwater through evapotranspiration.



Arsenic

33
As
75

Almost one-half of water samples from public-supply wells and one-quarter from domestic wells sampled as part of studies in the Rio Grande aquifer system contained arsenic at a concentration that exceeded the Maximum Contaminant Level.

Some geochemical conditions can cause arsenic in basin-fill sediments to dissolve into groundwater. As a result, groundwater in Southwest basin-fill aquifers commonly has arsenic concentrations that exceed the MCL of 10 µg/L. Many factors affect arsenic concentrations in groundwater—source rock type, geochemical conditions, the amount of time that groundwater is in contact with arsenic-containing rocks and sediment, the amount of groundwater moving through the aquifer, and evaporative concentration.

Arsenic is a nonmetallic trace element that commonly is present in rocks in the Southwest. Drinking water is the primary means by which people are exposed to arsenic, and long-term exposure is associated with many illnesses including skin, bladder, and lung cancers; immunological impairments; and cardiovascular disease. In 2001, the USEPA lowered the MCL for arsenic in drinking water from 50 to 10 µg/L.[25] Groundwater used for public supply in areas where the MCL is exceeded must be treated or mixed with water that contains lower arsenic concentrations to bring levels below the drinking-water standard. Many public suppliers have installed costly facilities to treat contaminated groundwater (see sidebar, The cost of arsenic contamination, p. 54).

Much of the information presented in this section is from the report "Predicted nitrate and arsenic concentrations in basin-fill aquifers of the southwestern United States" (available at http://pubs.usgs.gov/sir/2012/5065/).





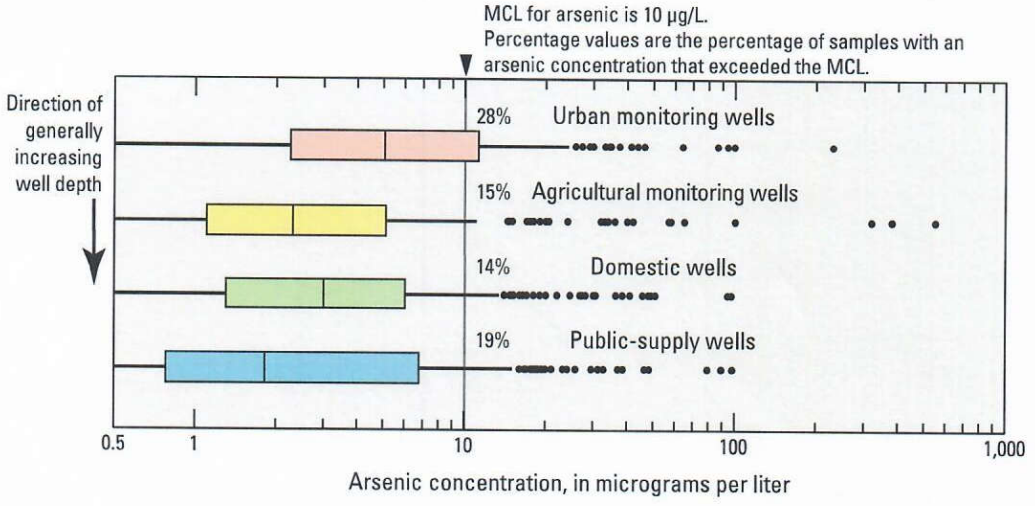
Photographs: Left, Michael Rosen; right, Doug Maurer, USGS

Arsenic occurs throughout the Southwest from geologic sources such as volcanic rocks (basalt, left) and geothermal water (discharge from a geothermal powerplant in Dixie Valley, Nevada, right).

Arsenic concentrations exceeded the MCL in about 16 percent of drinking-water wells sampled as part of studies of the Southwest Principal Aquifers (table 5–1). The MCL for arsenic was more frequently exceeded in domestic and public-supply wells in the Rio Grande aquifer system and Basin and Range basin-fill aquifers than in the Central Valley aquifer system or California Coastal Basin aquifers (table 6–1). Samples from almost one-half of the public-supply wells and one-quarter of domestic wells in the Rio Grande aquifer system exceeded the MCL for arsenic. Elevated concentrations—two or more times higher than the MCL—were measured in shallow groundwater sampled from monitoring wells, in addition to deeper groundwater sampled from drinking-water wells in the Southwest (fig. 6–2). Overall, arsenic concentrations exceeded the MCL in 19 percent of the 1,018 wells sampled as part of the NAWQA Program studies in the Southwest. This amount is consistent with a larger USGS dataset for the region (fig. 6–3) that was used to simulate arsenic concentrations.

Table 6–1. Percentage of samples with an arsenic concentration that exceeded the MCL of 10 µg/L. See appendix 2, table A2–2, for the number of wells sampled.

Type of well	All aquifers in Southwest Principal Aquifers group	Basin and Range basin-fill aquifers	Central Valley aquifer system	California Coastal Basin aquifers	Rio Grande aquifer system
Urban land-use monitoring wells	28	42	15	20	11
Agricultural land-use monitoring wells	15	51	10	Not sampled	3.3
Domestic wells	14	21	8.1	0	24
Public-supply wells	19	24	0	3.2	48
All sampled wells	19	30	8.8	6.3	17



See sidebar, Boxplots, p. 53

Figure 6–2. Arsenic concentrations in wells ranged from less than 1 to more than 100 µg/L. Although median concentrations in the monitoring, domestic, and public-supply wells were less than the Maximum Contaminant Level (MCL), many samples had concentrations up to 10 times higher than the MCL.

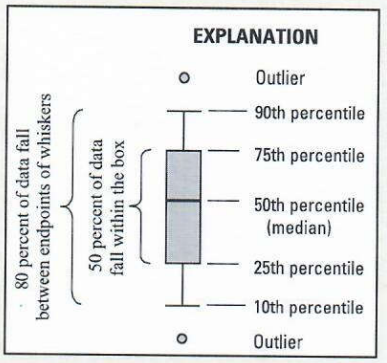
Boxplots

Boxplots are used to illustrate how results are distributed within a group. The "box" ranges from the 25th to the 75th percentile and represents 50 percent of the data. The horizontal line in the middle of the box is the median value—one-half of the values in the group are greater than the median and one-half are less.

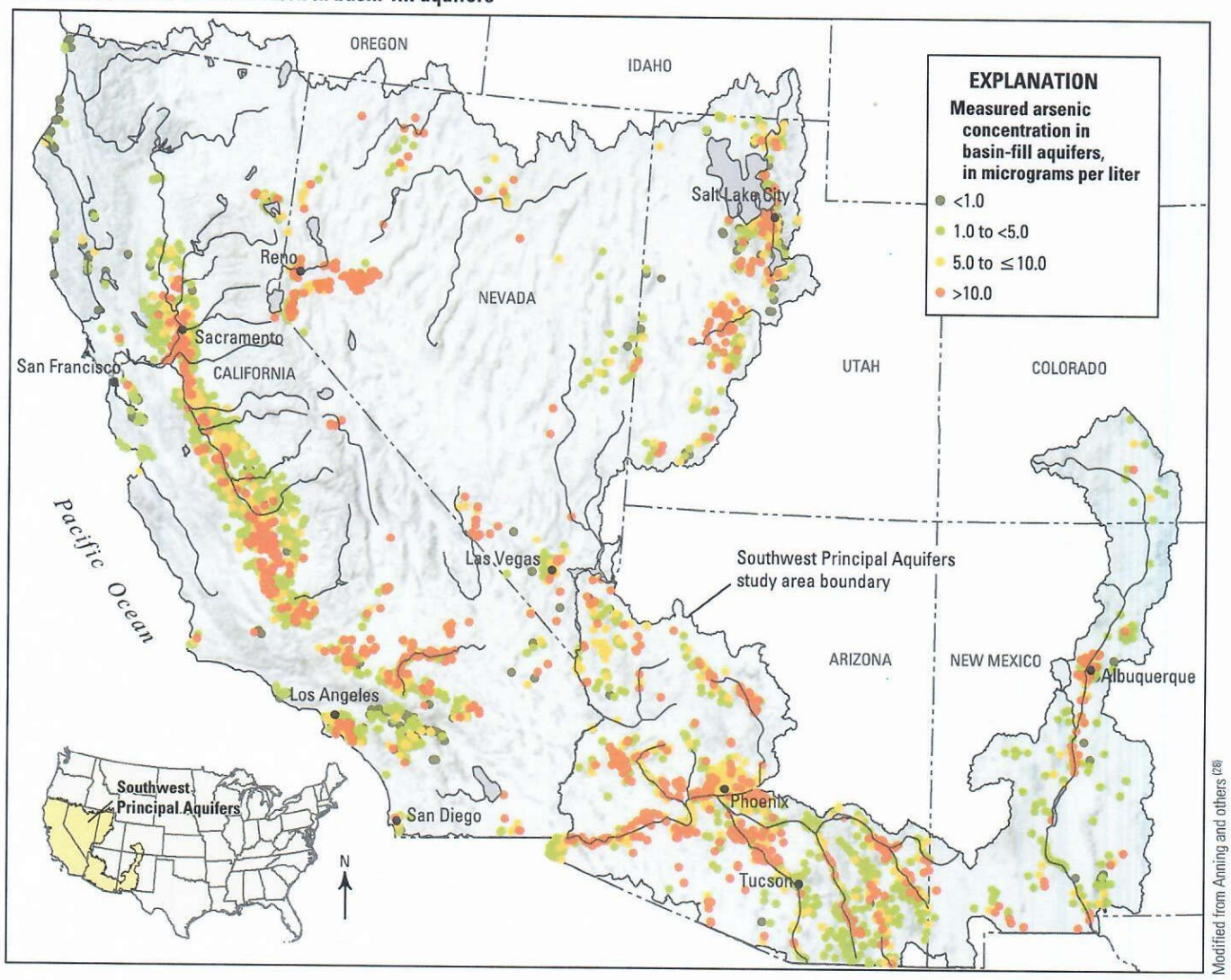
Percentiles describe the percentage of values in a group that are less than the given value: 25 percent of the values in a group are less than the 25th percentile; 75 percent of the values in a group are less than the 75th percentile. The median is also the 50th percentile.

If, for example, the 75th percentile for the measured concentration of a contaminant in a group of wells is equal to the human-health benchmark for that contaminant, then 75 percent, or three-fourths, of the wells have a concentration of that contaminant less than the benchmark, and 25 percent, or one-fourth, have a concentration greater than the benchmark.

The "whiskers" (vertical lines) in these figures extend to the 10th and 90th percentiles; box and whiskers together represent 80 percent of the data. Values greater than the 90th or less than the 10th percentile are shown as individual points (outliers).



Measured arsenic concentration in basin-fill aquifers



Modified from Anning and others [28]

Figure 6–3. During 1980–2009, USGS studies in the Southwest were conducted to measure arsenic in a total of 4,162 wells that tap basin-fill aquifers. About 19 percent of arsenic concentrations in these wells were greater than the MCL of 10 µg/L, consistent with data from this study (table 6–1). There are few or no arsenic data for groundwater in large areas in the Southwest, mostly because there are few people in these areas and, therefore, few wells.

The cost of arsenic contamination

The USEPA estimated in 2001 that the annual cost to reduce arsenic concentrations to below the MCL would range from $0.86 to $32 per household for customers of large public water systems (more than 10,000 people) to $165 to $327 per household for very small systems (25–500 people).[25] Water supplies in the Southwest are limited and often naturally contain arsenic concentrations high enough to require treatment. According to fiscal year 2010 statistics,[68] 274 public water systems in California, Nevada, Utah, Arizona, and New Mexico—mostly small systems that lack a large customer base to pay for water treatment—had a water source containing arsenic concentrations that exceeded the MCL for arsenic.

In Fallon, Nevada, groundwater supplying about 8,400 residents and a nearby Naval Air Station consistently contains arsenic concentrations exceeding the MCL. In 2004 a treatment facility was installed for arsenic removal at a cost of $19 million.[69] Upgrades to water systems throughout Nevada to remove arsenic have been estimated to cost many millions of dollars.[70]



Photograph by Jeff Ross

The arsenic treatment system for Fallon, Nevada, adds dissolved iron to the water. The iron reacts with the dissolved arsenic to form particles that then are filtered out of the water.

Rock Type, Climate, and Location Within a Basin Affect Arsenic Concentrations in Groundwater

The Southwest contains many areas with volcanic rocks, an arid to semiarid climate, and closed or constricted basins—all factors that contribute to elevated arsenic concentrations in groundwater. Arsenic commonly is found in Southwest basin-fill aquifers in areas with volcanic and crystalline rocks (see extent of volcanic rocks in figure 3–2), geothermal water, and (or) sulfide minerals associated with these geologic settings.[26] Low precipitation rates and high evapotranspiration rates result in low groundwater recharge rates to many Southwest basins. Arsenic remaining after water evaporates accumulates in aquifers in closed or constricted basins with low recharge rates. In contrast, basins with higher recharge rates have more groundwater to flush arsenic from the aquifer.

Volcanic rocks, an arid to semiarid climate, and closed or constricted basins contribute to elevated concentrations of arsenic in Southwest groundwater.

Arsenic concentrations increase as groundwater moves from recharge areas near mountain fronts through arsenic-bearing sediment in the basin toward discharge areas in the basin lowlands.[27] The long flow paths typical of Southwest aquifers contribute to elevated arsenic concentrations measured in basin lowlands because the water is in contact with the aquifer sediment for long periods of time, allowing important geochemical reactions to occur. The area where groundwater is located along a flow path in a basin can be used to infer groundwater age and geochemical conditions, which influence concentrations of dissolved arsenic and other constituents with geologic sources in an aquifer. In general, as groundwater moves along a flow path, pH increases and the concentration of dissolved oxygen decreases.

The interaction of arsenic with metal oxides, particularly iron oxide, is one of the most important processes by which groundwater can become enriched or depleted in arsenic. When geochemical conditions favor arsenic release (desorption) from oxide surfaces, groundwater concentrations are higher than when geochemical conditions favor arsenic attachment (adsorption) to oxide surfaces. Adsorption and desorption of arsenic are controlled largely by the concentration of dissolved oxygen in groundwater and by pH. Generally, if the pH of the groundwater is less than 8, arsenic adsorbs to iron oxides, removing it from groundwater (fig. 6–4). If the pH is greater than 8, arsenic tends to desorb from the iron oxides and dissolves into the groundwater. Under anoxic conditions, iron oxides dissolve and release iron and arsenic into the groundwater regardless of pH.

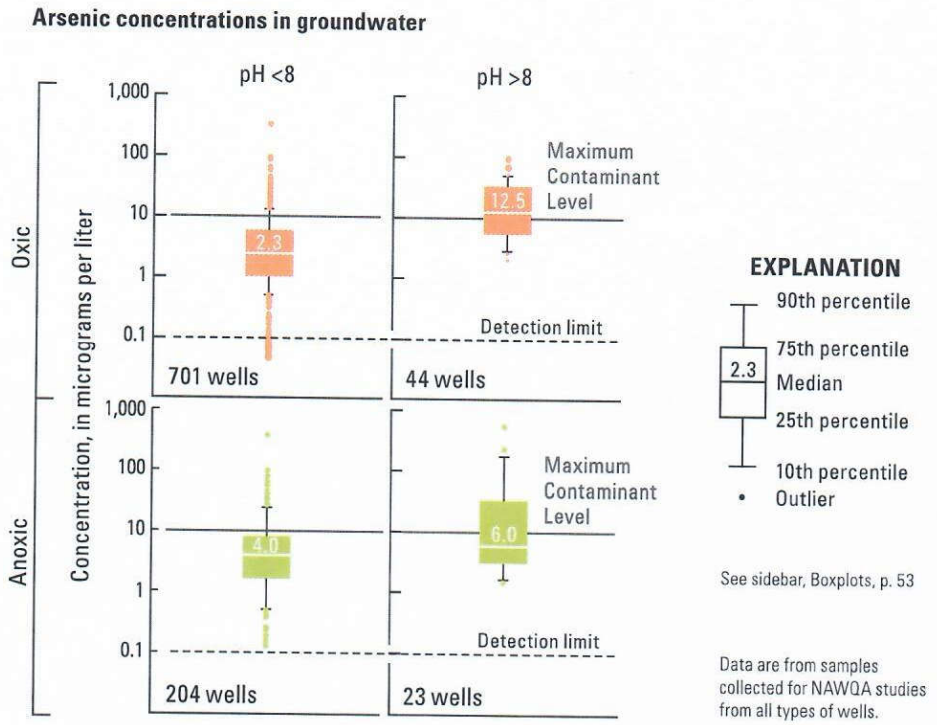


Figure 6–4. More arsenic typically is dissolved in groundwater from Southwest basin-fill aquifers under oxic conditions at a pH greater than 8 than under anoxic conditions at a pH less than 8. The pH and redox condition of the groundwater affect whether arsenic adsorbs to iron oxides on the aquifer sediment or is released into groundwater.



Photographs: Left, Michael Rosen; right, Susan Thiros, USGS

Arsenic can attach to iron oxide (reddish-brown color visible in photographs) that is present in cracks in rocks (left) and that coats basin-fill sediment (right). The pH and redox conditions in an aquifer determine if the arsenic remains attached to the iron oxide or dissolves into the groundwater. Recharged oxygenated irrigation water and groundwater pumping commonly cause the water table to fluctuate, which can release arsenic from basin-fill sediment into the groundwater.[32]

The Middle Rio Grande Basin—An example of the influence of geology, water source, and geochemical conditions on arsenic concentrations in groundwater



Arsenic concentrations greater than 20 µg/L—twice the current MCL—have been measured in groundwater throughout the Middle Rio Grande Basin, New Mexico. Groundwater is the main source of drinking water for many communities in the basin. To deliver drinking water that does not contain arsenic concentrations above the MCL, some public water suppliers use arsenic treatment systems, blend high-arsenic groundwater with low-arsenic water, or both. Groundwater was the primary source of drinking water for Albuquerque residents until late 2008 when low groundwater levels caused by pumping prompted the city to import and treat surface water; since that time, groundwater continues to be a secondary source of drinking water.

Arsenic in the Middle Rio Grande Basin originates predominately from one of two geologic sources, depending on the location within the basin:

- ***Groundwater inflow from the Jemez Mountains to the north.*** High arsenic concentrations in recharge water from the Jemez Mountains result from contact between water and volcanic rocks rich in arsenic. This source of groundwater recharge affects the aquifer primarily in the northwestern part of the Middle Rio Grande Basin.
- ***Deep mineralized groundwater.*** Groundwater circulating at depth in the Middle Rio Grande Basin has high concentrations of arsenic, chloride, and other elements. This deep groundwater comes into contact with shallower groundwater where it flows upward, primarily along fault zones throughout the basin. Evidence of this mixing of shallow and deep groundwater includes locally high dissolved-solids concentrations (exceeding 5,000 mg/L), hot water temperatures (exceeding 125 degrees Fahrenheit [°F]), and the occurrence of arsenite (the reduced form of arsenic) in groundwater at relatively shallow depths.

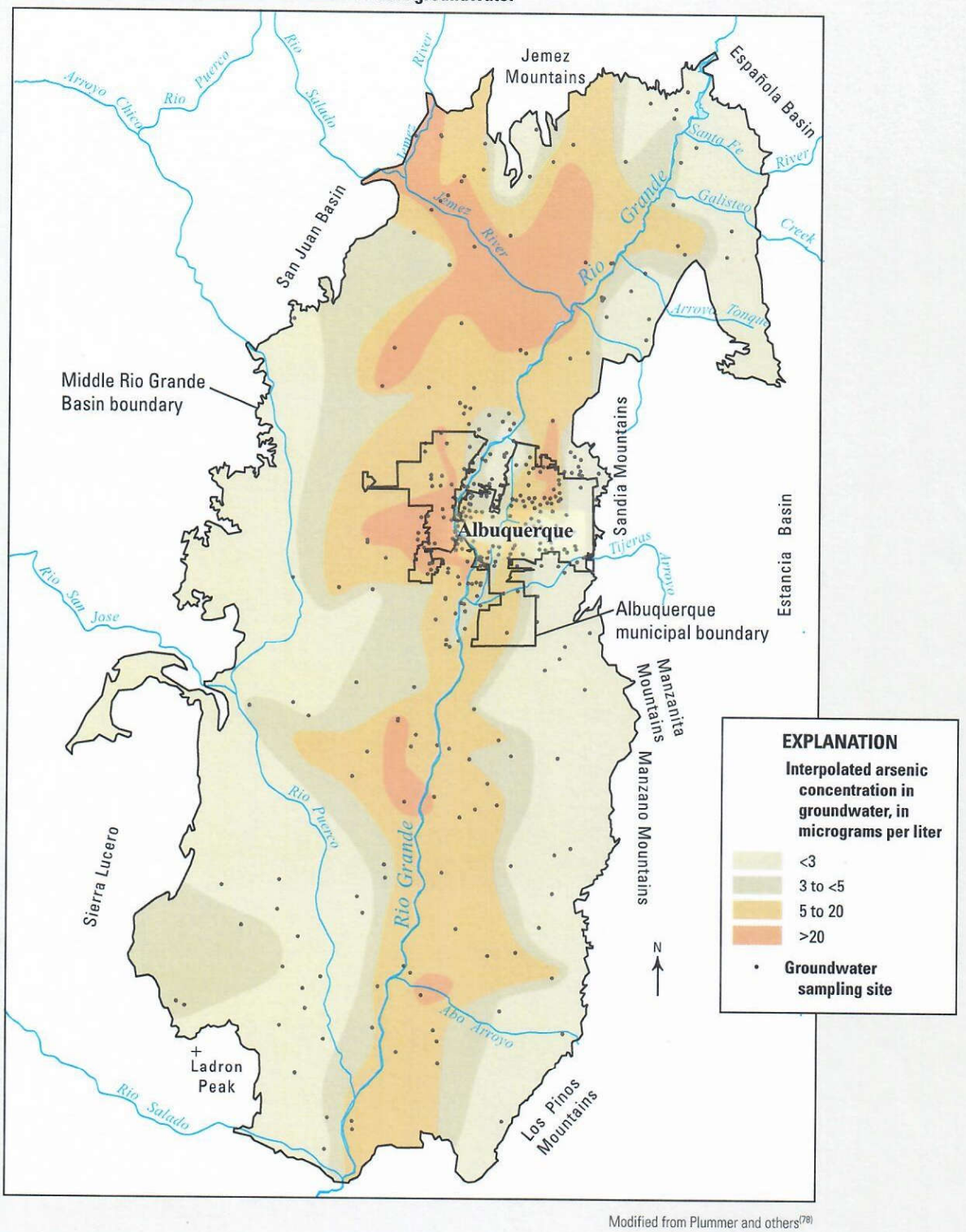
Arsenic concentrations in groundwater from the Middle Rio Grande Basin also are affected by pH-controlled desorption from iron oxides that coat the aquifer sediment. In some areas where the groundwater was oxygenated with a pH higher than 8.5, arsenic concentrations exceeded 20 µg/L. The arsenic dissolved in this groundwater was present primarily as arsenate (the oxidized form of arsenic).



Photograph by Johanna Siegmann Photography, www.johannasiegmann.com

Residents of the Albuquerque area, New Mexico, depend on water from the Rio Grande and from the basin-fill aquifer. Groundwater west and north of the city contains elevated concentrations of arsenic.

Arsenic concentration in Middle Rio Grande Basin groundwater



Modified from Plummer and others[78]

The highest concentrations of arsenic in groundwater in the Middle Rio Grande Basin are associated with volcanic rocks in the northern part of the basin and with fault zones through which deep, mineralized groundwater rises. Arsenic concentrations in groundwater generally are lower along the eastern and western margins of the basin, where low-arsenic recharge water enters the aquifer, than near the center of the basin, where groundwater has been in contact with arsenic-bearing sediment for a long time.

Estimating Arsenic Concentrations in Areas Where No Data Are Available

The relation between arsenic concentrations in groundwater and rock type, climate, and location within a basin (for example, basin lowlands) was explored using a statistical model.[28] The model provides estimates of arsenic concentrations in areas where no measurements are available (fig. 6–3).

The statistical model found that, in a basin surrounded by volcanic and crystalline rocks, arsenic concentrations are greater in areas with less recharge to the aquifer than in areas with more recharge (fig. 6–5). Areas with relatively low groundwater recharge rates tend to have a longer groundwater residence time resulting in less flushing of arsenic and other constituents from the aquifer than areas with higher rates of recharge. As groundwater moves along the flow

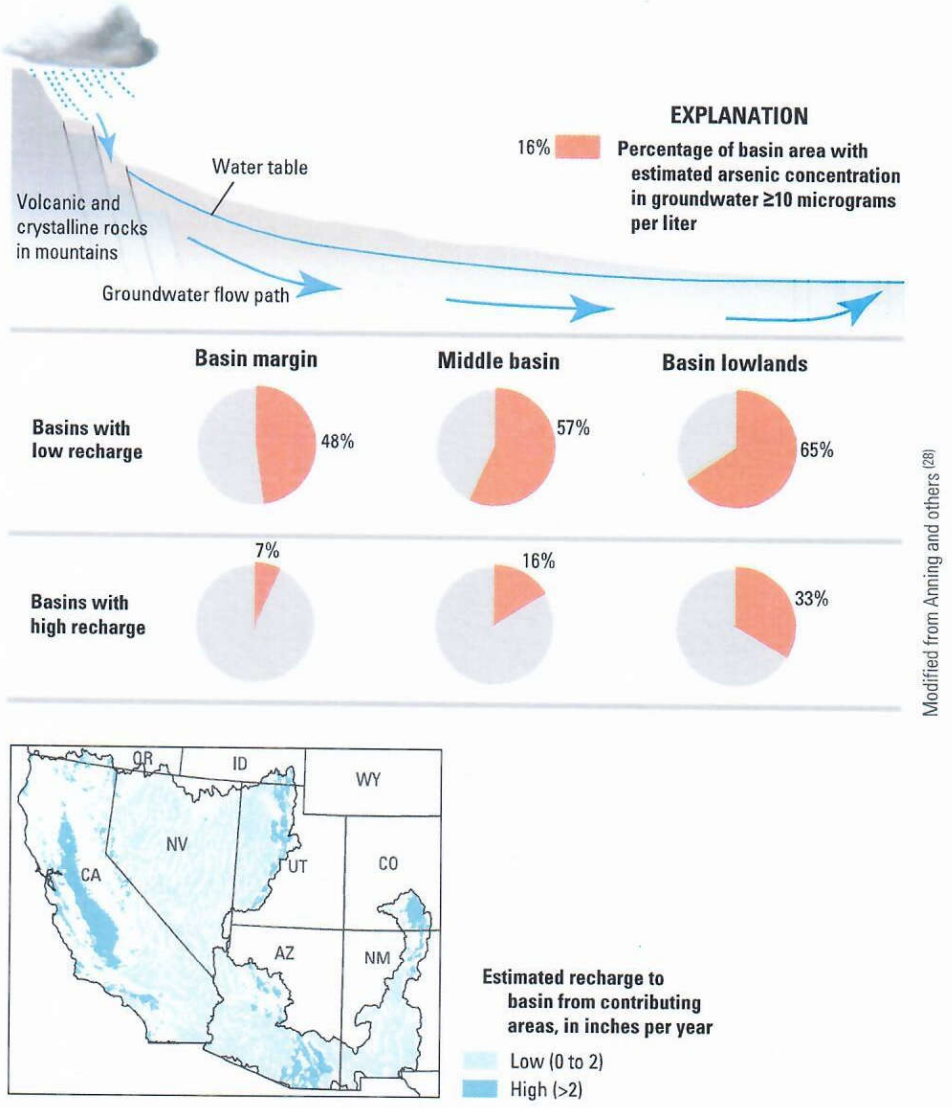


Figure 6–5. Arsenic concentrations in Southwest basins with volcanic and crystalline rocks in the adjacent mountains typically increase with distance along the groundwater flow path because of geochemical reactions between the groundwater and basin-fill sediments derived from the mountains. Aquifers in these areas that have relatively low recharge rates (less than about 2 inches per year) tend to have longer groundwater residence times and higher predicted arsenic concentrations than those that have higher rates of recharge.

path from recharge areas near basin margins to discharge areas in basin lowlands, arsenic concentrations were likely to increase. Arsenic concentrations greater than the MCL are more likely to occur in basin lowlands than in other parts of the basin because of a longer residence time in the aquifer and geochemical reactions between the groundwater and arsenic-bearing sediment.

The model estimates that 43 percent of the area with basin-fill aquifers has arsenic concentrations equal to or greater than 10 µg/L (fig. 6–6). This percentage is higher than might be expected on the basis of measured concentrations because of the inclusion of large areas with arsenic-bearing rocks and constricted groundwater flow. Many of the basins with these conditions are sparsely populated with relatively little groundwater pumping (fig. 4–5) so there are few data on concentrations, primarily because there are so few wells to sample.

Estimated arsenic concentration in basin-fill aquifers

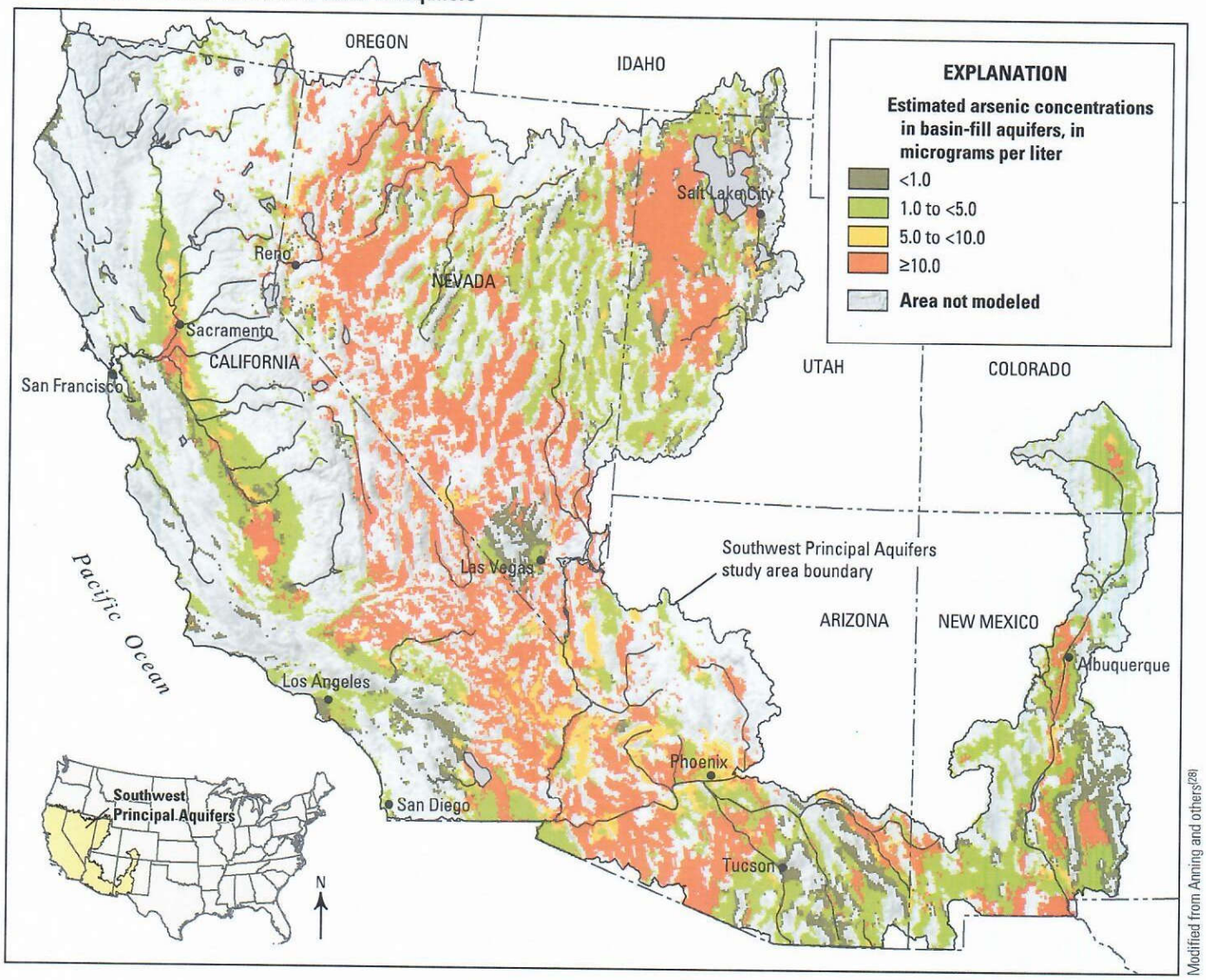


Figure 6–6. Almost half (43 percent) of the areal extent of Southwest basins likely has arsenic concentrations in groundwater that equal or exceed the MCL of 10 µg/L, on the basis of a statistical model. Proximity to volcanic rocks, an arid climate, and lack of groundwater drainage from a basin contribute to high arsenic concentrations. If used for public supply, groundwater in areas with these conditions likely would require treatment to decrease arsenic concentrations to levels acceptable for drinking.

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SUTTER-YUBA COUNTIES INVESTIGATION

September, 1952

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ceeded. A discussion of the characteristics of each group follows:

Group 1. This comprised unaltered normal ground water. Four analyses were available for Group 1 water. The wells which yielded this water were located within the present zone of high chloride concentration, and the samples were taken and analyses made in 1934 and 1935 prior to recent degradation of ground water in the zone. The water had total anions ranging from 4.72 to 6.31 equivalents per million, and chlorides from 0.85 to 2.06 equivalents per million. Its mineral quality was excellent.

Group 2. This group comprised waters containing a trace of salinity. Total anions ranged from 8.95 to 10.68 equivalents per million, and chlorides from 5.45 to 6.39 equivalents per million. Four analyses repre-

TABLE 20

COMPLETE MINERAL ANALYSES OF GROUND WATERS IN AREA OF SALINE DEGRADATION IN AND ADJACENT TO SUTTER-YUBA AREA, GROUPED IN ACCORDANCE WITH TOTAL ANIONS

Ground water group	Well location or number	Date of sample	Conductance, Ec × 10^6 at 25° C.	Boron, in ppm	Mineral constituents, in equivalents per million							Percent sodium
					Ca	Mg	Na	HCO_3 + CO_3	Cl	SO_4	NO_3	
1	$N\frac{1}{2}$ Sec. 9, T13N, R3E	5/31/34	483		1.40	1.81	1.51	3.30	1.33	0.09		32
	$S\frac{1}{2}$ Sec. 10, T14N, R3E	1/ 2/35	543		1.70	1.97	1.43	4.25	0.85	Trace		28
	$NE\frac{1}{4}$ Sec. 15, T14N, R3E	1/15/35	515		1.50	2.13	1.54	3.70	1.47	Trace		30
	$NW\frac{1}{4}$ Sec. 28, T14N, R3E	4/30/34	635		2.10	2.30	1.91	4.20	2.06	0.05		30
	Average		544		1.67	2.05	1.59	3.86	1.43	0.03		30
2	11N/3E-2B1	7/ /49	944	0.16	2.80	2.24	4.31	3.02	5.90	0.03	0.0	46
	13N/3E-3D1	7/ /49	980	0.09	3.59	5.02	2.05	4.20	6.39	0.09	0.0	19
	14N/3E-28R1	7/ /49	1,000	0.12	2.71	5.62	2.58	3.94	6.38	0.13	Trace	24
	14N/3E-33A2	7/ /49	1,037	0.0	2.98	4.29	3.32	5.09	5.45	0.03	0.0	31
	Average		990	0.09	3.02	4.29	3.06	4.06	6.03	0.07	Trace	30
3	13N/3E-2P3	7/ /49	1,317	0.17	3.13	3.39	6.46	3.78	9.21	0.04	0.0	50
	13N/3E-5K1	7/ /49	1,353	0.07	3.70	5.53	4.07	4.15	9.14	0.09	0.0	31
	13N/3E-10A1	7/ /49	1,190	0.05	4.40	5.83	2.13	3.91	8.06	0.22	0.0	17
	14N/3E-27E1	7/ /49	1,361	0.0	4.51	5.94	3.38	5.53	7.86	0.45	Trace	24
	14N/3E-29Q1	7/ /49	1,390	0.14	4.14	5.33	4.47	3.23	10.15	0.02	Trace	32
	14N/3E-34J1	7/ /49	1,087	0.0	4.05	5.76	2.57	6.84	3.40	2.01	0.10	21
	Average		1,283	0.07	3.99	5.31	3.85	4.54	7.97	0.14	0.02	29
4	13N/3E-2E1	7/ /49	1,503	0.49	2.96	3.05	8.75	3.78	11.11	0.03	0.0	59
	13N/3E-11D1	7/ /49	1,408	0.06	5.21	7.34	1.96	4.17	9.34	0.81	0.0	13
	13N/3E-14G1	7/ /49	1,307	0.06	4.43	6.85	3.44	6.20	7.49	0.71	0.06	23
	13N/3E-23H1	7/ /49	1,408	0.03	5.45	6.73	2.92	4.98	10.23	0.17	0.0	19
	13N/3E-24D1	7/ /49	1,460	1.64	3.23	2.15	9.05	3.90	11.68	0.03	0.0	63
	14N/3E-33A1	7/ /49	1,460	0.0	4.88	6.90	2.82	5.11	9.44	0.09	0.0	19
	Average		1,425	0.36	4.36	5.52	4.86	4.52	9.88	0.31	0.01	33
5	13N/3E-5C1	7/ /49	1,835	0.21	4.83	6.00	6.70	3.52	14.08	0.03	0.0	38
	13N/3E-11F1	7/ /49	1,710	0.85	3.29	4.51	9.40	3.26	13.04	0.28	0.0	55
	13N/3E-14J1	7/ /49	1,710	0.31	4.68	8.18	4.87	4.12	12.78	0.43	0.0	27
	14N/3E-28G2	7/ /49	1,653	0.0	5.18	6.92	4.51	5.21	10.95	0.37	0.0	27
	14N/3E-32F1	7/ /49	1,640	0.24	4.90	7.36	4.77	4.35	12.37	0.03	0.0	28
	Average		1,709	0.32	4.58	6.59	6.05	4.09	12.64	0.23	0.0	35
6	11N/3E-3B1	7/ /49	2,162	0.93	4.63	2.98	13.94	3.42	18.08	0.03	0.0	65
	13N/3E-2N1	7/ /49	1,802	0.07	5.71	6.31	6.02	4.63	13.61	0.15	Trace	33
	13N/3E-14R1	7/ /49	1,870	0.72	5.35	6.68	6.80	4.88	14.06	0.26	0.0	36
	13N/3E-16R1	7/ /49	2,222	0.03	5.96	8.25	7.27	4.24	17.42	0.03	0.0	34
	13N/3E-32L1	7/ /49	2,062	0.21	5.27	10.09	5.75	2.64	17.26	0.30	0.0	27
	Average		2,059	0.39	5.38	6.86	7.97	3.95	16.09	0.15	Trace	39
7	13N/3E-6K1	7/ /49	2,550	0.28	6.62	11.33	8.81	5.08	20.42	0.05	0.0	33
	13N/3E-23B1	7/ /49	3,390	0.0	11.83	16.80	6.71	5.50	29.04	0.34	Trace	19
	14N/3E-31J1	7/ /49	2,425	0.0	7.28	11.08	6.20	5.06	19.26	0.26	Trace	25
	14N/3E-31R1	7/ /49	2,552	0.07	7.36	11.09	6.97	4.98	20.44	0.12	0.0	27
	14N/3E-32L2	7/ /49	2,776	0.27	7.40	9.30	9.84	2.82	23.52	0.04	0.0	37
	14N/5E-21A1	8/ 3/49	2,702	1.71	10.78	4.17	12.60	1.72	22.94	2.01	Trace	46
	Average		2,732	0.39	8.55	10.63	8.52	4.19	22.60	0.47	Trace	31
8	$SE\frac{1}{4}$ Sec. 2, T12N, R2E	7/ 9/49	10,000	0.60	30.37	35.30	39.90	4.10	99.45	0.05	0.0	38
	$SW\frac{1}{4}$ Sec. 18, T12N, R2E	3/14/47	8,600	10.8	19.83	7.22	76.12	2.71	99.92	0.08		74
	Average		9,300	5.7	25.10	21.26	58.01	3.40	99.67	0.05		56

STRATIGRAPHIC ANALYSIS AND HYDROGEOLOGIC CHARACTERIZATION OF CENOZOIC STRATA IN THE SACRAMENTO VALLEY NEAR THE SUTTER BUTTES

Steven Taylor Springhorn
B.S., California State University, Chico, 2005

THESIS

Submitted in partial satisfaction of
the requirements for the degree of

MASTER OF SCIENCE

in

GEOLOGY

at

CALIFORNIA STATE UNIVERSITY, SACRAMENTO

SPRING
2008

6.0 FUTURE WORK

This study has focused on maximizing the use of existing data and integration of new data to generate a stratigraphic framework of the Valley and improve the overall understanding of the aquifer system. Based on the information collected, a number of data gaps exist and future work is needed. In this section, additional data collection needs are identified including:

- Elevated arsenic concentrations in groundwater related to the Sutter Buttes Rampart material.
- Additional subsurface information is needed in several areas within the central Sacramento Valley.
- Sequence stratigraphic analysis.

These data collection needs are essential to better understand the groundwater resources in the Sacramento Valley near the Sutter Buttes. These additional data will improve knowledge of the basin hydrogeology and significantly enhance the ability of water managers to cooperatively manage the shared resources in a manner that is economically and environmentally sustainable.

6.1 Elevated Arsenic Concentrations in Groundwater Related to Sutter Buttes Rampart Material

Data analyses suggest there is a connection between elevated arsenic concentrations in groundwater and the presence of the Sutter Buttes Rampart volcaniclastic material (which is derived from silicic and intermediate volcanic rocks). In stratigraphic units that occur above and below the Rampart, arsenic concentrations in

groundwater are generally less than 10 µg/l (micrograms/liter). In contrast, within Rampart material, arsenic concentrations in groundwater are found in much higher concentrations (10 to 370 µg/l).

Concentrations of arsenic in 27 spatially and depth distributed samples from DWR multi-completion monitoring wells ranged from < 0.1 to 370 µg/l. Concentrations in 15 of the samples exceeded the USEPA current drinking water Maximum Contaminant Level (MCL) of 10 µg/l, and 90 percent of groundwater samples collected from monitoring wells screened in Rampart volcaniclastic material have arsenic concentrations exceeding the MCL.

A detailed geochemical analysis of the relationship between elevated arsenic concentrations and Sutter Buttes Rampart material is needed, because of the health risks associated with this constituent. If a strong link is found between arsenic in groundwater and Rampart volcaniclastic material, the subsurface distribution of the Rampart presented in this thesis can be used in future geochemical investigations to delineate areas that have a high probability of containing elevated arsenic concentrations.

6.2 Location of Data Gaps and Additional Subsurface Data Needed

A significant amount of geologic, geophysical, and hydrogeologic data has been collected to date in the study area; however, there are many areas in the central Sacramento Valley that would benefit from additional geologic, geophysical, and dedicated groundwater monitoring data. These areas include (Figure 6.1):

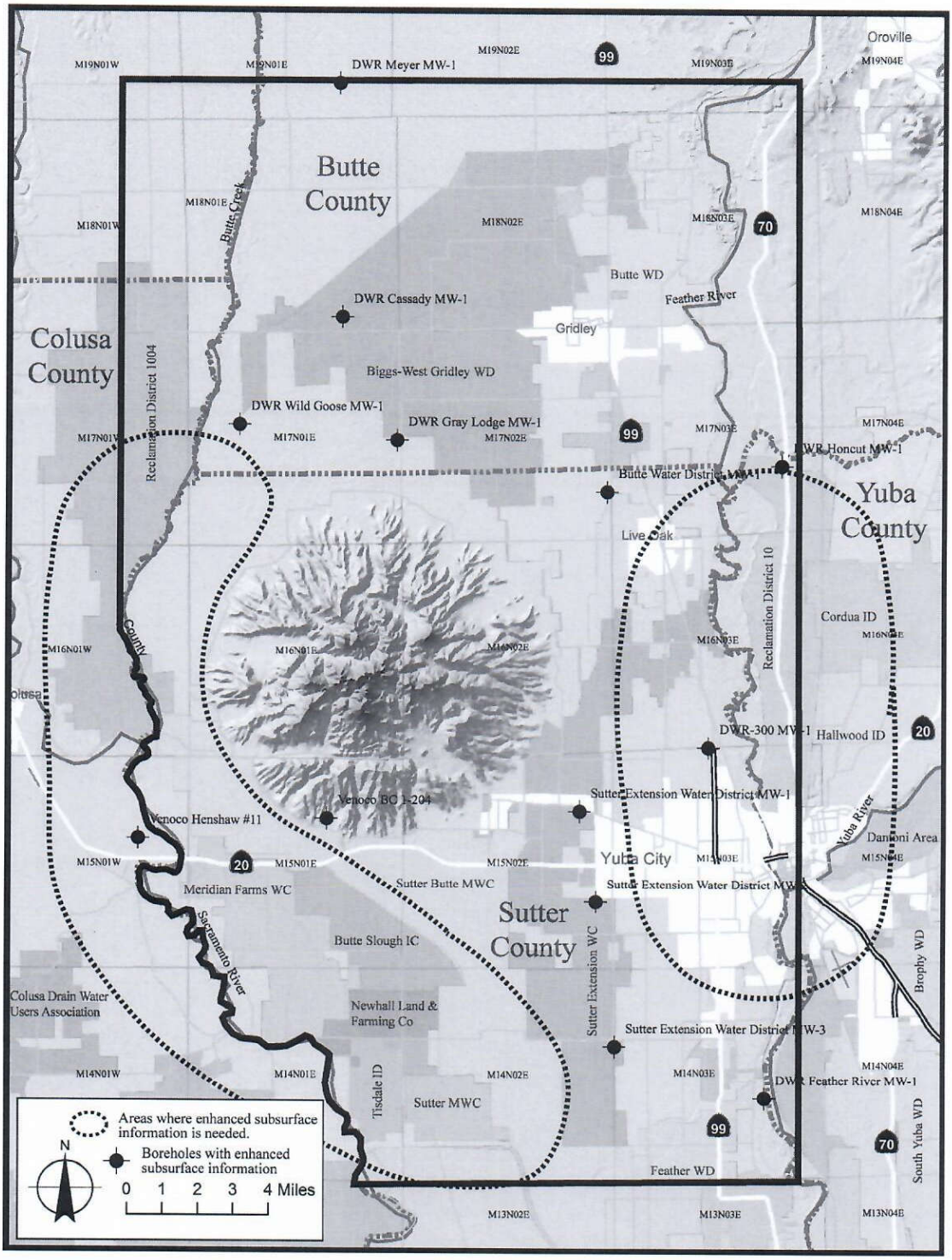

Figure 6.1: Areas where subsurface information is needed.

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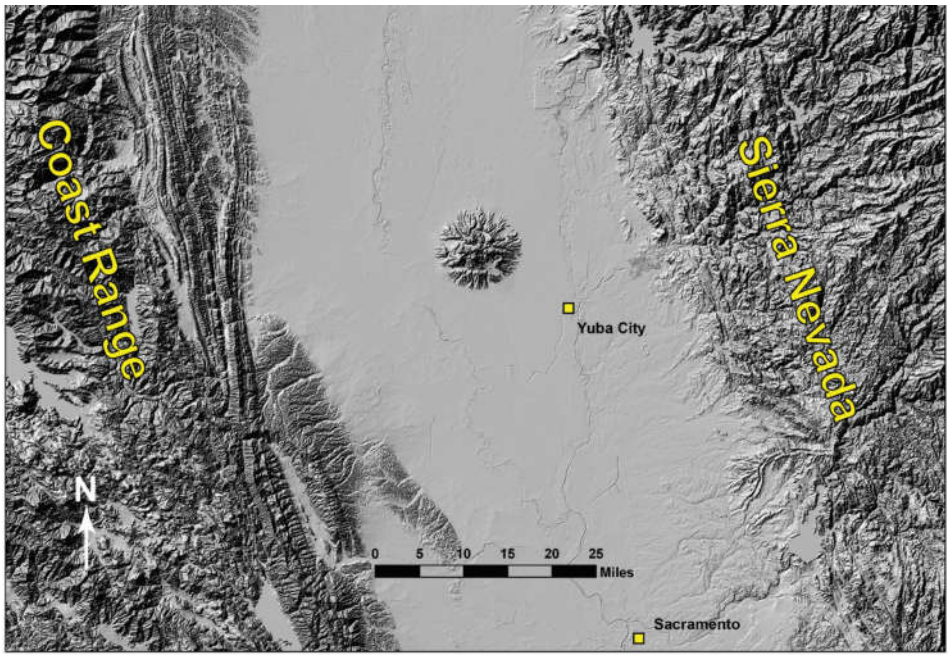
Sutter Buttes—The Lone Volcano in California's Great Valley

The volcanic spires of the Sutter Buttes tower 2,000 feet above the farms and fields of California's Great Valley, just 50 miles north-northwest of Sacramento and 11 miles northwest of Yuba City. The only volcano within the valley, the Buttes consist of a central core of volcanic domes surrounded by a large apron of fragmental volcanic debris. Eruptions at the Sutter Buttes occurred in early Pleistocene time, 1.6 to 1.4 million years ago. The Sutter Buttes are not part of the Cascade Range of volcanoes to the north, but instead are related to the volcanoes in the Coast Ranges to the west in the vicinity of Clear Lake, Napa Valley, and Sonoma Valley.



Rising 2,000 feet from the center of California's flat Sacramento Valley near Yuba City, the isolated Sutter Buttes were formed by volcanism more than 1 million years ago. Their dramatic isolation is well shown in this shaded-relief image. Base map from U.S. Geological Survey elevation data.

In the fall of 1841 an overland party from the United States Exploring Expedition led by Charles Wilkes traveled down the valley of the Sacramento River in central California, rejoining the expedition's ships later in San Francisco. The geologist of the expedition, James Dwight Dana, could not help noticing in the middle of that broad, flat valley an isolated cluster of hills that tower 2,000 feet above the valley floor "like an island in a vast prairie of millpond smoothness" (Dana, 1849). Dana explored the hills, now known as the Sutter Buttes, on October 16. He recognized them as the remains of an extinct volcano and described the various volcanic rocks found in them, becoming the first geologist to study this distinctive geologic and geographic feature of the valley. Dana also commented, "The whole country, we were told, was flooded during the winter freshets, and the deer and antelope of the plains then take to the Bute hills."



In 1841, an overland party from the United States Exploring Expedition led by Charles Wilkes explored the Sutter Buttes, camping southeast of South Butte, as shown in this lithograph. Engraved by J. W. Steel from a drawing by Alfred T. Agate, an artist with the expedition.

In the 170 years since the Wilkes Expedition, few other geologists have investigated the Sutter Buttes and the surrounding area. In 1929 Howel Williams, a Professor at the University of California at Berkeley, named the major landscape features and correctly outlined the basic geologic history (Williams, 1929). Nearly 50 years later, Williams and his Berkeley colleague, Garniss Curtis, revised and elaborated the volcanic history, aided greatly by radiometric dating of rocks (Williams and Curtis, 1977). In addition, the petroleum industry carried out investigations of sedimentary rocks adjacent to the Sutter Buttes and drilled many deep wells in search of natural gas. Although these investigations have determined the general history of Sutter Buttes, some aspects remain uncertain and are the subject of ongoing investigations.

U.S. Department of the Interior
U.S. Geological Survey

Fact Sheet 2011-3024
March 2011

Regional Geology and Anatomy of the Volcano

For much of the past 75 million years, the area of the Great Valley of California was a shallow sea that connected to the Pacific Ocean. Rivers carried sediments from the Sierra Nevada and Klamath Mountains and deposited them in this sea. Over time, these sediments were compacted to form an enormous thickness of marine shale and sandstone. The region eventually rose to just above sea level as an immense river valley, dominated by the Sacramento, Feather, and San Joaquin Rivers. Before the volcanic eruptions that formed the Sutter Buttes, the area was a uniform, flat plain on which rivers meandered back and forth, depositing sand, gravel, and mud on top of the earlier marine sediments.

The Sutter Buttes as we see them today consist of three major parts, termed by Professor Williams the "castellated core," the "moat," and the "rampart." The castellated core comprises the high, craggy peaks in the center of the Sutter Buttes. These were formed by batches of partly molten rock (magma) that rose to the surface as viscous plugs, forming steep-sided volcanic features known as "domes." The domes originally looked much like the Chaos Crags in Lassen Volcanic National Park. The fragmented surface materials of the Sutter Buttes domes have now been eroded away, exposing their resistant interior parts.

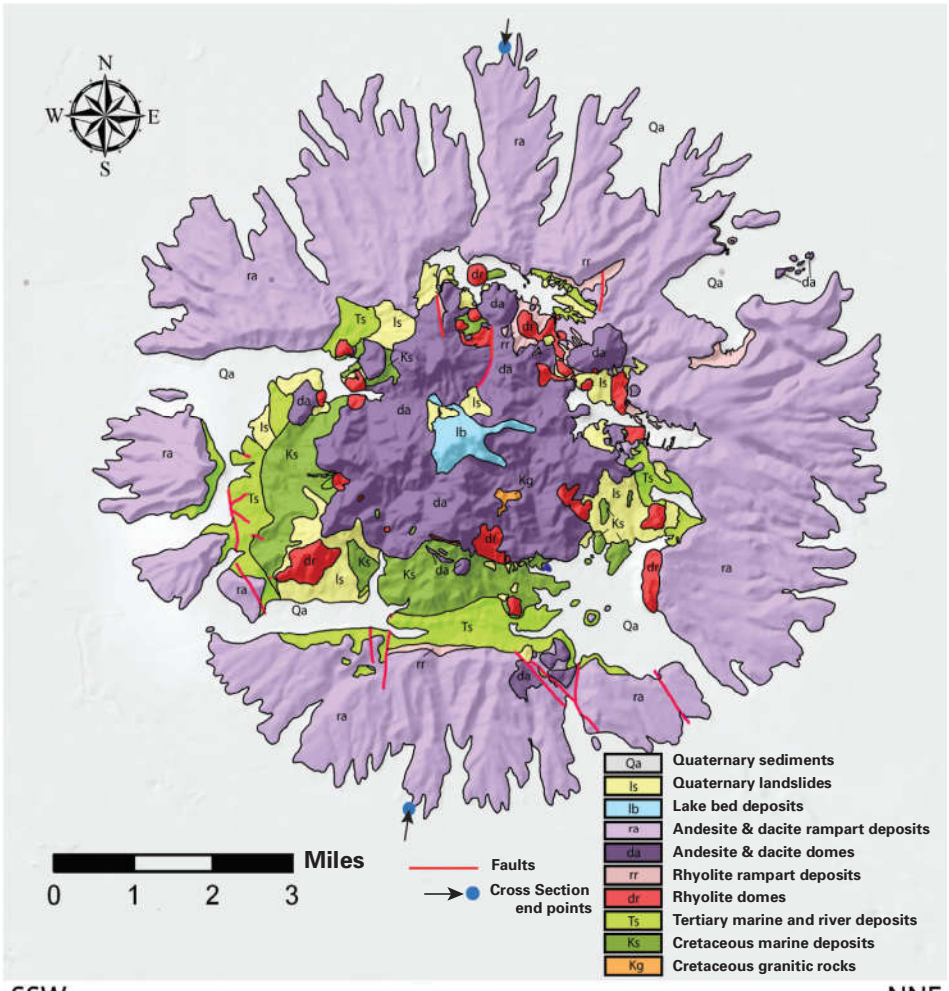
Immediately surrounding the castellated core is the moat. This low-lying ring of valleys is underlain by sedimentary rocks older than the Sutter Buttes volcano. These include layers of shale, sandstone, and conglomerate that range in age from late Cretaceous (~70 million years ago) to just before the Sutter Buttes first erupted about 1.6 million years ago. The sedimentary layers of the moat have been uplifted and steeply tilted by the intruding volcanic domes of the castellated core, and the soft, weak shales and sandstones have eroded away over time to form the moat valleys.

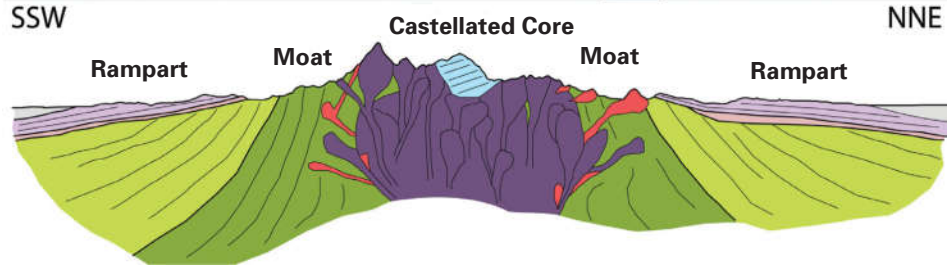
The outermost part of the Sutter Buttes is the rampart, a broad area of low, outward-sloping hills that were formed by flows of fragmental volcanic debris that moved radially outward from their source in the castellated core. Some of this material resulted from hot, explosive eruptions like most of the eruptions of Mount St. Helens, whereas other material was sloughed off the cooler outer parts of the domes and highland slopes of the castellated core and deposited as debris flows.

ACCESS TO SUTTER BUTTES

The Sutter Buttes are mostly in private ranches owned by families that have held title to the lands since the early 1900's. In order to enter these lands for hiking and other activities, nonresidents must arrange access through groups such as the Middle Mountain Foundation (http://www.middlemountain.org).

Geologic Map of the Sutter Buttes Volcano





Geologic map and diagrammatic cross section of the Sutter Buttes. Geology compiled from Williams and Curtis (1977), Thamer (1961), and new mapping by Brian Hausback. The cross section is vertically exaggerated 3X to emphasize the topography.

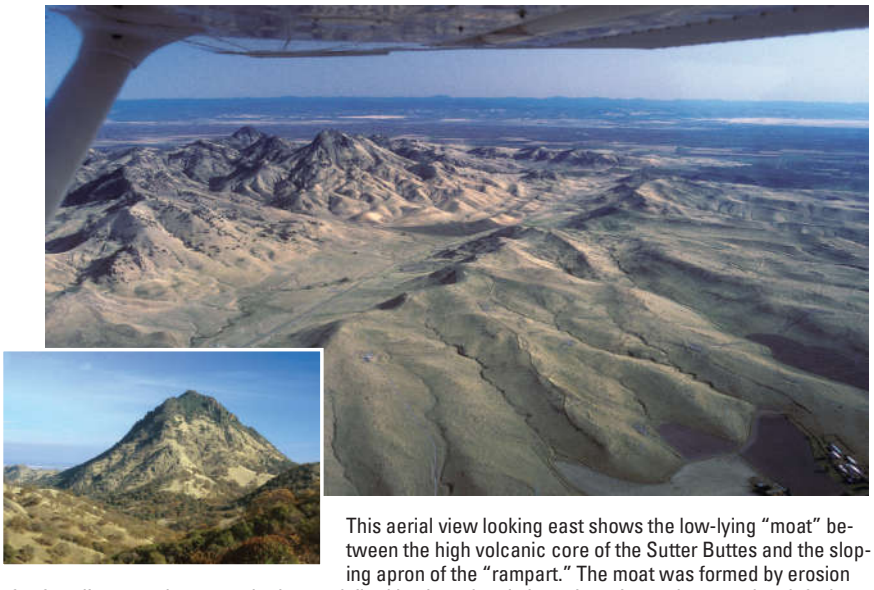
Volcanic History of the Sutter Buttes

The first eruptions at Sutter Buttes occurred about 1.6 million years ago, in the early Pleistocene, when magma pushed upward through the thick pile of Sacramento Valley sediments. Some of the magma breached the surface to form extrusive domes in the rocky core of the Buttes. Explosive eruptions pulverized the extruding magma, depositing blocky fragments and volcanic ash that hardened into pyroclastic ("fire-broken") rocks.

The first lavas to erupt were light-colored, often white, rhyolites—rocks rich in silica (SiO_2) and alkalis (potassium and sodium) but poor in magnesium and iron. The extruding lavas were so viscous that they accumulated at the surface as thick, pasty blobs, or lava domes. After about 30,000 years, these rhyolites were followed by more voluminous eruptions of andesite and dacite, lavas lower in silica and higher in magnesium and iron than the earlier rhyolites. Forming much larger domes, the andesites and dacites are darker in color than the rhyolite, typically medium to dark gray, contain abundant large crystals, and are commonly oxidized (rusted) to brick red.

The andesite-dacites erupted through numerous vents distributed throughout the castellated core. In addition to the magma that erupted at the surface, much andesite-dacite magma lodged below the ground as intrusive bodies, spreading and lifting the preexisting sedimentary layers. In this way, originally horizontal sedimentary layers around the perimeter of the volcano were bent upward to vertical and in some places overturned. This deformation is best displayed in the south moat of the volcano (see cross-section and map).

The eruption of voluminous andesite-dacite continued until about 1.4 million years ago, creating the mountainous interior of the Sutter Buttes. Eruptions of volcanic domes were at times explosive because of an abundance of gases (mostly water vapor, carbon dioxide, and sulfur gases) in the magmas. The explosive eruptions fractured the dome rocks into fragments ranging from fine ash to giant blocks. These pyroclastic materials were carried downslope from the domes as slurries of debris made fluid by either hot volcanic gases (pyroclastic flows) or liquid water (lahars). The very hot pyroclastic flows and the cooler lahars accumulated around the base of the castellated core in layer after layer of debris, forming the gently outward-sloping rampart, a continuous debris apron or "fan" all the way around the castellated core of volcanic domes and over the truncated top of the surrounding moat sediments.



This aerial view looking east shows the low-lying "moat" between the high volcanic core of the Sutter Buttes and the sloping apron of the "rampart." The moat was formed by erosion of soft sedimentary layers pushed up and tilted by the volcanic intrusions. Inset photograph at left shows North Butte, a high and well-preserved dacite dome in the central "castellated core" of the Sutter Buttes.



The sloping outer "rampart" of the Sutter Buttes was built by both volcanic mudflows (lahars) and hot flows of volcanic material (pyroclastic flows) that included large blocks, pictured here with a geologist (U.S. Geological Survey retired volcanolgist Robert L. Smith) for scale.

The lowermost, rhyolitic layers of the rampart are exposed in only a few areas on the outer part of the moat valleys. These rhyolitic pyroclastic deposits are overlain by thick deposits derived from andesitic-dacitic pyroclastic flows and lahars. The uppermost layers of the rampart contain the largest blocks (about 30 feet in diameter), derived from the youngest, tallest, and best preserved domes of the core (South, North, West, Williams, Curtis, and Twin Peaks).

Lakebeds

In the very center of the castellated core are the remnant deposits of a very deep lake that was formed during the volcanic eruptions of the Sutter Buttes. These layered deposits are mostly sands and gravels of andesite-dacite composition and are at least 1,000 feet thick. The lake may simply have filled a basin confined by volcanic domes, or the lake basin may have been excavated by powerful explosions during the andesite-dacite eruptive period. Today the lakebeds are surrounded and truncated by andesite-dacite domes that intruded into the layers and gently deformed and uplifted them to form a high central ridge in the Buttes.

Today's Topography

At the end of volcanism about 1.4 million years ago, the castellated core and the rampart looked much as they do today. The castellated core was dominated by the youngest, tallest andesite-dacite domes. The rampart was a thick accumulation of pyroclastic-flow and lahar deposits. Over the past 1.4 million years, however, the erosional effects of rain, running water, and wind have cut down into the softest and weakest of the geologic materials of the Buttes. Streams and landslides have preferentially cut into the relatively weak shale and sandstone sedimentary layers to carve the moat valleys. Outward-flowing streams have also cut down through the pyroclastic debris layers to form distinctive radial valleys in the rampart. However, the elevations of the hard volcanic domes have probably not been lowered much by erosion.

How Did the Buttes Get There?

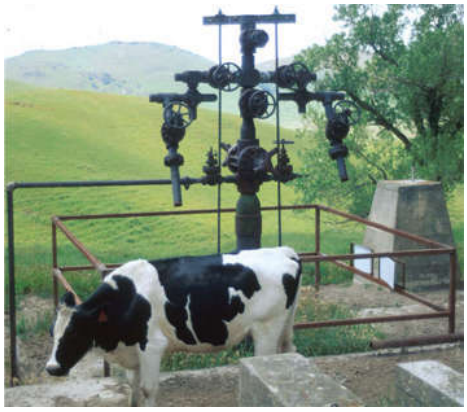
An important question is whether the Sutter Buttes are related to the Cascade Range, which extends from the volcanoes of southern British Columbia to Lassen Peak in northern California, or to the Coast Range volcanic

NATURAL GAS IN THE SUTTER BUTTES

For thousands of years, natural gas (largely methane) has leaked to the surface within and around the Sutter Buttes. Sometimes wildfires ignited these gas seeps, causing them to produce eerie blue flames that emerged from cracks in the ground and continued to burn long after the wildfires were quenched by rain. This phenomenon undoubtedly provoked a sense of awe and reverence for these dramatic crags located in the middle of a broad, flat valley. The native Maidu people named the Buttes "Histum Yani" or Middle Mountain.

Unlike the San Joaquin Valley (the southern part of California's Great Valley), the Sacramento Valley to the north has no appreciable deposits of oil, but it does have much natural gas. This gas was generated from microscopic plankton that died and sank to the ancient sea floor to be entombed in marine mud. Gradual burial by as much as 38,000 feet of overlying sediments created high temperatures and pressures that transformed the organic remains into gas. The volcanic upheaval that formed the Sutter Buttes pushed some of these sediments upwards, creating natural traps for methane and other gases rising from depth.

Exploration for gas in the Sutter Buttes area began in 1864, when a local worker and entrepreneur, Dexter Cook, sank a shaft near South Butte. The 30-foot-deep shaft filled with gas and inevitably exploded when he lit a candle at the bottom, injuring four men. The shaft was deepened to 65 feet and then sealed, leaving a pipe extending above the surface. The gas streamed out and for years produced a 5-foot-tall, blue, smokeless flame.



This discovery well at Sutter Buttes still produces gas.

The first commercial natural-gas well in the Sacramento Valley was completed to a depth of 2,727 feet in the southwestern moat of the Sutter Buttes in early 1933. This "discovery well" flowed at 3.4 million cubic feet of gas per day and still produces today, along with many other modern wells. Gas from the wells is collected into pipelines and distributed throughout northern California.

trend, which includes the Berkeley Hills volcanics, the Sonoma Volcanics, and the Clear Lake Volcanics (the youngest of these, with eruptions from 2.1 million years to 10,000 years ago). The Sutter Buttes do not fall on the geographic trend of either the Cascades or the Coast Range. However, the composition, texture, and age of the volcanic rocks suggest that the magmas that formed the Buttes are most likely part of the magmatic system of the Coast Range volcanoes.

But why did eruptions occur at this isolated location in the middle of the Sacramento Valley, far from other volcanoes? Geophysical studies have revealed a prominent north-south linear "ridge" that has anomalously high magnetism and gravity deep beneath the Sacramento Valley and directly under the Sutter Buttes. These geophysical features may be the expression of a buried, inactive fault that separates granitic and metamorphic rocks of the Sierra Nevada to the east from oceanic rocks of the Coast Range to the west. Additional faults intersect this deep crustal fault to provide possible conduits for Sutter Buttes magmas to rise to the surface. The Sutter Buttes contain the only lavas to erupt at the surface in the Great Valley, but rhyolites similar to those at the Buttes are found in the subsurface just to the west, along the Willows Fault.



Within the castellated core, layered lake-bed deposits, more than 1,000 feet thick, attest to the former existence of a lake in the center of Sutter Buttes.

The Sutter Buttes stand as a remarkable geographic and geologic feature of California's Great Valley, and they remain a subject of scientific interest and research. One curious feature is the presence at the surface in the castellated core of a huge block, one-quarter mile across, of crystalline rock (Cretaceous granite) characteristic of the Sierran basement. How was this block carried upward to the surface? Or is it perhaps the tip of an upfaulted sliver of the basement deep below? This is one of many puzzles remaining for geologists to solve in future studies.

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Brian P. Hausback[1], L.J. Patrick Muffler[2], and Michael A. Clynne[2]

Edited by *Peter H. Stauffer*

Graphic design by *Judy Weathers*

[1]California State University, Sacramento

[2]U.S. Geological Survey, Menlo Park, Calif.

COOPERATING ORGANIZATION

Middle Mountain Foundation—The Sutter Buttes Regional Land Trust

For more information contact:
Middle Mountain Foundation
P.O. Box 3359
Yuba City, CA 95992-3359
(530) 755-3568
http://middlemountain.org,
middlemountain@yahoo.com
For hike reservations, contact (530) 671-6116
or
mmfhikes@yahoo.com

From: Mary Fahey <mfahey@countyofcolusa.com>
Date: Friday, March 26, 2021 at 10:51 AM
To: Ben King <bking@pacgoldag.com>, Grant Davids <grant@davidsengineering.com>
Cc: "Ceppos, David M" <dceppos@csus.edu>, Lisa Hunter <LHunter@countyofglenn.net>, "DeBow, Danaka N" <danaka.debow@csus.edu>
Subject: RE: Budget Subarea

Good Morning, Ben;

Going forward please send all inquiries to me rather than directly to the consultants and I will get the information that you need. A good place to get your questions answered directly from the consultants is at the monthly Joint TAC meetings, and other public meetings. There will also be ample opportunity to comment on the GSP chapters as they are released, and again on the final draft GSP.

Regarding your concerns about the subarea water budgets, these have been developed only as a planning tool to support quality control of the model. There are no implications to landowners resulting from these subarea delineations and your parcel is not begin divided up in the plan, or assigned to different districts. As Grant explained, we are utilizing a regional model for the Colusa Subbasin and the resolution is not to the parcel scale, so model elements will not line up perfectly with jurisdictional boundaries.

Thank you,
Mary

From: Ben King [mailto:bking@pacgoldag.com]
Sent: Thursday, March 25, 2021 4:22 PM
To: Grant Davids <grant@davidsengineering.com>; Mary Fahey <mfahey@countyofcolusa.com>
Cc: Ceppos, David M <dceppos@csus.edu>; Lisa Hunter <LHunter@countyofglenn.net>; DeBow, Danaka N <danaka.debow@csus.edu>
Subject: RE: Budget Subarea

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Hi Grant,

When you review my parcels I think you can see a good rationale to include them all in the CDMWC budget subarea. Part of them are now and it would preserve the jurisdictional integrity of my membership in the CDMWC. If you do not think that is reasonable I will need to be convinced otherwise after reviewing your model assumptions and understanding your inputs.

Thanks again,

Ben

From: Grant Davids <grant@davidsengineering.com>
Sent: Thursday, March 25, 2021 3:56 PM
To: Ben King <bking@pacgoldag.com>; Mary Fahey <mfahey@countyofcolusa.com>
Cc: Ceppos, David M <dceppos@csus.edu>; Lisa Hunter <LHunter@countyofglenn.net>; DeBow, Danaka N <danaka.debow@csus.edu>
Subject: RE: Budget Subarea

Ben,

I understand your frustration but please recognize that the model structure is based primarily on subsurface physical conditions that affect the flow of groundwater. It's not intended to analyze land surface processes along parcel boundaries. I have not looked closely, but my guess is that most parcels in the subbasin lie completely in one subarea or another. But there are going be some, like yours, that fall on a subarea boundary.

Grant

From: Ben King <bking@pacgoldag.com>
Sent: Thursday, March 25, 2021 12:17 PM
To: Mary Fahey <mfahey@countyofcolusa.com>; Grant Davids <grant@davidsengineering.com>
Cc: Ceppos, David M <dceppos@csus.edu>; Lisa Hunter <LHunter@countyofglenn.net>
Subject: RE: Budget Subarea

Hi Mary,

My family has farmed these parcels for 160 years and I personally have managed them since I was 12 so-about 50 years.

You have split the parcel subareas between CDMWC and COLGWS on no basis that makes sense to me. How can I see the rationale for the designation?

Thanks for the information

Best Regards,

Ben

From: Mary Fahey <mfahey@countyofcolusa.com>
Sent: Thursday, March 25, 2021 11:59 AM
To: Grant Davids <grant@davidsengineering.com>; Ben King <bking@pacgoldag.com>
Cc: Ceppos, David M <dceppos@csus.edu>; Lisa Hunter <LHunter@countyofglenn.net>
Subject: RE: Budget Subarea

Ben, please see attached and let me know if this answers your question.
Mary

From: Grant Davids [mailto:grant@davidsengineering.com]
Sent: Thursday, March 25, 2021 9:51 AM
To: Mary Fahey <mfahey@countyofcolusa.com>; Ben King <bking@pacgoldag.com>
Cc: Ceppos, David M <dceppos@csus.edu>; Lisa Hunter <LHunter@countyofglenn.net>
Subject: RE: Budget Subarea

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Ben,

Mary is correct. The water budget subareas are defined by approximate jurisdictional boundaries. I say approximate because the boundaries of model "elements" (small areas for which water budget calculations are made) do not align perfectly with jurisdictional boundaries.

And, as Mary points out, none of this relates to Management Areas, discussion of which is ongoing, as you know.

Grant

From: Mary Fahey <mfahey@countyofcolusa.com>
Sent: Thursday, March 25, 2021 9:19 AM
To: Ben King <bking@pacgoldag.com>; Grant Davids <grant@davidsengineering.com>
Cc: Ceppos, David M <dceppos@csus.edu>; Lisa Hunter <LHunter@countyofglenn.net>
Subject: RE: Budget Subarea

Ben – I am working on a clearer map for you, coming soon.
I just want to point out, because there has been some confusion, that the water budget subareas are completely different from Management Areas. It is not proposed that the basin will be divided up by these water budget subareas. Grant can better explain the technical reasoning behind them. The jurisdictional boundaries are counties, water suppliers and groundwater-only areas.

Hope that helps,
Mary

From: Ben King [mailto:bking@pacgoldag.com]
Sent: Thursday, March 25, 2021 9:10 AM
To: Grant Davids <grant@davidsengineering.com>; Mary Fahey <mfahey@countyofcolusa.com>
Cc: Ceppos, David M <dceppos@csus.edu>; Lisa Hunter <LHunter@countyofglenn.net>
Subject: RE: Budget Subarea

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Hi Grant,

The map is not useful to me because there is a bid CDMWC right on top of the south west portion of my property. I can not tell is all my parcels are in the CDMWC subarea because the letters are larger on the map than the area in the portion of the Subarea under the letters. As I see the map, there is a possibility that a portion of my property is in RD108 subarea or COLGWS Subarea.

If I could see a map of the area due west and north west of Arbuckle I could decipher the boundaries.

When you mention jurisdictional boundaries – what do you mean?

Best Regards,

Ben

From: Grant Davids <grant@davidsengineering.com>
Sent: Wednesday, March 24, 2021 6:43 PM
To: Ben King <bking@pacgoldag.com>; Mary Fahey <mfahey@countyofcolusa.com>
Cc: Ceppos, David M <dceppos@csus.edu>; Lisa Hunter <LHunter@countyofglenn.net>
Subject: RE: Budget Subarea

Ben,

The subareas correspond approximately to jurisdictional boundaries. See attached map.

Grant

From: Ben King <bking@pacgoldag.com>
Sent: Wednesday, March 24, 2021 6:27 PM
To: Mary Fahey <mfahey@countyofcolusa.com>; Grant Davids <grant@davidsengineering.com>
Cc: Ceppos, David M <dceppos@csus.edu>; Lisa Hunter <LHunter@countyofglenn.net>
Subject: RE: Budget Subarea

Thanks Mary

Did Davids Engineering determine the budget subareas? What was the rationale for designation?

Best Regards,

en

From: Mary Fahey <mfahey@countyofcolusa.com>
Sent: Wednesday, March 24, 2021 2:12 PM
To: Grant Davids <grant@davidsengineering.com>; Ben King <bking@pacgoldag.com>
Cc: Ceppos, David M <dceppos@csus.edu>; Lisa Hunter <LHunter@countyofglenn.net>
Subject: RE: Budget Subarea

Hi Ben;
Just an FYI, I have taken this off of the Consultant's plate as I have access to GIS parcel layers. I will create an overlay of your parcel with the subarea water budgets and get that over to you as soon as I can. It might be a couple of days.
Thank you,
Mary

From: Grant Davids [mailto:grant@davidsengineering.com]
Sent: Tuesday, March 23, 2021 5:07 PM
To: Ben King <bking@pacgoldag.com>
Cc: Ceppos, David M <dceppos@csus.edu>; Mary Fahey <mfahey@countyofcolusa.com>; Lisa Hunter <LHunter@countyofglenn.net>
Subject: RE: Budget Subarea

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Thanks, Ben. I'll see what I can do. Grant

From: Ben King <bking@pacgoldag.com>
Sent: Tuesday, March 23, 2021 5:03 PM
To: Grant Davids <grant@davidsengineering.com>
Cc: Ceppos, David M <dceppos@csus.edu>; Mary Fahey <mfahey@countyofcolusa.com>; Lisa Hunter <LHunter@countyofglenn.net>
Subject: Budget Subarea

Hi Grant,

Thank you again for the reply.

I have attached a parcel map and a topographical map of my property near Arbuckle for your reference

If you could send a more localized map based on my reference maps that would be appreciated
.

Best Regards,

Ben

From: Grant Davids <grant@davidsengineering.com>
Sent: Tuesday, March 23, 2021 3:01 PM
To: Ben King <bking@pacgoldag.com>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; Lisa Hunter <LHunter@countyofglenn.net>; Ceppos,

David M <dceppos@csus.edu>
Subject: RE: Feb 24 TAC Follow Up

Hi Ben,

Do you need a map or can we just tell you which subarea your Arbuckle property is in?

Also, a map of your property rather than an approximate location would help on our end.

Grant

From: Ben King <bking@pacgoldag.com>
Sent: Tuesday, March 23, 2021 1:47 PM
To: Grant Davids <grant@davidsengineering.com>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; Lisa Hunter <LHunter@countyofglenn.net>; Ceppos, David M <dceppos@csus.edu>
Subject: RE: Feb 24 TAC Follow Up

Hi Grant,

My apologies if you are working on this but I wanted to follow up about a more detailed map around property near Arbuckle. As I mentioned I can not determine what subarea my property near Arbuckle is located in. Can you send me a more detailed map?

Thanks again for your assistance.

Best Regards,

Ben

From: Ben King
Sent: Friday, March 19, 2021 4:40 PM
To: Grant Davids <grant@davidsengineering.com>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; Lisa Hunter <LHunter@countyofglenn.net>; Ceppos, David M <dceppos@csus.edu>
Subject: RE: Feb 24 TAC Follow Up

Hi Grant,

Thanks again for the reply. I cant tell what Subarea I am in since there are 3 subareas near my property NE of Arbuckle. My property is east of Grimes Arbuckle Road and west of the Colusa Basin Drain , South of Hahn Road and North of Tule Road. Is there a more detailed map of this area. We were founding members of the Colusa Basin Drain Mutual Water Company but it is not clear all of our parcels are included in this subarea.

Best Regards,

Ben

From: Grant Davids <grant@davidsengineering.com>
Sent: Friday, March 19, 2021 3:03 PM
To: Ben King <bking@pacgoldag.com>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; Lisa Hunter <LHunter@countyofglenn.net>; Ceppos, David M <dceppos@csus.edu>
Subject: RE: Feb 24 TAC Follow Up

Hello Ben,

Grant Davids here, responding for Byron who has been dealing with some health challenges. Apologies for taking so long to get back to you.

I've responded to each of your various requests and questions posed in your emails to Dave Ceppos. Please see the red text below, and let me know directly by email if you have any further questions.

Grant Davids, P.E. | President/Principal Engineer **|** Davids Engineering, Inc.
1772 Picasso Avenue Suite A Davis, CA 95618**|** office 530.757.6107 x104 **|** mobile 530.304.8655

From: Ben King <bking@pacgoldag.com>
Sent: Friday, March 19, 2021 8:55 AM
To: Ceppos, David M <dceppos@csus.edu>; Mary Fahey <mfahey@countyofcolusa.com>
Cc: Ben King <bking@pacgoldag.com>
Subject: RE: Feb 24 TAC Follow Up

Good Morning Dave,

I wanted to follow up again on my information request.

You should know that local farmers are telling others that the sustainable yield for the Basin is 1.9 AF. This needs clarification. The sustainable yield is much, much greater than 1.9 AF, or do you mean 1.9 AF **per acre**? Please clarify.

I just checked the CGA website and I do not see any updates. Updates of what, sustainable yield?

Am I correct that there will be a public disclosure of the Draft Basin Setting? Release of GSP Chapters 1 through 4 is scheduled for early April, including the Basin Setting (Chapter 3). If the 1.9 AF number is correct wouldn't this have to relate to a specific management area or mean that the management area boundaries have already been decided? Not 100% sure what you're asking, but sustainable yield is calculated for the entire basin, and is not tied to any particular sub-portion of the basin.

Thank you in advance for any clarifications. I am assuming that the public can request information regarding the proposed management areas before they are determined so as the public comments could be meaningfully considered. Please let me know if I am correct or not. This is a question or Mary or Dave, but I can tell you that the decision of whether or not to form MAs has not yet been made.

Best Regards,

Ben

From: Ben King
Sent: Friday, March 12, 2021 8:11 AM
To: Ceppos, David M <dceppos@csus.edu>; Mary Fahey <mfahey@countyofcolusa.com>
Cc: Ben King (bking@pacgoldag.com) <bking@pacgoldag.com>
Subject: RE: Feb 24 TAC Follow Up

Good Morning Dave,

I wanted to follow up about the information I requested.

I have orchards in both sub areas and want to understand what the impact of the Model and the potential Management Areas will have.
There are 32 subareas. When you say both, I assume you're referring to Subareas CDMWC and COLGWE? And when you say the Model, I assume you mean model results? I would say that the model results do not have direct impacts, but the results are used to establish the Minimum Thresholds (MTs) and Measurable Objectives (MOs), which could have impacts, particularly the MTs. That's why MTs have been discussed so much at TAC meetings, and will be addressed yet again at the next (4/9) TAC meeting. I don't think potential impacts of Management Areas (MAs) can be addressed until the decision whether or not to form MAs has been made. If the decision is yes, and discussion of MA boundaries begins, that would be the time to assess potential impacts. It's premature now in my opinion.

Thank you again for your time

Best Regards,

Ben
HelloFrom: Ben King <bking@pacgoldag.com>
Sent: Saturday, February 27, 2021 1:09 PM
To: Ceppos, David M <dceppos@csus.edu>; Mary Fahey <mfahey@countyofcolusa.com>
Cc: Ben King <bking@pacgoldag.com>
Subject: Feb 24 TAC Follow Up

Hi Dave,

Can I get a map of all the model subarea in the Colusa County portion of the Colusa Basin? Please see the attached map. It covers the entire subbasin, not just the Colusa County portion.

Also – Does the example on Page 24 tie into real numbers? Yes. The numbers are draft, but they are real. The numbers and graph on the left side of Page 24 seem different than the graphs on Page 20 for example? The information on Page 20 and 24 are for different subareas, so the information will not agree. Page 20 presents information for the GCID – Colusa subarea, while page 24 has information for the CDMWC subarea.

Could I get the data tables for Subareas CDMWC and COLGWE? These tables are in the attached PDF of the Subarea Water Budget technical memorandum. I believe this was provided in advance of the 2/24 Joint TAC meeting.

Thanks for your assistance

Best Regards,

Ben

From: William Vanderwaal <wvanderwaal@rd108.org>
Sent: Thursday, April 8, 2021 9:41 AM
To: Derick Strain <dstrain@strainranches.com>; Mary Fahey <mfahey@countyofcolusa.com>; Jim Wallace Colusa Drain Mutual Water Co. <jimwallace@ecolusa.com>; Lewis Bair <lbair@rd108.org>; Hilary Reinhard (rh_reinhard@yahoo.com) <rh_reinhard@yahoo.com>
Cc: Lisa Hunter <lhunter@countyofglenn.net>; Grant Davids <grant@davidsengineering.com>
Subject: Re: Colusa Subbasin Hydrographs for TAC Review

Mary,
Jim Wallace, Derrick Strain, Lewis Bair, Hilary Reinhard and I looked through these last week and we had some questions. Hopefully, they get to Grant in time so that he can answer them during the meeting tomorrow.

From the Tech Memo:
In "Initial Observations and Comments" point number "2) In general, groundwater levels are more sensitive to surface water supply reductions at wells distant from the Sacramento River as compared to wells near the river. This results in part from near-river pumping causing increased leakage from the river or capture of groundwater that would have otherwise discharged to the river."
This highlighted sentence doesn't make sense to us. Maybe you are trying to say wells near the river are more stable because of their proximity to the river, where as wells distant from the river are more sensitive because they don't have the immediate recharge available(?).

We really like and appreciate the Google Earth set up.

There are two potential controlling factors that determine the MT. Please label which controlling feature it is that controls for each well.

I see from a cursory look at the package for the upcoming meeting that you've included MO's but we noted on these there were not MO's.

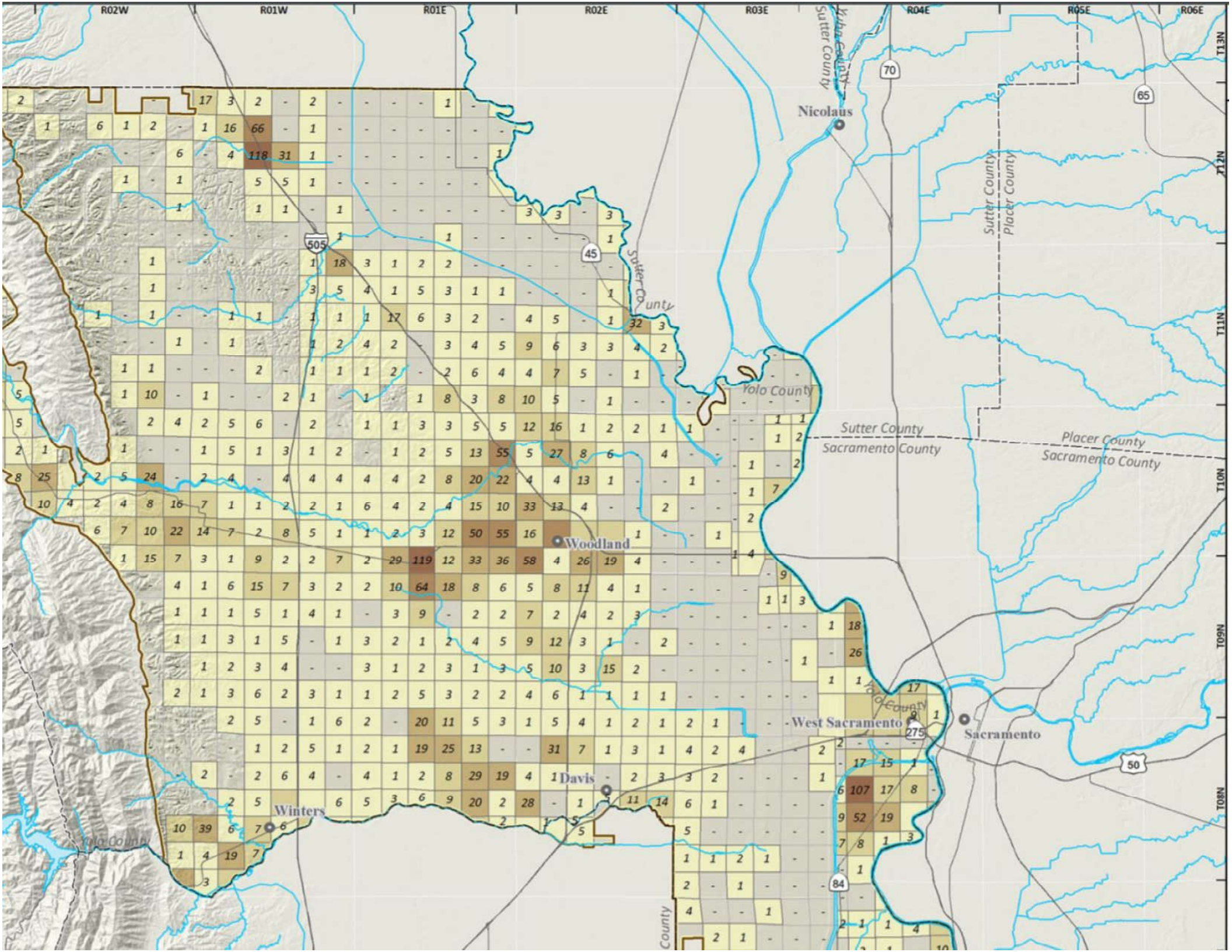
We would like to see the MT/MO compared with the historical well data. We requested and appreciate seeing these compared to the model runs but also want to see how they compare to actual historical. Some MT's seem extremely deep on the initial look.

It would be helpful to also see the number of wells per polygon for each well. That would help us understand the magnitude of wells that could be impacted if the controlling feature is the 20% of domestic wells criteria. I've attached a screen shot of what Yolo has provided in the past that shows domestic well density as an example of what could be helpful.

We have some questions about the water budgets (we were looking through those also). We noticed in CCWD, that the change in storage and the net recharge numbers don't seem to align with what we'd expect. For example, change in storage increases in 'Dry' years, but decreases in 'BN' and 'Critical' years. Also, net recharge is greater (or less extreme) in 'Dry' vs 'BN'. Is there any known explanation for that? Also, this doesn't just occur in CCWD, we're not picking on them, it's just where we noticed it first.

Thanks
Bill V

William Vanderwaal, P.E.
Deputy Manager - RD-108
Manager - Dunnigan WD
(530) 812-6276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T08N
Nicolaus
Sutter County
Yuba County
Placer County
Yolo County
Sacramento County
Woodland
West Sacramento
Sacramento
Davis
Winters
70
65
505
45
84
50
275

From: Bills, Donald J <djbills@usgs.gov>
Sent: Monday, April 12, 2021 6:14 PM
To: Lisa Hunter <LHunter@countyofglenn.net>
Cc: Bills, Donald J <djbills@usgs.gov>
Subject: Some additional questions and comments about the Land Subsidence Discussion at the 4/9 Joint TAC meeting.

Lisa,

A couple of points were made during the discussion on subsidence in the TAC meeting on Friday April 9th. I had comments to add to the discussion but was having difficulty with an unstable ZOOM connection and was unable to contribute. Please feel free to pass this on to however is most appropriate. The points I wanted to comment on are:

1.—Subsidence in the regional aquifer is mostly going to be due to dewatering of clays. Little subsidence occurs related to dewatering of sand and gravels.

2.—Subsidence is largely a surface problem.

3.—There is a significant lag time between groundwater withdrawals and subsidence.

4.—What is critical infrastructure?

5.—Surveyed subsidence monuments every 5 years is not enough.

CAUSES OF SUBSIDENCE (most relevant to Glenn-Colusa area but not discussed)

Natural Processes: Long-term climatic change, which may result in lowering of the water table, drying out of soil and sediment.

Human Causes of subsidence: Withdrawing subsurface fluids, such as water, petroleum, **natural gas, or brine.** Saturating near-surface, low-density, collapsible sediment (i.e. wetlands). Draining or reclaiming land that causes clay to dry out, peat**,** or other organic-rich sediments to decompose, etc.Manipulating certain surface-water and ground-water systems on a large scale (i.e. Stony Creek).

1.—Clays because of their small size have more pore space per volume sand or gravels. When saturated, therefore, they also contain more water that sand or clays. In addition, because of their small pore size, they take a very long time to drain and dry out completely. Once compressed in this manner it is very difficult to re-saturate them. Sand and gravel however can drain and compact quickly in response to groundwater withdrawal. This is the result of the loss of the buoyant support that the water gives the sediment and the compression weight of the overlying sediments as groundwater withdrawals increase. The volume of space occupied by the sediment (sand and gravel) decreases, as does the size of the pores (storage loss). Groundwater caused subsidence like this has been documented in unconsolidated sediments of the San Joaquin Valley as well alluvial basins in Central and Southern Arizona. Recharge, natural or artificial, can

recover some of the loss in storage and slow, stop, and even reverse the subsidence. But, the loss in storage and land subsidence cannot be fully recovered.

2.—Subsidence is just one of the surface manifestations of a larger problem in the subsurface; loss in storage. In unconsolidated sediment aquifers common to the Sacramento Valley (sand, gravel, sandy gravel, silty sand, sandy silt, and silty sandy, gravel), compaction will result is a certain amount of storage loss that is not recoverable. The impact will be less groundwater available to water users in the long run. Another surface manifestation of groundwater subsidence are earth fractures and fissures caused by differential settling of dewatered portions of the aquifer.

3.—Groundwater declines resulting from natural, or human caused withdrawals are quickly apparent on local spatial and short term (seasonal and annual) temporal scales. The resultant subsidence, however, may take months, years, or decades to become apparent. Once subsidence is apparent at the surface, it can continue for years or decades after groundwater withdrawals are curtailed (irrigation conservation methods, less consumptive crops, etc.) and/or artificial recharge programs (basin spreading of treated or reclaimed water, instream flow requirements, etc.) established (demonstrated in the San Joaquin Velley and Arizona).

4.—In addition to all the critical infrastructure located at lands surface, I would argue that the aquifer itself is also critical infrastructure. There is a direct impact on ground water users as a result. Land surface around wells compacts or subsides resulting in the need to protect, move, or replace well surface infrastructure. Declining water levels and reduces storage mean less water available to wells and the need for groundwater users to re-develop or deepen existing wells or drill new and deeper ones.

5.—Surveyed subsidence monuments every 5-years is not enough. By the time you notice a change between two measurements the damage is already done and likely to continue for years. There was mention of using the CDWR annual INSAR to fill in between the 5-year monument survey. This is a good start. Another method I did not hear mentioned is gravity measurements both on the ground and via on-orbit remote-sensing. Gravity methods are very sensitive to very small changes in the Earth's local and regional gravity field. Gravity monuments are at least as easy to establish as surveyed monuments (in fact the same sites can be used), or cheaper if established topographic benchmarks are used. Surface gravity measurements can detect storage changes of as little as 0.10ft. On orbit gravity measurements (GRACE and NexGen Grace) are capable of nearly the same accuracy on regional scales. The algorithms to convert gravity measurements to +/- storage change are already available and in broad use. Use of on the ground measurements with remotely sensed data improves the accuracy of both and provide an independent check of the data. In Arizona Seasonal and longer-term trends in storage change have been detected and with groundwater level data provide an early warning of impending subsidence.

Selected References

Davis, S.N., 1983, Measurement, prediction, and hazard evaluation of earth fissuring and subsidence due to ground-water overdraft: University of Arizona, Department of Hydrology and Water Resources, Office of Wa ter Policy Project B-092-ARIZ Report, 44p

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Ireland, RL., Poland, J.F., and Riley, F.S., 1984, Land subsidence in the San Joaquin Valley, California, as of 1980: U.S. Geological Survey Professional Paper 437-I, 193 p., scale 1:126,720.

Lofgren, B.E., and Klausing, R.L., 1969, Land subsidence due to groundwater withdrawal, Tulare-Wasco area, California: U.S. Geological Survey Professional Paper 437-B, 101 p.

Schumann, H.H., Laney, R.L., and Cripe, L.S., 1986, Land subsidence and earth fissures caused by ground-water depletion in southern Arizona, in Anderson, T.W., and Johnson, A.I., eds., Regional aquifer systems of the United States—Southwest alluvial basins of Arizona: American WaterResources Association Monograph Series 7, p. 81-91.

Donald Bills
Emeritus Scientist/Hydrologist
Flagstaff Science Campus
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2255 N. Gemini Dr.
Flagstaff, AZ 86001
(928) 556-7742

djbills@usgs.gov

From: Mary Fahey
To: Ken Loy
Cc: Ceppos, David M; Choppin, Corin
Subject: FW: Arsenic Near Grimes
Date: Friday, October 29, 2021 8:39:14 AM

FYI,
Mary

From: Ben King [mailto:bking@pacgoldag.com]
Sent: Friday, October 29, 2021 7:46 AM
To: Mary Fahey <mfahey@countyofcolusa.com>
Cc: Ceppos, David M <dceppos@csus.edu>
Subject: RE: Arsenic Near Grimes

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Thank you Mary,

Great explanation. The 200 ug/L typo was concerning since it would be the highest observed arsenic observation west of the Sacramento River south of the Sutter Buttes – this was my concern. I also appreciate that he identified the source as being the public supply system for Colusa County WWD#1. Unfortunately I just found out that the well for the Meridian elementary school also has arsenic contamination around the 28 ug/L also.

Best Regards,

Ben

From: Mary Fahey <mfahey@countyofcolusa.com>
Sent: Friday, October 29, 2021 7:18 AM
To: Ben King <bking@pacgoldag.com>
Subject: FW: Arsenic Near Grimes

Ben – please see below from Ken Loy.
Mary

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Mary:

The 200-µg/L arsenic concentration Ben King referred to in his email below was an error in the first draft of Chapter 3 of the Colusa Subbasin Groundwater Sustainability Plan (GSP) announced for public review on April 8, 2021. This error was corrected in the complete draft of the Colusa Subbasin GSP announced for public review on September 14, 2021. This correction was also documented in the GSP comment-response summary table (Appendix 2B-1) of the September 14, 2021 public draft GSP.

The correct arsenic concentration of 28 µg/L was measured in January 2012 by Colusa County WWD #1 – Grimes in their Well 1 and reported to the State Water Resources Control Board (State Board) Division of Drinking Water. The data are available at the State Board California Drinking Water Watch website.

https://sdwis.waterboards.ca.gov/PDWW/

The specific result can be found at this link:

https://sdwis.waterboards.ca.gov/PDWW/JSP/WSamplingResultsByStoret.jsp?SystemNumber=0600008&tinwsys_is_number=142&FacilityID=001&SamplingPointID=001&SystemName=COLUSA+CO.+WWD+%231+-+GRIMES&SamplingPointName=WELL+01&Analyte=&ChemicalName=&begin_date=&end_date=&mDWW=

Thank you,

Ken

Ken Loy

Principal Hydrogeologist
We're hiring! Visit our career site, here

WEST YOST
direct 530.792.3276

From: Ben King <bking@pacgoldag.com>
Sent: Thursday, October 28, 2021 2:17 PM
To: Mary Fahey <mfahey@countyofcolusa.com>
Cc: Ken Loy <kloy@westyost.com>
Subject: RE: Arsenic Near Grimes

[This message has originated from outside of West Yost]

Hi Mary,

Do you have an answer about the 200 ug/L – where is this well? The current draft just states that it is 28 ug/L – this seems to be the public supply well for Grimes. What about the 200 ug/L well?

Thanks

Ben

From: Mary Fahey <mfahey@countyofcolusa.com>
Sent: Tuesday, July 6, 2021 4:29 PM
To: Ben King <bking@pacgoldag.com>
Subject: RE: Arsenic Near Grimes

HI Ben – this question has been forwarded to the Tech. team. This will likely take a little time to get an answer as well due to the pending release of draft Chapters 5 and 6.
Mary

From: Ben King [mailto:bking@pacgoldag.com]
Sent: Wednesday, June 30, 2021 6:51 PM
To: Mary Fahey <mfahey@countyofcolusa.com>
Subject: Arsenic Near Grimes

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Hi Mary,

Here is an excerpt from Chapter 3 of the GSP.

3.2.5.2.1 Arsenic Arsenic is a naturally occurring constituent in groundwater and commonly occurs at concentrations ranging from 10 to 50 µg/L in the western United States, where it is typically associated with alluvial- lacustrine basin-fill deposits and volcanic rocks and sediments (Welch, et. al., 1988). The primary MCL for arsenic in drinking water is 10 µg/L (SWRCB, 2018a**). Arsenic has been detected near Grimes at concentrations of approximately 200 µg/L. A** federal program was initiated to install filters on water connections and reduce the arsenic concentration (Glenn County, 2005). Recent concentrations of arsenic in wells near Grimes have been less than 20 µg/L. The elevated arsenic concentrations near Grimes were determined to be due to natural conditions (Glenn County, 2005), and is potentially impacted by Sacramento River stream channel and its proximity of the Sutter Buttes and the Colusa Dome.

Can you send me the information regarding the location and measurement for the 200 ug/L measurement for Arsenic near Grimes?

Best Regards,

Ben

Choppin, Corin

From: Mary Fahey <mfahey@countyofcolusa.com>
Sent: Monday, October 25, 2021 11:53 AM
To: Choppin, Corin; Ceppos, David M
Cc: Lisa Hunter
Subject: FW: Sycamore Marsh Farm Recharge PMA Comments

Hi Corin – please add Ben King's comments below to the Admin record.
Thank you,
Mary

From: Mary Fahey
Sent: Monday, October 25, 2021 11:51 AM
To: 'Ben King' <bking@pacgoldag.com>; Grant Davids <grant@davidsengineering.com>
Subject: RE: Sycamore Marsh Farm Recharge PMA Comments

Ben;
Thank you for your comments and providing your family's background in the project area. Your comments will be added to the Admin. Record. I have also been contacted by the Dunlaps who are interested in participating in recharge projects in the area and they have submitted a PMA Solicitation Form.

As you know, projects in the Plan that the GSAs will oversee will not be implemented until they are vetted, refined and approved by the GSA boards. At that time, any coordination or integration with other project proponents can be defined.

Thank you,
Mary

From: Ben King [mailto:bking@pacgoldag.com]
Sent: Monday, October 25, 2021 11:38 AM
To: Mary Fahey <mfahey@countyofcolusa.com>; Grant Davids <grant@davidsengineering.com>
Cc: Ben King <bking@pacgoldag.com>
Subject: Sycamore Marsh Farm Recharge PMA Comments

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Hi Mary and Grant,

I was able to see the PMA submission for the Sycamore Marsh Farm Recharge Project. It seems like a great project but I wanted to point out that part of the project area is land that is owned by T&M King Farms LLC which is owned and managed by me. I have included the map that was part of Appendix 2C and circled the portion of the parcel owned by T&M on the east side of the Colusa Basin Drain. I also want to mention that there should be close coordination with the land owned by John and Tina Dunlap directly to the south of the Marsh project area since it is also part of the Sycamore Slough. Since the project includes the Sycamore Slough the whole of the Slough south of Grimes Arbuckle road will have to be included in the project since it is part of the same waterway and ecosystem. I know this area well

because the Dunlap property and parts of the Marsh property because it was originally owned by my great grandparents as part of the Sherer and King pioneer farms.

We would love to be included on this project.

Best Regards,

Ben

From: Mary Fahey
To: Choppin, Corin
Cc: Ceppos, David M; Lisa Hunter; Grant Davids
Subject: FW: Public Meeting Follow Up
Date: Thursday, November 4, 2021 9:18:45 AM

Hi Corin;
See below, questions from the October 13 virtual SGMA Series meeting (she watched the recording), for the admin record.

I also have some information to share from our legal counsel regarding what comments need to be documented in the record and in Appendix 2A. Maybe we can discuss on the call today if that is still on?

Thanks,
Mary

From: Mary Fahey
Sent: Thursday, November 4, 2021 9:12 AM
To: 'Ashley Driver' <ashley.mcarthur13@gmail.com>
Subject: RE: Public Meeting Follow Up

Hi Ashley;
To answer your questions:
Was follow-up information provided on how the groundwater pumping fees will be calculated?
There have been no decisions regarding a pumping fee. Those discussions will start happening early next year. It is still to be determined how/if fees will be instated. Those discussions and decisions will happen at public GSA Board meetings. There may be other subcommittee meetings where recommendations for the Boards will be developed.

Also, how easy is it to adjust our compliance markers (e.g. minimum thresholds)? Is there a formal process, is the public included, and does the state have to approve changes?
The GSAs are required to report annually on their progress and to update the Plans every five years. They can adjust the Sustainable Management Criteria during these updates. Any adjustments will need to be justified to DWR with data and reasoning, and DWR will have to approve any changes. It will be a public process, likely similar to what has been done the last couple years with information coming to the Technical Advisory Committees at public meetings and then to the Boards at their public meetings for final decisions.

I hope that answered your questions. Let me know if anything is not clear.
Thank you,
Mary

From: Ashley Driver [mailto:ashley.mcarthur13@gmail.com]
Sent: Wednesday, November 3, 2021 11:24 AM

To: Mary Fahey <mfahey@countyofcolusa.com>
Subject: Public Meeting Follow Up

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Hi Mary!

Thank you for sharing the meeting recording. I finally had enough time to watch it this morning, and a lot of my questions were answered. I appreciate the recording and you sharing it.

I do have a couple more questions, and I am wondering if you can answer them. Was follow-up information provided on how the groundwater pumping fees will be calculated? If not, where can I find that information? Also, how easy is it to adjust our compliance markers (e.g. minimum thresholds)? Is there a formal process, is the public included, and does the state have to approve changes?

Thank you, again, and have a wonderful day!

Ashley

--
Ashley Driver, Ed.S.
(530) 665-3441
Driver Performance Improvement

From:	Ben King
To:	Mary Fahey; Gosselin, Paul
Cc:	Buck, Christina; Ben King
Subject:	Arsenic and Connate Sea Water Contamination around the Sutter Buttes
Date:	Monday, July 06, 2020 1:17:17 PM
Attachments:	Sutter_County_Final_GMP_20120319 (1).pdf Sutter County GMP Figures.pdf CA-Arsenic-Report.pdf

CAUTION: This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Hi Mary, Paul and Christina,

I wanted to follow up regarding my public comment on the last Butte Basin call. As mentioned in my call, my concern is that the connate seawater under the Sutter Buttes is contaminating groundwater and drinking water quality.

I have previously sent the SWCB Bulletin No. 6 from 1952 and the PHD Paper by George Curtin from 1971. Bulletin No. 6 reported that pumping depressions were drawing salt brines to the surface causing groundwater contamination. Curtin's paper proposes that the connate seawater is moving laterally through faults around the Buttes and researched several hundred gas well logs to express this opinion.

According to the Sutter County GMP on Page 23 "The Sutter Buttes Rampart consists largely of gravel, sand, silt and clay sediments which were deposited circumferentially around the Buttes as a geologic apron. These sediments may extend up to 15 miles north and west beyond the Sacramento River. " On Page 32 the GMP addresses the arsenic contamination issue - "… recent data analysis suggest a possible correlation between elevated arsenic concentrations and the presence of volcaniclastic material of the Sutter Buttes Rampart formation." Since the Colusa and Butter Basins are within the 15 mile circumference of the Sutter Buttes this would impact the analysis for Lower Water Quality and potentially Seawater Intrusion SGMA Sustainability metrics. I am mentioning the Seawater Intrusion metric because of the hydraulic components of pumping depressions and the physics of natural occurring contaminants moving laterally from higher elevations to lower elevations in combination of the force of pulling water to the surface by the operation of groundwater wells.

You will see the elevated EC levels and arsenic levels in the GMP Figures attachments. On Figure 19, there was an observation at T15NR3E of arsenic at 350 ppm and an EC of 1126. To the south at 14NR2E the observation of arsenic at 370 ppm and an EC of 1400. Since this study was focused on Sutter County there were not observations for Colusa County and Butter County. For Colusa County – the attached report regarding Arsenic contamination in public drinking water systems has the Grimes water district at 23.9 ppm which is the worse levels of toxicity of any public system in the Sacramento Valley. To the northwest of the Buttes there is a USGS Gamma well ESAC 21 which seems to be located in the Colusa County portion of the Butte Basic which has an arsenic reading of 80 ppm. Finally ESAC 11 which is due north of the Buttes and appears to be located in Grey Lodge

has an arsenic level of 70.

I can also note that the EPA assessment of the wastewater treatment facility for Yuba City reported that the high levels of arsenic in the wastewater was apparently from the portion of the Yuba infrastructure. Since most of the source of the water for Yuba City is surface water from the Feather River the arsenic contamination is pronounced where ground water is used. Finally as I mentioned in the past you probably are aware that the EPA has entered into an mitigation agreement with Sutter County regarding the arsenic contamination at Robbins. As you know Robins is at lower elevation and due south of the Buttes which would explain the contamination so far away from the Buttes. Robbins arsenic levels are less than the levels observed at Grimes.

I will send the Yuba City EPA report and the USGS Gamma documents next.

My suggestion would be to pick up where the SWRCB left off in 1952 and examine salt water and arsenic levels within a 15 mile circumference around the Buttes and set up a monitoring network to monitor changes in ground water quality going forward. This would not only focus on the southern part of the Buttes but within the whole circumference.

Thank you for your time and consideration.

Best Regards,

Ben

From:	Ben King
To:	Mary Fahey; Gosselin, Paul; Buck, Christina
Cc:	Ben King
Subject:	Arsenic Attachments Part II
Date:	Monday, July 06, 2020 1:38:28 PM
Attachments:	USGS Water Quality.pdf EPA Arsenic yuba_city_2004-05-28_inspection.pdf

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Hi Mary, Paul and Christina

The 2006 USGS Study presents the observations wells on Figure 3 – Page . I have attached a photo of the link to the USGS GAMMA website sorting for Arsenic. I have also include USGS Laux Road which is ESAC 21 and USGS Gray Lodge which is ESAC 11. On the website you can see the actual locations on the satellite imagery.

The 2004 EPA assessment for the Yuba City Sewage infrastructure addresses the arsenic issue on Page 10. It ascribes more than half of the arsenic contamination to groundwater.

Thanks again for your time and consideration

Best Regards,

Ben

From: Ben King
To: Buck, Christina; Mary Fahey; Gosselin, Paul
Subject: RE: Arsenic and Connate Sea Water Contamination around the Sutter Buttes
Date: Wednesday, July 08, 2020 2:10:07 PM

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Hi Christina,

Thank you very much. I appreciate the follow up.

Best Regards,

Ben

From: Buck, Christina <CBuck@buttecounty.net>
Sent: Wednesday, July 8, 2020 2:06 PM
To: Ben King <bking@pacgoldag.com>; Mary Fahey <mfahey@countyofcolusa.com>; Gosselin, Paul <PGosselin@buttecounty.net>
Subject: RE: Arsenic and Connate Sea Water Contamination around the Sutter Buttes

Hi Ben,

Thanks for the information and additional reports. I did reference some of the reports you had sent me earlier in the draft of the HCM for the Butte subbasin. That document will hit the street for public comment later this summer.

I will pass your emails and attachments along to the consultant team (Davids Engineering) for their reference and consideration as they continue supporting GSP development and completion.

I will also forward your emails to Tania Carlone, the facilitator for the Butte Advisory Board (BAB), so she can include it as correspondence in the future to the BAB since this is helpful follow up to the comment you made at their last meeting.

Best,
Christina

From: Ben King <bking@pacgoldag.com>
Sent: Monday, July 06, 2020 1:16 PM
To: Mary Fahey <mfahey@countyofcolusa.com>; Gosselin, Paul <PGosselin@buttecounty.net>
Cc: Buck, Christina <CBuck@buttecounty.net>; Ben King <bking@pacgoldag.com>
Subject: Arsenic and Connate Sea Water Contamination around the Sutter Buttes

ATTENTION: This message originated from outside **Butte County**. Please exercise judgment before opening

attachments, clicking on links, or replying.

I wanted to follow up regarding my public comment on the last Butte Basin call. As mentioned in my call, my concern is that the connate seawater under the Sutter Buttes is contaminating groundwater and drinking water quality.

I have previously sent the SWCB Bulletin No. 6 from 1952 and the PHD Paper by George Curtin from 1971. Bulletin No. 6 reported that pumping depressions were drawing salt brines to the surface causing groundwater contamination. Curtin's paper proposes that the connate seawater is moving laterally through faults around the Buttes and researched several hundred gas well logs to express this opinion.

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You will see the elevated EC levels and arsenic levels in the GMP Figures attachments. On Figure 19, there was an observation at T15NR3E of arsenic at 350 ppm and an EC of 1126. To the south at 14NR2E the observation of arsenic at 370 ppm and an EC of 1400. Since this study was focused on Sutter County there were not observations for Colusa County and Butter County. For Colusa County – the attached report regarding Arsenic contamination in public drinking water systems has the Grimes water district at 23.9 ppm which is the worse levels of toxicity of any public system in the Sacramento Valley. To the northwest of the Buttes there is a USGS Gamma well ESAC 21 which seems to be located in the Colusa County portion of the Butte Basic which has an arsenic reading of 80 ppm. Finally ESAC 11 which is due north of the Buttes and appears to be located in Grey Lodge has an arsenic level of 70.

I can also note that the EPA assessment of the wastewater treatment facility for Yuba City reported that the high levels of arsenic in the wastewater was apparently from the portion of the Yuba infrastructure. Since most of the source of the water for Yuba City is surface water from the Feather River the arsenic contamination is pronounced where ground water is used. Finally as I mentioned in the past you probably are aware that the EPA has entered into an mitigation agreement with Sutter County regarding the arsenic contamination at Robbins. As you know Robins is at lower elevation and due south of the Buttes which would explain the contamination so far away

from the Buttes. Robbins arsenic levels are less than the levels observed at Grimes.

I will send the Yuba City EPA report and the USGS Gamma documents next.

My suggestion would be to pick up where the SWRCB left off in 1952 and examine salt water and arsenic levels within a 15 mile circumference around the Buttes and set up a monitoring network to monitor changes in ground water quality going forward. This would not only focus on the southern part of the Buttes but within the whole circumference.

Thank you for your time and consideration.

Best Regards,

Ben

2B-4. Projects and Management Actions Submittal Forms

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COLUSA SUBBASIN

Colusa Subbasin GSP Projects and Management Actions (PMAs) Submittal Form

Overview

The purpose of this form is to gather ideas for potential projects and management actions (PMAs) that could be evaluated and ultimately included in the Colusa Subbasin GSP. Once ideas are gathered, an initial screening and evaluation process will be conducted, followed by ranking of potential PMAs for more detailed evaluation and inclusion in the initial GSP.

Potential PMAs may fall under several categories, including but not limited to the following:

- Recharge projects
- Supply augmentation projects
- Water conservation projects
- Projects to reduce non-beneficial consumptive use
- Groundwater pumping allocations
- Monitoring programs (groundwater pumping, water levels, stream flows, etc.)

Please provide supporting documentation and/or links to that documentation for each question, if available. **NOTE: It is recognized that much of the requested information may not be available at this time. Please provide as much information as you can.**

Project Name and Contact

Project or Management Action Name: Boards In Program

Contact Person: Lewis Bair or Bill Vanderwaal

Organization/Affiliation (Project Proponent): RD-108

Contact Phone: 530.437.2221

Contact Email: wvanderwaal@rd108.org

Project or Management Action Description and Status

Project or Management Action Description:

Institute a voluntary or financially incentivized program to have landowners leave their spill board in place during the winter to capture rainfall and hold it on the fields for recharge.

COLUSA SUBBASIN

Project or Management Action Location (please provide a map if available): Any fields with spill boards throughout the subbasin.

Which Sustainability Indicator(s) does this Project or Management Action address:

1. Groundwater levels

Project or Management Action Status (Conceptual, In Design, Ready for Implementation):

Ready for implementation

Has a feasibility assessment been conducted? If so, please list the agency and provide the documentation (or provide web link to download).
Not required for a voluntary program.

Estimated Cost:
Zero for voluntary program.

Potential Funding Sources:

Management Action or Project Yield (e.g. water contributed to the groundwater system, acre-feet per year):
Depends on rainfall and infiltration rate of field. It might be low for high clay content fields but still better than letting the precipitation runoff.

Please describe any required Permitting and Regulatory Process and status of permitting and CEQA/NEPA compliance:
N/A for voluntary program.

Does this Management Action or Project serve a disadvantaged community? If so, which one(s)?

Additional Information Sources:

Other Information:

Byron Clark

From: Emil Cavagnolo <ecavagnolo@oawd.org>
Sent: Tuesday, July 7, 2020 5:22 PM
To: Byron Clark
Cc: Lisa Hunter
Subject: OAWD Recharge Information
Attachments: SCF WIRME conceptual model 2003 r.pdf; SCF WRIME Hydro model 2003 r.pdf; Stony Creek Fan CWMP Feasibility Investigation r.pdf; MAR_Orland 02-2019.pdf; OAWD VanTol Recharge Project 2017.pdf

Follow Up Flag: Flag for follow up
Flag Status: Completed

Byron,

I attached some files on recharge projects the District has participated in. OAWD has a group of farmers who are investigating annexing over 7,000 acres into the District. They will be looking to integrate recharge projects to make the annexation more appealing. We are in the early stages but it is something to be thinking about.

Best regards,

Emil Cavagnolo, General Manager
Orland-Artois Water District
P.O. Box 218
6505 Road 27
Orland, CA 95963
O 530-865-4304
F 530-865-8497
C 530-518-5060
ecavagnolo@oawd.org **NEW**
https://www.oawd.org/

Stony Creek Fan
Conjunctive Water Management Program

Feasibility Investigation

---

1. Plan Formulation
2. Existing and Baseline Conditions
3. Project Alternatives

Prepared for:

Glenn-Colusa Irrigation District
Orland-Artois Water District
Orland Unit Water Users' Association

Prepared by:

Grant Davids, Davids Engineering
Roger Putty, MWH
Susan Burke, MWH

February 2004
(DRAFT)

NOTE TO READERS:

This volume represents a major milestone in development of the Stony Creek Fan Feasibility Investigation. It contains the following three major sections:

1. **PLAN FORMULATION** is a statement of the goals and objectives of the SCF Partners and Partnership, along with a general discussion of the approach to development of conjunctive water management programs and of the physical and institutional factors that influence alternatives formulation. While additional editing needs to be done to smooth this section out, it is critical that this section be read and understood, because it explains why the alternatives take the shape that they do.

2. **EXISTING AND BASELINE CONDITIONS** documents and expands on information presented to the Partners in both group and one-on-one meetings. Remember that the baseline condition is hypothetical...it is a reference condition used to measure and compare the benefits of project alternatives. The key things to review are the projected land uses and water demands associated with the Baseline; these are the potential future water demands that the alternatives are designed to meet. Note that the description of existing and baseline conditions for the groundwater-only areas with the SCF Project Area have not yet been prepared.

3. **PROJECT ALTERNATIVES** describes the alternative actions that could be taken under the Program to meet the Partner's goal and objectives. Emphasis is placed on the "Solo Alternative", which initially would not involve actual physical sharing of resources among the Partners, but nonetheless could (and should) be viewed as a coordinated SCF Partnership effort. The collaborative alternatives are not as beneficial to each partner as the Solo Alternative *under present basin conditions.* Bear in mind that these materials simply describe the alternatives; no effort has been made yet to compare, evaluate and "fine tune" the alternative formulation. This work comes next and will likely lead to a SCF Preferred Alternative.

SECTION 1. PLAN FORMULATION

INTRODUCTION

The Stony Creek Fan Partnership (the Partnership) was established to investigate the potential for a conjunctive water management program to mutually benefit one or all of the entities that comprise the partnership. The three individual entities that comprise the partnership are the Orland Unit Water Users' Association (OUWUA), the Orland-Artois Water District (OAWD), and the Glenn-Colusa Irrigation District (GCID). The basis for this partnership, as with any partnership, is that each individual entity is able to make better use of its resources by operating within the partnership rather than operating outside the partnership. The partners agreed, through a Phase I Agreement, dated September 6, 2001, to cooperatively pursue development of the Stony Creek Fan Conjunctive Water Management Program (Program). A map of the Study Area is attached.

To determine the feasibility and practicality of developing a conjunctive water management program and related facilities the partners began the Stony Creek Fan Feasibility Investigation. The purpose of this investigation is to evaluate the potential conjunctive water management opportunities in the Stony Creek Fan area. The planning approach to completing this investigation is the focus of Section 1 of this document. The plan formulation describes the goals and objectives of the SCF Partners and Partnership, a discussion of the general approach to developing conjunctive water management programs, and of the physical and institutional factors that influenced the plan formulation process for the Stony Creek Fan Conjunctive Water Management Program.

COMMON GOALS AND INDIVIDUAL NEEDS

From the very beginning, it was recognized that the three Partners share some common goals, but also have different individual needs that they hope to fulfill, in whole or in part, through participation in the SCF Conjunctive Water Management Program (**Table 1-1**). Common goals include the following:

- **Protect local surface water and groundwater resources consistent with Glenn County ordinances**, specifically the Glenn County Groundwater Management Plan Basin Management Objectives (BMOs) and State and federal laws. This ensures that any plan to more fully utilize available water resources to meet the Partner's needs recognizes and allows for the needs of other water users within and neighboring the SCF Project Area.
- **Pursue opportunities to maximize Program benefits through strategic, synergistic linkages with other regional water management activities and authorities**. Increasingly, water management initiatives are being approached and implemented at a regional scale. While the SCF Partnership purposely began and has been maintained thus far with only three members, the Partners recognize that linkages with other water management initiatives and parties can provide mutual benefit. Potential linkages exist with Glenn County and the independent pumpers within and neighboring the SCF project area, as well as regional initiatives such as the Sacramento Valley Water Management Program and the State Water Project and Central Valley Project.
- **Secure water supply reliability locally and provide opportunities for improved water supply reliability for water users elsewhere in the State**. Fundamentally, the SCF Partnership exists to provide reliable, affordable water supplies to local users. However, the Partners understand that a proactive stance toward addressing regional and Statewide water supply reliability ultimately yields benefits to local initiatives. Thus, the Partner's will look for opportunities to participate in regional and Statewide initiatives that are consistent with the goals of the Partnership

- **Seek ways to achieve environmental benefits that are compatible with Program operations.** The Partners recognize that water management initiatives that also yield environmental benefit are more widely supported by the public and environmental advocates, and stand a better chance of attracting public financial support. Where feasible, the Partners will look for opportunities to fold environmental purposes into project formulation.

Table 1-1. Common Goals and Individual Needs

Common Goals		
• Protect local surface water rights and contract entitlements of each individual partner. • Manage groundwater resources consistent with Glenn County ordinances, specifically the Glenn County Groundwater Management Plan Basin Management Objectives (BMOs) and State and federal laws. • Pursue opportunities to maximize benefits through strategic, synergistic linkages with other regional water management activities and authorities. • Secure water supply reliability locally and provide opportunities for improved water supply reliability for water users elsewhere in the State. • Seek ways to achieve environmental benefits that are compatible with Program operations.		
Individual Needs		
GCID	**OAWD**	**OUWUA**
Improved reliability and increased flexibility through integration of basin surface and groundwater resources.	Secure reliable, affordable water supply in all years.	Enhanced management of surface water resources. Improvements to aging and obsolete irrigation infrastructure.

The individual needs of the Partners are very different. GCID has a relatively reliable water supply, being subject to shortages of only 25% in critically dry years. Therefore, the District's water supply reliability emphasis is on improving the ability to recapture system and farm losses in years of shortage. Additionally, the District's facilities are extensive and prone to ordinary deterioration, posing a significant and growing ongoing maintenance expense as costs generally escalate.

OAWD faces dual problems of water supply adequacy and affordability. Over recent years, the District has derived about half of its total water supply from its CVP water supply contract and half from groundwater supplies pumped by private landowners. Looking to the future, however, the amount of water available under its CVP contract is expected to decrease while water demands increase. This will lead to a supply mix of about one-third surface water and two-thirds groundwater, which may or may not be sustainable or affordable. At the same time, CVP water costs are escalating much more rapidly than other costs, raising concerns about the affordability of CVP water over the long-term. Thus, OAWD's primary need is adequate, affordable water.

Finally, the OUWUA is fortunate to have an extremely reliable water supply, but its storage, conveyance and distribution facilities are approaching obsolescence. For example, the Association's distribution system is capable of operating only on a rotation schedule, which is generally adequate for forage crop production, but not for production of high value crops and modern irrigation systems. Here the need is primarily to generate financial revenues to fund system modernization.

While the individual conditions and needs of the Partners are very different, they can be expressed in terms of either *new water* that would be used directly to achieve water supply reliability, and *financial revenues* derived from water transfers. Fundamentally, the challenge to the Partnership is to generate water supplies for direct use or for transfer to generate financial revenues.

GENERAL DISCUSSION OF CONJUNCTIVE USE AND PROTECTING BASIN

Conjunctive use involves the coordinated use of groundwater and surface water to minimize the impacts of shortages and increase supply reliability. Coordinated use means using groundwater to meet demand in dry years (when surface water supplies are limited) and using surface water to meet demand in wet years (when surface water supplies are not limited). Generally, one of the goals of a conjunctive use program is to maintain and protect the health of the groundwater basin. Basin Management Objectives (BMOs) are often established for this purpose.

In some geographic areas, basin health can be maintained without a formalized program if the rate of groundwater extraction is less than or equal to the rate of natural recharge. If, on the other hand, the groundwater extraction rate is greater than the natural recharge rate, then the health of the groundwater aquifer may be compromised. In such a case a formalized conjunctive use program may be required. A formalized conjunctive use program often develops methods to artificially recharge the groundwater aquifer. Artificial recharge can occur either through in-lieu programs or through direct recharge. These artificial recharge programs, combined with natural recharge, maintain the health of the groundwater aquifer.

A year in which artificial recharge occurs is often referred to as a 'put' year. Whereas, a year in which groundwater is extracted is called a 'take' year. It is the combination of these put and take years that characterize the conjunctive use cycle.

This conjunctive use cycle is shown in **Figure 1-1**, exhibiting an idealized pattern of alternating put and take cycles, which, operating in conjunction with one another would ensure the health of the basin as measured by long-term groundwater levels (i.e. long-term basin management objectives are met).

Because groundwater basins are complex, dynamic physical systems, the pattern of put and take cycles varies considerably among basins and with time. **Figure 1-2** is an hypothetical example where basin groundwater levels start out above a hypothetical BMO and remain above that level for several cycles (years) despite continued groundwater pumping from the basin. Perhaps during these years favorable hydrologic conditions have ensured the health of the basin, or perhaps the inflow (natural recharge) to the basin is adequate under the groundwater pumping circumstances. **Figure 1-2** suggests that eventually, however, the basin groundwater levels drop below the BMO levels. At that time the basin enters a put-cycle phase and implementing artificial recharge through in-lieu or direct means, or both, ensure that BMO objectives are achieved. For example, perhaps here-to-for unutilized winter flows could be redirected and recharged into the basin. Or, available dry-year surface water supplies could be used for in-lieu recharge.

Figure 1-3 shows the same types of hypothetical conjunctive use program, however in this example the initial basin elevation is below the long-term average BMO. In this hypothetical example the program would begin with put-years in order to recharge the basin until groundwater elevations approach the long-term average BMO elevation. Once the groundwater elevation begins to approach the long-term average BMO elevations then the basin would be managed with put and take cycles as needed to maintain the average condition.

The SCF investigation was designed to explore the basin's characteristics, including the basins ability to be operated under put and take cycles. The findings from this investigation influenced the plan formulation process and subsequent alternatives. This outcome is discussed in the following section.

FACTORS INFLUENCING THE APPROACH TO FORMULATING SCF CONJUNCTIVE USE ALTERNATIVES

Over the course of the feasibility investigation, new information regarding different and very unique physical aspects of the area combined with the institutional aspects arising from the SCF Partnership arrangement served as fundamental drivers of the alternatives formulation process. In particular, a field

investigation undertaken as part of the SCF study revealed new information about the Project Area's hydrogeologic and recharge characteristics. This new information improved each partner's understanding of the resources available to him or her and how best to manage those resources. And, more importantly, the fact that a conjunctive use program alternative must consider and serve the needs of three Partners, not a single entity, required an approach capable of revealing individual benefits to each partner's involvement in an integrated conjunctive use program as compared to operating independent of the partnership. Each of these factors is discussed further below.

Discussion of Physical Factors Influencing Alternatives Formulation

The basic components of a conjunctive use system are shown in **Figure 1-4**. Of paramount importance to a system of this type are, one, the basin's ability to produce groundwater without undesirable effects, and, secondly, the degree to which this ability can be enhanced by replenishing depleted groundwater supplies with artificial recharge. The Stony Creek Fan area would appear to be well suited for development of a conjunctive use system given the following characteristics[1]:

- Existing distribution and extraction facilities well positioned to support groundwater production and in-lieu recharge operations;
- The presence of the Stony Creek Fan, formerly thought of as the primary subsurface geologic feature beneath the Project Area, thought to have extensive groundwater storage and yield properties as well as highly permeable and transmissive properties capable of accepting natural and artificial recharge at relatively rapid rates;
- Viable surface water supply sources for storage and replenishment of groundwater through direct and/or in-lieu artificial recharge; and
- A strategic institutional alliance formed between GCID, OAWD, and OUWUA, bringing these key physical elements together.

As mentioned previously, "Put" and "Take" cycles govern the operation of a conjunctive water management project. The Stony Creek Fan Feasibility Investigation developed an understanding of the overall goals and needs of the districts, the water sources potentially available to the project, the various legal and institutional factors that effect the management of district resources, and an improved understanding of the groundwater basin and its response to hydrologic variations, pumping, and recharge. This analysis process is shown conceptually in **Figure 1-5a** and described in the following paragraphs.

Determine Yield Allocation: Project configurations are defined principally by the magnitude and allocation of Project yield, which shape the Project's extraction, or "Take" cycles (see **Figure 1-5a**, Determine Yield Allocation). Basic options include allocation to satisfy district unmet water demands, or to meet market demand. These options help define the primary features that drive the formulation of the project alternatives.

Assess Basin Response: The hydrogeology of the Stony Creek Fan is not well known, and a major objective of the feasibility investigation was to characterize the factors that influence groundwater behavior in the Study Area. Determining how to maximize project yield by strategic pumping or artificial recharge, thereby maintaining healthy groundwater conditions, are critical to the plan formulation process. The outcome of these evaluations will guide formulation of recharge and recovery strategies.

Determine Feasibility of Artificial Recharge: Depending on basin response to different project yield configurations, artificial recharge can be a critical component of a project configuration. The feasibility of

[1] It was recognized that the geology of the Stony Creek Fan was not well known, and a major objective of the feasibility investigation would be to characterize the factors that influence groundwater management in SCF Study Area. The outcome of these investigations changed the above thinking considerably, which is discussed further below.

artificial recharge depends largely upon the surface water supply sources and their compatibility with the recharge mechanism, in-lieu or direct recharge. Compatibility is measured both in physical terms which is governed by hydrology and also institutional terms which is governed by legal and contractual characteristics unique to each source. Also critically important are is the groundwater basins physical characteristics and hydrologic conditions, both of which govern the potential benefit of artificial recharge. For instance, a full basin may receive very limited benefit from artificial recharge in terms of long-term groundwater storage.

Figure 1-5a does not reveal the multitude of steps critical to the formulation and analysis of conjunctive use projects alternatives. These detailed steps are shown in flowchart form in **Figure 1-5b** ("Put" Cycle) and **Figure 1-5c** ("Take" Cycle). The following sections use these flowcharts to discuss the factors that influenced path followed by Stony Creek Fan Feasibility Investigation.

Assessment of Artificial Recharge Potential ("Put" Cycle)

The in-lieu leg of the flowchart (see **Figure 1-5b**) begins with the question "History of groundwater pumping per district?" If the answer is no, in-lieu recharge is not possible because there is no pumping to stop in order to achieve the in-lieu recharge. If the answer to the question is yes, then an assessment of the volume of surface water available for use as a substitute during the in-lieu recharge period is required. Finally, the assessment of surface water would be combined with the estimates of historical pumping volumes in order to estimate the size of the in-lieu potential.

The SCF investigation initially estimated the historical volume of groundwater extracted by each district to the as an initial assessment of the feasibility of in-lieu recharge. **Table 1-2** summarizes these findings.

Table 1-2
Summary of District Groundwater Pumping

District	Approximate Number of Groundwater Wells	Range of Historical Annual Groundwater Pumping (1000 AF/Yr)	Approximate In-lieu Capability (1000 AF/Yr)
GCID	200	4 to 17	17
OAWD	400	5 to 55	55
OUWUA	50	3 to 13	13
Total	**650**	**12 to 85**	**85**

The results of this initial review suggested that in-lieu recharge was possible given the amount of historical pumping. A review of surface water supplies that could be used in-lieu of pumping groundwater revealed two possible sources: unused Base Supply; and unappropriated Stony Creek water. These findings helped further shape the conjunctive use alternatives. More detailed discussion of this source identification and the characteristics of these potential in-lieu sources is provided later in this report.

The other method of artificial recharge represented on the flowchart is direct recharge. Following the "Direct Recharge" leg of the flowchart the first question asks whether or not favorable infiltration rates exist. If the answer were "No" then direct recharge would not be viable. For instance, soils consisting of fine sand to silty clay conditions are typically unsuitable for artificial recharge due to relatively low infiltration rates.

A field investigation of the Stony Creek Fan area was completed to determine infiltration characteristics within the Project Area and to help asses the feasibility of recharging the groundwater basin using constructed direct recharge basins. Candidate sites were identified throughout the area and were evaluated

based on specific site selection criteria[2]. Three sites were ultimately chosen for pilot recharge testing[3]. The three sites are considered to be representative of areas favorable for groundwater recharge throughout the Project Area.

The pilot recharge tests were conducted over a several week period under varied conditions. Infiltration rates varied from several feet per day to ten's of feet per day. The range of infiltration rates are summarized in **Table 1-3**. These infiltration rates are considered highly favorable for direct recharge operations.

Table 1-3
Pilot Recharge Test Infiltration Rates

Site	Long Term Infiltration Rate (ft/d)	
	Spreading Basin	Flooded Field
Van Tol	22	2
Jasper	45	6
Olivarez	10	0.5

1 Spreading basins are shallow ponds excavated to relatively shallow depths (2 to 6 feet) through low permeability soils and/or through shallow hardpan.
2 A flooded field refers to the groundwater recharge technique of applying shallow water to a bermed field (approximate berm height, 2 feet).

With the finding that favorable infiltration rates exist in the Project Area, the next logical question along the "Direct Recharge" path is "Does recharge water reach the target aquifer?" If the answer is "yes' then proceed to the next step. If the answer is "No", then direct recharge may not be effective. The SCF investigation found that the recharge water, under the existing state of the basin, might not be reaching the target aquifer, the Tehama formation.[4] Instead the recharge water appears to enter the Stony Creek Fan alluvium, where it may only reside in storage for a relatively short period - weeks or months as opposed to several months to several years – before being discharged from the area. It is postulated that the high conductivities associated with the alluvial materials result in lateral movement and lateral spreading of the recharge water, and little downward migration. This is evident by the shallow, mid, and deep groundwater level hydrographs shown for the Van Tol site. The groundwater levels associated with the shallow monitoring well show evidence of the recharge water reaching the surface of the water table, however, the mid and deep monitoring wells are not effected. This observation is typical of the monitored groundwater levels at all three pilot recharge testing sites. Furthermore, recent field work completed by the Northern District of the California Department of Water Resources suggests that the hydrogeology of the Stony Creek Fan alluvium is a relatively thin water-bearing zone of layered sands and gravels 50 to 80 feet thick (see **Figure 1-6**). This relatively thin "veneer" is layered on top of relatively impermeable clays comprising the Tehama formation; there is believed to be little interconnection between the alluvium and this formation.[5] This proposed distinction is in stark contrast to the previously accepted theory that the Stony Creek Fan aquifer consisted of sand and gravel layers associated with the younger alluvial

[2] The Pilot Recharge Test Site Selection Criteria are: soils and geologic conditions; groundwater conditions; land availability; water availability; site access; environmental issues; geographic variability. For a complete description refer to Stony Creek Pilot Test Site Selection Criteria Memorandum, MWH, October 2001.
[3] See Technical Memorandum 2:Pilot Recharge Test Designs and Monitoring Program, MWH, August 2002
[4] The Tehama Formation typically includes confined (or semi-confined) water-bearing layers occurring at multiple depths, which are believed to be the source of groundwater pumped by most irrigation wells in the Study Area.
[5] This is partly corroborated by results of well interference tests that suggest there is little interaction between the unconfined surface layer (Stony Creek Fan Alluvium) and the deeper confined aquifers (the Tehama formation) (personal communication with Toccoy Dudley, DWR-ND).

materials interbedded and interconnected with the silts and clays that are characteristic of the older alluvium, or Tehama formation.

The results of the field work described above suggests that in-lieu recharge may be more effective than direct recharge in managing the long-term health of groundwater resources in the Project Area. Assuming the artificial recharge water reaches the target aquifer, the next question on the flowchart is "Does the recharge water appear to positively impact the storage of the basin?" In other words, does the recharge water improve basin conditions (e.g. groundwater elevations) or does the recharge water appear to run-off? If the answer to this question is "Yes" then artificial recharge appears viable. If the answer to the question is "No" then recharge water is being rejected possibly because the basin is already "full."

The term "full", as used here, is referring to groundwater conditions that are relatively stable, or in balance. Under these conditions water leaving the basin is approximately equal to water entering the basin on a long-term average annual basis. For instance, groundwater storage conditions in the Project Area have varied over the course of the last 30 years due to varied hydrologic and water supply conditions, however, the cumulative change in storage conditions has been minimal. This is supported by the following information:

- A water balance completed for the Project Area shows a net recharge on average of approximately 1.1 acre-feet per acre per year; and
- Review of groundwater level hydrographs throughout the region indicate groundwater levels typically return to pre-pumping conditions the following spring.

Based on the above findings, it was concluded that average annual natural recharge to the basin has generally exceeded average annual extractions from the basin, and artificial recharge at this time would not provide any additional direct benefit. However, as described previously, operating the basin in a "take" mode could require additional artificial recharge at some point in the future. For this reason, consideration of artificial recharge using in-lieu methods is pursued as part of the conjunctive use alternatives formulation effort.

Assessment of Additional Groundwater Yield Potential

[This section needs further discussion of the need to transfer water for the purposes of revenue generation to help each District achieve their goals/needs as discussed at the beginning of Section 1.]

The 'take' cycle, shown n **Figure 1-5c**, begins by asking "Transfer dry-year water?" If the answer to the question is no then the pumped groundwater would be used to meet local demand. Note that both legs of the flow chart could be followed and some water could be used to meet local demand while some could be reserved for transfer. If the answer to the transfer question is 'Yes' then a series of questions must be answered.

The first question is, does the groundwater pumping entity have access to dry year surface water supply to transfer. If there is no dry-year supply then a transfer is not possible. If the answer to the question is yes then the question is, "Is there conveyance for the transfer?" For example, both GCID and OAWD have relatively efficient conveyance for transfer water. Both districts would leave water in the Sacramento River. OUWUA is relatively more challenged for conveyance. The Stony Creek is believed to be a losing creek for much of the stretch between OUWUA and the Sacramento River.[6] Therefore transfers down Stony Creek are jeopardized by high losses. Potential transfers of OUWUA water may require involving exchanges with TC contractors.

If there is both dry-year surface water and conveyance ability the next question to answer is "is the transfer possible per the water code?" In general, groundwater substitution transfers have little trouble

[6] Personal conversations with Toccoy Dudley of DWR.

with a legal review. The legal 'transfer-ability' of source water available to the SCF partners, other than groundwater substitution water, is not as clear.

The components necessary to a groundwater substitution transfer are summarized in **Table 1-4.** The three components are 1) dry year water supply 2) groundwater pumping capacity and 3) conveyance. The OAWD is limited in their dry-year surface supply but possess the other two attributes. The OUWUA has limited groundwater pumping capacity but possess the other two components. GCID posses all three components. In addition, field investigations have confirmed the presence of a potentially high-producing confined aquifer, the Lower Tuscan formation: Hydrogeologic investigations underway by DWR-Northern District have documented the presence of this formation in the vicinity of the Project Area. Evaluation of well logs supported by recently developed wells support the notion that this groundwater source could potentially provide new supplies to the Partners.[7]

Table 1-4
Components of a Dry-year Groundwater Substitution Transfer

Partner	Groundwater Substitution Transfer Component		
	Dry Year Surface Supply	Groundwater Pumping Capacity	Conveyance of dry-year surface water
OAWD	Limited *(Junior CVP entitlement)*	Not limited	Not limited *(Forebear diversion into TC canal from Sacramento River)*
OUWUA	Not limited *(Adjudicated Pre-1914 storage and direct diversion rights)*	Limited	Limited *(Forbear diversions from Stony Creek – either travel down Stony Creek (high loss factor, or move water from South Canal to TC canal and ultimately Sac River at the drain).*
GCID	Not limited *(Base supply and supplemental CVP supply)*	Not Limited	Not limited *(Forbear diversions into the GCID from the Sacramento River)*

Summary of Physical Factors Influencing Alternatives Formulation

In summary, the field investigations and modeling analysis narrowed the set of alternative components. Initially the set of alternative components was believed to include variations of artificial direct recharge, in-lieu recharge, supply sources, extraction volumes, and yield destinations. However, as a result of the field investigations and subsequent modeling, artificial direct recharge was determined to offer less opportunity than originally thought. Furthermore, examination of historical water level data supported by modeling analysis indicates that the basin is more resilient than previously thought and is capable supporting additional production. In addition, greater understanding of the hydrogeology has revealed new sources of potential groundwater supplies. These findings combined have lead too more focused alternative formulation as discussed below.

Discussion of Institutional Factors Influencing Alternatives Formulation

An alternative that combines the resources of two or more partners is successful only if it provides each partner benefits that exceed those that each could achieve on their own. The most important implication

[7] It is noted that development of the Lower Tuscan formation as a source of new supply poses risks not yet fully identified or understood. For example, there remains limited understanding of the potential range of well's yields, the potential physical effects of long-term pumping, and the potential political ramifications of landowners predisposed to using private landowner wells rather than district-owned wells. These unquantified risks will be addressed through future efforts to compare and analyze SCF project alternatives.

this had to the alternatives formulation process was that each Partner needed to have a good sense of the individual water management options that they could pursue alone, so that they could weigh the benefits of collaboration versus individual actions. This resulted in organizing alternatives into two primary groupings, "Solo" Alternatives and Collaborative Alternatives, defined accordingly:

- *Solo Alternatives*: A solo alternative consists of individual action(s) identified for each Partner.
- *Collaborative Alternatives*: A collaborative alternative involves the joint operation of two or more district resources through either physical or institutional means, or both.

A series of focused meetings were held with each Partner individually to identify the water management options available to them, and to combine those options into a strategic plan of action. The individual strategic plans, or solo alternative, for each Partner serve the essential purpose of providing each Partner a means of judging the value of a collaborative approach relative to an individual (or solo) course. The approach to developing these two primary groups of alternatives is discussed further below under *Approach to Formulating the Project Baseline and Alternatives*.

[An expanded discussion will be added to address other institutional factors such as BMOs, air quality, SVWMP, CVPIA, etc]

APPROACH TO FORMULATING THE PROJECT BASELINE & ALTERNATIVES

Focused Alternatives Formulation Approach

The formulation process for developing conjunctive water management alternatives can involve a systematic identification and extensive evaluation of all potential sources of recharge water, all means and locations of groundwater recharge and production, and various combinations of these components. However, the fundamental implications stemming from the factors discussed above are that (1) Solo Alternatives are essential to the plan formulation process, and (2) the benefit of artificial recharge may be relatively small, effectively narrowing the field of potential collaborative alternatives. Thus, attention was concentrated on formulation of the Solo Alternatives and on identifying and formulating the types of collaborative alternatives most likely to succeed; i.e., those involving in-lieu recharge and offering opportunity to derive value or benefit from resources that otherwise would go unutilized.

Baseline Condition

As noted earlier, the Project Baseline is used as a reference condition for measuring the benefit or value of the various Solo and Collaborative alternatives. It is a hypothetical future condition that is assumed to exist if none of the alternatives was implemented; it is therefore sometimes also referred to as the "future without the project" or "without-project" condition.

The traditional standard for identifying possible future actions to include in a project baseline is the standard of "reasonably foreseeable", which is intended to exclude highly speculative actions. The Partners agreed that the project baseline should be comprised of non-speculative actions that clearly could be accomplished by each Partner. The parameters and actions ultimately included in the Project Baseline are described in Section 2.

"Solo" Alternatives

The purpose in developing the Solo Alternatives is to identify the combination of water management initiatives that each Partner would most likely pursue in the absence of participation in potentially more beneficial, collaborative alternatives. The Solo Alternatives serve as "yardsticks" for each Partner to gauge the advisability of entering into an alternative which involves some level of joint operation of

partner resources, as compared to an alternative which involves one partner proceeding alone. The approach used to identify each district's "Solo" Alternative is described below.

Collaborative Alternatives

Collaborative alternatives involve some degree of joint operation of district resources. This could involve the actual physical exchange of resources among the districts, and institutional mechanism that enables each district to modify their own resource utilization under a joint program, or a combination of the two. As noted previously, the realm of viable collaborative alternatives is narrowed as a result of the limited benefit of artificial recharge. In particular, it appears that the most fruitful opportunities for partnership are ones involving in-lieu recharge and where presently unutilized resources can be put to use.

Identification of "Solo" and Collaborative Alternatives

The project team worked closely with each district to define and refine their "Solo" Alternatives and to identify potential Collaborative Alternatives. The GW Model was used to evaluate the effect of each District's actions on the basin and the effect these actions would have if implemented together. An economic analysis was also conducted to compare the present value of project costs to the present value of project benefits, to determine economic feasibility. This analysis explored and improved the understanding of how each Partner's water supplies could best be managed in terms of quantity, distribution, and timing. The primary objective of developing this information was to educate the Partners and the Project Team so that the "Solo" Alternatives and Collaborative Alternatives could be refined as needed. The Project Team worked with each Partner to identify specific questions and/or planned actions.

SECTION 2. DESCRIPTION OF EXISTING AND BASELINE CONDITIONS

INTRODUCTION

This section describes the existing and baseline conditions in the Project Area. Both conditions are described in sections dedicated respectively to the Orland Unit (Subunit 1), Orland-Artois Water District (Subunit 2), Glenn-Colusa Irrigation District (Subunit 3) and the independent pumper areas (Subunits 4-7). The descriptions of existing conditions are based on observations and interpretations derived from the historical (1970 through 2000) water balances prepared for the various subunits (see **Map 1**)and in aggregate for the Project Area. The project baseline represents conditions that are predicted to occur in the future, if one of the project alternatives is not implemented. It is a hypothetical condition developed primarily to serve as a yardstick for measuring the relative merits of the various alternatives.

Discussion begins with examination of the assumptions that are common and applied uniformly to all three Partners to establish the project baseline. This is followed by sections describing each Partner's pertinent background information, water resources setting, and existing and individual baseline condition.

The information presented here is derived primarily from the prior tasks completed for the Feasibility Investigation:

- Initial Field Investigations (Task 3)
- Collect and Review Existing Data (Task 4)
- Characterize Existing and Future Hydrologic Conditions (Task 5)

COMMON BASELINE ASSUMPTIONS

The Baseline Condition is a hypothetical future condition that would exist if Solo or Collaborative project alternatives are not pursued. Development of Baseline conditions requires making certain assumptions about future conditions, some of which are unique to the individual Partners, and others of which are common among the Partners. This section describes the baseline assumptions that are common among the Partners.

Planning Horizon

The planning horizon refers to the point in time for which Baseline Conditions are developed. Factors that influence selection of the time horizon includes the presence of trends in historical land use and cropping, the time that would likely be required to implement the project alternatives, the horizons used for other related planning efforts, and other factors. Based upon review by, and discussion with, the SCF Partners a time horizon of 2025 was assumed for planning purposes. This is consistent with other planning efforts recently completed, such as the USBR water needs analysis completed for contract renewals, regional planning ongoing for CALFED, and the California State Water Plan Update (DWR Bulletin 160).

Hydrologic Conditions

The hydrologic period over which the alternatives are analyzed and evaluated must include enough variability to reveal how the alternatives would function under conditions of prolonged water shortages and surpluses. The historical water balances prepared for the Project Area cover the period of 1970 through 2000. This period probably includes sufficient hydrologic variability, but does not match the longer and even more variable period of 1922 through 1994, which is used by DWR, the USBR and

CALFED for planning purposes. Therefore, the historical hydrologic record spanning the period of 1922 to 1994 is used to develop Baseline Conditions, and for formulation and comparison of alternatives.

Future Land Use & Cropping Patterns

With minor exception, projections of future irrigated area and cropping patterns within each subunit were based on trends observed during recent years. The basic assumption is that recent trends are acceptable indicators of change that will occur between 2000 and 2025. The methodology described here was developed in consultation with staff of DWR's Northern District, to ensure comparable results with DWR land use projections. The first step was to assign the total land area within each subunit to the broad classifications of "cropped", "non-cropped" and "idle". The cropped area in 2025 was assumed to be the same as the maximum cropped area observed anytime between 1991 and 2000. (An exception was made for OAWD where land is still being developed for irrigation. In that case, 1,352 acres was added to the maximum observed cropped area, to account for land connected to the OAWD distribution system and paying assessments, but which has not yet been developed.) The non-cropped area in each subunit was then increased at a constant annual rate to account for urbanization, based on the growth in urban lands observed between 1993 and 1998 (the two years for which DWR land use data are available). Finally, lands not accounted for as cropped or non-cropped were assigned to an "idle" classification as a closure calculation.

Land within the cropped category was assigned to specific crops based on the percentage observed in 2000, plus the percentage change observed between 1996 and 2000, with a dampening factor allied to moderate the compounding effect.

The results of the cropping projections are presented in the appropriate following sections.

Irrigation Management Practices

Irrigation management practices, including irrigation methods and existing technologies, are assumed to be the same as those currently in place in the Project Area. The only exception to this assumption is for alternatives that may have as a key feature some change in the irrigation scheme within a district or districts.

ORLAND UNIT WATER USERS' ASSOCIATION (SUBUNIT 1)

Background

The Orland Unit Water Users' Association (OUWUA) is located in north central Glenn County (see **Map 1**). The OUWUA is a Non-Profit California Corporation. Founded in 1906, the Association petitioned the Secretary of the Interior to encourage the USBR (then the Untied States Reclamation Service) to develop an irrigation project near the town of Orland. As a result, the USBR began construction of the Orland Project in 1909. The facilities of the Orland Project deliver water from the Stony Creek watershed to the shareholders of the OUWUA.

There are 1,099 shareholders within the OUWUA. The average farm size in the OUWAU is relatively small, and some shareholders maintain hobby farms (33 percent of the shareholders having 5 acres or less). The average farm size is 18 acres. Approximately 25 percent of the farms are greater than 20 acres.

The OUWUA service area enjoys favorable growing conditions for agriculture. A thermal belt, with very few frosts, warms the Orland area. The soil is considered some of the richest and most productive in the nation (USBR). The textures of the soils in the OUWUA are predominately loam, gravelly loam and gravelly sandy loam. Average rainfall is 18 inches, most of which is measured between the first of November and the first of April.

The primary facilities of the Orland Project include East Park reservoir and Stony Gorge reservoir. The Project was constructed between 1909 and 1928. In 1954 the OUWAU took over operation and maintenance of the Project from the USBR. These reservoirs are upstream of the US Army Corps of Engineers (USACE) Black Butte Dam, constructed in 1962 for flood control.

Flows from Black Butte Reservoir are controlled by the USACE and are released to meet the total demands required by OUWUA. After calculating the total delivery demands for the day and adding 10 percent for losses, OUWUA calls the USACE at 7:00AM to give its daily order. At 1:00PM in the afternoon OUWUA has the opportunity to change their order if needed. Surface water is distributed in open channels to approximately 17,600 of the 20,200 acres of the OUWUA through 17 miles of canals; and 139 miles of laterals (CALFED 2003 [1]).

The project is divided into six geographic areas called 'beats'. Surface water deliveries are made to the six beats on a rotational basis. Regardless of the crop being grown, the soil texture, or the evapotranspiration rate, water is delivered every 12 days during the peak demand period from June through September and every 14 days at the beginning and end of the season when crop demand is lower. During the months of peak demand, it is not possible to shorten the rotation period because of capacity constraints mostly in the main laterals. Some growers augment surface water supplies with groundwater were the physical constraint of these rotational periods result in surface water delivery patterns that do not meet crop demands for producing maximum yield. Some growers use groundwater exclusively where surface water is not available. Of the 20,200 acres of the OUWUA, 17,600 are receiving surface water. Of the 2,600 acres that are not supplied surface water, approximately 500 acres are irrigated with groundwater and the rest are fallow.

Six fulltime ditchriders, one for each beat, control flows by manually adjusting turnout gates and checks. Irrigators are informed in advance of the time they will be provided water and it is their responsibility to open and close their farm turnout(s) at the right time. Water deliveries are not measured at farm turnouts, except for several piped turnouts with meters, but are typically estimated from experience and measurement at upstream flumes and weirs.

Due to the nature of the open channel distribution system an the limited use of meters within the OUWUA estimates of conveyance losses and operational spills are 20 percent of total diverted water.

The OUWUA has investigated modernizing its existing distribution system in order to enhance conservation (CALFED 2003 [1]). Three estimates of the volume of water that could be conserved were 40,100, acre-feet (AF) per year 25,400 AF per year and 14,400 AF per year depending on the size of the investment in infrastructure. The range of capital investments for the three alternatives are $221,640,000, $53,499,000 and 18,489,000, respectively. The OUWUA is currently deciding which, if any, of the conservation measures to adopt and is examining various financing scenarios. This topic is discussed in the section of this Technical Memorandum that describes SCF Partner Alternatives.

OUWUA employs a total of fifteen fulltime staff; six ditchriders, two dam-tenders, four maintenance workers, one foreman, one office manager and on manager. The current overall O&M cost for OUWUA is $869,000. Shareholders pay $29.50 per acre per year that entitles them to 3.0 AF per acre. For additional water, it costs $9.83 per AF for up to 2 AF and $10.90 per AF thereafter.

Water Resources Setting

Surface Water

With very little snow, winter runoff from the Stony Creek watershed occurs almost immediately after precipitation. The Stony Creek watershed had an average annual runoff of 410,000 AF for the period 1921 to 2001. The low of 17,000 AF occurred in 1977. The high of 1,435,000 AF occurred in 1983.

The reservoir capacity on the Stony Creek watershed is as follows: East Park Reservoir is 50,900 AF, Stony Gorge Reservoir is 50,000 AF and Black Butte Reservoir is 136,000AF (DWR). Approximately 90 percent of the time precipitation is sufficient to fill the OUWUA reservoirs, East Park and Stony Gorge. The total reservoir capacity in the upper watershed is not adequate to provide regular planned inter-annual carryover storage.

Black Butte Reservoir, while originally built for flood control was financially and operationally integrated with the CVP, authorizing use of conservation storage for irrigation and recreation.[8] Operations of the three reservoirs were coordinated under a 1964 agreement to increase the net benefits of the system.

The rights to water available to the Orland Project as summarized in **Table 2-1**. Many of the rights to the water delivered by the Orland Project's facilities were adjudicated in the terms of the Decree in the case of The United States of America vs. H. C. Angle, et al, 1930. Water rights from the Angle Decree provide for both storage of water and direct diversion of water. The Angle Decree provides a total of 85,050 af (not to exceed 279 cfs) of direct diversion rights for irrigation and reclamation. The Angle Decree provides rights for storing water in East Park Reservoir (51,000 af of Little Stony Creek water) and a maximum of 250 cfs of water on Big Stony Creek for irrigation and reclamation. In addition to the water rights adjudicated in the Angle Decree, the USBR holds 50,200 af of rights to storage of Stony Creek water. This storage water is contained in Stony Gorge Reservoir. [Need to comment on the USBR storage and diversion right of S006354.

Table 2-1
Summary of the Water Rights Available to the Lands of the Orland Project

Quantity	Type of Right	Date of Right	Time	Source
85,050 af not to exceed 279 cfs	Direct Diversion on Stony Creek	10//10/1906	Irrigation season as available	Angle Decree, Article VIII (1)
51,000 af	Storage of Little Stony Creek water	10/11/1906	Year round as available	Angle Decree, Article VIII (3)
250 cfs	Storage and conveyance of water from Big Stony Creek	3/25/1913	Year round as available	Angle Decree, Article VIII (4)
50,200 af	Storage, water of Stony Creek	Permit issued on 12/2/1925 License on 5/15/1944	November 1 to May 1	SWRCB Application number A002212 held by USBR for Orland Project

Groundwater

The lands of the Orland Project overlie the Stony Creek Fan (alluvium). Historically, surface water supplies are sufficient to meet irrigation demands, however some of the lands within the Project use groundwater for irrigation due to conveyance constraints of the Project. The quantity of ground water pumped in any year is estimated to average 3,000 af. A detailed description of the hydrogeology of the basin will be provided in TM 3.

Historical Water Demands & Supplies (1970 – 2000)

A water balance analysis was prepared for the Orland Unit for the period 1970 through 2000 as a means of understanding historical water demands and supplies, irrigation efficiency, and the relationship

[8] In addition to the USBR, USACE and OUWUA the City of Santa Clara operates a 6.2 MW hydroplant on Black Butte dam. The hydroplant is operated under a cooperative agreement between the City of Santa Clara, USACE and OUWUA.

between Unit operations and regional hydrology (see Technical Memorandum #3 for more information). The primary purpose in developing the historical water balances is to provide a factual basis for forecasting future cropping patterns and water demands under the Baseline Condition and project alternatives. Pertinent aspects of the water balance analysis are described below.

Cropping Patterns (Historical)

The total land area within the Orland Unit is 24,130 gross acres, of which approximately 15,000 to 17,000 acres were cropped and irrigated over the period of analysis. Exceptions to this were the critically dry years of 1977 and 1996, when water supply shortages resulted in reductions in irrigated area. The cropping pattern is dominated by pasture and forage, which accounts for roughly 60% to 70 % of the total cropped area. The dominance of pasture and forage is believed to be associated with the large number of small parcels in the Orland Unit that are not commercially farmed, and a rotational water delivery pattern that is conducive to forage production, and less so to production of other crops. Permanent crops, although a minor percentage of the total, have steadily expanded in acreage, from about 2,700 acres in 1970 to 3,500 acres in 2000. Field crops have at times been planted to more than 4,000 acres; however, field crops have seen a steady decline in recent years, falling to less than 2,000 acres in 2000. The maximum total irrigated area observed during the period of analysis was about 17,500 acres in 1982.

Water Diversions and Demands

The total measured historical water diversions in the Orland Project between 1970 and 2000 have ranged between 126,308 af/yr and 26,299 af/yr. The average diversion for that period has been 95,372 af/yr. Approximately 20 percent of that diversion is estimated to be conveyance losses (see **Figure 2-1**). The remainder of diversions after conveyance losses is available to meet applied water demand. Applied water demand is the sum of (ETaw) and the irrigation efficiency requirement. [9]

Figure 2-2 represents the various uses of surface water and groundwater to meet ETaw. The surface water diversions are categorized by conveyance losses, irrigation efficiency losses and ETaw. The average estimate of historical ETaw (given conveyance and irrigation efficiency losses) is 49,593 af/yr. On average, water demand is comprised 40% of ET of applied water, 40% on-farm losses and 20% system losses, indicating significant potential for demand reduction through reduction of losses. Private Pumping is negligible in most years, except in water-short years like 1976, 1977 and 1998. The maximum volume of private pumping ever to occur in the Orland Unit was about 13,000 af in 1976.

Baseline Condition (2025)

As noted earlier, the Project Baseline (or Baseline Condition) is used as a reference condition for measuring the benefit or value of the various Solo and partnership-based alternatives. It is a hypothetical future condition that is assumed to exist if none of the alternatives was implemented; it is therefore sometimes also referred to as the "future without the project" or "without-project" condition.

Assumptions

Common to all of the partner's baseline, or without project condition, is the assumption that the planning horizon looks out to 2020. Therefore estimates of future water demand and available water supply of the OUWUA were developed.

[9] To maintain the water balance, changes from year to year in water stored in the root zone must also be accounted for. A decrease in stored water across years is counted as a component of supply, while an increase in storage is represented as a component demand. The volumes of water associated with storage changes are generally small both year to year and cumulatively over the period of analysis, and can generally be neglected.

Cropping Patterns

The cropping pattern in the OUWUA is expected to shift slightly to more pasture and forage than what was historically grown, reflecting the expected increase in the already large number of small parcels that are not commercially farmed. Although the management of the OUWUA is anticipating that, either through the implementation of a solo alternative or a collaborative alternative, the existing rotational water delivery system can be replaced through system modernization it is not anticipated that the cropping patterns over the next 15 years will reflect this change

Water Supply and Demand

Water supply is not expected to change from historical. The OUWUA has relatively senior water rights (as discussed above) and the availability of water under those rights is not expected to change. The challenge before the OUWUA is to make certain that those rights are not reduced through environmental actions.

The demand for water in OUWUA is not expected to change significantly from historical. See **Figure 2-3** for a comparison of the historical and baseline demand. The average historical demand is 79,780 af. The average of the estimated baseline demand is 85,270 af. The difference of approximately 5,000 af per year represents the change to more water intensive pasture and forage crops.

ORLAND-ARTOIS WATER DISTRICT (SUBUNIT 2)

Background

The Orland-Artois Water District (Subunit 2) is located between the Orland Unit (Subunit 1) to the north and GCID (Subunit 3) to the south and east (**Map 1**) The District was formed in 1954 for the purpose of contracting with the United States (Bureau of Reclamation) for a supplemental surface water supply from the Central Valley Project (CVP). The parties originally entered into Contract No. 14-06-200-467-A on April 19, 1963; that contract was amended on September 15, 1964. The original contract, as amended, provided for supplemental surface water to be delivered to OAWD via the Tehama-Colusa Canal (TCC), a feature of the CVP construction of which had not yet begun when the contract was executed.

The original contract was superceded by Contract No. 14-06-200-8283A, entered into by the parties on February 26, 1976. The 1976 contract superceded the original contract with respect to provision of supplemental surface, and provided for the design, construction and repayment of a distribution system to deliver the contract water supply to District lands. According to the agreement, the Bureau provided design and construction management services. Since the expiration of the 1976 contract in 1995, the District has continued to receive Central Valley Project (CVP) water under a series of two-year interim contracts with the United States, each with the same maximum contract amount (53,000 acre-feet) as the 1976 contract. Along with other CVP water contractors, the District is currently negotiating long-term renewal of its water supply contract with the United States.

The District is comprised of 30,290[10] (gross[11]) acres of land interspersed with non-District lands in a checkerboard-like pattern. This pattern reflects the decisions made by individual landowners to join the District or not. The District's assessed area is 28,988 (gross) acres.

[10] According to District records, there are 30,290 gross acres within the District's boundaries. The area digitized to represent OAWD in the water balance analysis was comprised of 31,264 acres because it included some adjoining acreage as well as OAWD lands. This difference is not considered be significant for purposes of the Feasibility Investigation.

[11] Unless otherwise indicated, all references to irrigated areas are to net acreages actually planted to crops and receiving water for irrigation. In general, net acreages are about 6% less that assessed or gross acreages, and

Construction of the distribution system under the District's contract with the United States began in 197? and was completed in 198?. Delivery of CVP water began in 1976 and expanded gradually, year by year, as construction proceeded. The system consists of approximately 100 miles of buried asbestos-cement pipeline with diameters ranging from 8 to 96 inches (Figure ____) *(Note: OAWD distribution system map to be included in subsequent draft documen.)*. The combined delivery capacity through the 5 permanent and 3 temporary turnouts from the TCC is 427 cubic feet per second (cfs). The TCC bisects the District, running east to west across the northern portion of the District, then from north to south across the west side of the District. About 16,767 assessed acres lie down-gradient (generally south and east) of the TCC and are served by gravity, without the need for pumping. The remaining 12,221 assessed acres lie up-gradient (generally north and west) of the TCC and are served by canal side pumping plants that were constructed as components of the distribution system. The maximum elevation difference between the TCC and highest farm delivery is about ____ feet.

Water users are required to place water orders with the District, specifying the volume of water to be used at each turnout on each day. User's orders are compiled for each lateral pipeline system and associated TCC turnout, and submitted to the Bureau of Reclamation daily to enable coordinated operation of the TCC. The District pipelines are closed systems; they operate in response to grower demands, allowing growers to take delivery of their ordered volumes at the rates and durations that are most efficient or convenient for farm operations. There is no spillage from the system, and the District maintains a leak detection program to prevent appreciable leakage. Thus, system losses are negligible. Water deliveries are made to farms through individual farm turnouts with totalizing flow meters. District staff read meters monthly, with meter readings and water bills sent monthly to water users.

Water Resources Setting

Water demands within OAWD are satisfied by a combination of surface water and groundwater sources; both sources are described in the following sections.

Surface Water Sources

OAWD is traversed by several small, ephemeral creeks that originate in the foothills west of the District. The largest among these is Walker Creek, which at times poses a flood hazard. Some irrigation diversions are made from the creeks to District lands in the spring; however, these diversions are unrecorded and are generally believed to be insignificant from a District water supply perspective[12]. Thus, the District's main sources of surface water are imported, including CVP supplies provided under Contract No. 14-06-200-8283A (described above) and occasional, temporary (year to year) water transfers from other CVP water contractors. The maximum water quantity available under the District's CVP contract is 53,000 acre-feet annually (March 1 through February 28); however, this maximum is subject to limitation, depending on overall CVP water supply conditions and Bureau water allocation policy.

Because OAWD is generally water-short, each year the District seeks to augment its CVP contract supplies with short-term water transfers, primarily from CVP contractors that have temporary CVP contract surpluses. Throughout the mid- to late-1980s, due to favorable water supply conditions and prior to enactment of the Central Valley Project Improvement Act (CVPIA) in 1992, the District was successful in transferring significant quantities of water into the District. Since enactment of the CVPIA, and due to poor water supply conditions, water transfer opportunities have been limited.

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therefore generally do not agree with acreage records maintained by Districts. The difference between net and gross acreage is the land area occupied by roads, farmsteads, canals, ditches, etc.

[12] Based on discussions with District staff, average annual diversions from local surface water sources were estimated to be 200 acre-feet annually, during March and April. For purposes of this Feasibility Investigation, this supply source is considered to be insignificant.

In addition to the surface supply source described above, OAWD filed an Application to Appropriate Water with the State Water Resources Control Board on May 15, 2002 (Application #31324). The State Board issued a Notice of Application on May 12, 2003, drawing protests from several interested parties; resolution of those protests is currently pending. If permitted as applied for, OAWD would be allowed to divert water from the Sacramento River at a rate of up to 400 cfs between the dates of October 1 and May 31, not to exceed 30,000 acre-feet for direct diversion for irrigation and frost control purposes, and not to exceed 80,000 acre-feet for diversion for underground storage. The total volume of direct diversion plus diversion to storage would not exceed 80,000 acre-feet during the permitted diversion period. At this time, it is uncertain whether a water right permit will be granted by the State Board or whether the application will be modified in response to protests or State Board concerns.

Groundwater Sources

While surface water is used in OAWD exclusively for agricultural purposes, groundwater serves both agricultural and rural domestic purposes. Groundwater production wells are owned and operated by individual landowners; OAWD does not own or operate any groundwater production wells. Customers having private wells use them to supplement their CVP water supply, particularly during drought conditions when deliveries are curtailed. It is not known how many privately owned and operated groundwater wells exist in OAWD, nor is amount of groundwater pumping known since wells are typically not metered. A description of the regional hydrogeology of the area is provided in Technical Memorandum No. 3 [*to be provided*].

Water Source Preferences

Because groundwater is generally available throughout the District, and because District surface water supplies are not sufficient to meet the total demands of each farm, most growers rely on a combination of surface water and groundwater to meet irrigation demands. The notable exception is certain locales on the west side of the District, where groundwater is not readily available in adequate quantities. In those areas, growers are strongly dependent on District surface water supplies. The District estimates that about 5,000 acre-feet of surface water is needed annually to serve lands that have limited groundwater.

The primary factors that growers consider in selecting water source are discussed below.

- Cost – Cost is widely regarded as the strongest single factor affecting water source decisions. In comparing costs between District surface water and private groundwater, most growers neglect capital recovery associated with private wells costs. Thus, private groundwater production tends to be favored whenever the variable costs of groundwater pumping (energy and pump O&M) are lower that the costs of purchasing surface water from the District. As noted above, however, there are areas on the District's west side where groundwater production is not feasible; in these areas, surface water is the only viable option.
  Moss/Algae – Due to a number of factors, District surface water at times contains high concentrations of moss and algae. Primary contributors are low velocities, long resident times and warm water temperatures in the TCC, which create conditions favorable for algae growth. Moss and algae do not significantly affect surface irrigation systems, but do pose serious problems to operation and maintenance of filtration systems used with drip and micro-spray systems. Thus, drip irrigators tend to favor groundwater as the preferred water source.
- Temperature – The temperature of District surface water varies seasonally, being cold in the winter and spring and warmer in the summer. In contrast, groundwater temperature is relatively stable year-round. Thus, compared to surface water, groundwater is very warm in the winter and warmer in the summer, depending on the depth from which groundwater is pumped. During the frost control season, growers definitely prefer to use groundwater, because it is more effective in preventing frost

damage to the crop. To the extent that groundwater is warmer in the summer, it is preferred by rice growers.

- Pathogens/Disease – Some crops are sensitive to water-born pathogens that may at times be present in surface water sources. Farmers concerned about such pathogens prefer to use groundwater.

Historical Water Demands and Supplies (1970 – 2000)

A water balance analysis was prepared for OAWD for the period 1970 through 2000 as a means of understanding historical water demands and supplies, irrigation efficiency, and the relationship between District operations and regional hydrology (see Technical Memorandum #3 for more information). The primary purpose in developing the historical water balances is to provide a factual basis for forecasting future cropping patterns and water demands under the Baseline Condition and project alternatives.

Cropping Patterns (Historical)

Prior to the start of surface water deliveries in 1976, roughly 10,000 acres within OAWD were identified as being irrigated with groundwater; the remaining District acreage was dry-farmed or idle. Since 1976, the irrigated area has expanded to between 22,000 and 23,000 acres (**Figure 2-4**). The dominant crop type initially was pasture and forage with relatively minor acreages of field crops and permanent trees and vines. It appears that there was no rice irrigated with groundwater prior to CVP deliveries. The area planted to field crops increased sharply in 1976 with the introduction of supplemental CVP water. This increase in field crop acreage, together with increases in rice and permanent crop acreage, resulted in a gradual increase in total irrigated area between 1976 and 1983, corresponding more or less to the period of construction of the distribution system. Since 1983, the areas planted to permanent crops and rice have continued to expand, while pasture and forage acreage have gradually declined. The maximum area irrigated was about 24,000 acres in 1997.

Water Demands and Supplies (Historical)

Irrigation demands in Orland-Artois are comprised of two components: (crop) ET of Applied Water and Farm Losses. Conveyance Losses from the pipe District distribution system are considered insignificant[13]. Irrigation demands have ranged from roughly 33 taf in 1975 before the introduction of surface water, to a high of 92 taf in 1988. The median demand is roughly 64 taf and occurred in 1991 **(Figure 2-5a; Table 2-2).** After the introduction of surface water, demand has consistently been comprised of 70% ET of Applied Water and 30% Farm Losses, reflecting a District-wide average on-farm efficiency of 70% since 1977.

Water supply sources include District Surface Water, including water received under the District's CVP water contract and occasional, one-year water purchases from other CVP contractors, and Private Pumping[14] (**Figure 2-5b**). The total utilized[15] supplies have met the demands described above, ranging from 33 taf to 92 taf with a median of 64 taf over the period of record. The supply source varies significantly from year to year depending on the availability of surface water under the District's CVP contract and through CVP water purchases. In 1992, during the drought, the water supply was comprised

[13] To maintain the water balance, change in storage across years is also accounted for. This results in a typically small, artificial component of demand in years when storage increases from year to year. This is called Storage Demand.

[14] To maintain the water balance, change in storage across years is also accounted for. This results in a typically small, artificial component of supply in years when storage decreases from year to year. This is called Storage Supply.

[15] The utilized supply is the quantity actually diverted from available sources to meet water demands; thus, the total utilized supply is equal to total demand. Additional water supplies may have been available, but were not used.

of only 23% District Surface Water and 77% Private Pumping while in 1988 the corresponding fractions were 93% District Surface Water and only 7% Private Pumping. On average, the water supply is comprised of 66% District Surface Water and 34% Private Pumping, reflecting a District-wide average efficiency of 66% over the 1970 to 2000 period.

Since the start of surface water deliveries in 1977, the District has transferred in an addition 6,400 af annually. However, over the period 1990 to 2000, transfers have amounted to less than 2,000 of annually, due to the effects of drought and CVPIA.

Table 2-2. Subunit 2 (OAWD) –Minimum, Maximum, and Average Values of Water Demand and Supply Components (1970-2000)

	Demand				Supply				
	ET of Applied Water	Farm Losses	Conveyance Losses	Storage Demand	District Surface Water	District Pumping	Private Pumping	Private Diversion	Storage Supply
Minimum	27,010	5,151	-	-	-	-	4,152	-	-
Maximum	54,030	42,687	-	3,016	84,127	-	54,361	-	2,828
Average	38,576	22,985	-	361	36,566	-	24,678	-	678

Regional Perspective

Prior to the import of surface water in 1976, activities on OAWD lands resulted in a positive net extraction of groundwater in all but one year (1973), meaning that groundwater pumping exceeded deep percolation from the combination of applied water and precipitation (**Figure 2-6**). Net extraction averaged about 15 taf during the 1970 to 1976 period. With the gradually increasing import of surface water between 1976 and 1983, the area transitioned from an area of net extraction to an area of net recharge. Even during years when CVP supplies were constrained and private pumping reached new highs (e.g., 1992 and 1994), net extraction was essentially zero, meaning that groundwater pumping was offset by an equal volume of groundwater recharge.

Baseline Condition (2025)

As previously described, the Partners agreed to use a modest forecast of Baseline Conditions featuring non-speculative assumptions and actions that clearly could be accomplished by each Partner. The assumptions used to shape the Baseline Condition for OAWD are discussed below, followed by discussion of the implication of the assumed conditions to future OAWD water demands and supplies.

Baseline Assumptions

The assumptions common to all Partners' baseline condition were discussed earlier. Following are the assumptions that are unique to OAWD's Baseline Condition.

1. **CVP Water Supplies:** OAWD's contract with the United States will be renewed at its current maximum amount of 53,000 afa. Pursuant to the Central Valley Project Improvement Act, tiered pricing provisions will be included that have the effect of making the top two 10-percent tiers unaffordable, thereby reducing the maximum useable quantity to 42,400 afa. Additionally, water availability will be constrained by federal water allocation policy and CVP water supply conditions. The assumed availability of water under OAWD's contract, by hydrologic year type, is tabulated below, reflecting the factors noted above as they would apply over long-term hydrologic cycles.
2. **CVP Water Cost:** Despite recent increases in CVP contract rates, it is assumed that the 80 percent of the contract supply not subject to tiered pricing will remain affordable to growers, including the District's operating charges. Thus, it is assumed that all water available under the District's CVP contract below the tiered pricing threshold would be purchased and used by OAWD growers.

Hydrologic Year Type	Assumed Contract Yield	
	(% of 53,000 af Contract max.)	TAF
W	80	42.4
AN	80	42.4
BN	50	26.5
D	25	13.3
CD	10	5.3

3. **Water Transfers:** Opportunities to supplement surface water supplies through short-term purchases will not exist, nor will OAWD sell water out of the District to generate revenues.
4. **Pending Water Rights Application:** It is highly speculative whether OAWD will be granted a permit to divert winter water from the Sacramento River and, if a permit is granted, whether the necessary arrangements can be made with the Bureau of Reclamation under a Warren Act contract for conveyance of the water from the Red Bluff Diversion Dam to the District. Thus, it is assumed that no water will be available to the District under the pending application.
5. **Participation in the Sacramento Valley Water Management Agreement (Phase 8):** Reflecting current OAWD Board policy, it is assumed that the District will not participate in this Agreement.

Cropping Patterns (Baseline)

By 2025, it is anticipated that the total (*net*) irrigated area within OAWD will be 25,312 acres (**Figure 2-7**). The major cropping difference compared to existing conditions would be a significant expansion of permanent crop acreage, reflecting continuation of the expansion in almond plantings observed in recent years. The expansion in permanent cropped area would be accompanied by minor expansions of rice and pasture/forage acreage and a modest reduction in field crop acreage. The non-cropped land area within the District would decrease to accommodate the overall growth in irrigated land area.

Water Demands & Supplies (Baseline)

Under the 2025 cropping pattern discussed above, and based on simulations using 1922 to 1994 hydrologic conditions (precipitation and runoff/water supply), the average on-farm ET of applied water (ETaw) demand would be 63 taf annually, ranging between 52 and 71 taf annually (**Figure 2-8**), depending on hydrologic conditions. The total applied water demand, based on 70% on-farm efficiency, would range between 75 and 101 taf annually, averaging 90 taf annually over the long term (**Figure 2-8**). Because water losses from the District distribution system are negligible, the total District water demand is the same as the applied water demand at the farm level, including on-farm losses.

Subject to the previously discussed assumptions, it is estimated that OAWD's CVP contract would yield an average of 27 taf annually, satisfying less than one-third of the long-term average applied water demand. The supply would range between 5 taf and 42 taf annually, depending on hydrologic conditions (**Figure 2-9**). Water demands in excess of available CVP supplies would be met entirely by groundwater supplies pumped by OAWD landowners. Average pumping would be 63 taf annually, ranging between 35 taf and 95 taf annually, as needed to fill shortages in surface water supplies (**Figure 2-10**). All pumping would be by private landowners, primarily from the Tehama Formation.

Discussion

Relative to existing conditions, the main consequence under the assumed Baseline Condition would be a significant increase in groundwater pumping needed to offset the anticipated reduction in CVP supplies and expansion of applied water demands. From a regional hydrology perspective, OAWD would change

from being a net groundwater recharge area under existing conditions to being a net groundwater discharge area under the Baseline Condition.

(Note: need a graph or table to illustrate this change.)

GLENN-COLUSA IRRIGATION DISTRICT (SUBUNIT 3)

Background

GCID is located in the central portion of the Sacramento Valley on the west side of the Sacramento River, as illustrated on **Map 1** (Glenn County portion only). The District's service area extends from northeastern Glenn County near Hamilton City to south of Williams in Colusa County. The east side of the District stretches toward the Coastal Range and Tehama-Colusa (TC) Canal. GCID's main facilities include a 3,000 cfs pumping plant and fish screen structure located on the Sacramento River at the northern end of the District, just north of Hamilton City, a 65-mile Main Canal, and approximately 900 miles of laterals and drains.

With 175,000 acres, GCID is the largest irrigation district in the Sacramento Valley. The soils within this area generally consist of clay-like and loam characteristics. The low infiltration rates of the tight soils within much of the District are conducive to furrow and border irrigation. To that end, rice is the predominant cultivated crop. Other crops include, but are not limited to, tomatoes, vine crops, sunflowers, prunes, almonds, and walnuts.

GCID uses an arranged schedule to deliver irrigation water to District customers. The main canal is situated along the west side of the District and supplies various laterals that supply individual farms and refuges. GCID does not supply municipal or industrial water.

In 1990 the District's Sacramento River diversion was identified as a significant impediment to the downstream migration of juvenile salmon. Following the state and federal listing of the winter-run Chinook salmon as endangered through the Endangered Species Act, pumping restrictions were imposed on GCID by a court-ordered injunction, preventing the District from diverting its full water entitlement. A long-term solution was developed to provide both safe fish passage past the GCID diversion facilities and to ensure a reliable water supply to GCID by allowing the District to divert their maximum capacity of 3,000 cfs. Key components of the solution included enlargement and improvement of the fish screen structure and the construction of a gradient facility in the main stem of the Sacramento River to stabilize the river channel. These facilities were complete in 2002.

In response to the reduced diversions described above, and three years in the last decade classified as "critically dry years," resulting in contract supplies being reduced to 75% of entitlement, the District developed a number of programs to supplement these reduced supplies, including an aggressive drainwater recapture program, an emergency water conservation program, a voluntary groundwater conjunctive water management program, and an in-basin water transfer program.

Water Resources Setting

Lands within GCID rely primarily on surface water and only a small fraction of landowners also pump groundwater. These sources are discussed further below.

Surface Water Sources

The Sacramento River serves as the principal water source for GCID. Its diversion is the largest surface water diversion on the river. The District holds both pre- and post-1914 appropriative water rights to divert water from the natural flow of the Sacramento. GCID also has adjudicated pre-1914 water rights under the Angle Decree, issued in 1930 by the Federal District Court, Northern District of California, to

divert water from the natural flow of Stony Creek. In addition, as the successor in interest to Central Canal and Irrigation Company, GCID has, under a May 9, 1906 Act of Congress the right to divert up to 900 cfs from the Sacramento River (Pub. L. No. 151, Ch. 2439).

GCID entered into a negotiated agreement with the USBR in 1964, quantifying the amount of water GCID could divert from the Sacramento River (Contract No. 14-06-200-0855A (Contract No. 0855A)). The resulting negotiated agreement recognized GCID's annual entitlement of a Base Supply of 720,000 ac-ft/yr of flows from the Sacramento River and also provided for a 105,000 ac-ft/yr allocation of Project Water, resulting in a total contract entitlement of 825,000 ac-ft/yr. The 825,000 ac-ft/yr entitlement recognized under contract for GCID is inclusive of their entitlement recognized under their Angle Decree rights, which, on average, yield about 15,000 to 18,000 ac-ft/yr. This negotiated agreement will remain in effect until March 31, 2004. Under the terms of a separate wheeling agreement with USBR, GCID can request to receive a portion of its entitlement water through the Tehama-Colusa Canal via two points on interconnections with the Tehama-Colusa Canal. The use of the Tehama-Colusa Canal for delivery of entitlement water is subject to available capacity as determined by USBR.

Contract No. 0855A does not limit GCID from diverting water for beneficial use during the months of November through March, to the extent authorized under California law. GCID has recently obtained a water right permit for non-contract period diversions in the amount of 182,900 ac-ft (up to 1,200 cfs). Although some pre-irrigation occurs within the District, non-contract period diversions are predominantly used for rice straw decomposition and waterfowl habitat. GCID also holds water rights to divert from a number of small tributaries to the Sacramento River, including Hunters Creek (2 cfs), an unnamed stream tributary to Funks Creek (2 cfs), Stone Corral Creek (11 cfs), and Colusa Basin Drain (134 cfs).

Reuse and Recirculation

As mentioned above, an aggressive drainwater recapture program, which includes both groundwater seepage and tailwater runoff from cultivated fields from within GCID's service area, is a part of GCID's overall water management program. GCID recaptures this water with both gravity and pump systems. Recaptured water is delivered to either laterals or the main canal for reuse by both in-District and out-of-District users. It is estimated that GCID currently recycles approximately 155,000 ac-ft annually.

Much of GCID's drainwater is captured for use by downstream districts such as the Provident Irrigation District (PID), Princeton-Codora-Glenn Irrigation District (PCGID), and Maxwell Irrigation District (MID). GCID is one of the irrigation districts that signed the Five Party agreement of June 2, 1956. This agreement represents a cooperative effort by GCID, PID, PCGID, MID, and two entities that have since dissolved (Compton-Delevan Irrigation District and Jaciento Irrigation District) to share operation and maintenance of the drains within their respective service areas and to share the right to recirculate the water in those drains. In addition, Colusa Basin Drain Mutual Water Company members (57,000 acres, gross) rely on tailwater from GCID and other upstream water users.

Groundwater

Approximately 200 privately owned wells are located within the District's boundaries. GCID operates one well with an approximate capacity of 10 cfs. Groundwater has been placed to greater use since Endangered Species Act (ESA) restrictions on GCID in the early 1990's. While historical records of groundwater pumping are not available district-wide, the California Department of Water Resources estimated that in 1993 approximately 4,200 acres were irrigated with 17,000 acre-feet of groundwater. This is believed to be representative of total independent private pumping throughout GCID in any given year aside from district-sponsored programs such as the voluntary groundwater conjunctive water management program discussed below. A description of the regional hydrogeology of the area is provided in Technical Memorandum #3 *(to be provided).*

In recent years, the District has supplemented its surface water supplies with groundwater from local production wells. It has accomplished this with a voluntary conjunctive water management program. This District-managed program involved more than 100 private landowners that were reimbursed by the District per acre-foot contributed to GCID's supply. The program has contributed up to an estimated 72,000 ac-ft in a single year (1992) in response to reductions in surface water supply.

Water Source Preferences

The circumstances associated with the Districts' Sacramento River entitlement, particularly the seniority and size of the water right, make it the preferred and primary source. Rather than developing and depending upon alternative supplemental sources, the District has emphasized the development of programs designed to make the best use of this source, programs such as those described previously.

Drainwater recovery and reuse is an important source of water to farmers within and outside GCID. Although not a new source of water, reuse of drainwater allows water users to manage the timing and quantity of water delivered, providing flexibility and maximizing water use efficiency in the area. The District has, and continues to, augment its drainage system to enable recovery of tailwater for reuse. In terms of relative costs, it tends to be the cheapest alternative to the Sacramento River entitlement. Continued expansion of drainwater recovery capabilities within the District may occur at the expense of impacting downstream users and must be carefully considered to avoid conflict. There is also a potential for salinity buildup on fields due to drainwater reuse, and the potential impacts on crop yields must be assessed.

The production of groundwater for local use by privately owned wells, either independent or in coordination with District operations, is the next most cost-effective option. Independently produced groundwater tends to be very small, less than 3% of total supply, and the pattern of this use has not changed significantly in recent years. The reasons for a farmer's preference to augment their surface water supply with groundwater vary. The most common reason is to accommodate crops susceptible to temperature and water quality changes. Supplies originating from the Sacramento River would tend to exhibit wider ranges seasonally as compared to groundwater. Groundwater produced as part of the District-managed conjunctive water management program has been a cost-effective tool in terms of offsetting reduced surface water supplies, as discussed previously. In more recent years the District-managed program has been used to help meet water needs outside of the District. The compensation for this water made to the District and its growers has enhanced the affordability and reliability of the District's supplies.

Water conservation measures such as canal lining, conveyance system automation, district-level water measurement, farm-level metering, precision farming techniques, and other irrigation technology improvements have been used effectively within GCID in last decade to improve water use efficiency and reduce diversions in times of shortage. Within the last decade, District diversions have been reduced as much as 25 percent (increased drainwater recovery and reuse also contributed to this savings). However, water conservation measures are typically the most expensive options and can be in conflict with the regional water management characteristics of the area. The hydrologic characteristics of the region GCID lies within, the Colusa Basin, can be described as a "flow-through" system, in that the vast majority of the water not consumptively used returns to drains and is rediverted by others, percolates into the ground and potentially pumped by others, or returns to the river and is reused downstream. Therefore, the actions of an upstream district such as GCID can have a considerable effect on downstream areas. Currently, GCID is participating, along with other Sacramento River Settlement Contractors and the U.S. Bureau of Reclamation, in a study to assess the potential for improved water measurement. The primary objective of this study is to identify the potential benefits of improved district-level and sub-basin-level water measurement and the potential issues and impacts that might arise.

Historical Water Demands and Supplies (1970 – 2000)

A water balance analysis was prepared for GCID for the period 1970 through 2000 as a means of understanding historical water demands and supplies, irrigation efficiency, and the relationship between District operations and regional hydrology (*Technical Memorandum #3 discusses the water balance in detail and will be provided later*). The primary purpose in developing the historical water balances is to provide a factual basis for forecasting future cropping patterns and water demands under the Baseline Condition and project alternatives. The water balance was developed for the Glenn County-portion of GCID only because of its close linkage to the proposed SCF Conjunctive Water Management Program area.

Cropping Pattern (Historical)

The total land area within GCID-Glenn County (Subunit 3) is 72,643 acres, with the cropped area ranging between roughly 32,000 acres and 60,000 acres over the 1970 to 2000 period (**Figure 2-11**). Rice is the predominant crop, accounting for approximately 85 percent of the District's irrigated acreage. Other important crops include tomatoes, orchards, vineseeds, cotton, alfalfa, and irrigated pasture.

Although the irrigated area varies considerably from year to year, there appears to have been an overall expansion in irrigated area over the period, with the irrigated area holding more or less constant at about 55,000 acres over recent years. The expansion in irrigated acreage is explained almost entirely by an increase in the dominance of rice, which increased in acreage from about 24,000 acres initially to 48,000 acres throughout most on the 1990s. Over the same period, the combined area of non-rice crops has remained essentially constant at 10,000 to 12,000 acres, while other non-cropped land uses declined in area by about 20,000 acres.

Water Demands and Supplies (Historical)

The GCID annual diversions are bimodal, a reflection of the cultural practices of growing rice. Near the beginning of the irrigation season when farmers are flooding their rice fields, beginning in the spring months, the District typically relies upon their entire allotted monthly contractual amounts. This need for water typically peaks during the hot, dry summer month of July, during which time maximum monthly diversions usually occur. This pattern is followed by a gradual decrease in diversions until later in the year when a much smaller peak occurs in the fall. This last peak is again a result of farmers flooding their rice fields, this time post-harvest for straw decomposition.

Historically, GCID has used all of its Base Supply and diverted a majority of their Project Supply. In 1981 and 1984, GCID purchased additional CVP water above the 105,000 ac-ft amount provided for in the contract. During the critical months, GCID diverted CVP water every year from 1964 to 1997, as shown on **Figure 2-12**.

The water demands were met primarily through District surface water with small supplemental amounts of private pumping (**Figure 2-13**). The water supplies are consistently composed of 97% District surface water and 3% private pumping throughout the period of record. Historical surface water supplies estimate for the Glenn County portion of GCID ranged from 292 taf to 507 taf per year, averaging 416 taf per year. Estimated private pumping ranged from 0 to 31 taf per year, with an average of 10 taf per year.

Regional Perspective

The water balance analysis indicates GCID is an area of recharge over the period of record from 1970 to 2000, meaning deep percolation from the combination of applied water and precipitation exceeded groundwater pumping. Net extractions ranged from roughly -111 taf to -277 taf per year and averaged roughly -188 taf or -2.6 AF/acre per year. Variability in net extractions can be mainly attributed to variability in annual rainfall (**Figure 2-14**). It is not surprising to see such large net recharge given the

large proportion of surface water supply available to the District. Even during critically dry years when the District surface water supply is reduced 25%, such a 1992, net recharge remains significant.

Baseline Condition (2025)

The assumptions used to shape the Baseline Condition for GCID are discussed below, followed by discussion of the implication of the assumed conditions to future GCID water demands and supplies.

Baseline Assumptions

1. Ongoing contract renewal efforts associated with GCID's Sacramento River supplies will likely result in similar contract entitlements. The renewed contract is also expected to include better provisions with regards to water transfers allowing for more flexibility. For the purposes of the feasibility investigation it is assumed that the renewed contract in its current form will be renegotiated and in place. For the purposes of defining GCID's baseline conditions, it is assumed GCID renews its settlement contract for 720,000 acre-feet of Base Supply and 105,000 acre-feet of Project Water Supply, totaling 825,000 acre-feet annually.

2. It is also assumed that GCID will continue to recover drainwater from district drains to generate supplies for local water supply reliability, especially in 75% supply years. Drainwater recapture is assumed to occur at levels similar to recent historical conditions. For the purposes of this investigation, the range of drainwater recapture is assumed to be between 25,000 acre-feet and 200,000 acre-feet per year.

3. Groundwater production for local use is expected to occur similar to recent historical conditions, and is assumed to meet all remaining unmet demands.

4. Outside of a potential SCF partnership, GCID will take measures to ensure local water supply reliability and to generate financial revenues to ensure affordability of surface water supplies to District water users, and to finance system modernization. The underlying strategy is to protect the District's water rights by maintaining a substantial base of surface water users. Groundwater substitution programs to support potential water transfers outside of the district are expected to continue and possibly expand in the future. This is the subject of further discussion under the Solo Alternatives section below.

5. GCID has one district-specific action that is included in the Baseline Condition. As part of the Sacramento Valley Water Management Agreement (i.e. Phase 8 settlement agreement) GCID has agreed to implement a groundwater substitution program. Environmental documentation and related efforts are underway to implement this and other related programs for other parties to the SWVMA. For this reason, the Baseline Condition for the SCF Feasibility Investigation assumes GCID's SVWMP project will be in place.

   As part of the SVWMP, GCID plans to transfer up to 30,000 acre-feet of water in below normal, dry, and critically dry years. The transfer water would be made available through the substitution of surface water, under the District's pre-1914 water right, for groundwater pumped within the District. It is assumed the transfer water would be regulated in and released from the Bureau of Reclamation's Shasta Lake, and would flow through the Sacramento River and then to the Delta. Transfer water reaching the Delta would be available for salinity and water quality control within the Delta, or for export to users within the SWP or CVP service areas.

   GCID will implement similar management and operational schemes used successfully in recent years to support similar groundwater substitution programs. For example, in June and July 2001, private well pumpers participated in producing 33,000 ac-ft of supply as part of the 2001 Water Forbearance Program executed between GCID, Bureau of Reclamation, and Westland's Water District. Facility

operations are assumed to include full utilization of the network of existing private landowner wells that have contracted with the District in past conjunctive use programs. The project components are summarized in **Table 2-3**.

Table 2-3: GCID Groundwater Substitution Program Components for 30,000 ac-ft SVWMP (Phase 8)

COMPONENT	DESCRIPTION/ASSUMPTION
Yield (ac-ft/yr)	30,000
Frequency	Below Normal, Dry and Critically Dry Year types (a)
Pumping Zone	Tehama Formation
Potential Recipients	Water users participating in DWR's Dry Year Water Purchase Program Environmental needs. CVP water users.
Surface Water Source	GCID's pre-1914 appropriative water rights on the Sacramento River.
Delivery Pattern	Irrigation pattern, June through October.
Pumping Location	Pumping will occur within the 175,000 acreage of GCID with approximately 80% in Glenn County and 20% in Colusa County. The precise location of wells would depend upon landowner participation. GCID estimates 100 to 115 wells would participate, approximately 85% diesel and 15% electric.
(a) Water year classification based on the Sacramento Valley Index.	

Cropping Pattern (Baseline)

By 2025, it is anticipated that the total (*net*) irrigated area within GCID (Subunit 3) will be 57,593 acres (**Figure 2-15**). Review of trends in recent historical crop acreage distributions in GCID suggest rice will continue to be the predominant crop in the future with small shifts towards higher value, more permanent crops and small reductions in lower valued crops, such as field and pasture crops. The non-cropped land area would remain virtually unchanged relative to recent observed conditions, suggesting negligible overall change in the total irrigated area within GCID (Subunit 3).

Water Demands & Supplies (Baseline)

For the feasibility investigation it is assumed that GCID's settlement contract will be renewed according to the conditions discussed above. For this reason it is not expected that the availability of GCID's Sacramento River water supply will change significantly.

Projected water demands for GCID are anticipated to remain relatively the same as current conditions (Sacramento River Basinwide Water Management Plan, Sep. 2002). The average historical demand for GCID-Glenn County based on the water balance analysis was estimated at 427 taf annually. The average of the estimated projected baseline demand is 450 taf over the same period of record. This is an estimated increase of approximately 5% on average. The difference is primarily attributable to a small assumed increase in rice and permanent crop acreage represented under the baseline condition as compared to recent historical conditions.

Discussion

Relative to existing conditions, the main change under the assumed Baseline Condition would be an increase in groundwater pumping in conjunction with the Phase 8 30 TAF per annum groundwater substitution program. From a regional hydrology perspective, under the Baseline Condition GCID's contribution as a net groundwater recharge area would be diminished as a result of this activity.

(Note: need a graph or table to illustrate this change.)

GROUNDWATER ONLY AREAS (SUBUNITS 4-7)

Background

[to be completed after review of this initial draft document]

Cropping Pattern (Historical)

The Ground Water only areas, Subunits 4-7 encompass 74,965 acres. The irrigated area has remained more or less constant from 1970 to 2000 ranging from 40,000 acres during the drought years of 1976 and 1977 to 55,000 acres with and average of 49,000 acres (**Figure 2-16**). A major trend displays steady increases in permanent crops offset by decreases in pasture and idle lands throughout the areas. Permanent crops have increased from 6,000 acres in 1970 to 20,000 acres in 2000. Pasture has decrease from 22,500 acres in 1970 to 13,000 acres in 2000. Other non-cropped land uses including idle lands have declined by roughly 5,000 acres. Field crop acreage has varied considerable from year to year ranging from 15,000 to 28,000 acres and averaging 20,000 acres; however there appears to be no increasing or decreasing trends. Rice acreages have remained relatively constant averaging roughly 900 acres.

Water Demands and Supplies (Historical)

The Ground Water only areas water demand components are (crop) ET of applied water and farm losses (**Figure 2-17a**). They have ranged from a low of 105 taf in 1998 to a high of 182 taf in 1994, the median year occurring in 1999 at 152 taf. The variation is directly related to variation in spring rain, 1998 had large quantities of spring rain while 1994 had relatively low quantities of spring rain. ET of Applied Water on average comprises approximately 70% of the water demand, while Farm Losses are 30% of the water demand. The only source of water supply is Private Pumping (**Figure 2-17b**).

Regional Perspective

The Groundwater only areas are net extractors averaging 49 taf or 0.62 AF per acre per year for the 1970 to 2000 period (**Figure 2-18**). Over this period there were four years (1973, 1983, 1995, and 1998) when these areas had net annual recharge to the Groundwater System cause by record high annual rainfalls leading to high levels of Deep Percolation of Precipitation.

Baseline Water Supplies and Demands (2025)

[to be completed after review of this initial draft document]

[see Figure 2-19 and 2-20]

SECTION 3. DESCRIPTION OF PROJECT ALTERNATIVES

INTRODUCTION

At the outset of this Feasibility Investigation, the expectation was that the project alternatives would involve some degree of actual sharing of physical resources between or among the Partners to implement the groundwater recharge and recovery cycles of a conjunctive water management program. However, as the hydrogeology of the Project Area became better defined, primarily by virtue of the efforts of the DWR Northern District, it became evident that the opportunities for conjunctive water management were more likely to involve independent actions pursued by each Partner and not actual, physical sharing of resources. The factors contributing to this outcome were discussed previously; briefly restated, the two primary contributing factors are:

The fact that groundwater system is essentially full, meaning that additional groundwater recharge is not needed or effective for implementing conjunctive water management *at this time.* The new source of water represented by the Lower Tuscan aquifer, which is believed to be substantial in quantity and developable at low cost, supplants the value of cooperative action, at least in the context of achieving local water supply reliability objectives.

In view of these conditions, primary emphasis was placed on developing a Solo Alternative comprised of the physical actions that the individual Partners were most likely to take to meet their respective objectives, but planned and conducted in a coordinated manner, with certain administrative and institutional functions served by the Partnership. Collaborative alternatives based on actual physical sharing of resources were also investigated. Both the Solo Alternative and the collaborative alternatives are described in the section.

SOLO ALTERNATIVE

As mentioned above, the Solo Alternative is comprised of the physical actions that each Partner would most likely take to pursue its individual objectives, combined with certain common administrative and institutional functions served by the Partnership. The physical actions that would be undertaken by each Partner represent the conjunctive water management program that best achieves that Partner's respective individual objectives with its available resources. Although the Partners would operate independently, the individual conjunctive water management programs comprising the Solo Alternative were formulated in a coordinated, integrated manner, particularly concerning potential effects on the groundwater system.

The administrative and institutional functions that would be performed by the Partnership include *monitoring* of groundwater conditions to ensure compliance with County BMO's and possibly other standards, *marketing* of water generated by the individual Partners and *environmental compliance*.

The individual conjunctive water management programs and the Partnership's administrative functions comprising the Solo Alternative are described below.

Orland Unit Water Users Association

Background

The goals of the OUWUA are to protect the Association's water rights by maintaining a substantial base of surface water users and to manage the water resource for local and state benefit. Maintaining a substantial base of surface water users could be achieved by transitioning from the Association's existing rotation delivery service to a more flexible, responsive water delivery service. Such an improvement in water delivery would allow the Association to better provide for the irrigation needs of its members,

particularly to those with relatively smaller parcels of land. A portion of the capital required for such an investment could be generated by contributing to the state's water shortages via voluntary transfers of water.

The SCF pursued two types of solo alternatives for the OUWUA. In addition to analyzing groundwater substitution transfers, as was done for the other two partners, the SCF investigation also analyzed the potential for the OUWUA to generate new yield via reservoir re-operation. Each of these two types of alternatives is discussed below in more detail.

Solo Alternative 1: Groundwater Substitution Transfers

The analysis of groundwater substitution transfers in OUWUA focused on two topics.

- Considerations for the production of the groundwater given the legal status of the Association as a California corporation.
- Conveyance of the forgone surface water down Stony Creek

Each of these two topics is discussed below in turn.

Production of Groundwater

Given the legal status of the OUWUA as a California corporation the ability of the Association to own wells and pump groundwater for distribution throughout its system should undergo a legal review. If the Association can legally own and operate wells for use in a groundwater substitution transfer then the Association needs to determine if it would choose to develop its own wells and/or whether it would rely on members to produce the groundwater.

If the Association is legally precluded from operating wells it owns for a groundwater substitution transfer then production of the groundwater falls to its members. In which case the volume of water available for transfer could depend on the existing capacity of pumping in the basin, and/or the incentives that could be offered members to construct new wells.

The water balance analysis described in the 'Baseline' section of this report estimates that the historical maximum amount of groundwater pumping in OUWUA is 13,000 acre-feet. Assuming this represents the existing groundwater pumping capacity, OUWUA could participate in annual groundwater substitution transfers of up to 13,000 acre feet annually. The capacity of a proposed program could be limited by two factors, namely:

- Not all growers who own the wells would choose to participate in the proposed program.
- Some of the existing pumps, used to produce the water, may not be allowed in the program if there are restrictions placed on the use of diesel pumps due to air quality constraints.

For purposes of evaluating this alternative it is assumed that 10,000 af could be transferred in any one year. The volume of a potential transfer will be more clearer understood during the development of the Groundwater Production Element Study.

The revenue generated by the proposed transfer would be used to compensate the members participating in the program that normally use surface water, for pumping groundwater. The remainder of the revenue, net of costs is, available for distribution to the Association and the members. The distribution of the net revenue would be based on a negotiation between participating members and the Association. **Table 3-1** shows per af net revenue available from a transfer. The transfer prices shown in **Table 3-1** reflect those used in the Sacramento Valley Water Management Plan, Short-Term Agreement. Pumping costs are an estimate, and could vary.

Table 3-1
Per Acre Foot Revenue and Costs of Groundwater Substitution by Year Type

Transfer Component	Year Type			
	Wet to Above Normal	Below Normal	Dry	Critical
Price	$50	$75	$100	$125
Pumping Cost	$20	$20	$20	$20
Net Revenue	$30	$55	$80	$105

Figure 3-1 shows the exceedance probability of the present value of the net revenue of a groundwater substitution transfer over 25 years. The figure shows the value of transferring 10,000 af in dry years and critical years and the value of transferring 10,000 af in below normal, dry and critical years. The dry year and critical year transfer has a 50 percent exceedance value of approximately $5.5 million. The average annual transfer volume over the 25 year project is 4,000 af. The transfer that occurs in above normal, dry and critical years has a 50 percent exceedance value of just over $9.0 million over 25 years. The average annual transfer volume when water is transferred in below normal, dry and critical years is 5,900 af.

Figure 3-2 shows the *annual* net revenue for the same information presented in **Figure 3-1**. The annual net revenue generated by a transfer is $550 thousand, $800 thousand and $1,050 thousand in below normal, dry and critical years, respectively. The frequency of the transfers is based on the Sacramento Valley River Year-type Index for the period from 1922 to 1994.

Facts to help generalize the information presented in **Figure 3-1** and **Figure 3-2**:

- The net revenue may not be available only to the Association. In the past some local districts that have participated in groundwater substitution transfers have paid members who pump between approximately 60 percent and 90 percent of the transfer price.
- The information presented in **Figure 3-1** and **Figure 3-2** is scalable, e.g. to estimate a transfer of 20,000 af in each specified year type multiple the estimates of net revenue and net present value times 2. To estimate the value to distributing the net revenue between the pumping-members and the Association multiple the estimates of net revenue by an appropriate factor.

Figure 3-3 provides a conceptual view of how to estimate the change in storage in the aquifer as a result of a groundwater substitution transfer of 10,000 af in dry and critical years. The natural recharge rate for the aquifer is not known with certainty. **Figure 3-3** shows three different estimates of the change in storage volume under three different estimates of natural recharge rates; 10,000 af per year, 7,500 af per year and 5,000 af per year. If the natural recharge rate were 5,000 af an the estimated change is storage over the hydrologic trace ranges from negative 70,000 acre feet to positive 15,000 acre feet. Likewise, the change in storage when recharge rates are estimated to be 7,500 af per year and 10,000 af per year show similar reductions in storage and relatively higher increases. In all likelihood the increases in storage volume represented by the conceptual drawing would not be as high as they are shown because at some storage level the basin rejects recharge because it is full when the transfers began. **Figure 3-3** is intended to provide an intuitive understanding of how modest groundwater substitution transfers that occur in only the two most dry year types can have minimal impact on the storage of the basin.

Conveyance of Transfer Water

The last issue to be discussed under this alternative is the potential challenge faced by conveying transferred water down Stony Creek. Recent work by the DWR suggests that Stony Creek is a loosing stream for most of the area between OUWUA Eastern boundary and the Sacramento River. The rate of loss may be a factor in a transfer if the potential buyer of the water believes that the loss rate is too high. One possible solution to this challenge would be to adjust the price (or quantity) of the transfer to reflect the loss. Another possible solution to the challenge that is more advantageous, is to time the transfer to occur when there is already water in Stony Creek. Thus, avoiding or reducing the loss. There may be a

limit to how much timing can be used to avoid the challenge based on the potential buyers needs. The solution would have to be found once more particulars of a potential transfer were know.

Solo Alternative 2: Reservoir Re-operation

The combined storage of East Park and Stony Gorge reservoirs is approximately 100,000 af. To the extent that the reservoirs could be re-operated to put new water in the system OUWUA may have the opportunity to transfer that water. In order to prove-up the availability of new water under a re-operation alternative OUWUA would have to show that it can lower the end of year storage of the reservoirs below the historical levels. Using this method to 'prove-up' the existence of new yield would prove to the potential buyer and participating agencies that the re-operation is 'pushing' water out of the reservoir, essentially spilling water, that would not have otherwise been there but for the transfer.

The steps to proving-up this sort of transfer start by analyzing the historical end of season storage to see if the current operations of the reservoir creates a predictable end of season storage that is nearly always the same. **Figure 3-4** shows the end of month storage for the sum of East Park and Stony Gorge Reservoirs over the hydrologic trace from 1956 through 2003. What can be seen by examining **Figure 3-4** is that there is a wide variance in end of season storage. This variance may prove an obstacle to prove-up that a change in the end of season storage, that would result from a transfer, would not have occurred anyway. It may still be possible to affect a re-operation transfer however much more work would have to go into understanding how the end of season storage for the reservoirs is planned. Since the Stony Creek Fan was an investigation of conjunctive use and how best to utilize the groundwater aquifer, further work on re-operation alternative was determine to be outside the current scope of work. However, OUWUA may benefit from continued investigation of a re-operation.

Solo Alternative 3: Reservoir Reoperation Combined with Conservation

As part of a CALFED study OUWUA examined the possibility of providing new water by investing in system modernization. One of the alternatives of the report entitled, *OUWUA Distribution System Modernization and Water Conservation Project* proposed an investment of $53,499,000 in 'Canal Rehabilitation' thereby conserving 25,400 af annually. One of the stated purposes in the study was examine the ability of OUWUA to transfer this conserved water.

California Water Code §1011 authorizes the transfer of water made available because of "water conservation efforts". However, the State Water Resources Control Board (SWRCB) has clarified the State's position in its 1999 Order WR 99-012 on the petition by Natomas Mutual Water Company to transfer conserved water. The Order states:

> *The SWRCB concludes that, pursuant to Water Code section 1725, Natomas may transfer the right to use the amount of water that Natomas would have consumptively used but for Natomas's conservation efforts. A reduction in diversions that does not reduce consumptive use cannot be transferred pursuant to section 1725.*

For this reason the SCF Investigation feasibility study team recommends that OUWUA does not pursue a transfer of conserved water.

At the same time as the aforementioned report was being completed there was an additionally, CALFED investigated underway that investigated the possibility of increasing yield to the Tehama Colusa Canal via water use efficiency. The document entitled *OUWUA and TCCA Regional Water Use Efficiency Project* describes the findings. The document suggests that re-operating the existing reservoirs on Stony Creek in conjunction with a well field new yield may be available to the region. The document was intended to examine the physical nature of a program and not the legal aspects of water rights.

The SCF study team followed the direction of the CALFED study by examining the potential for OUWUA to create new yield by combining conservation efforts with re-operation. So that rather than

transferring conserved water the OUWUA would be offering to change the pattern of water deliveries to a potential buyer through re-operation. This alternative would face the same challenges in a potential transfer as the challenges faced in Solo Alternative 2, none the less the study team attempted to estimate the volume of water that could be made available by combining conservation with re-operation.

A CALSIM model of the Stony Creek system was obtained from the Bureau and estimates where made of changes to end of year storage from a 25,400 af reduction in irrigation demand. **Table 3-2** shows the results of this modeling effort. The estimated change in end of September storage for the three reservoirs is 15,600 af. The range of changes is from a maximum of 47,200 af to a negative 14,300. The extent to which that OUWUA can transfer any or all of this water is met with the same challenges as described in Solo Alternative 2. It may still be possible to affect a transfer under Solo Alternative 3 however much more work would have to go into understanding how the end of season storage for the reservoirs is planned and how the revenue necessary to generate the conservation could be raised.

Table 3-2
Change in End of September Storage Statistics

	East Park	Stony Gorge	Black Butte	Total
Average	4.9	4.1	6.7	15.6
Maximum	17.6	11.1	18.5	47.2
Minimum	-5.5	-3.0	-5.9	-14.3

In summary, it appears that the OUWUA has multiple alternatives available to them both for re-operation and groundwater substitution transfers. The conclusion of this analysis is that the alternative that presents the fewest challenges for 'proving-up' a transfer, and the least cost is the groundwater substitution transfer.

General Issues for OUWUA Alternatives

As a nonprofit corporation OUWUA is limited in the amount of revenue that can be generated from other than their specified non-profit purpose. For example, if a nonprofit corporation engages in profit-making activities unrelated to its recognized nonprofit purpose, it must set up a separate corporation to engage in that activity or risk losing its nonprofit, or tax exempt, status, or pay tax on the revenue. The OUWUA is limited to only earn 15% of total revenue from activities such as water transfers without facing taxation. The OUWUA may want to consider what legal structure serve, it best under future operations.

Orland-Artois Water District

Under Baseline Conditions, it was shown that OAWD's 2025-level water demands would increase relative to existing demands, while the availability of surface water supplies under its CVP contract and through short-term water would decrease. The effect would be that OAWD landowners would need to pump substantially more groundwater from the Tehama Formation than has ever been pumped historically, which may not be sustainable. These conditions compel the District to take positive measures to fulfill its fundamental mission of providing reliable, affordable water supplies to its landowners. These measures, discussed below, comprise the District's Solo Alternative.

- District Development of Lower Tuscan Groundwater – District-sponsored development of groundwater drawn from the Lower Tuscan Formation. The Lower Tuscan is generally regarded as being separate from the overlying Tehama and Stony Creek formations, thus representing a new, essentially undeveloped water supply source. The District's plan would be to develop sufficient

capacity from the Lower Tuscan so that, combined with available surface water supplies, the resulting magnitude of private pumping from the Tehama Formation would be sustainable.

- Pricing Incentives – Provision of pricing incentives that encourage growers to use District CVP surface water supplies and District-produced groundwater in favor of privately produced groundwater. This means that the blended cost of District water supplies (CVP surface water and District-produced groundwater) must be maintained below the cost of private groundwater production. With this incentive, landowners would use District water supplies to exhaustion before relying on their own wells, thereby limiting extractions from the Tehama to sustainable levels.
- Strategic Marketing of CVP Supplies – Marketing of modest portions of the District's CVP contract supply, when market conditions are favorable, to generate revenues as needed to implement the pricing incentives described above.

District Development of Lower Tuscan Groundwater

As described under the Baseline Condition, the expected long-term yield of the District's CVP supply is about 27 taf annually. In addition, based on historical observations and experience, the District believes that the safe yield from the Tehama formation, the source of most private pumping, is about 30 taf annually. Thus, currently available supplies total to just 57 taf annually on average, or about 33 taf short of OAWD's projected long-term average water demand of 90 taf. To fill this shortage, the District has embarked on a program to develop additional groundwater supplies from the Lower Tuscan Formation.

The District completed a 1,520-foot test hole into the Lower Tuscan in late 2003. The e-log results were promising, so the District is proceeding with construction of a 1,320-foot production well, which reportedly will be the deepest groundwater well yet to be constructed in the Sacramento Valley. Interpretation of the e-log by DWR Northern District staff indicates that the well should produce at the rate of approximately 3,000 gpm (6.7 cfs). The well will be located strategically to tie into the existing Lateral 35.2 at a point where relatively large downstream demands will allow maximum production opportunity each year. Additionally, the selected site has electrical power available nearby, so the pump can be electrically driven. (Cost estimates reveal that at current rates diesel is marginally less expensive than electricity for powering groundwater wells, neglecting powerline extension costs. However, concerns about emerging air quality regulations that could apply to diesel engines lead to an overall preference for electrical energy.) Operations studies conducted by the District indicate that the well should be able to produce up to 3,300 af annually, depending on the magnitude and distribution of demand.

The cost of the Lower Tuscan well is estimated to be $230,000 *(need to confirm this with OAWD staff)*, complete with pump, motor, controls, inter-tie to the existing distribution system, and SCADA improvements to enable automatic operation and remote monitoring and control override. The annual cost of the well is estimated to be $48,000, including $13,600 in capital recovery, $3,300 in annual O&M and $31,100 in annual energy charges. Thus, the cost of water produced by the well will be about $15/af, which is lower than the cost of the District's CVP supply and privately-produced groundwater. The District is planning to monitor groundwater conditions as the first well is operated, and to construct additional wells to the extent that the Lower Tuscan system can accommodate additional development. Ultimately, the District would install about 10 wells to achieve the targeted 33 taf of annual production capacity. Studies conducted by the District indicate that the unit water cost should not change appreciably as additional wells are constructed and production capacity is scaled up.

The quality of the Lower Tuscan water is reportedly very good. Coming from deep aquifers, it is anticipated to have a year-round temperature of 70 to 74 degrees F. This relatively high temperature will provide benefits to rice farmers and growers who apply water for frost control purposes.

Pricing Incentives

To achieve sustainable conjunctive water management, OAWD needs to ensure that use of available District surface water and groundwater supplies is maximized, so that GW extractions from the Tehama Formation by landowners are minimized. (This strategy also benefits other pumpers drawing from the Tehama Formation, which includes nearly all neighboring independent pumpers.) However, this priority of use will not occur naturally, because District supplies are generally more costly than privately-produced groundwater. To achieve the desired use priority, the District intends to use pricing incentives. Neglecting intangible factors that influence landowners' water source preference, the blended per acre-foot cost of surface water and groundwater delivered by the District must be less than the per acre-foot cost of privately produced groundwater. Under projected average water supplies and present pricing conditions, the total subsidy would be $282,000 on average, or $4.70 per acre-foot for the 30,000 acre-feet pumped by landowners on long-term average (Table ___) *(table not yet developed)*. This amount would vary between $66,000 and $402,000 annually, depending on the amount of CVP water available each year. Because CVP is the most expensive of the three available sources, the maximum subsidy would be needed in full CVP water supply years and the minimum in years of zero CVP supply.

The effect of the subsidy would be to maintain the effective price of District water equal to the price of groundwater, or about $16 per af under existing conditions. In practice, the subsidy would require occasional "tuning" to achieve the intended result, because of changes in relative water costs and to account for intangible factors that are also reflected in landowners water source preferences. In particular, the subsidy would have to be increased if CVP water costs increase as expected.

The revenues needed to implement the price subsidies would be derived from the sale of modest proportions of available District CVP water supplies, as described in the following section.

Strategic Marketing of CVP Supplies

As a water-short district, the District Board is philosophically opposed to transfers of water out of the basin before in-basin needs are first satisfied. However, the Board has taken the position that marketing a portion of its CVP supply is justified if it enables a net expansion or ensures affordability of its total water supply. In this context, the District plans to market CVP water in selected years, when water prices are high and significant revenue can be generated from the sale of modest volumes of water. The anticipated sales of CVP water would be conducted pursuant to the water transfer provisions of the CVPIA. Key provisions of the CVPIA as they relate to the planned transfer/sale of CVP contract supplies by OAWD are listed below.

1. Transfers are effectively limited to other CVP contractors, because water transferred to non-CVP contractors must be repaid at the greater of the full cost or cost of service rates.
2. The water available for transfer is limited to the water that would have been consumptively used or irretrievably lost to beneficial use during the year or years of the transfer (*unless* the transfer is to another CVP contractor located within the county or area of origin, in which case the full unused volume may be transferred).

Considering these factors, and given the objective to seek out high prices, logical transfer partners north of the Delta would be the federal wildlife refuges and south would be water-short CVP contractors, such as Westlands, San Benito County and Santa Clara County Water Districts.

A number of water marketing strategies were tested using a monthly operations model developed specifically for OAWD. The model operates with the long-term demands presented earlier, and allows the user to input certain parameters, priorities and constraints. The following parameters were input for a series of runs aimed at testing various market strategies:

1. The District's CVP contract would yield the annual percentages discussed previously under the Baseline Condition.
2. The District must reserve a minimum of 5,300 af annually of its CVP supply to meet water demands an lands that do not have access to groundwater, located primarily on the west side of the District.
3. The District's groundwater pumping capacity from the Lower Tuscan Formation is 33 taf annually.

The water marketing strategies tested are distinguished primarily by the different percentages of CVP contract supply that would be marketed in different year types, ranging from marketing modest amounts of water in dry years only to marketing appreciable amounts of water in D, BN and AN years. This progression generally maintains the highest possible price per acre-foot of water sold as the marketed volume increases (**Table 3-3**). Despite the fact that the highest price occurs in CD years, OAWD does not contemplate marketing water in those years, to ensure that the small amount of CVP water available under contract to the District is available to landowners in areas without groundwater.

Table 3-3. OAWD Water Marketing Scenarios

Scenario	Volume Marketed (AF)			Remaining CVP Water Available (AF)	Revenue Generated ($)	
	Min	Max	Average		Average Total	Average $/AF)
Base Case (No Marketing)	0	0	0	26,863	$0	$0
1: (25%D)	0	3,313	726	26,137	$72,603	$100
2:(50%D)	0	6,625	1,452	25,411	$145,205	$100
3: (20%D; 20%BN)	0	5,300	1,597	25,266	$134,315	$84
4: (50%D; 50%BN)	0	13,250	3,993	22,870	$335,788	$84
5: (50%D; 50%BN; 50%AN)	0	21,200	6,897	19,966	$480,993	$70

Scenario 1 looks at marketing 25% of available CVP supplies in D years only. The volume marketed in any particular year would range between 0 and 3,313 af, averaging 726 afy and preserving 26,137 afy of CVP supply for in-District uses. All water would be sold at the assumed D year price of $100 per af, generating revenues of about $73,000.

Scenario 2 is identical to Scenario 1, except that the D year percentage is increased from 25% to 50%, doubling the maximum and average marketed volumes as well as the average transfer revenue. The amount of CVP water retained for in-District uses would decrease slightly to 25,411 afy.

Scenario 3 involves marketing 20% of available CVP supplies in D and BN years. The volume marketed in any particular year would range between 0 and 5,300 afy, averaging 1,597 afy. The volume of CVP water remaining available for in-District uses would be 25,266 afy on average. The average price received for marketed water would be $84 per af.

Scenario 4 is identical to Scenario 3, except that the D and BN year percentages are increased from 20% to 50%, increasing the maximum year marketed volume to 13,250 af and the average marketed volume to

nearly 4,000 afy. The average market revenue increases to nearly $336,000, while the price per af remains at $84. The average volume of CVP supply retained for in-District uses falls to 22,870 afy.

Scenario 5 is the most aggressive strategy evaluated; it looks at marketing 50% in D, BN and AN years. The maximum marketed volume would be 21,200 afy in AN year types, and the average marketed volume would be nearly 6,900 afy. The average price received would be $70 per af, earning the District an average of just over $480,000. About 20,000 afy would be retained for in-District uses.

A summary of these results is shown in **Figure 3-5**, which shows a plot of market revenues in relation to market volume. It can be seen that the District would need to market roughly 3,200 afy on average to generate the $282,000 of revenue needed to subsidize District water supplies. The average price received at this level of market participation, subject to the strategies laid out above, would be roughly $88 per af. It should be noted that this analysis neglects water transfer transaction costs, such as would be needed for environmental documentation, monitoring and meeting other possible requirements.

Glenn-Colusa Irrigation District

Outside of a potential SCF partnership, GCID will take measures to ensure local water supply reliability and to generate financial revenues to ensure affordability of surface water supplies to District water users, and to finance system modernization. As an example of the measures being taken to support this strategy, GCID is developing a water transfer project in support of the Sacramento Valley Water Management Program (SVWMP). (This measure is include in GCID's Baseline Condition and is described above.) GCID may also pursue strategic water transfers above those dedicated to the SVWMP. These additional transfers are what define GCID's Solo Alternative. The features of GCID's Solo Alternative are summarized below, and discussed in the following sections.

Solo Alternative: Groundwater Substitution Transfers

As described under the Plan Formulation, a greater understanding of the physical behavior of the basin indicates that the basin is more resilient than originally thought and that direct recharge through artificial spreading facilities does not significantly enhance basin yield. In consideration of these findings, GCID's Solo Alternative is designed to explore the District's ability to implement transfers of Base Supply water made available through groundwater substitution.

The groundwater substitution-based strategies initially tested for the GCID Solo Alternative were distinguished by the frequency of the annual water transfer, and by the groundwater production scheme. Each of these topics is discussed below.

Source and Frequency of Transfer Water

The source of the transfer water made available under the groundwater substitution program would be GCID's pre-1914 appropriative water rights on the Sacramento River, referred to as Base Supply under GCID's Sacramento River Settlement Contract with the United States Bureau of Reclamation (Reclamation) (Contract No. 14-06-200-855A). The transfer water would be delivered on a pattern similar to that which GCID would have required for irrigation. The water will stay in the river for export to potential customers downstream. For the purposes of this analysis it is assumed that upstream reservoirs (i.e. Oroville or Shasta) will account for this transfer water and will manage these reservoirs to assure releases occur at times when exports south of the Delta could be made.

The transfer water will be made available in below normal (BN), Dry (D), and critically dry (CD) year types. For purposes of exploring the differences, economically and hydrologically, of reducing the frequency of the water transfer, a variation of the groundwater substitution program is to make transfer water available in D and CD years only.

Production of Groundwater

As described in the Existing and Baseline Condition discussions, GCID has pumped groundwater in conjunction with groundwater substitution-based programs with no long-term changes to the groundwater basin. For the purposes of developing GCID's Solo Alternative, similar management and operational schemes used successfully in recent years are also assumed for this evaluation.

Based on review of past pumping programs, GCID's Solo Alternative assumes that 90,000 af could be produced in a given water transfer year. The initial analysis assumes that the entire 90,000 af will be produced by private well pumpers. The location of groundwater wells is assumed to be the 200 approximate privately owned wells, of which roughly 80% are located in Glenn County and 20% are located in Colusa County. The degree of certainty to which these well owners would all participate is unknown. In addition, analysis of past programs indicates that average production of participating wells is approximately 500 af per year per well; 200 wells would produce, then, 100,000 af/yr which is 20,000 af/yr short of the assumed 90,000 af/yr (Solo Alternative) plus 30,000 af/yr (GCID SVWMP included in the Baseline Condition). For the feasibility investigation, it is assumed that 240 privately-owned wells would participate. The level of actual participation and potential production capacity per well will be the subject of detailed examination as part of the Groundwater Production Element investigation. During this investigation emerging air quality regulations that could apply to diesel engines used to drive agricultural wells will also be given additional consideration, given that approximately 85% of the privately owned wells within GCID are diesel driven.

Recognizing the above concerns and in light of the developments regarding the potential viability of utilizing the Lower Tuscan Formation as a "new" supply source, a variation of the GCID Solo Alternative is to utilize District-developed wells in this formation. Recent explorations of this formation by others in the region, including OAWD, indicate the cost of water produced by wells tapping this resource can be as low as $15/af (see OAWD Solo Alternative discussion). Selecting sites strategically to tie into existing conveyance facilities is critical to allow for proper distribution of water produced. Furthermore, sites located where electric power is nearby could provide advantages in terms of emerging air quality regulations mentioned previously. However, stand-by charges associated with PG&E power supplies can also be cost-prohibitive. These issues will be further addressed as part of the subsequent alternatives evaluation (to be completed following review of this document) and also as part of the Groundwater Production Element investigation.

Groundwater Substitution Transfer Scenarios

The groundwater substitution scenarios considered for GCID are summarized in **Table 3-4**, and described briefly below.

Scenario 1 considers transferring 90,000 af/yr in BN, D, and CD years. Groundwater pumped in substitution of this transfer would occur from existing private owned wells. **Scenario 2** is identical to Scenario 1, except that transfers only occur in D and CD years. **Scenario 3** is identical to Scenario 1, except that groundwater pumped in substitution of the transfer water would occur from new District-owned wells developed in the Lower Tuscan formation. **Scenario 4** is identical to Scenario 1, except that half of the groundwater pumped in substitution of the transfer water would occur from existing private owned wells and half from new District-owned wells developed in the Lower Tuscan formation.

Table 3-4:
GCID Groundwater Substitution Program Components for Solo Alternative

COMPONENT	DESCRIPTION/ASSUMPTION			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Yield (ac-ft/yr) (a)	90,000	90,000	90,000	90,000
Frequency (b)	BN/D/CD	D/CD	BN/D/CD	BN/D/CD
Pumping Zone	Tehama	Tehama	Lower Tuscan	Tehama and Lower Tuscan
Private or District Owned Wells	Private	Private	District	Both
Well Locations	Depends upon landowner participation. Assume uniform distribution similar to the 200+ wells known to exist.		Adjacent to the Main Canal AND where the Lower Tuscan is present.	Combination of uniform distribution of known wells and District wells along Main Canal.
No. of Wells	240 (c)		40 (d)	120 Private and 20 District
Potential Recipients	• Water users participating in DWR's Dry Year Water Purchase Program • Environmental needs. • CVP water users.			
Surface Water Source	GCID's pre-1914 appropriative water rights on the Sacramento River.			
Delivery Pattern	Irrigation pattern, June through October.			

a) The yield shown for each scenario is the amount above the Phase 8 30,000 ac-ft already include in the GCID Baseline Condition. For each scenario it is assumed the Phase 8 yield is produced in the same manner (same Frequency, Pumping Zone, Wells, etc.) as the 90,000 ac-ft, unless otherwise specified.
b) Water year classification based on the Sacramento Valley Index (Year-type abbreviations: BN=Below Normal; D=Dry; CD=Critically Dry).
c) Assumes 500 AF/Y per privately owned well, based on analysis of past pumping programs which have averaged as high as 581 AF/Y per well (1994). Thus, total capacity of 240 wells equals 120,000 ac-ft.
d) Assumes 3000 AF/Y per District-owned well, based on operations studies conducted by OAWD. Thus, total capacity of 40 wells equals 120,000 ac-ft.

Groundwater modeling analysis (using the GW Model) was conducted to evaluate the effect of the additional groundwater pumping as a result of the 90,000 af/yr transfer program. Locations throughout the study area were identified for review of simulated groundwater levels under Baseline Conditions and the Solo Alternative. Review of simulated well hydrographs indicate the following:

- Under Scenario 1, groundwater levels in and adjacent to the groundwater pumping region within GCID consistently showed declines in groundwater levels relative to Baseline Conditions of between 5 and 10 feet, with a maximum difference of approximately 18 feet in the middle of the pumping area. Simulated groundwater levels showed no long-term decline in groundwater storage.
- Under Scenario 2, groundwater levels responded favorably to the pumping in only D and CD years. Simulated groundwater levels were between 3 and 5 feet less than those under Scenarios 1. Also of particular note is that in areas adjacent to the pumping region, simulated groundwater levels under Scenario 2 returned to near Baseline Condition levels following periods of wetter than normal conditions, before declining below Baseline Condition levels in subsequent D and CD year combinations. This is indicative of a basin that is being replenished by natural recharge under the circumstances.

- Under Scenario 3 and 4, groundwater modeling results were somewhat inconclusive because of the poor hydrogeologic understanding of the Lower Tuscan formation, particularly the understanding of its influence on the groundwater aquifer layers, that compromised the GW Models ability to accurately simulate these conditions. It is expected, however, that groundwater levels in the Tehama formation would decline very little, if at all, because of the information suggesting that the Lower Tuscan formation which is relatively isolated from the Tehama formation due to the presence of the overlying confining layer known as the Upper Tuscan formation.

It should be noted that details of this hydrologic analysis will be presented as part of documentation summarizing the groundwater modeling efforts *(to be provided following review of this document)*. In addition, further economic and financial analysis of GCID's Solo Alternative will be completed for the purposes of completing the alternative evaluation effort for the feasibility investigation final report.

COLLABORATIVE ALTERNATIVES

[to be completed]

Overview of this section

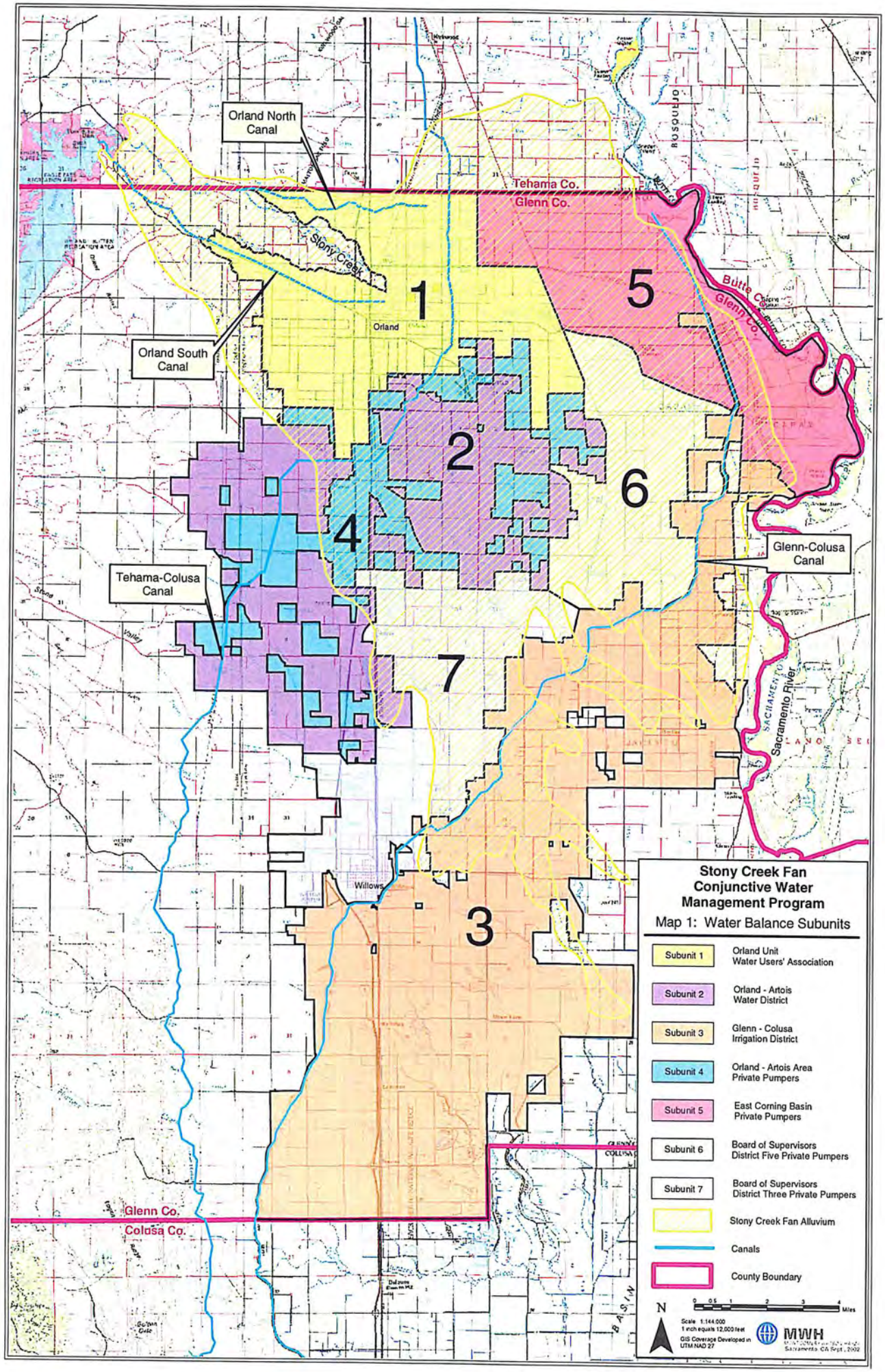
- *Review the partner's objectives. Describe the need to examine how to use available resources more effectively.*
- *Summarize the partner resources, surface water and groundwater supplies and potential relationships.*
- *Describe how various collaborative alternatives were screened.*
- *Introduce the collaborative alternatives and describe them below.*

Alternative C1

- *Collaborative Alternatives that examine using OUWUA dry-year supplies with OAWD's conveyance system.*

Alternative C2

- *Collaborative Alternatives that examine using GCID Unused Base Supplies for In-lieu Recharge in OAWD*


Orland North Canal
Orland South Canal
Tehama-Colusa Canal
Glenn-Colusa Canal
Tehama Co.
Glenn Co.
Stony Creek
Orland
Willows
Sacramento River
Butte Co.
Glenn Co.
Glenn Co.
Colusa Co.
1
2
3
4
5
6
7
Stony Creek Fan
Conjunctive Water
Management Program
Map 1: Water Balance Subunits
Subunit 1
Orland Unit
Water Users' Association
Subunit 2
Orland - Artois
Water District
Subunit 3
Glenn - Colusa
Irrigation District
Subunit 4
Orland - Artois Area
Private Pumpers
Subunit 5
East Corning Basin
Private Pumpers
Subunit 6
Board of Supervisors
District Five Private Pumpers
Subunit 7
Board of Supervisors
District Three Private Pumpers
Stony Creek Fan Alluvium
Canals
County Boundary
N
0 0.5 1 2 3 4 Miles
Scale 1:144,000
1 inch equals 12,000 feet
GIS Coverage Developed in
UTM NAD 27
MWH

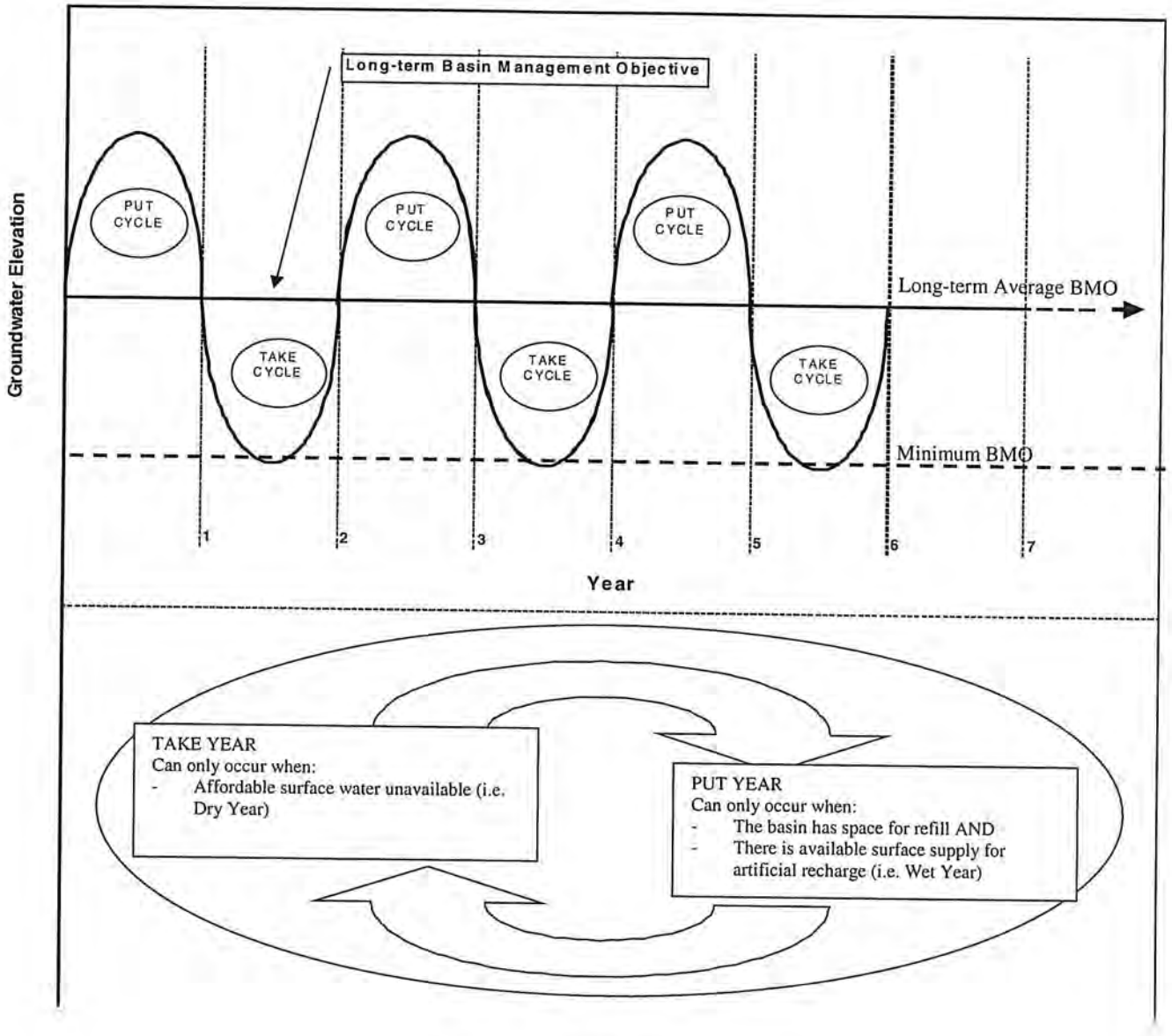


Figure 1-1

The Conjunctive Use Cycle

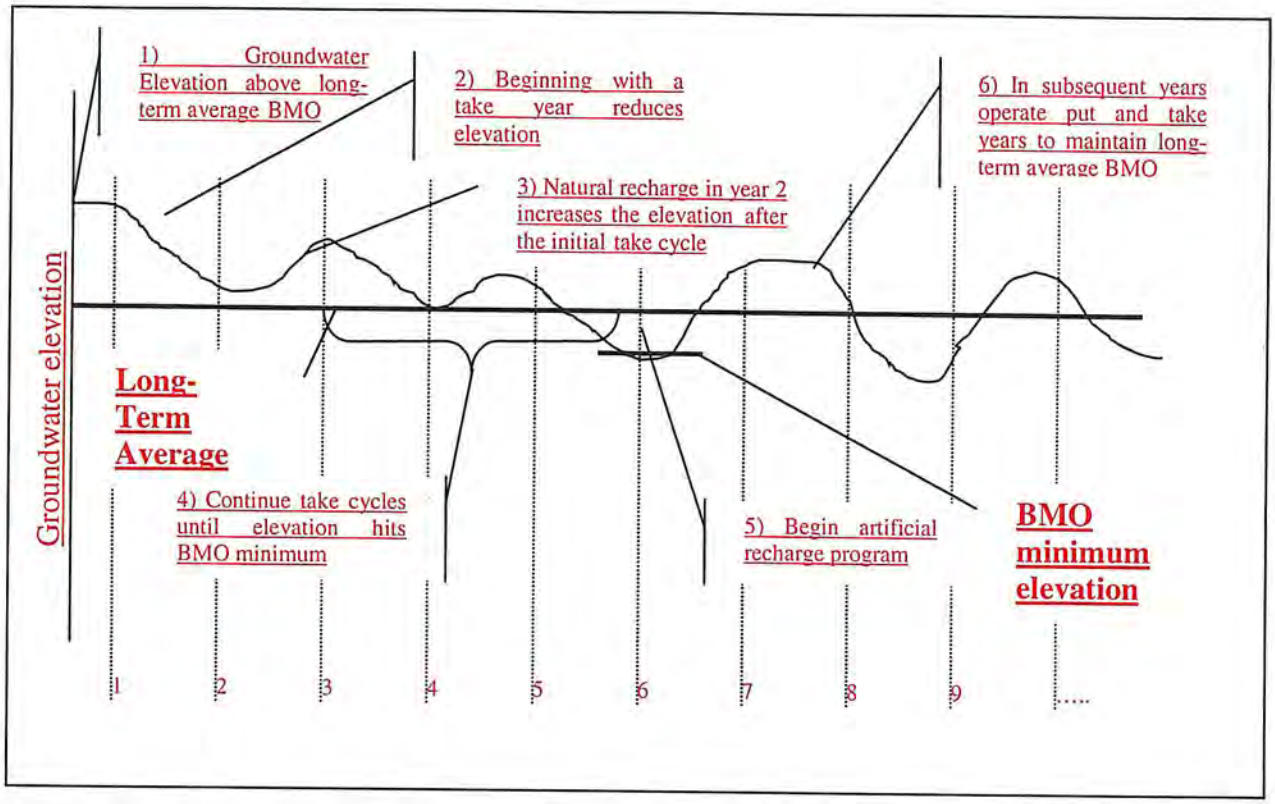


Figure 1-2

Hypothetical Conjunctive Use Program

Beginning with a Put year

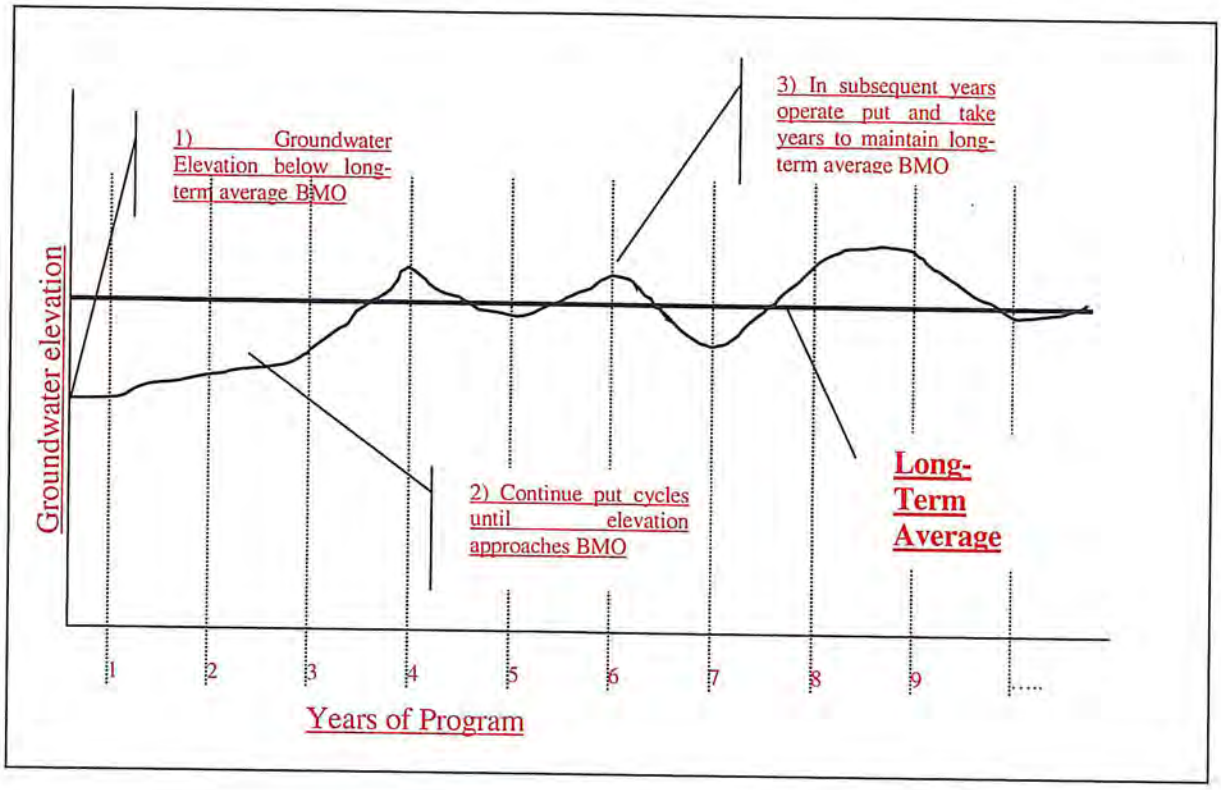


Figure 1-3

Hypothetical Conjunctive Use Program

Beginning with a Take year

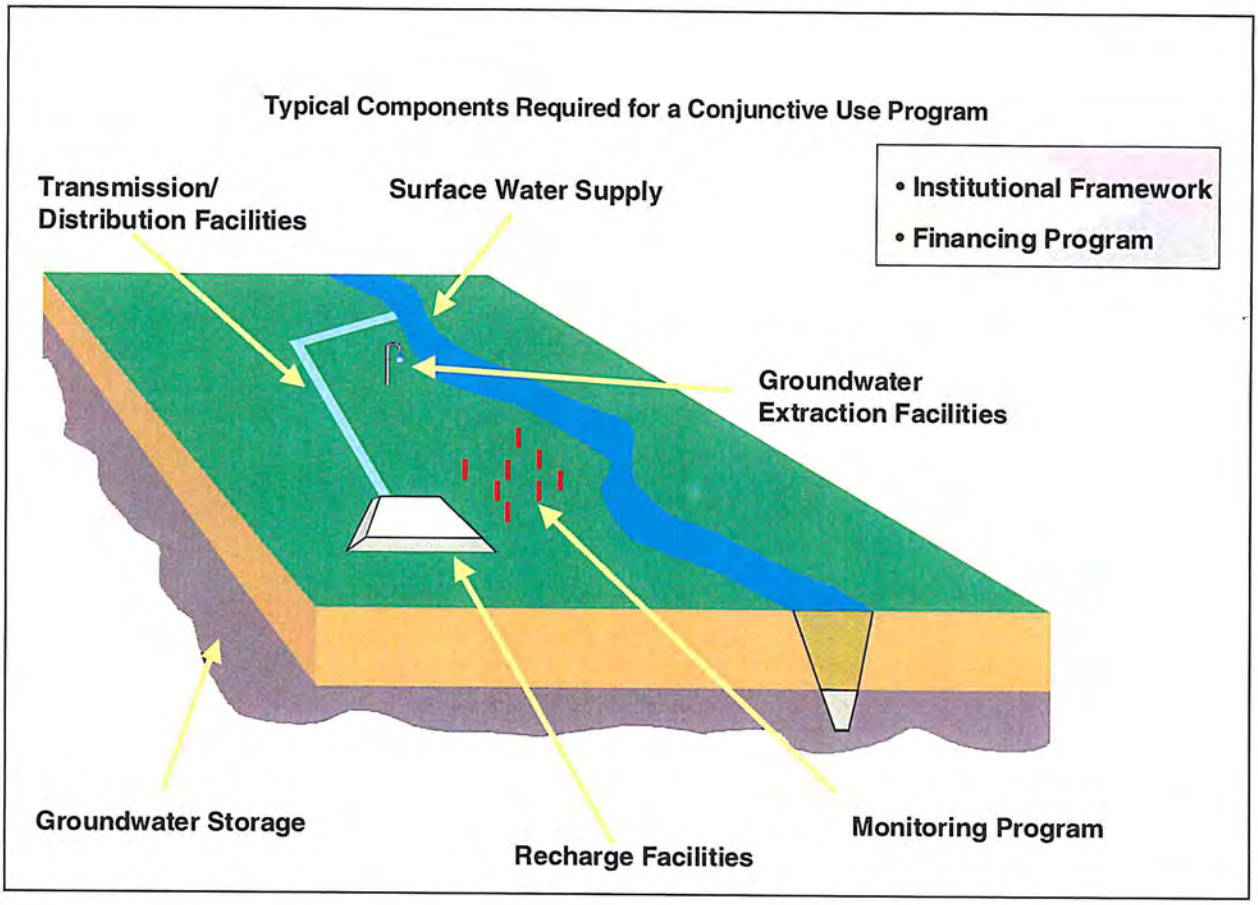
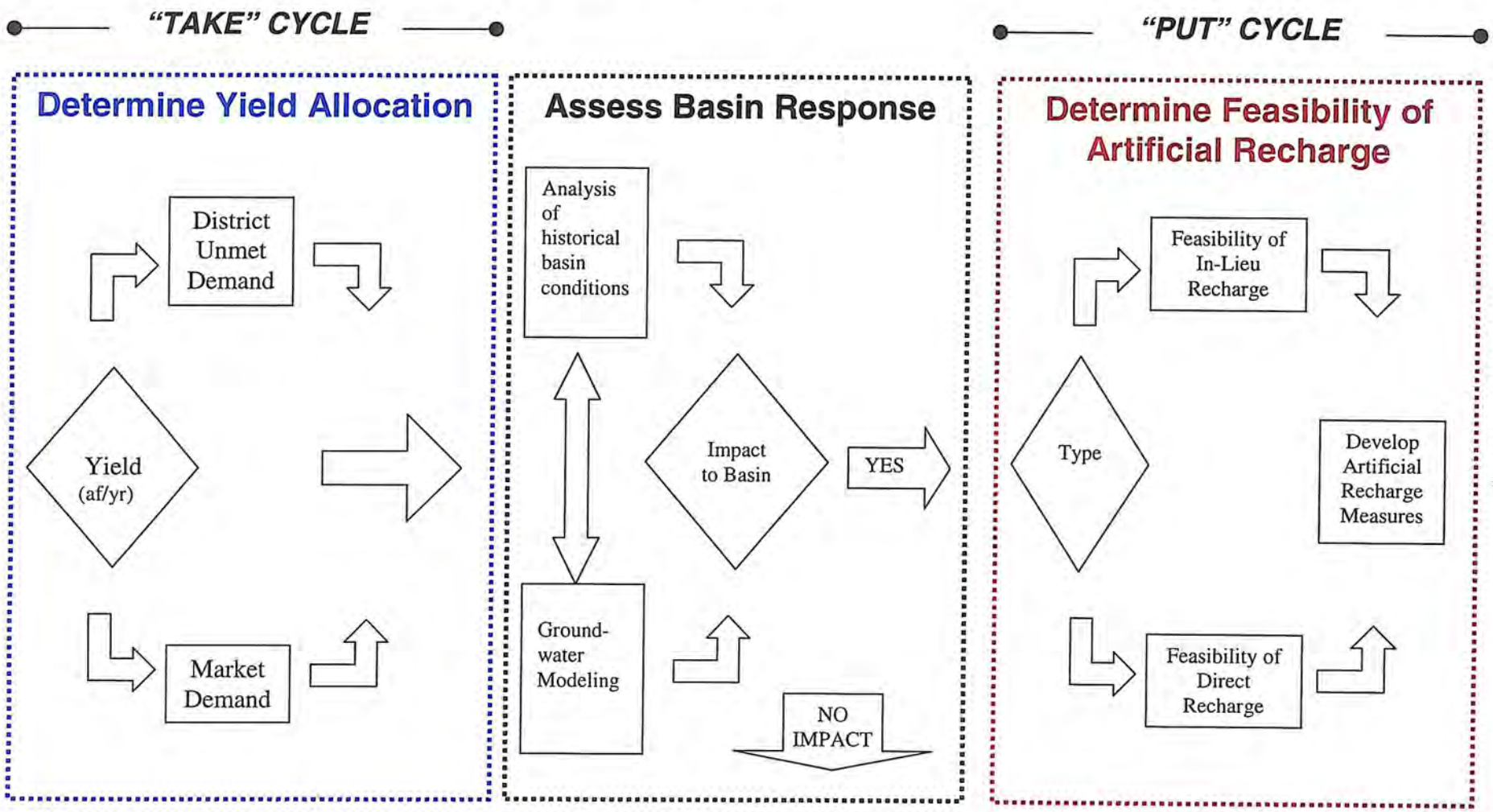


Figure 1-4
Typical Components Required for a Conjunctive Use Program

Figure . 5a
Formulation and Analysis of Conjunctive Use Projects



Basin capable of supporting yield allocation

Operate "Put" and "Take" cycles according to basin and water year conditions, and consistent with institutional/legal requirements. Monitor and assess conditions and make adjustments to program based on updated assessments.

Figure 1-5b
Decision Tree for Conjunctive Use Operation to Increase System Yield - "PUT" Cycle

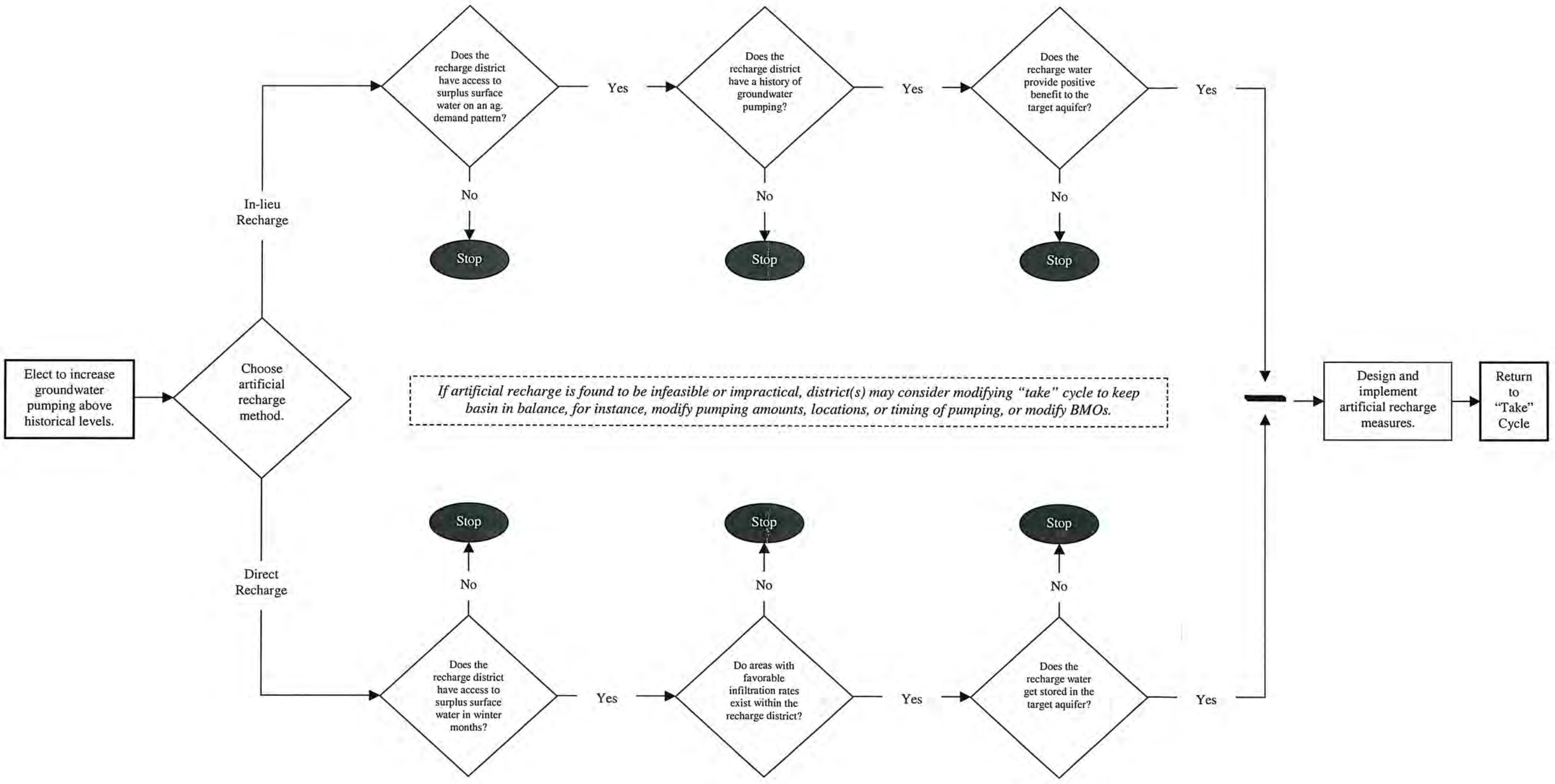
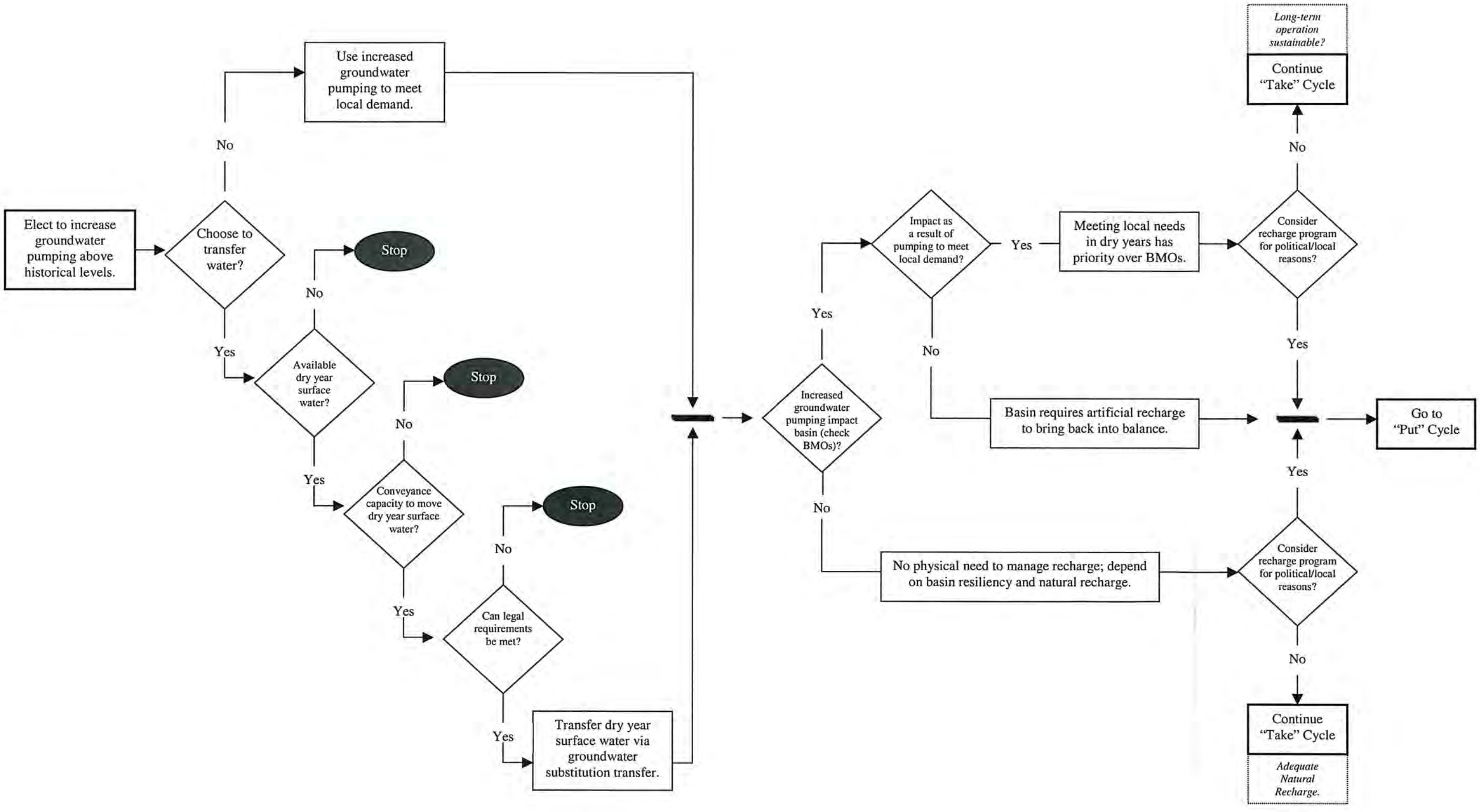
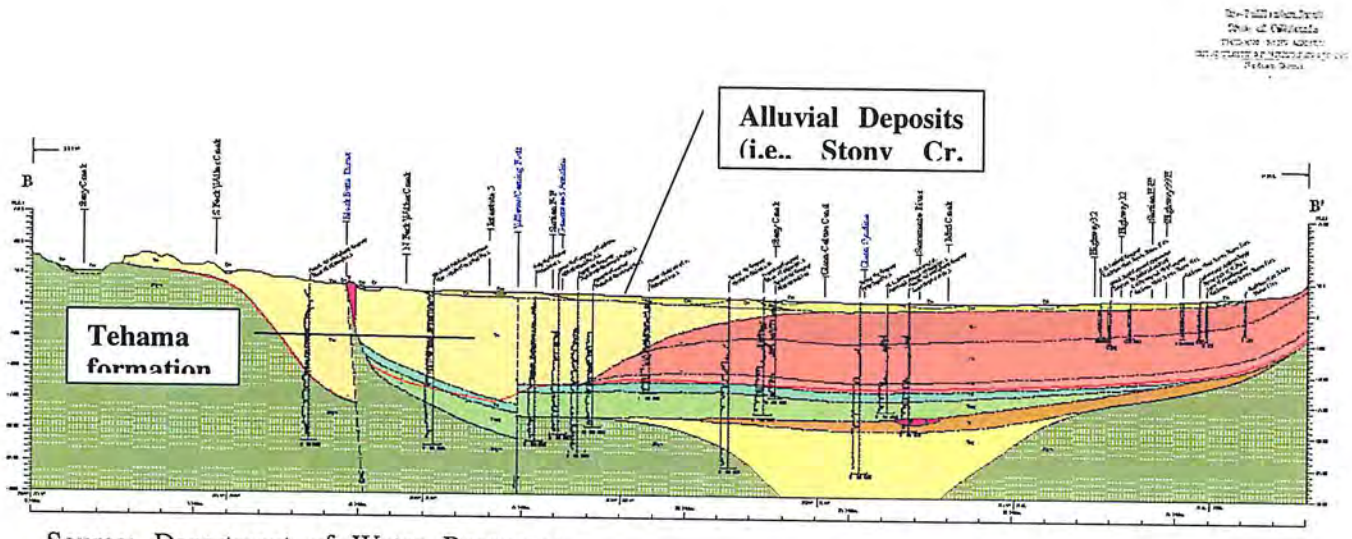


Figure 1-5c
Decision Tree for Conjunctive Use Operation to Increase System Yield - "TAKE" Cycle





Source: Department of Water Resources

Figure 1-6
Geology of the Stony Creek Fan Area, Glenn County, California

Figure 2-1

Orland Unit Historical District Diversions
(includes system losses)

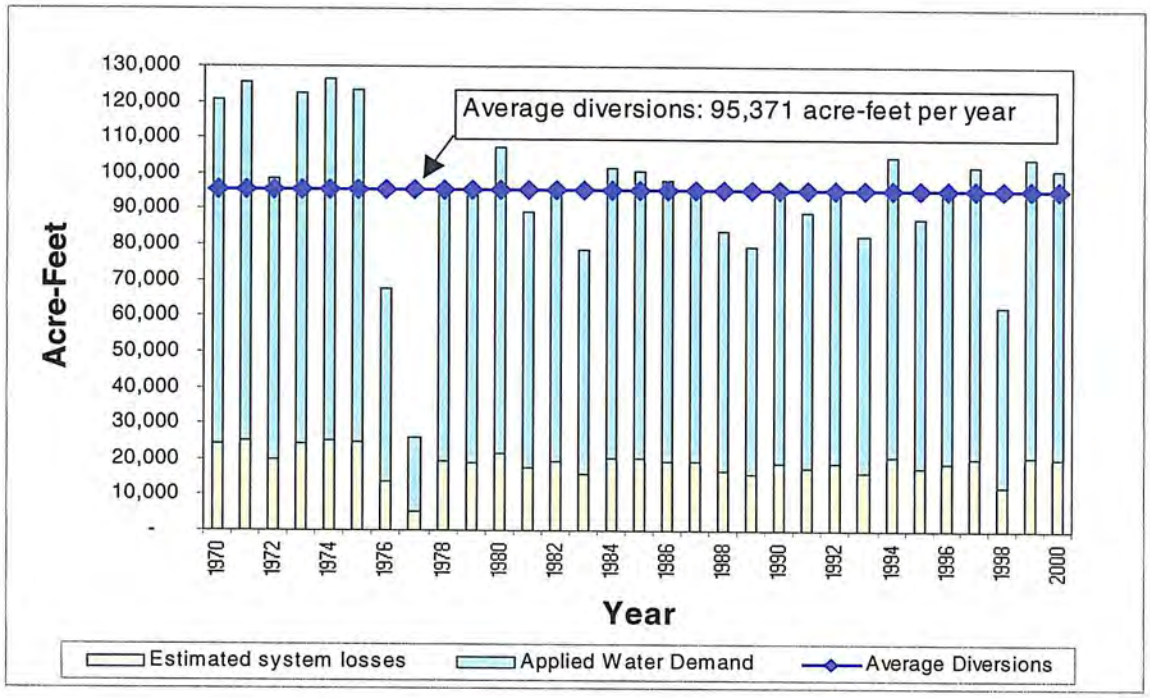


Figure 2-2
Surface and Ground Water Necessary to Meet ETaw

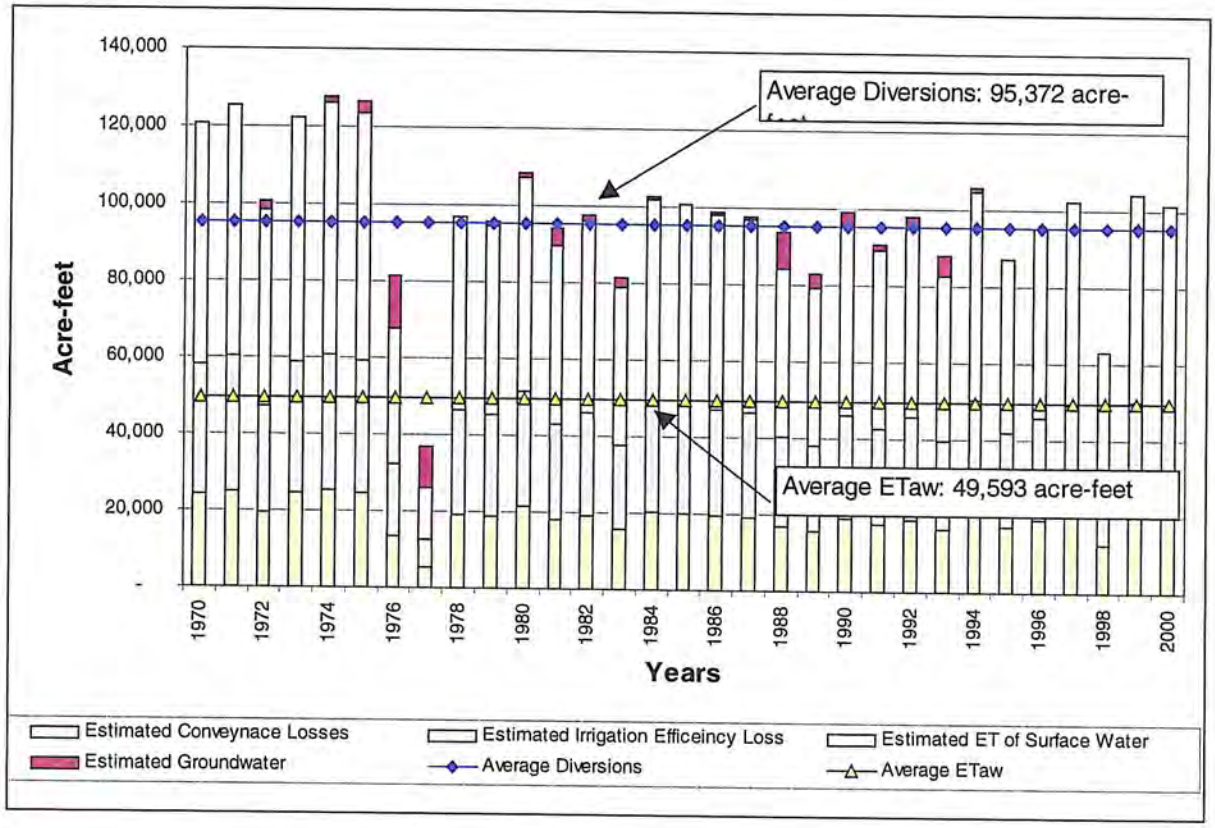


Figure 2-3

Historical and Baseline ETaw for the OUWUA

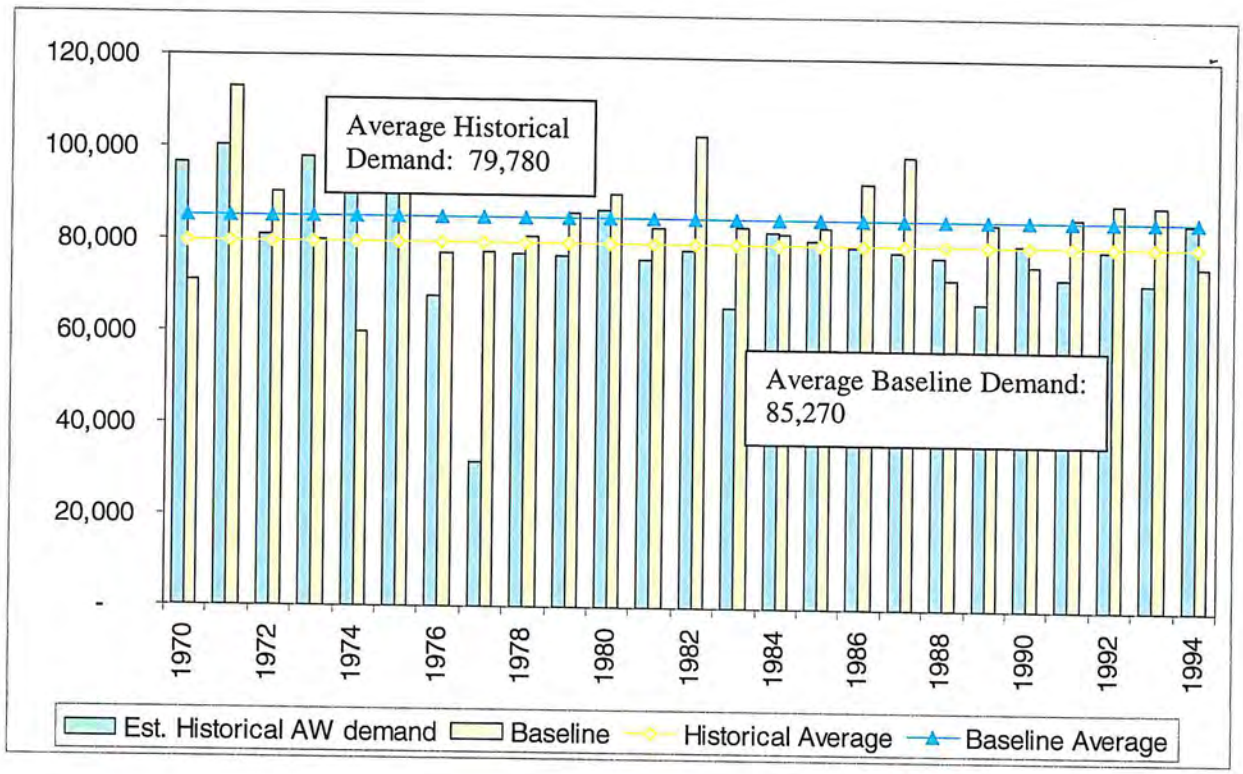


Figure 2-4. Historical Cropping Pattern for Subunit 2 (OAWD) 1970-2000

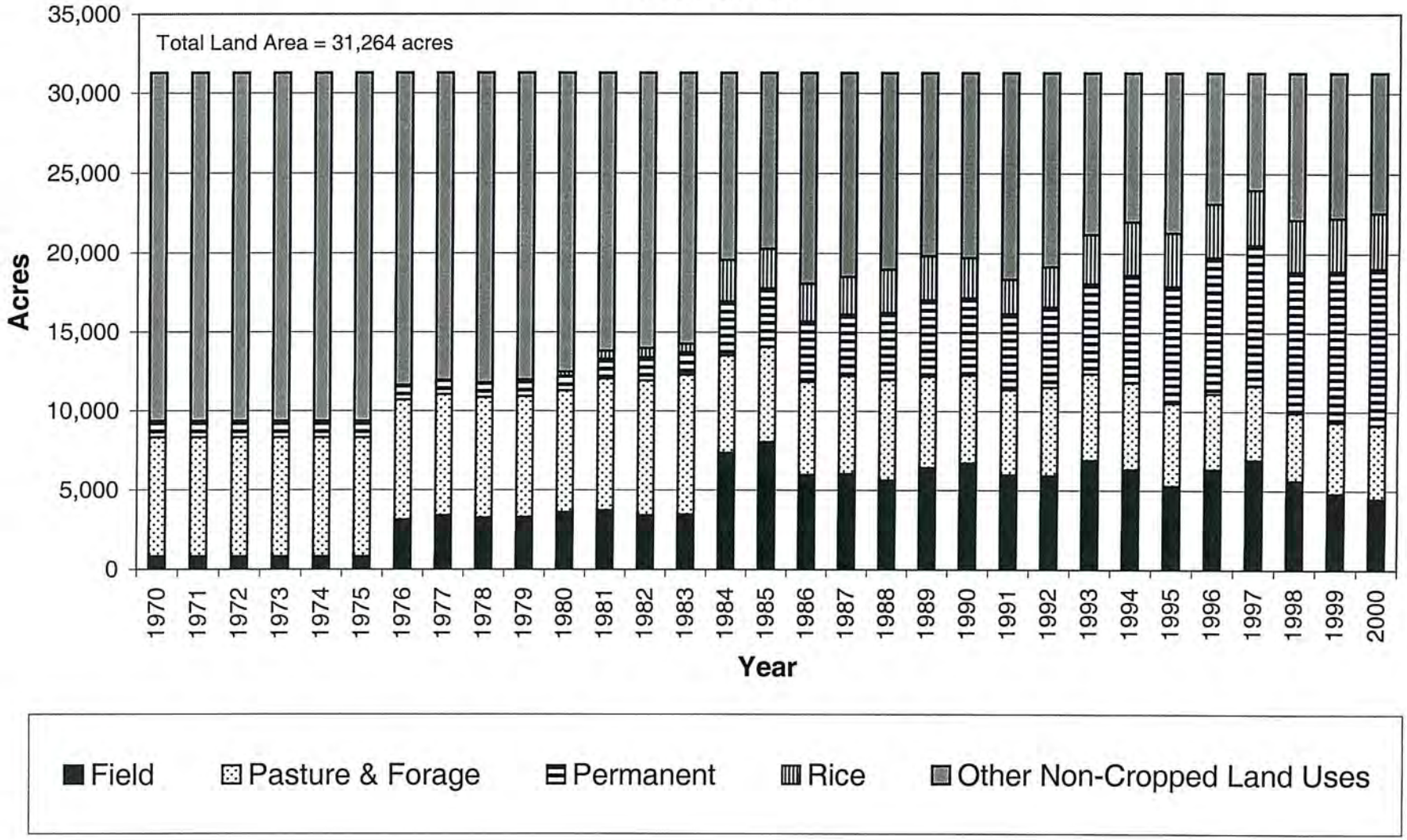


Figure 2-5a. Subunit 2 (OAWD) Historical Water Demands

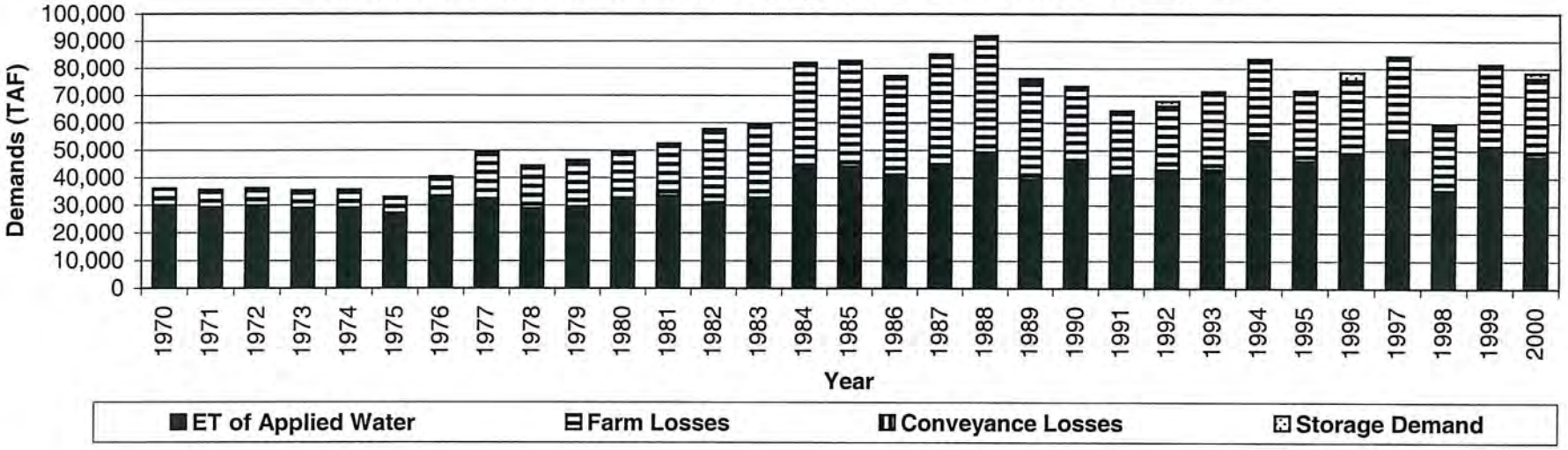


Figure 2-5b. Subunit 2 (OAWD) Historical Water Supplies

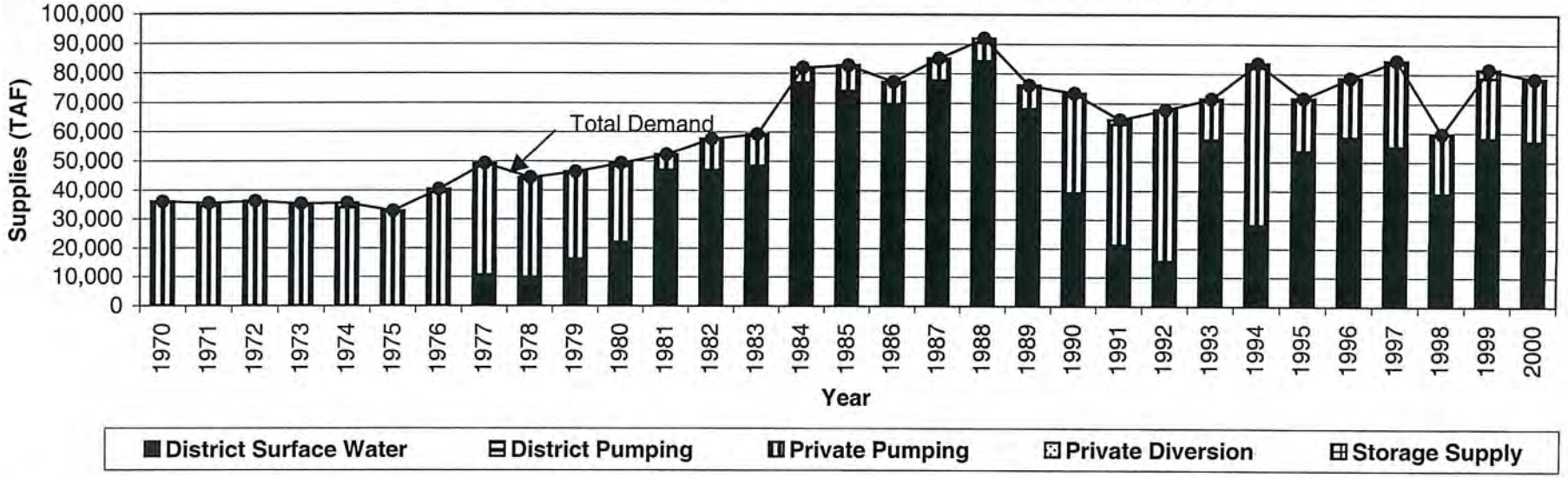


Figure 2-6. Net Extraction for Subunit 2 (OAWD) from 1970-2000 (Total Area = 31,264)

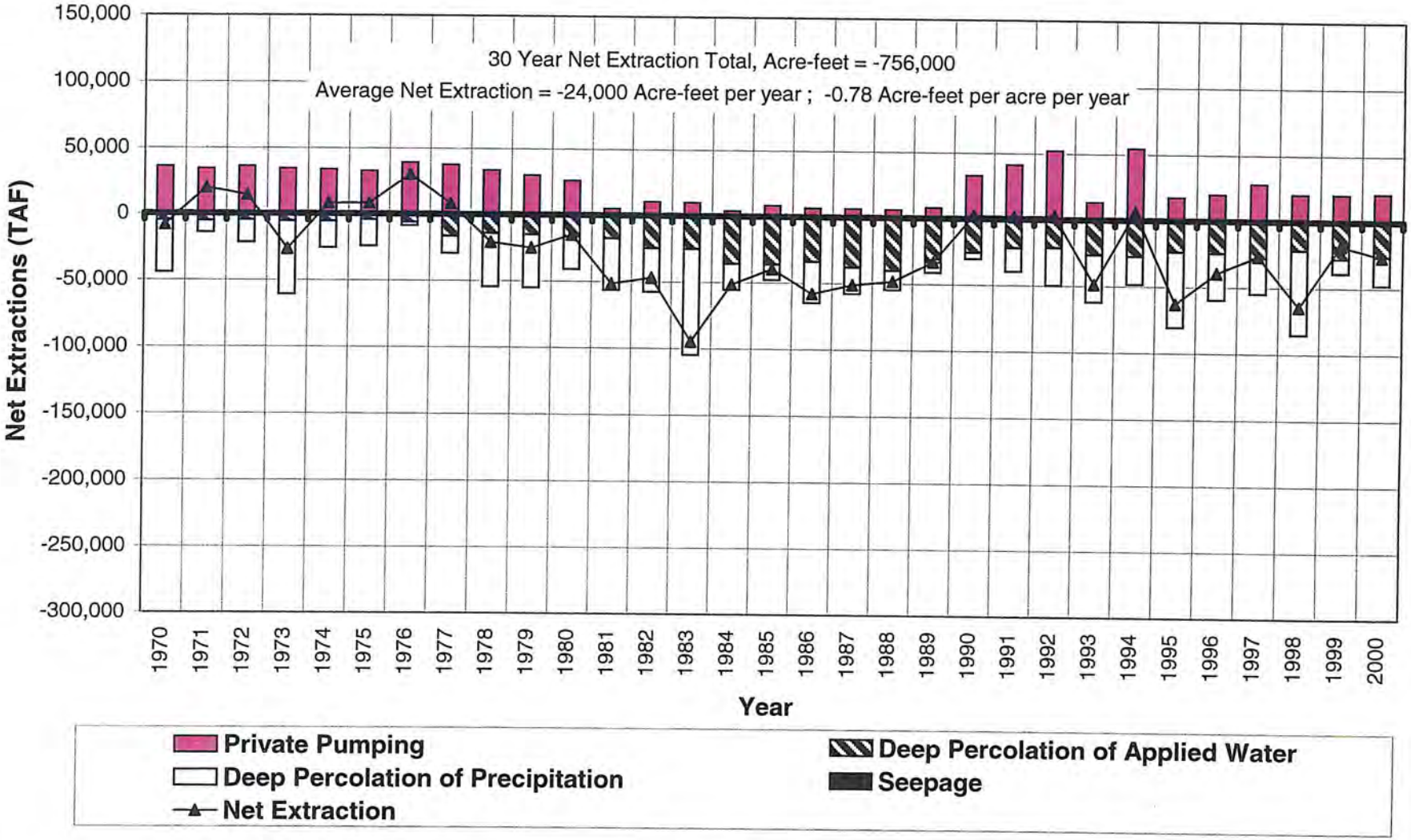


Figure 2-7. Historical and Baseline Cropping Patterns for Subunit 2 (OAWD)

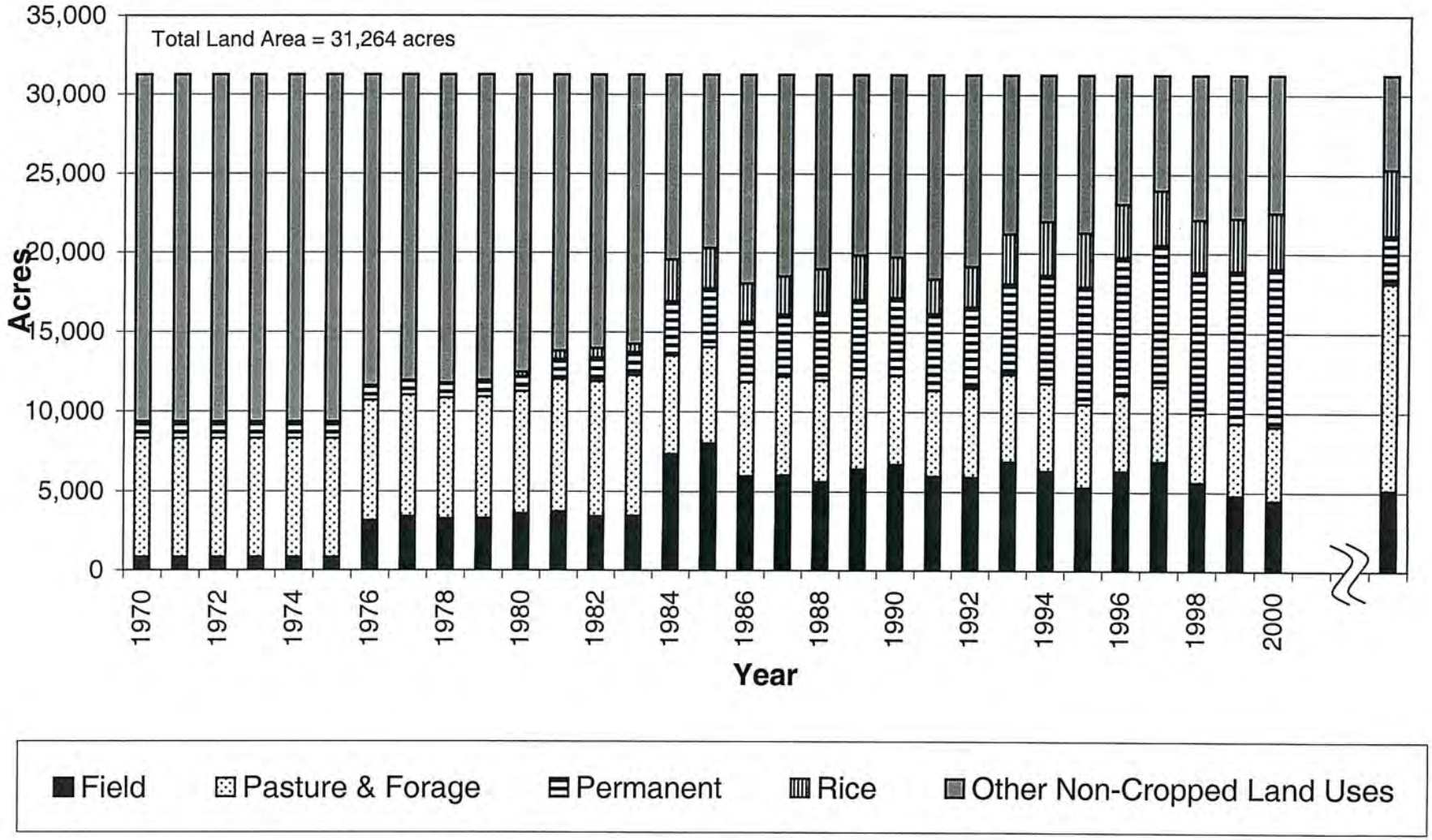


Figure 2-8. OAWD Baseline ETaw and Applied Water Demands (1922 to 1994 Hydrology; Projected 2025 Land Use; 70% On-farm Irrigation Efficiency)

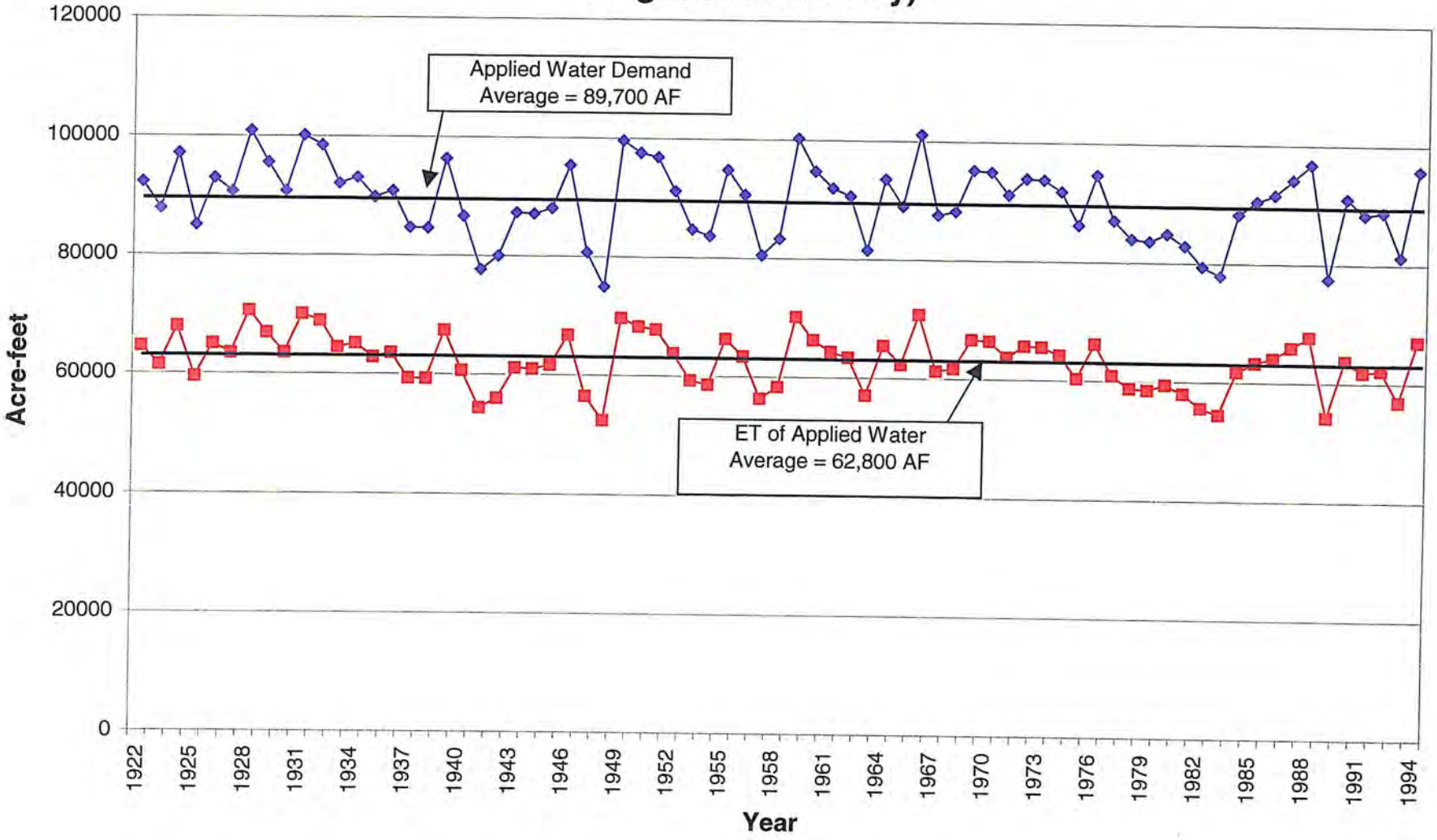


Figure 2-9. OAWD Baseline CVP Water Supply (1922-1994 Hydrology; Projected 2025 Land Use; Future (80%) CVP Contract; No Purchases; No Marketing)

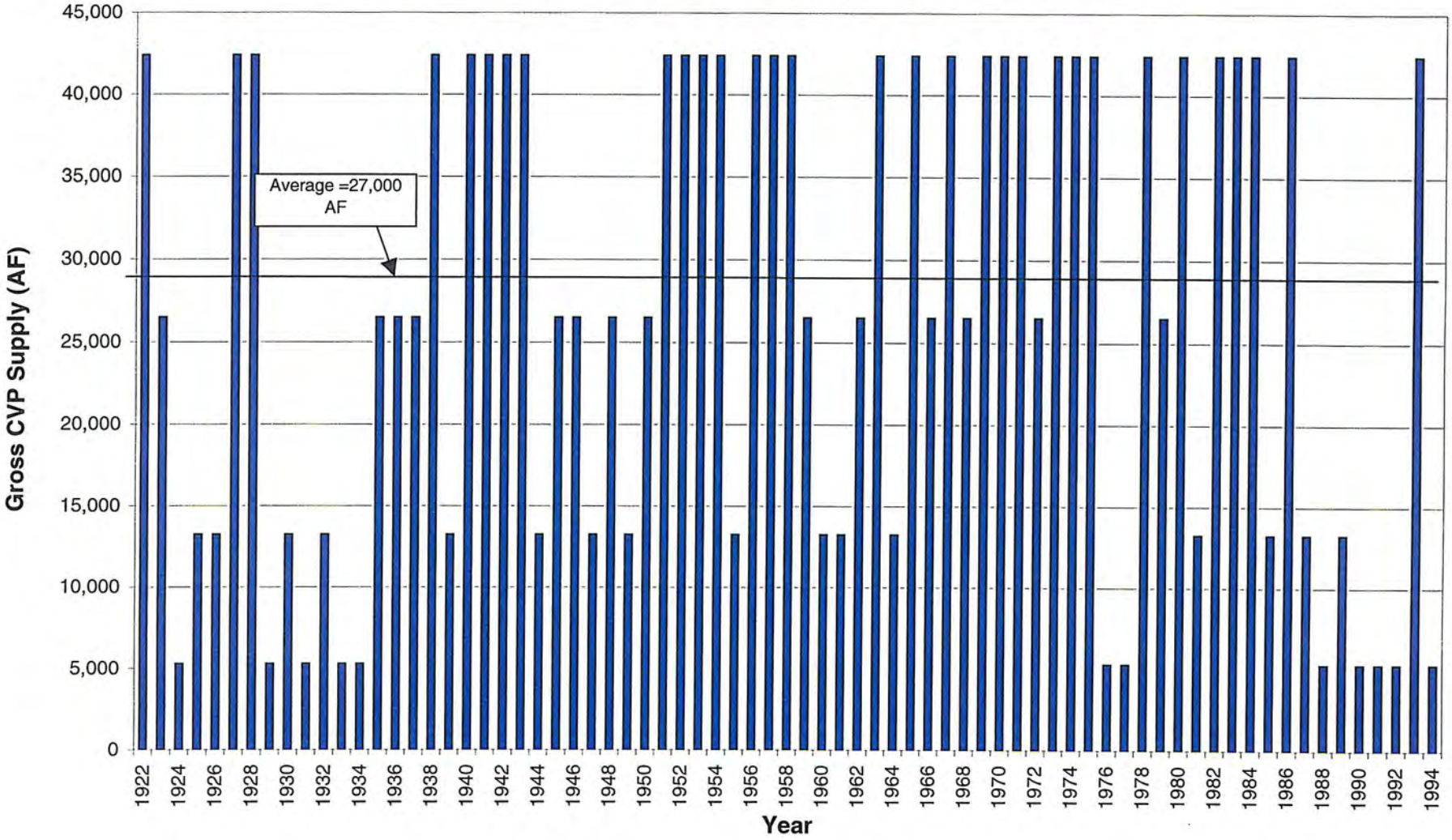


Figure 2-10__. OAWD Baseline Private Pumping (1922-1994 Hydrology; Projected 2025 Land Use; Future (80%) CVP Contract; No Purchases; No Marketing)

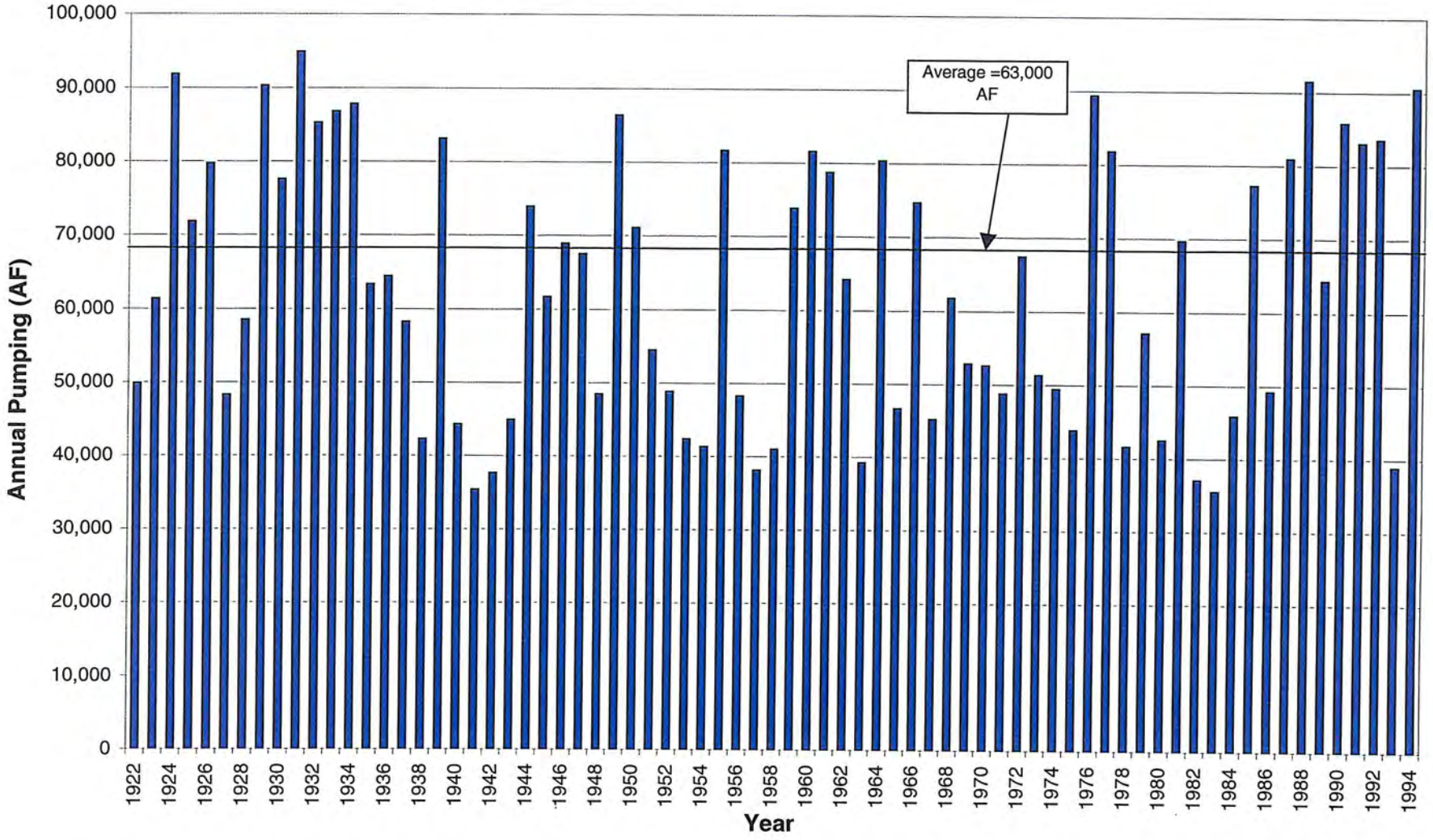


Figure 2-11. Historical Cropping Pattern for Subunit 3 (GCID) 1970-2000

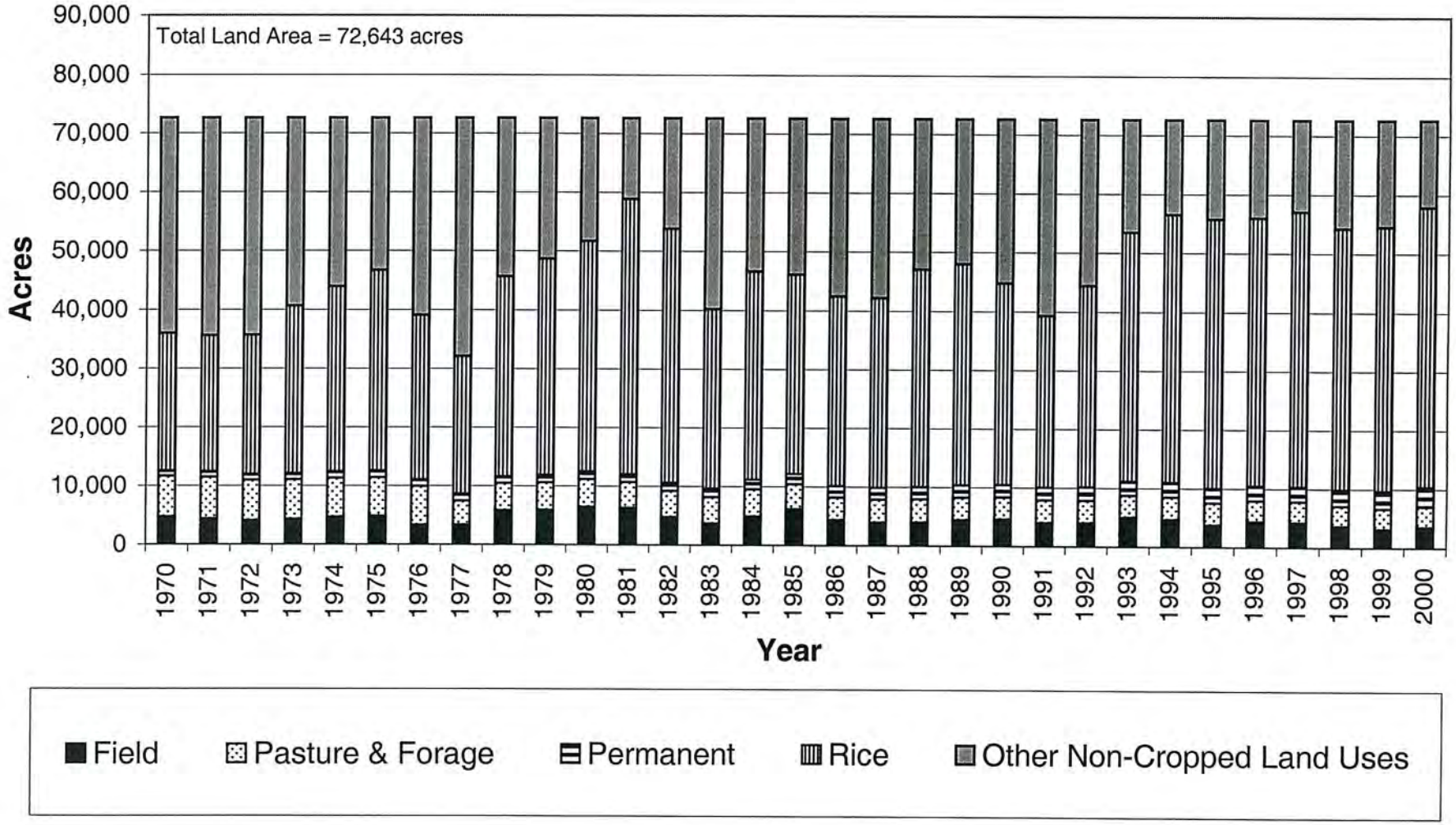
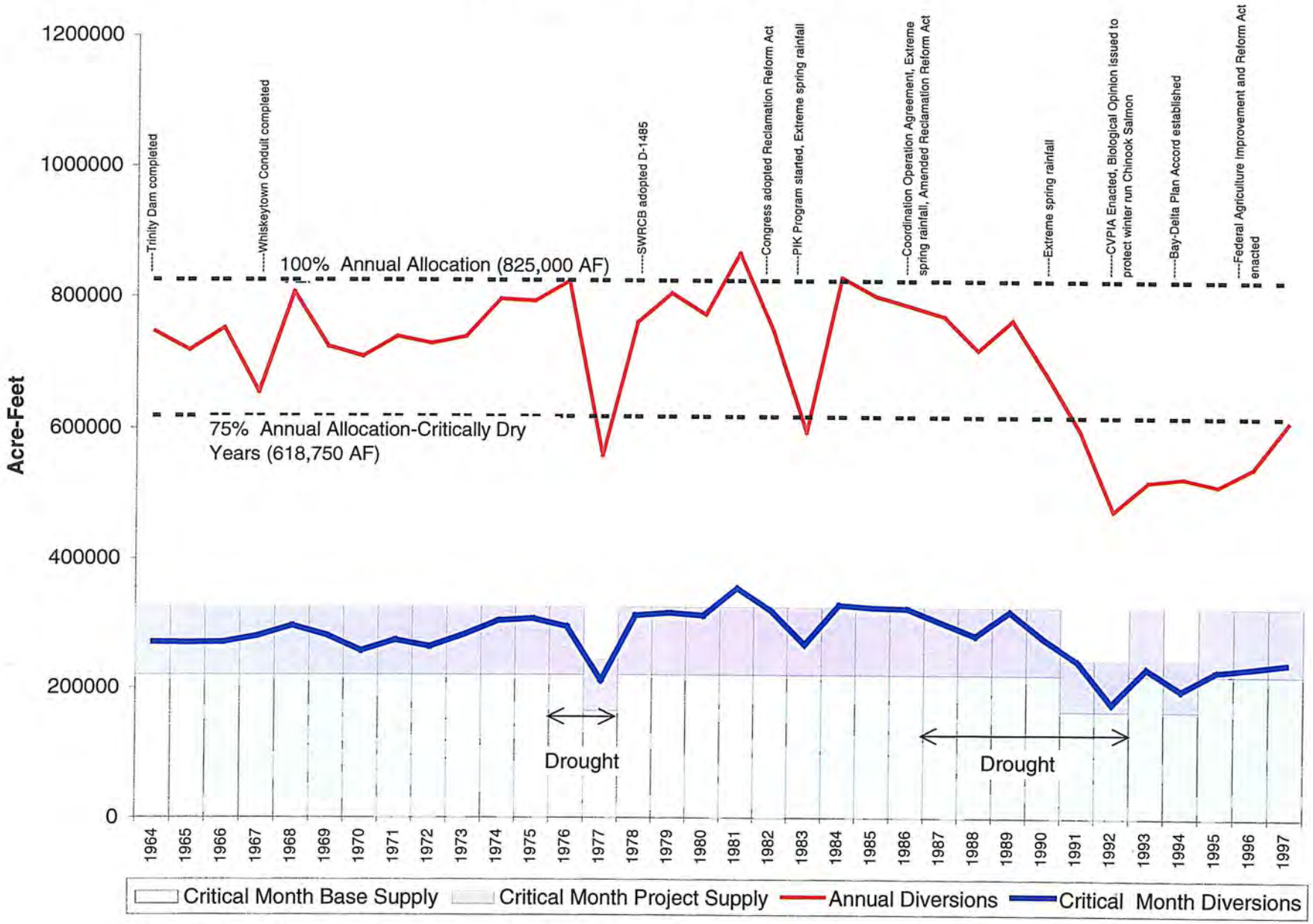


Figure 2-12

Glenn-Colusa Irrigation District
Project Supply and Base Supply Diversions



Note: Annual quantities are based on contract period from April to October; Critical Months include July and August

Figure 2-13. Subunit 3 (GCID) Historical Water Supplies

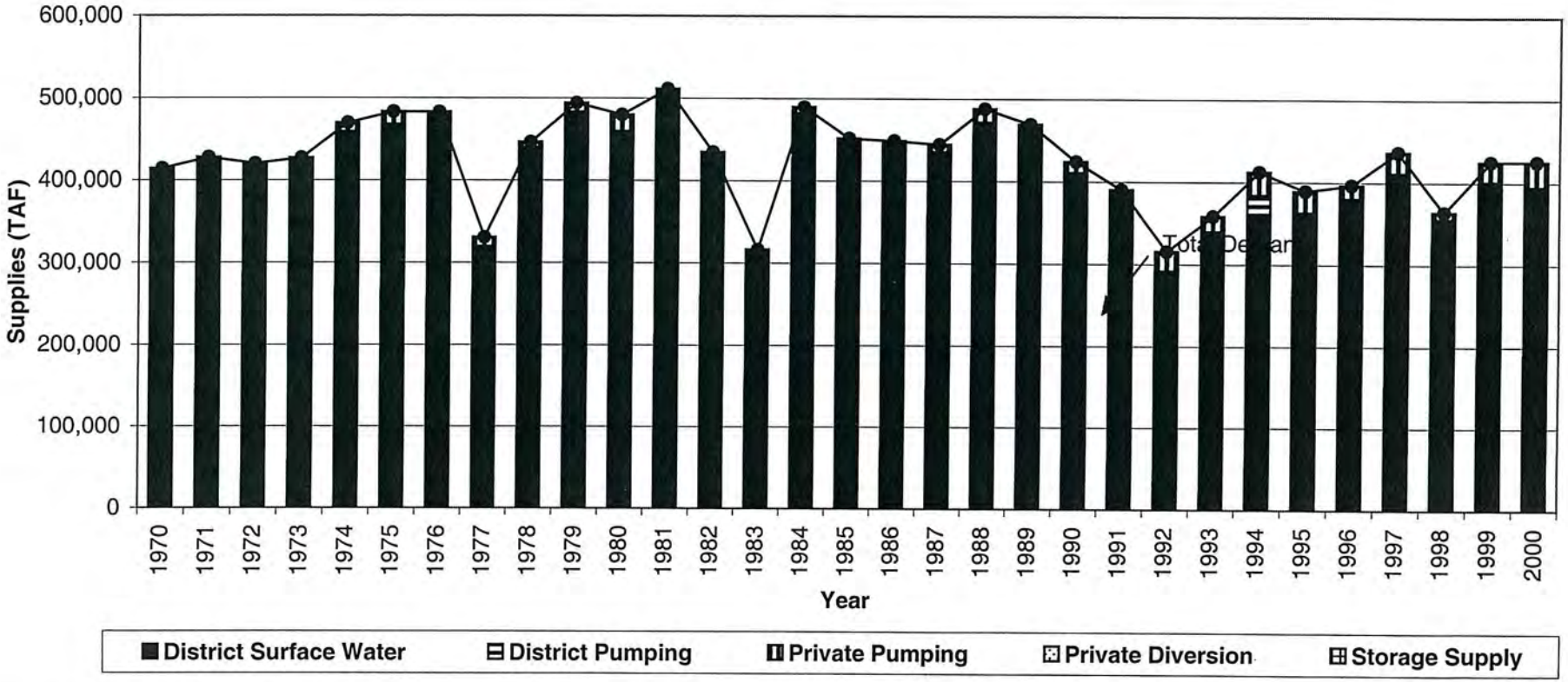


Figure 2-14. Net Extraction for Subunit 3 (GCID) from 1970-2000 (Total Area = 72,643)

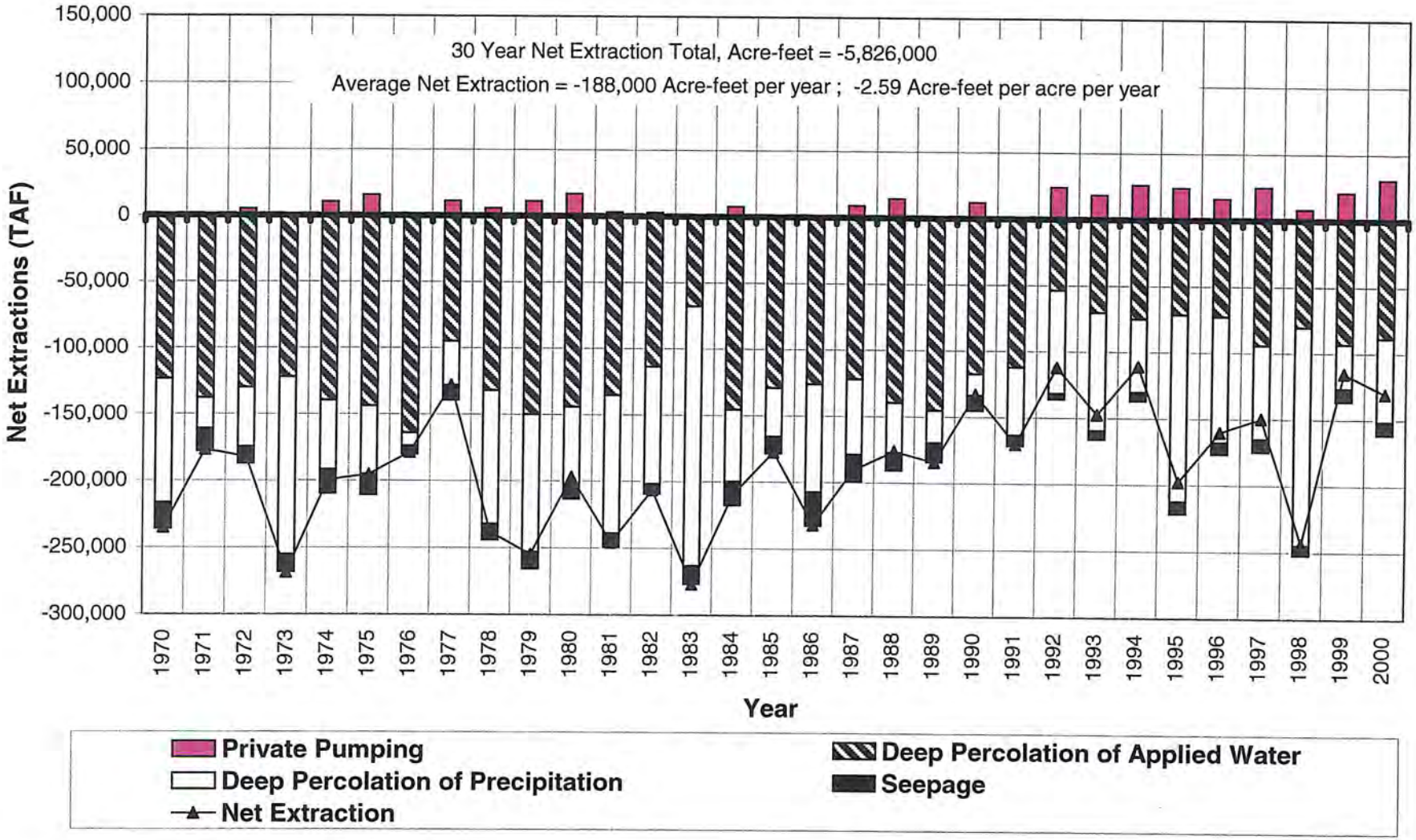


Figure 2-15. Historical and Baseline Cropping Patterns for Subunit 3 (GCID)

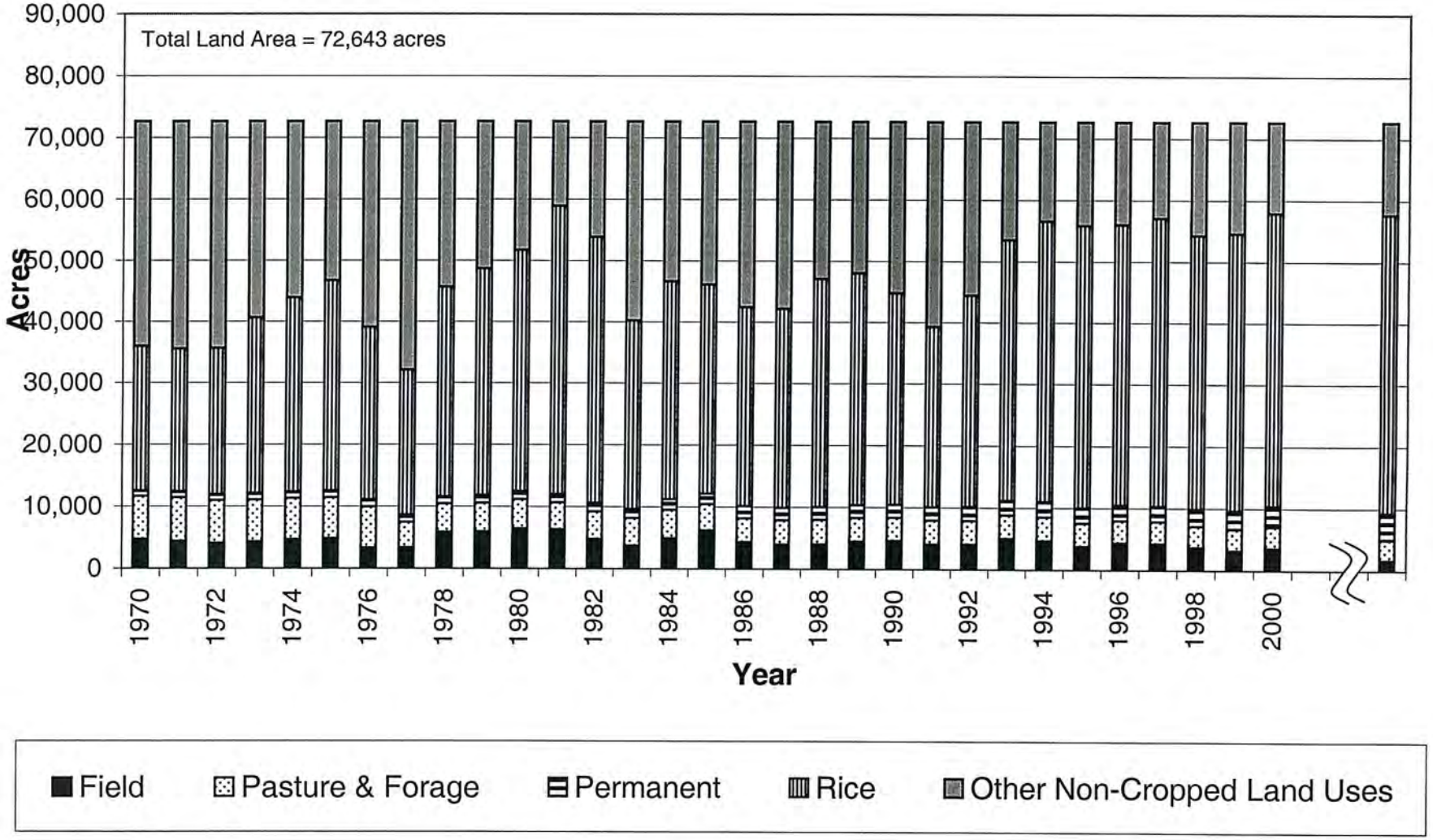


Figure 2-16. Historical Cropping Pattern for Subunit 4-7 (GW only) 1970-2000

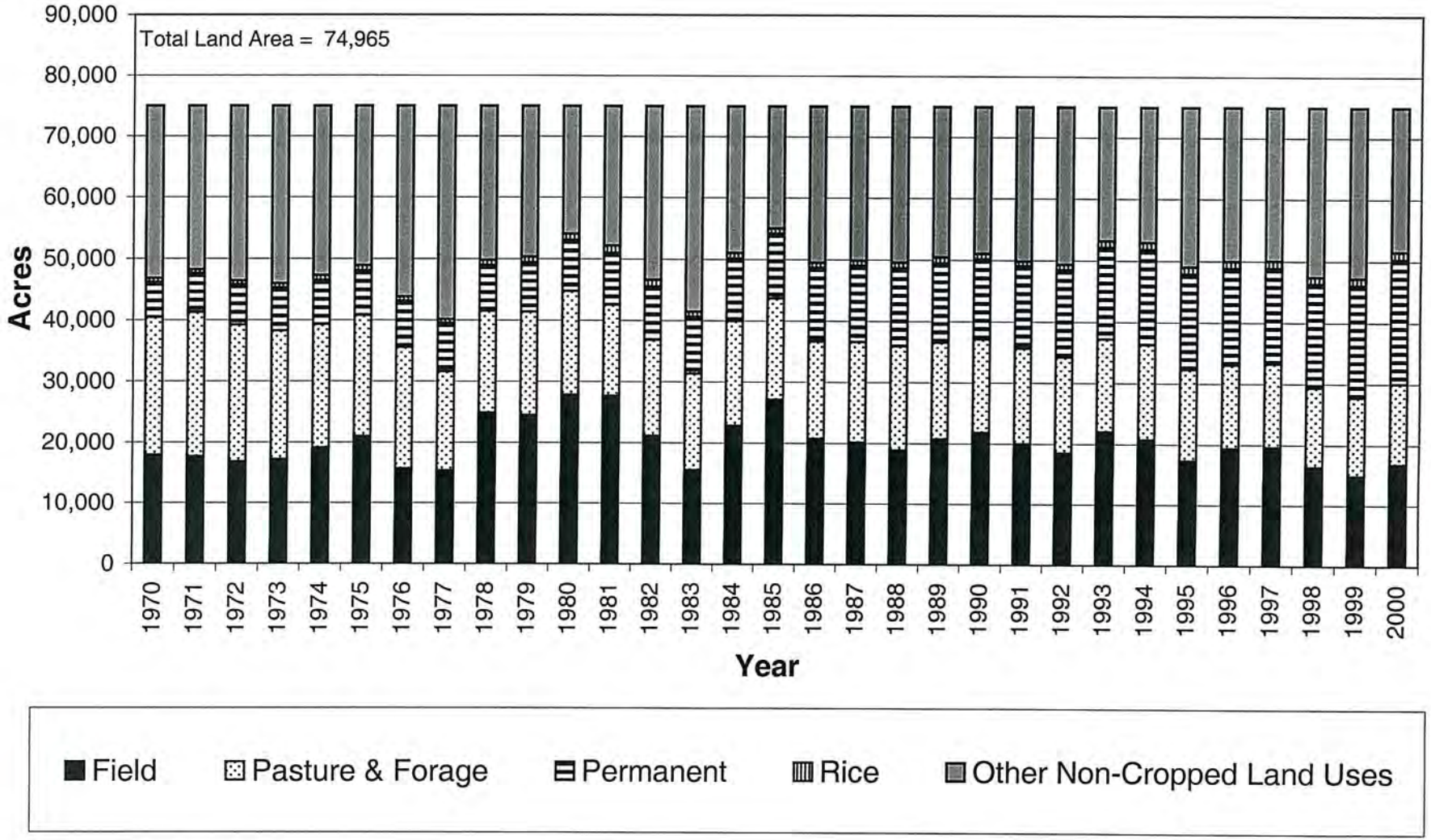


Figure 2-17a. Subunit 4-7 (GW only) Historical Water Demands

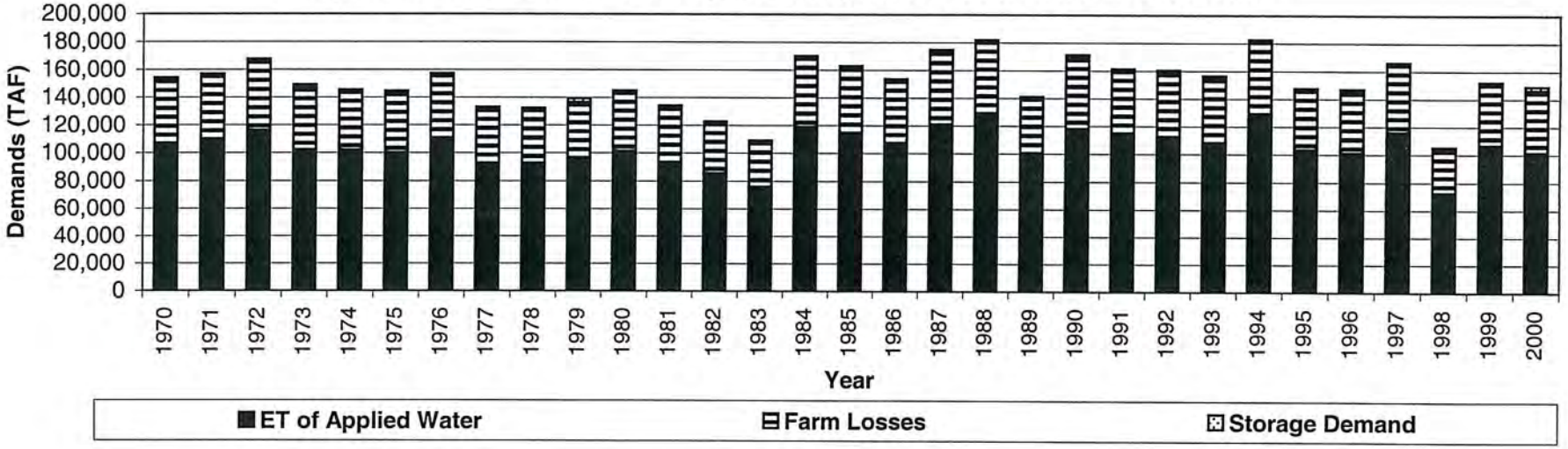


Figure 2-17b. Subunit 4-7 (GW only) Historical Water Supplies

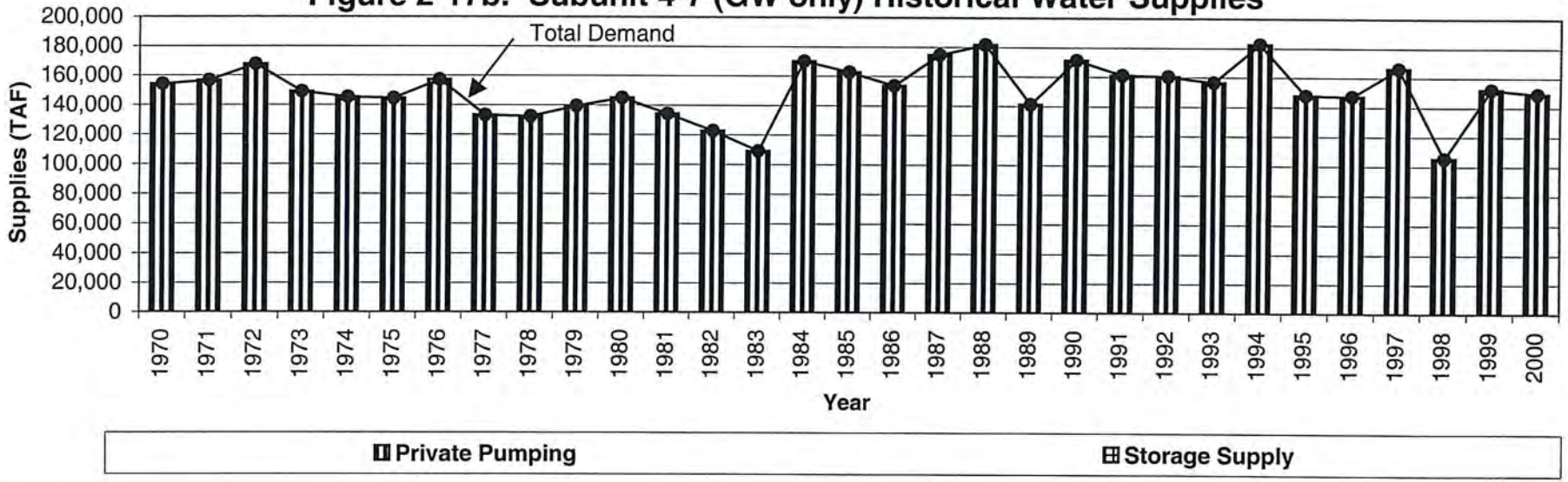


Figure 2-18. Net Extraction for Subunits 4-7 (GW only) from 1970-2000 (Total Area = 74,965)

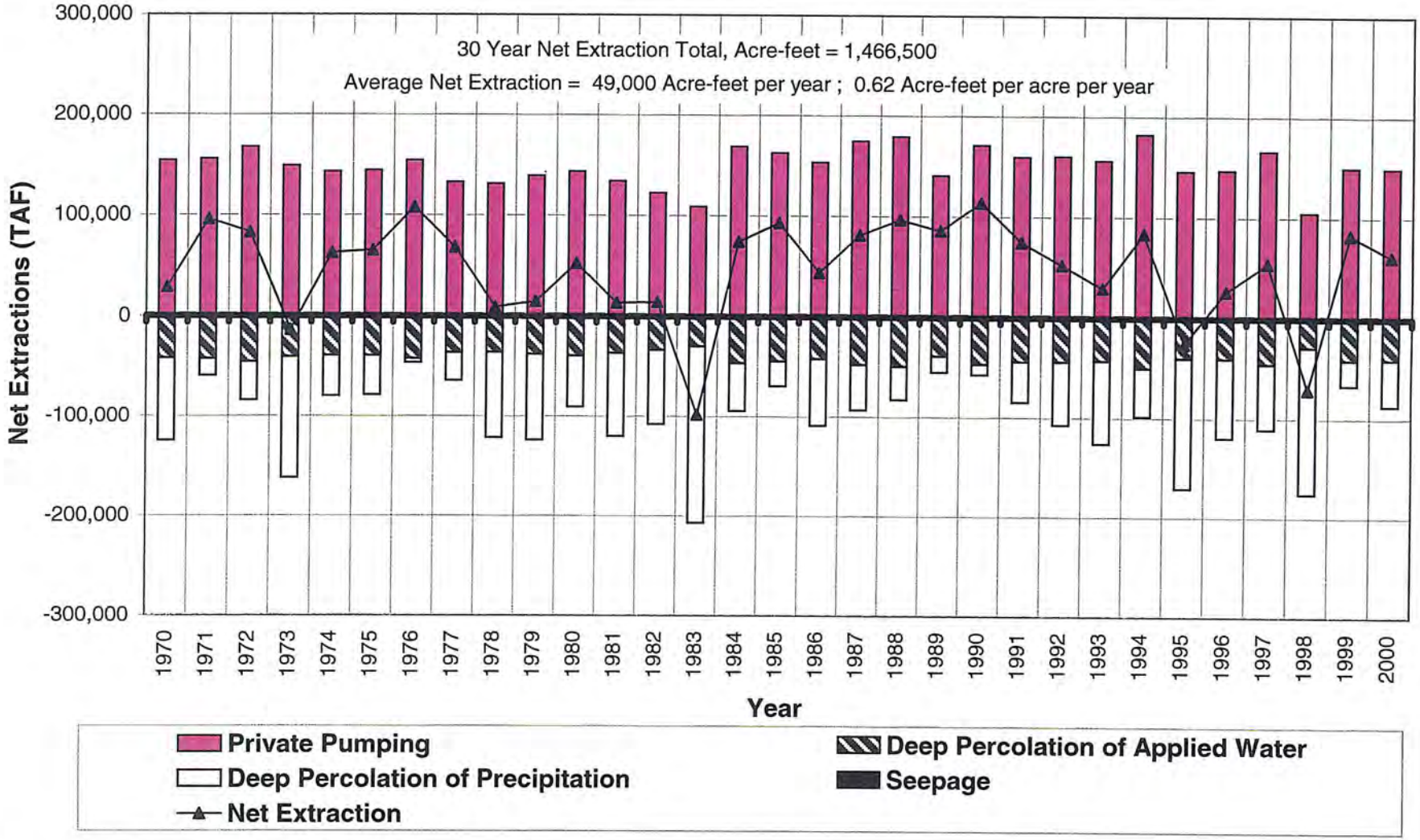


Figure 2-19. Historical and Baseline Cropping Patterns for Subunit 4-7 (GW only)

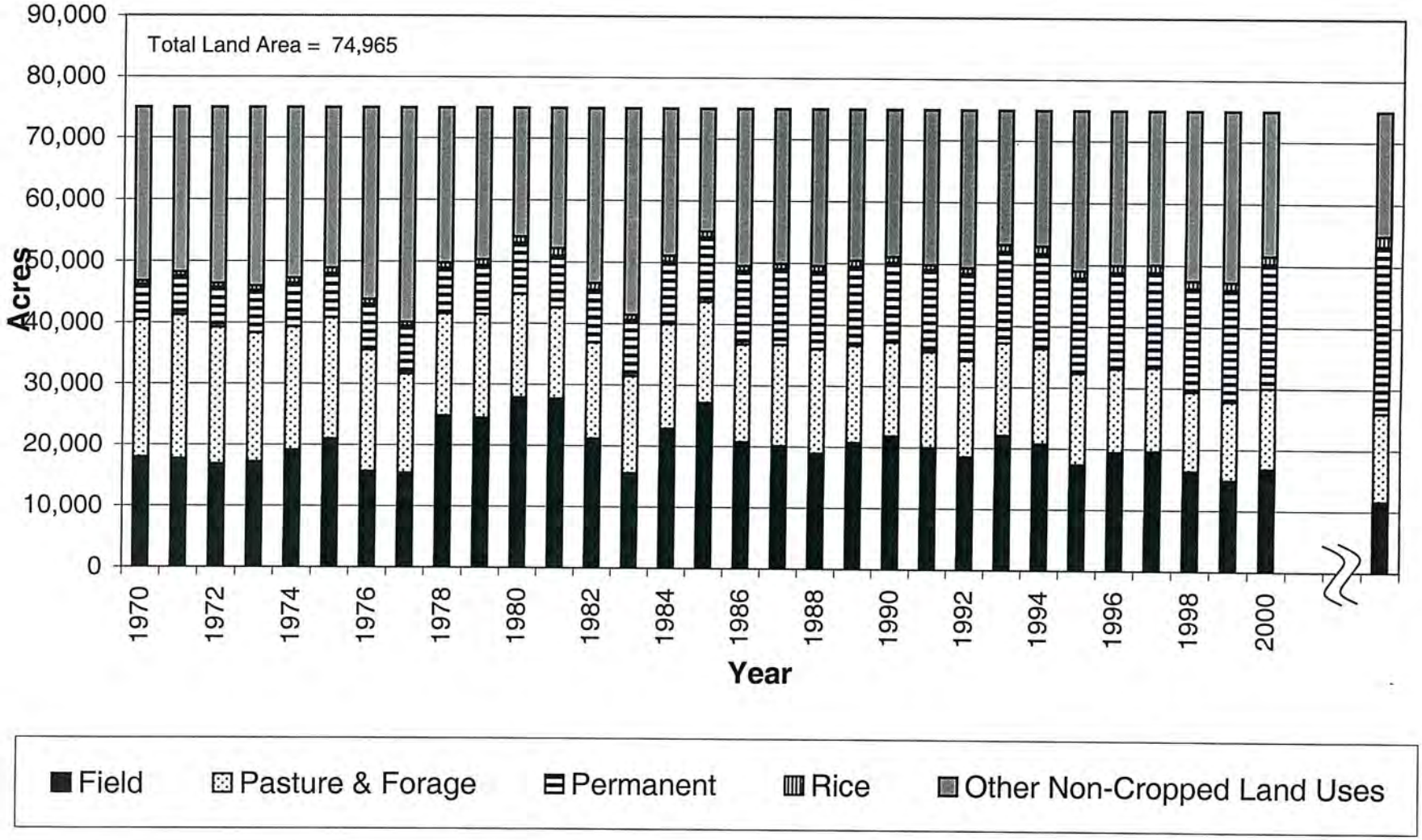


Figure 2-20. Subunits 4-7 (GW-only) Baseline ETaw and Applied Water Demands

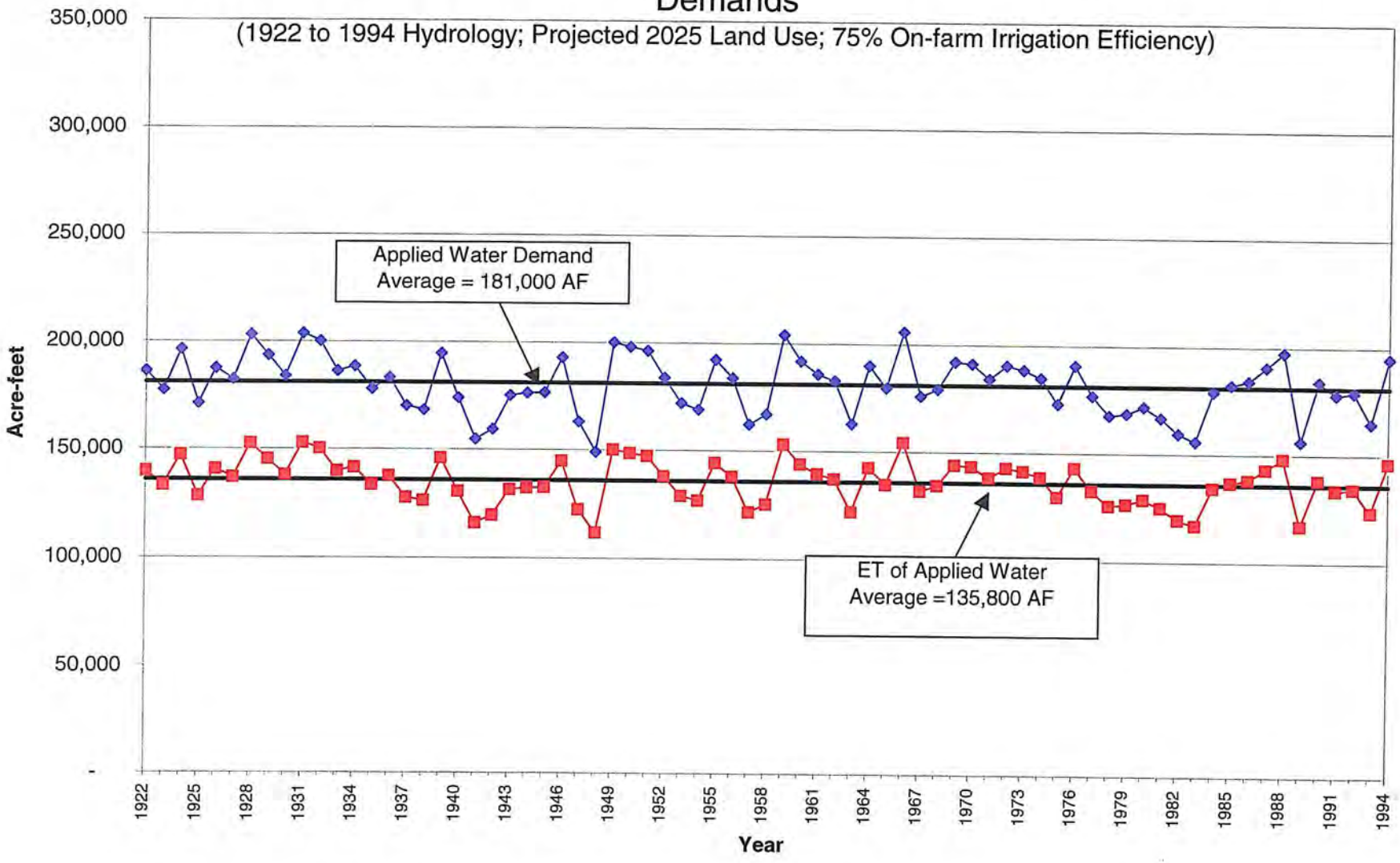


Figure 3-1
Percent Exceedance of the Value of Net Revenue for a 10,000 af Groundwater Substitution Transfer over 25 Years in Specified Year Types

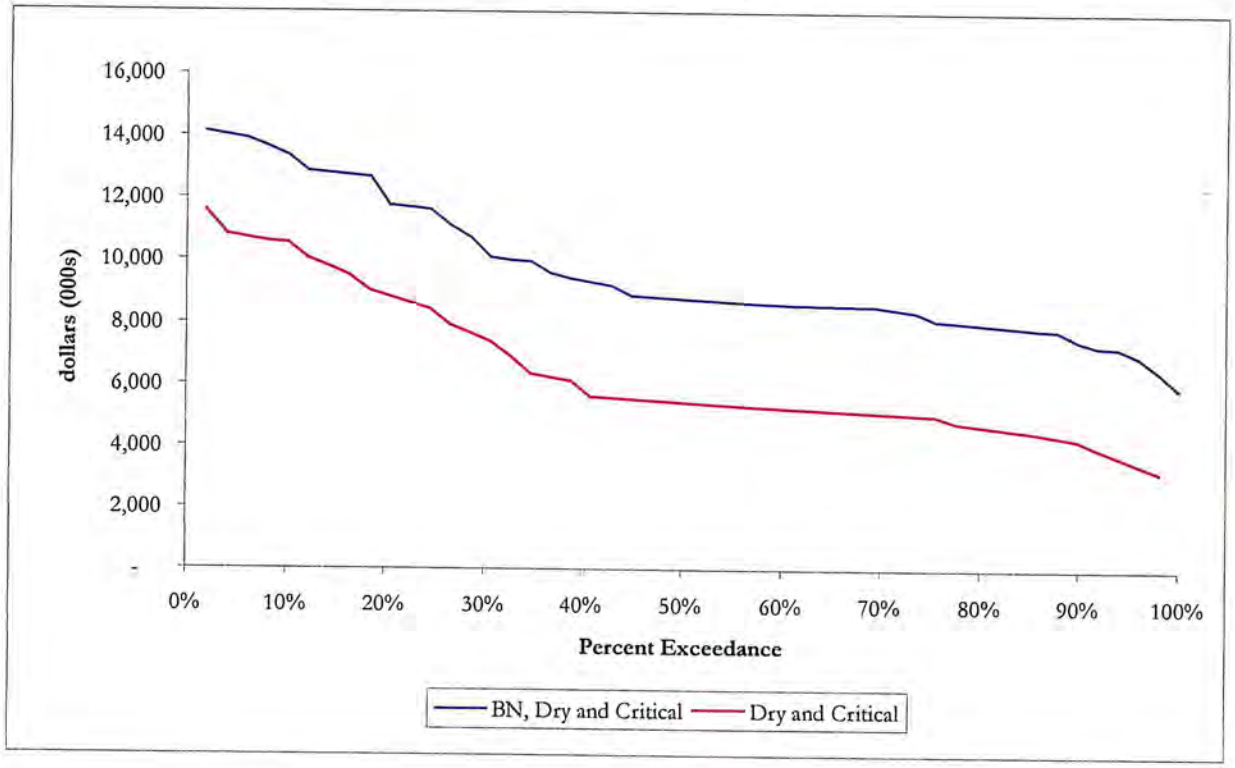


Figure 3-2
Total Annual Net Revenue of 10,000 af Groundwater Substitution in Specified Year Types

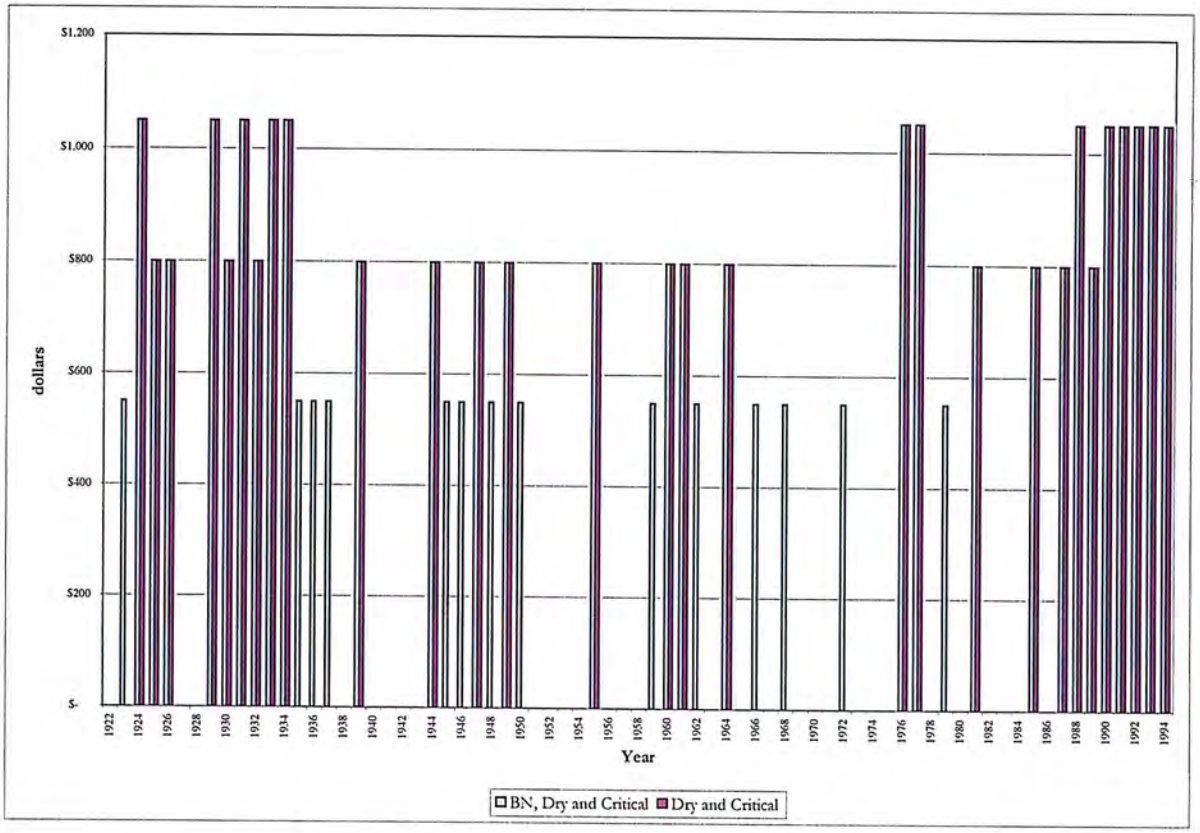


Figure 3-3
Estimated Change in the Volume of Storage in the Aquifer as a Result of a Groundwater Substitution Transfer in Dry and Critical Years under Varying Estimates of Average Annual Recharge

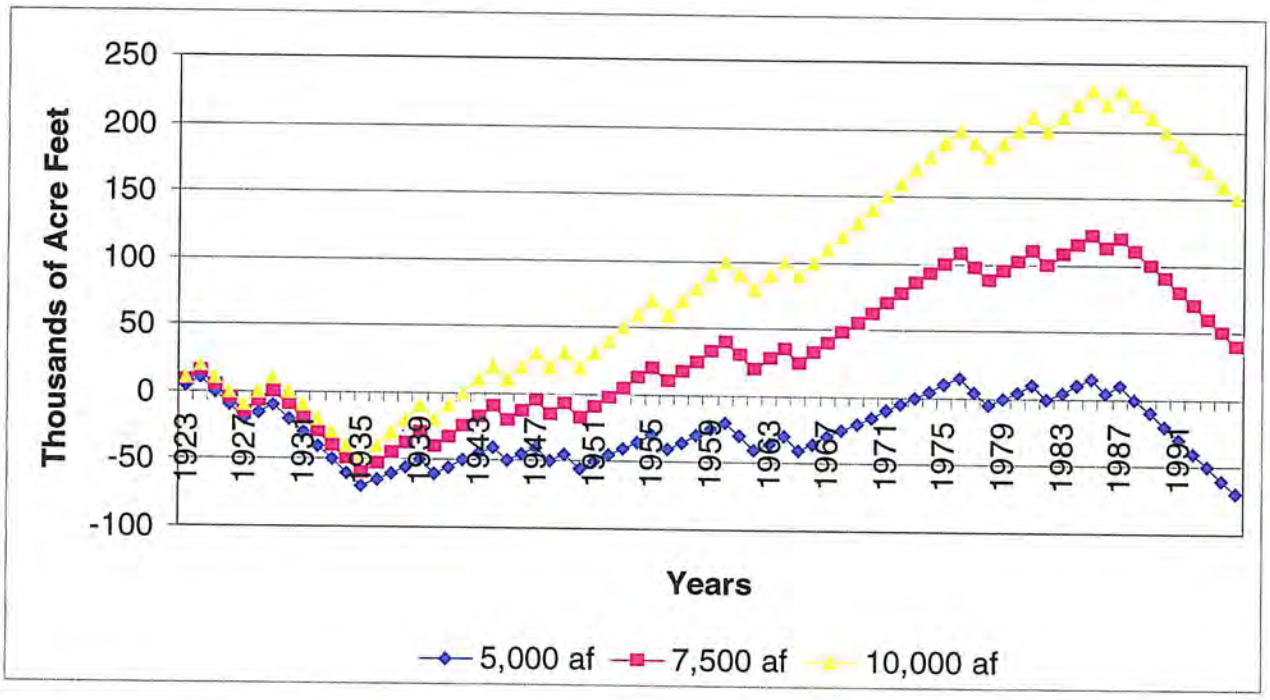


Figure 3-4
Actual Cummulative End of Month Storage for East Park Reservoir and Stony Gorge Reservoir Annually from 1922 to 2003

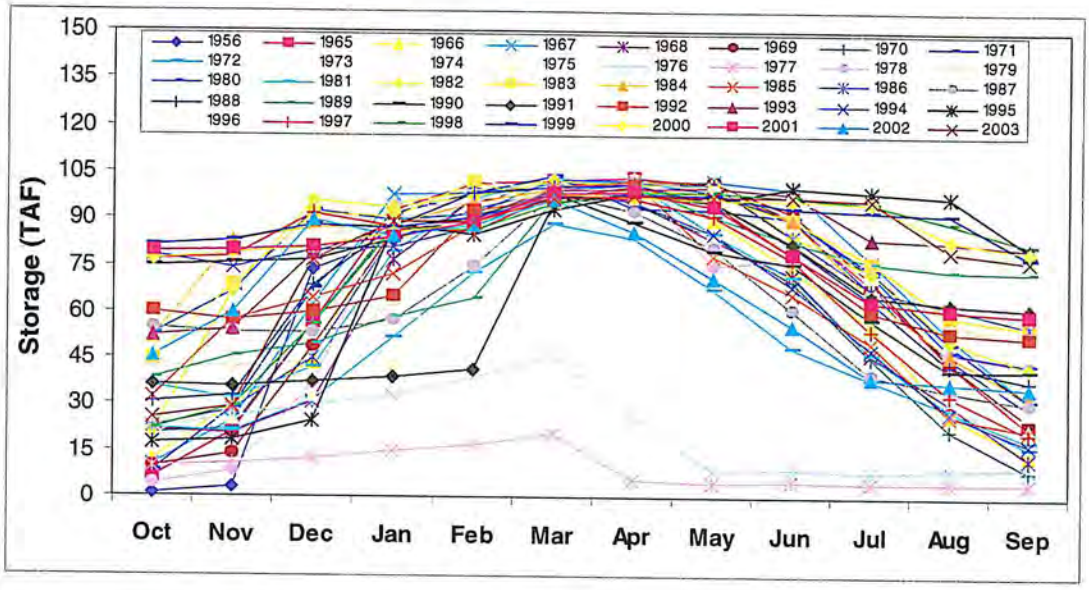
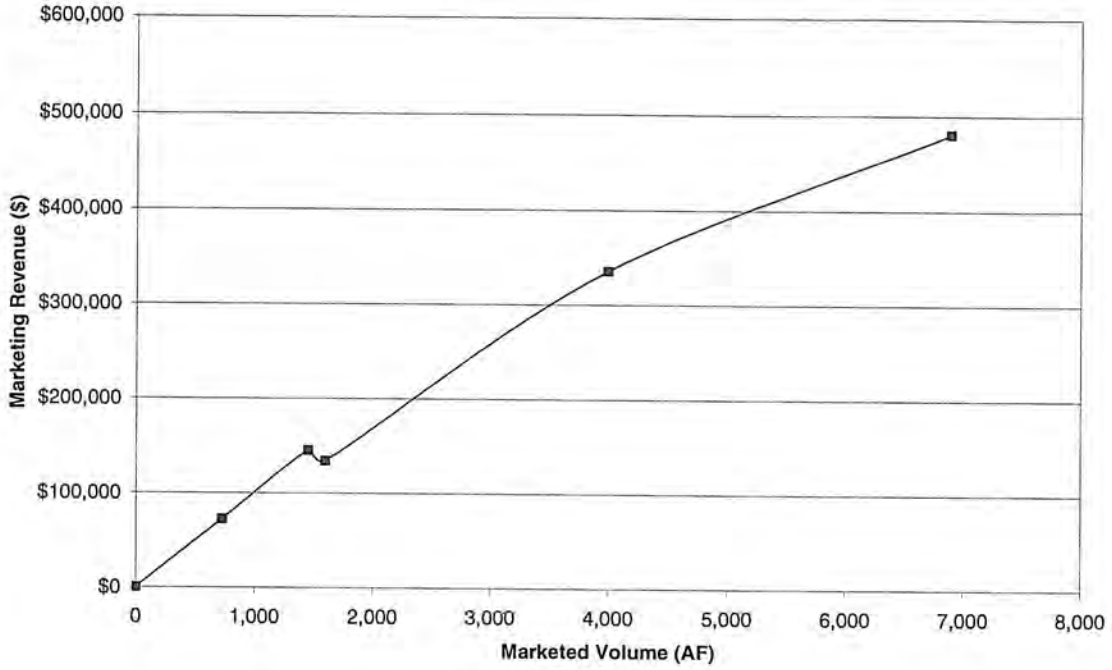
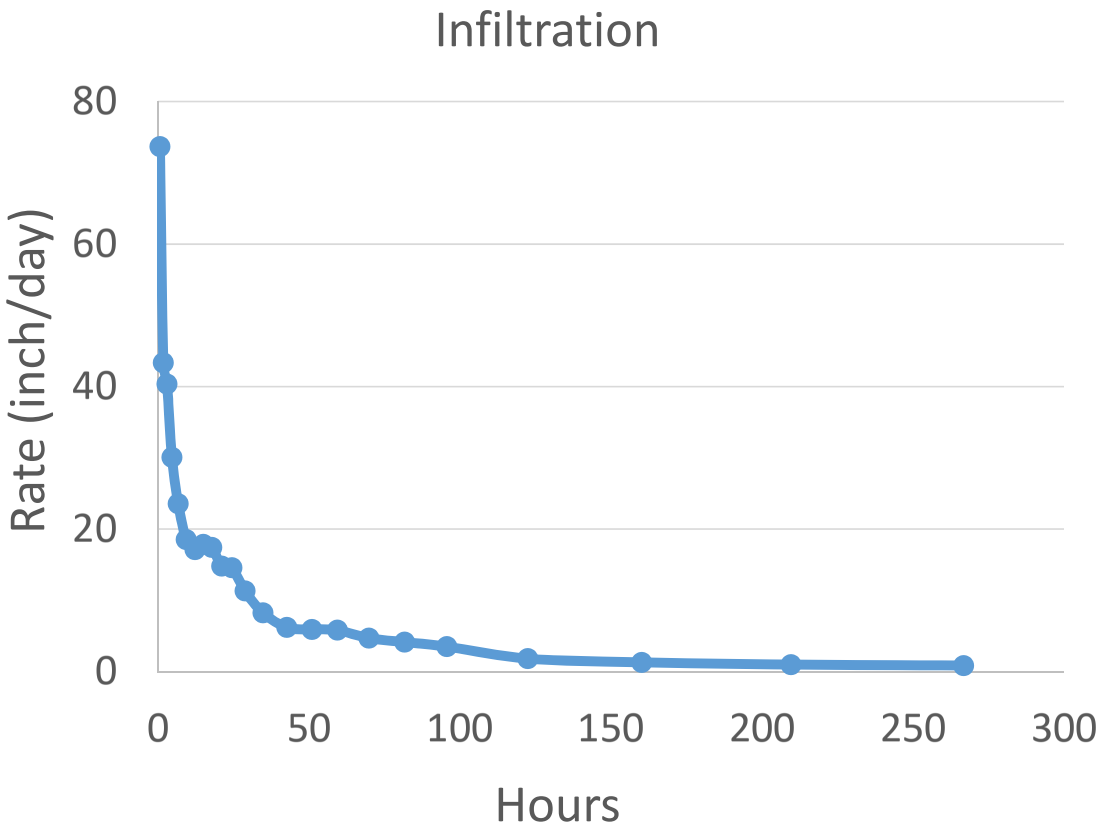


Figure 3-5

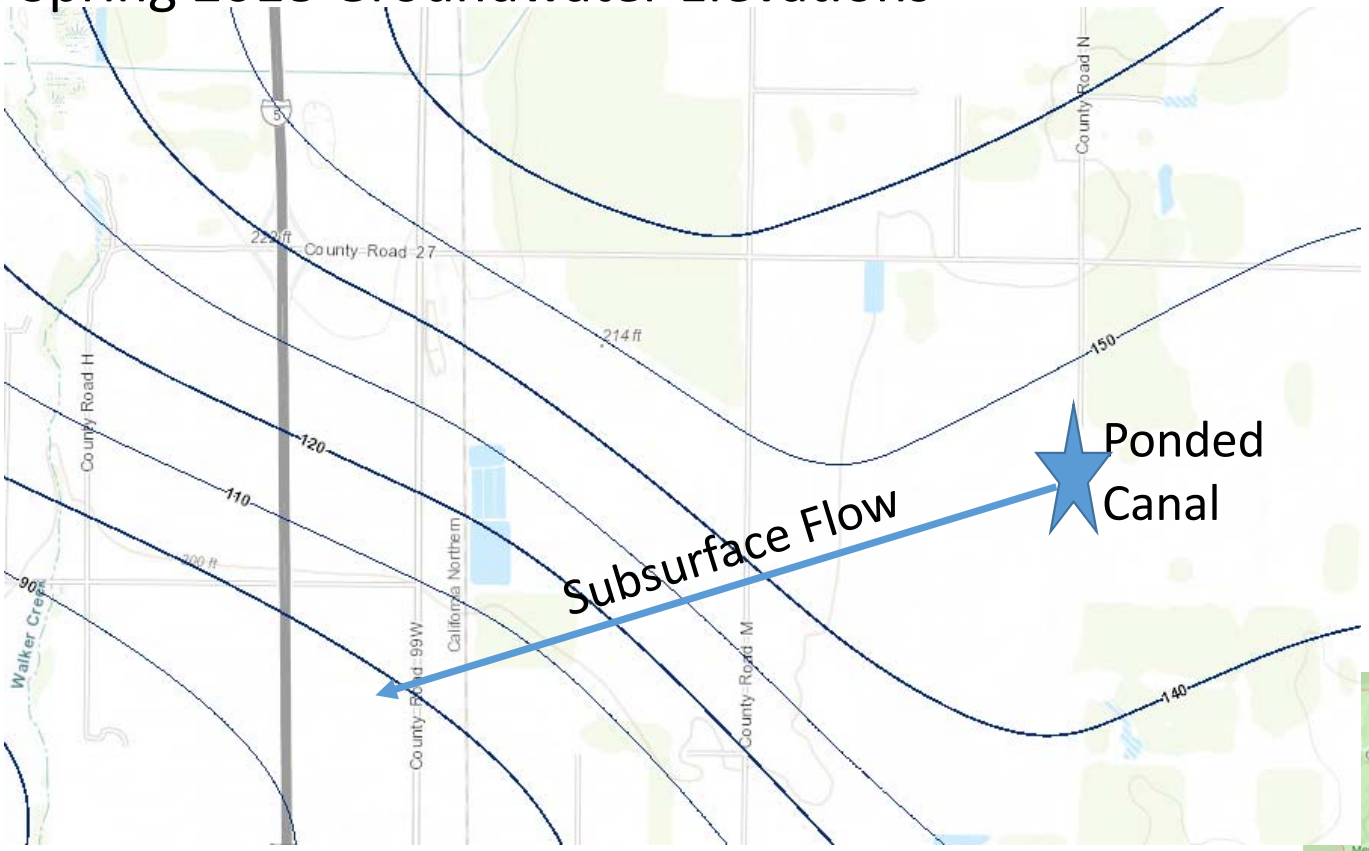
Water Marketing Revenue vs Volume for OAWD

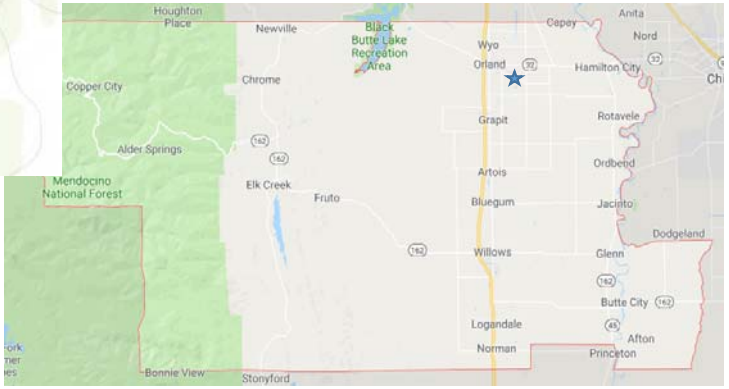


- Infiltration is a function of soil structure and hydraulic gradient
- With 0.8 foot of head saturated infiltration occurs in approximately 125 hours yielding a value of 1.1 inches per day
- There is a linear relationship between infiltration and the hydraulic gradient



Spring 2018 Groundwater Elevations





Project Area: County Road N and 27

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TECHNICAL MEMORANDUM

DRAFT

Stony Creek Fan Conjunctive Water Management Program

SCFIGSM Conceptual Model

To:	Eric Hong, DWR	**CC:**	Sue King Rick Massa Van Tenney Toccoy Dudley Derrick Louie Ron Milligan Roger Putty Grant Davids
From:	Saquib Najmus Mike Cornelius	**Date:**	March 31, 2003
Subject:	**Stony Creek Fan Integrated Groundwater and Surface Water Model (SCFIGSM) Conceptual Model**		
Project Reference:	Contract No.: 4600000734 Task Order: WRIME-Glenn-0901-001		

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SECTION 1 INTRODUCTION

The purpose of this report is to present the conceptual model developed for the Stony Creek Fan Integrated Groundwater and Surface water Model (SCFIGSM).

The purpose of developing a conceptual model is to simplify the modeling problem and organize the relevant field data and information so that the hydrogeologic system can be analyzed (Anderson and Woessner, 1992). The actual hydrogeologic system is too complicated to model; therefore, it needs to be simplified as much as possible. However, a conceptual model should retain enough complexity and level of detail in the representation of the actual field conditions so that the numerical model can reproduce the physical system responses with reasonable accuracy. It has been found that the long-term regional groundwater response projections require the following:

1. assessment of the hydrologic components of the physical system being modeled;
2. delineation of hydrogeology;
3. specification of associated land and water use processes that affect groundwater levels;
4. description of boundary conditions; and
5. definition of horizontal and vertical flow regimes within the system.

Development of a sound conceptual model is essential to understanding how the groundwater basins in a study area may respond to different water management strategies. The conceptual model serves as the basis for the development of a numerical simulation model.

PROJECT BACKGROUND

The Stony Creek Fan is a geologic feature located in Glenn and Tehama counties, near Orland. The coarse grained nature of the Stony Creek alluvial fan provides potential opportunities for direct recharge of the surface water during years of excess surface water supply. However, additional exploration and studies are needed to help determine the optimum approach to conjunctive use operations and methods of groundwater recharge (direct and in-lieu) and recovery of stored groundwater. In addition, studies are needed to assure compliance with the local groundwater management plans, ordinances, and Basin Management Objectives (BMO).

Three Sacramento Valley water purveyors, Orland-Artois Water District (OAWD), Orland Unit Water Users' Association (OUWUA), and Glenn-Colusa Irrigation District (GCID), hereinafter

referred to as "Program Sponsors", agreed through a Memorandum of Understanding (MOU) earlier this year to cooperatively pursue development of the Stony Creek Fan Conjunctive Water Management Program (Program).

The SCFIGSM is being developed in coordination with the California Department of Water Resources (DWR) and the three Project Sponsors to serve as an analytical tool that can provide quantitative information on a comparative basis to help answer different questions on the groundwater and surface water system characteristics and to evaluate alternative conjunctive water management strategies.

STUDY AREA

The general study area, shown in Figure 1.1, extends about 30 miles from west to east and about 70 miles from north to south. The study area includes three reservoirs (the East Park Reservoir, the Stony Gorge Reservoir, and the Black Butte Lake), three major streams (the Thomes Creek, the Stony Creek, and the Sacramento River), five major water distribution canals (the Tehama-Colusa Canal, the Glenn-Colusa Canal, the Colusa Basin Drain, the Orland North Canal, and the Orland South Canal), and several small creeks.

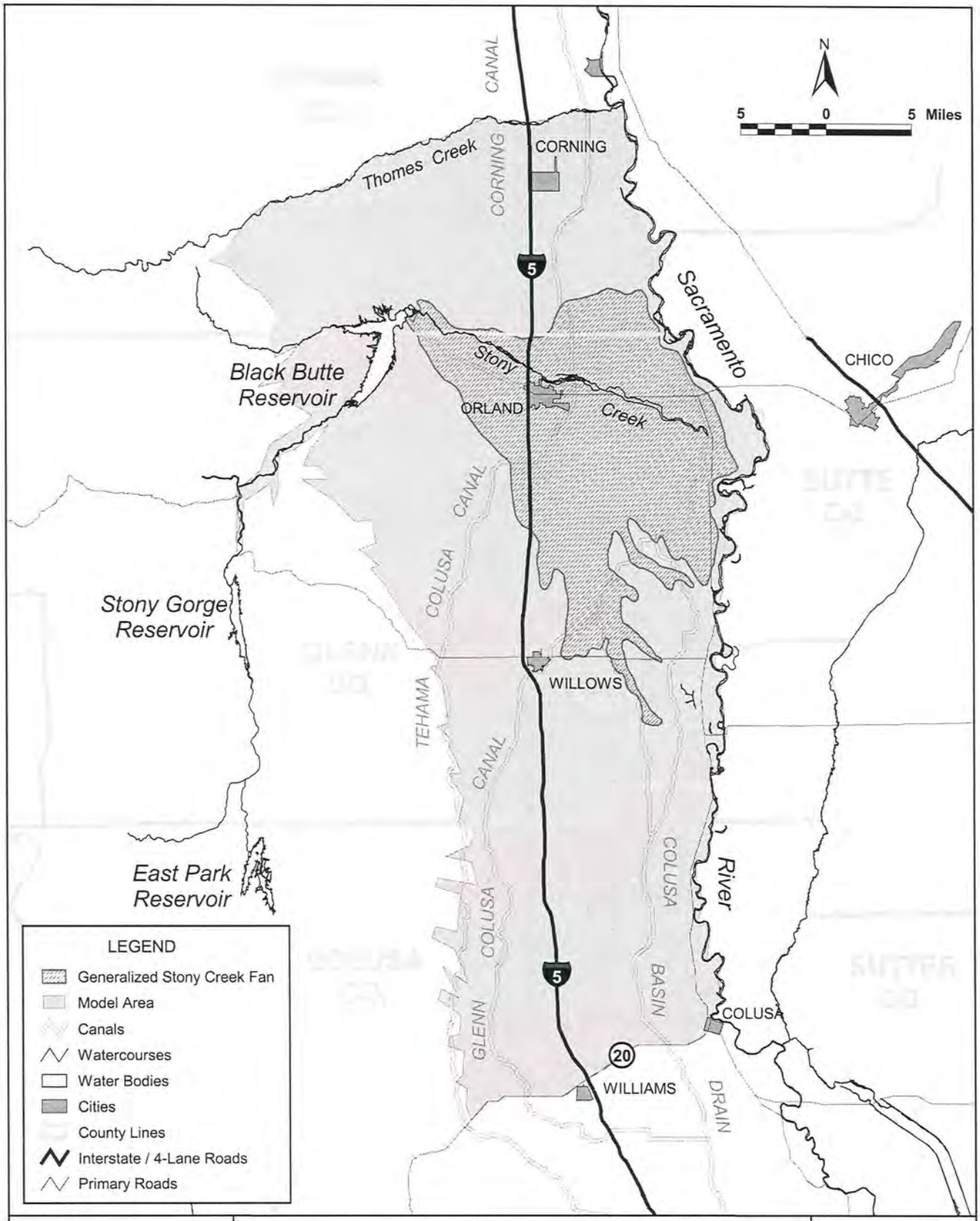
The Stony Creek Fan, shown as a hatched area in Figure 1.1, is a highly permeable near surface formation that extends southeast from the Black Butte Reservoir in the Glenn County. The study area for this project includes the Stony Creek Fan and the areas surrounding the Fan that are included in the model.

The SCFIGSM model area is smaller than the general study area because it follows the hydrogeologic boundaries and features of the underlying groundwater aquifer that is being modeled. The model area is bounded on the north by Thomes Creek and on the south by Highway 20. The model area extends east from the geologic contact with the Coast Ranges Foothills to the Sacramento River.

ORGANIZATION OF THE TECHNICAL MEMORANDUM

The SCFIGSM Conceptual Model Technical Memorandum is organized into the following sections:

- **Section 1: Introduction** describes the purpose, project background, study area and organization of this technical memorandum.
- **Section 2: Hydrogeology** describes the hydrogeology of the Stony Creek Fan Model Area.



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STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM

Model Study Area

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FIGURE 1.1

- **Section 3: Hydrology** describes the general hydrology of the study area.
- **Section 4: Modeling Goals and Objective** describes the goals and objectives of the modeling, which guides the model formulation and development
- **Section 5: Conceptual Model** describes the conceptual model for the study area.
- **Section 6: Summary** presents a summary of conceptual model development and potential model uses.

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SECTION 2 HYDROGEOLOGY

The description of the study area geology provided in this technical memorandum builds on DWR's recent geologic mapping of the area, well log data analysis, and previous investigations by various agencies and authors.

The DWR Northern District is currently in the process of completing comprehensive geologic mapping of the Stony Creek Fan. Several geologic cross sections were developed based on analysis and interpretation of recent and E-logs, and oil and gas logs. These geologic cross-sections are not yet published but were provided as preliminary data to the project study team solely for the purpose of use in the development of conceptual model for SCFIGSM.

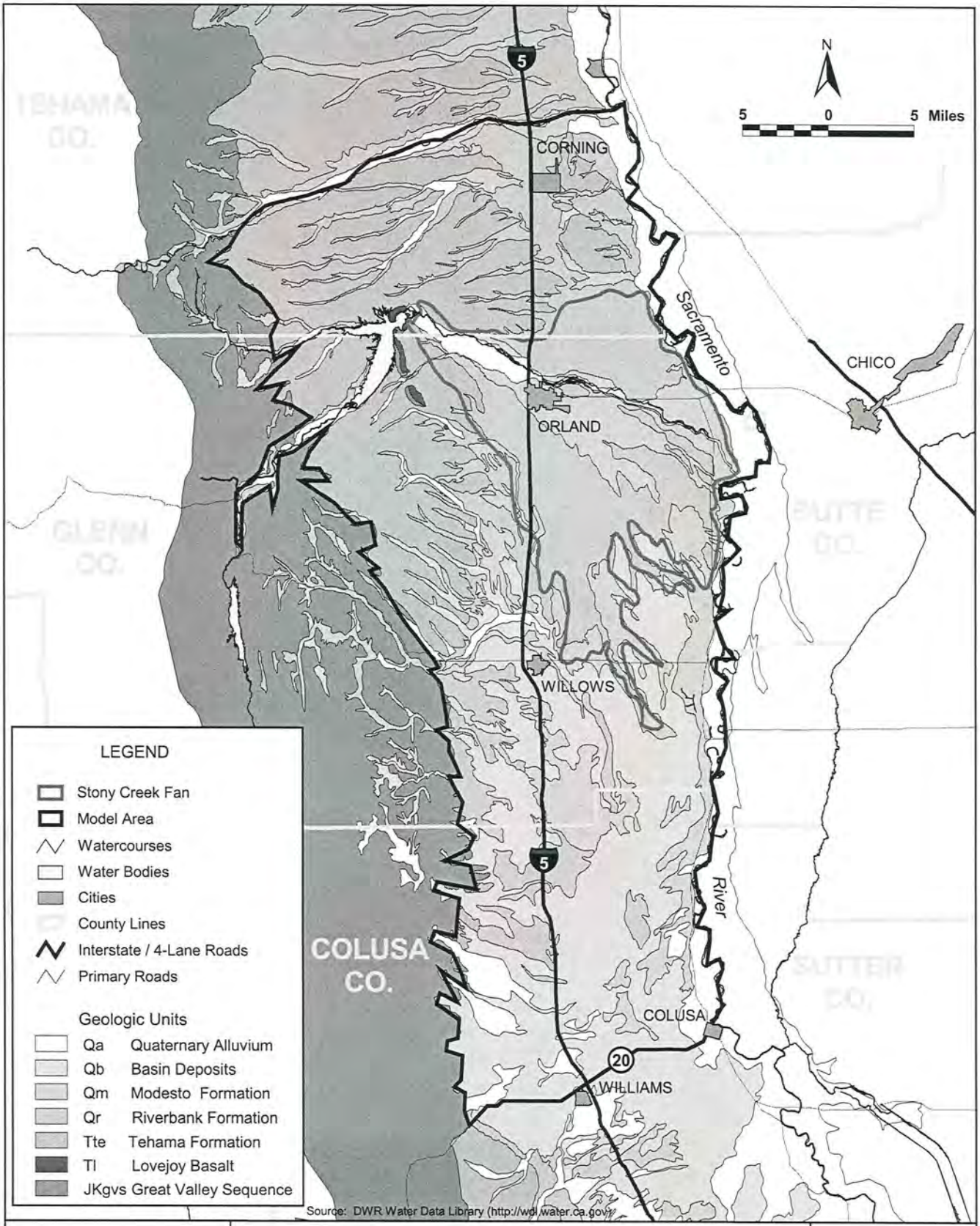
This geologic mapping effort of DWR has resulted in the redefinition of the hydrogeologic setting of Sacramento Valley north of the Sutter Buttes. Until recently, it was believed that the northern Sacramento Valley alluvial aquifer system consisted primarily of a thick layer of interbedded sands and clays. The recent aquifer mapping by the DWR Northern District provides more detailed information about the different aquifer layers that are present in the northern Sacramento Valley.

Monitoring and production well logs for the Counties of Glenn, Tehama, and Colusa are also available as hardcopy data at the DWR Northern District office in Red Bluff. About 400–500 driller's logs were reviewed and screened for the geographic coverage and the level of detail reported in the well log. About 154 driller's logs were further analyzed, interpreted, and used to supplement the existing geologic cross-section data to develop an understanding of the hydrogeology.

DEPOSITIONAL ENVIRONMENT

The geology of the Stony Creek Fan area consists of both marine deposits and continental deposits. The older marine deposits contain saline water and underlie the younger continental deposits. The freshwater bearing continental deposits are the geologic units of interest in the Stony Creek Fan Conjunctive Water Management Program. The geologic units present in the study area are shown in Figure 2.1 and a brief description of the characteristics of these units is provided in Table 2.1.

During the Cretaceous Period to early Miocene Epoch, the present Sacramento Valley trough was inundated by an inland sea, which deposited thousands of feet of marine sediments above the pre-Cretaceous granitic basement rocks. After withdrawal of the marine waters in the



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Surficial Geology

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FIGURE 2.1

Table 2.1
Description of Geologic Units in Study Area

System and Series		Geologic Unit	Lithologic Character	Maximum Thickness[1] (ft)	Water-bearing Character
QUATERNARY	Holocene	Alluvium Qa	Unconsolidated unweathered gravel, sand, silt, and clay[1].	80	Deposits are moderately to highly permeable with high permeability gravelly zones yielding large quantities to shallow wells[2]. Although deposits along Stony, Chico, and Thomes Creeks are important recharge areas[2], extensive water bearing capacity is restricted by thickness and areal extent[1].
		Basin Deposits Qb	Unconsolidated[5] fine-grained silts and clays, locally interbedded with stream and channel deposits along the Sacramento River[1].	150	Deposits are typically saturated nearly to the ground surface[2]. The low to moderate permeability results in yields of small quantity and poor groundwater quality to domestic wells[1,2].
	Pleistocene	Modesto Formation Qm	Poorly sorted[5] unconsolidated weathered and unweathered gravel, sand, silt, and clay[3].	200	Moderately to highly permeable[1].
		Riverbank Deposits Qr	Poorly sorted[5] unconsolidated to semi-consolidated[3] pebble and small cobble gravels interlensed with reddish clay, sand, and silt[1].	200	Water-bearing capability is limited by thickness. These poorly to highly permeable deposits supply moderate groundwater amounts to domestic and shallow irrigation wells. Deeper irrigation wells may be supplied if the wells contain multiple perforation zones[1].
TERTIARY AND QUATERNARY	Pliocene and Pleistocene	Tehama Formation Tte	Fluviatile moderately consolidated pale green, gray, and tan sandstone and siltstone enclosing lenses of sand and gravel; silt and gravel; and cemented conglomerate derived from the Coast Ranges[1,3].	2,000	Local high permeability zones within this characteristically low to moderate permeability unit, widespread distribution, and deep thickness cause this formation to be the principle water bearing unit in the area. Deep well yields are typically moderate, but are highly variable[2].
TERTIARY	Pliocene	Tuscan Formation Tt	This series of volcanic flows, consolidated tuff breccia, tuffaceous sandstone, and volcanic ash derived from the Cascade Range interfingers with the Tehama Formation as it westerly grades into volcanic sands, gravels, and clays[1,2]. The formation is divided by layers of thin tuff or ash units into four lithologically similar units A-D[1].	1,500	Within this formation, moderately to highly permeable volcanic sediments are hyraulically confined by layers of tuff breccias and clays[2]. Units A and B are the primary water-bearing zones and are composed of volcanic conglomerate, sandstone, and siltstone layers interbedded with lahars. Stragraphically higher, the massive lahar deposits of unit C confine groundwater in the permeable beds of units A and B[1].
		Nomlaki Tuff Member	Tuff breccias and white tuffs of dacitic composition. This member of the Tehama and Tuscan Formations serves as an important stratagraphical marker bed in northern Sacramento Valley[5].	60[5]	Poorly permeable.
	Miocene	Neroly Formation Tn	Marine to non-marine tuffaceous andesitic sandstone interbedded with tuffaceous shales and tuff layers. Contains local conglomerate lenses[4].	500	This formation of variable permeability contains interstitial fresh water under confined conditions[4], however, deposits of the Neroly Formation are typically located below the base of fresh water.
		Lovejoy Basalt Tl	Black, dense, hard microcystalline basalt[3].	65	Largely non-water bearing.
	Miocene and Oligocene	Upper Princeton Valley Fill Tupg	Non-marine sandstone containing mudstone, conglomerate, and sandstone conglomerate interbeds[3].	1,400	Largely non-water bearing or contains saline water.
	Eocene	Lower Princeton Submarine Valley Fill Tlpg	Marine conglomerate and sandstone interbedded with silty shale[3].	2,400	Largely non-water bearing or contains saline water.
CRETACEOUS		Great Valley Sequence JKgvs	Marine siltstone, shale, sandstone, and conglomerate[3].	15,000	Largely non-water bearing or contains saline water[2].
PRE-CRETACEOUS		Basement Complex pTb	Metamorphic and igneous rocks.	n/a	May contain groundwater, mainly saline, in fractures and joints.

Notes:

[1] Department of Water Resources web page (www.wq.water.ca.gov).
[2] Department of Water Resources, Bulletin 118-6, 1978.
[3] Department of Water Resources, Bulletin 118-7 (Draft, not published).
[4] Department of Water Resources, Sacramento River Basin-Wide Water Management Plan-Draft, 2000.
[5] Department of Water Resources, Groundwater Levels in the Sacramento Valley Groundwater Basin, Glenn County, 1997.

Miocene Epoch, there was a period of erosion dominated by the deposition of continental deposits.

During the Pliocene Epoch, the northern Coast Range uplift was initiated and the Sacramento Valley began to assume its current form. Coast Range uplift and related erosion of the uplifted block resulted in deposition of the Tehama Formation onto the heavily eroded, subsiding valley floor. In late Pliocene period, volcanic activity on the southern Cascade Range caused the widespread deposition of the Nomlaki tuff across the northern Sacramento Valley. This extensive ash layer is found near basal deposits of the Tehama and Tuscan Formations. Continuous volcanism in the southern Cascade Range produced consecutive mudflows of basaltic and andesitic composition. These igneous deposits were reworked coincident with volcanic activity resulting in the Tuscan Formation on the east side of the Sacramento Valley.

The deposition of the Tehama and Tuscan Formations occurred simultaneously during the Pliocene Epoch. These thick, widespread deposits overwhelmed the previous topography, creating a relatively flat plain that was repeatedly dissected by meandering and braided streams.

Fluviatile sedimentation of the Tehama Formation was continuous on the west side of the Sacramento Valley throughout the Pliocene and possibly into the Pleistocene period. During the middle part of the Pleistocene period, mountain-building activity brought the Coast Ranges to their current structure and shape. The Tehama Formation deposits, along with older deposits, were involved in this folding and faulting event, and formed low hills and dissected uplands. Intense erosion concurrent and following this orogenic activity reworked the Tehama Formation and redeposited the sediments near the center of the Valley. Much of these sediments were carried away by the Sacramento River.

Quaternary sedimentation is represented in the deposition of broad alluvial fans and flood plains. In the vicinity of the Stony Creek Fan, the newly eroded surface of the Tehama Formation was covered with poorly sorted gravel deposits of the Pleistocene Modesto and Riverbank Formations. Gravels of these terrace deposits were partially supplied by continued erosion of the Coast Ranges. The northwest Sacramento Valley cycle of valley deposition continues to the present day.

The low hills and dissected uplands appear between the Coast Ranges and the alluvial fans of the valley. An abrupt increase in the land slope marks the transition between the alluvial fans and the uplands. These hills are topographic expressions of subsurface folding and faulting of the Tehama Formation and older underlying sediments.

As streams draining east from the Coast Ranges leave the low hills and dissected uplands, they flow out into the relatively flat valley floor. This change in slope causes them to deposit their bed load, forming broad alluvial fans. Alluvial fan deposits are an intricate system of buried channels formed by a dynamic fluviatile depositional environment. An example of an alluvial fan is the Stony Creek Fan (Figure 1.1 in Section 1), the focus of the current study. This fan is the largest and most complex alluvial fan in the northwest portion of the Sacramento Valley and was deposited by Stony Creek. The apex of the Stony Creek Fan is approximately five miles northwest of the town of Orland, where Stony Creek flows out of the low hills. The Stony Creek Fan extends east to the Sacramento River flood plain, and south to the Colusa basin deposits near the town of Willows. The surface of the fan is not smooth, but rather cut by many abandoned channels. Smaller and less impressive fans have been deposited by intermittent streams south of the Stony Creek Fan. In general, these deposits are much finer grained than the deposits of the Stony Creek Fan.

In flat, low-lying basins between the alluvial fans and the Sacramento River, distal alluvial fan sediments merge with the fine-grained basin deposits. During flooding events along the Sacramento River, water spills over the natural river levee and accumulates in these basins. The trapped water creates temporary lakes, and the quiescent environment allows for deposition of fine-grained suspended material. The Colusa Basin, which extends 60 miles south of the Stony Creek Fan, is an example of this depositional phenomenon.

The Sacramento River and Stony Creek have deposited a large quantity of coarse material in the northwest Sacramento Valley over thousands of years. These deposits form the alluvial aquifer in the study area. The Sacramento River and Stony Creek are also the primary sources of surface water to the study area.

GEOLOGIC FAULTS

The Sacramento Valley is an asymmetrical northward-trending syncline partially filled with sedimentary deposits. Several faulting, folding, and uplift events tilted the Sierra Nevada block relative to the Coast Ranges. Latter orogenic events are expressed in folding and faulting of Pre-Middle Pleistocene basal deposits. Faults related to this geologic activity include the Paskenta, Willows, Corning, and Black Butte Faults.

WATER BEARING FORMATIONS

The key characteristics of the water-bearing geologic formations of the study area are summarized in Table 2.1, presented previously. These units include the Pliocene Tuscan

Formation; Pliocene and Pleistocene Tehama Formation; Pleistocene Modesto and Riverbank Formations; and the Holocene alluvial, basin, and flood plain deposits.

Marine sediments in the study area include the Miocene Neroly Formation, the Miocene and Oligocene Upper Princeton Valley Fill, the Eocene Lower Princeton Submarine Valley Fill, and the Cretaceous Great Valley Sequence. These deposits define the subsurface freshwater aquifer boundary. In general, these largely non–water bearing deposits occur below the base of fresh water; thus they may contain small amounts of saline water.

Pliocene Tuscan Formation

Tuscan deposits are characterized by their Cascade Range origin and volcanic signature. This extensive series of basaltic and andesitic volcanic flows, consolidated tuff breccia, tuffaceous sandstone, and volcanic ash is primarily located on the northeastern portion of the Sacramento Valley. The Tuscan Formation underlies much of the Valley floor and extends from the Cascades to the center of the Valley where it grades into volcanic sands, gravels, clays, and interfingers with the Tehama Formation. Thin tuff or ash units separate the Tuscan Formation into four distinct, yet lithologically similar Units A, B, C, and D (D being the youngest). Only A, B, and C are found in the project study area. Unit C is composed of massive lahar (mudflow) deposits with volcanic sandstone and conglomerate interbeds. Tuscan Formation Unit C is referred to as the Upper Tuscan Formation. Tuscan Units A and B are largely composed of layered, inter-bedded lahars, siltstone, and volcanic sandstone and conglomerate; they are referred to as the Lower Tuscan Formation. Unit A is distinguished from Unit B by the presence of metamorphic rock fragments in siltstone layers. This formation contains fresh water.

Pliocene-to-Pleistocene Tehama Formation

Deposits of the Tehama Formation are characterized by their fluviatile nature and origin from the Klamath Mountains and Coast Ranges. This assemblage of moderately consolidated sandstone and siltstone with local coarse lenses is located in the northwest portion of the Sacramento Valley. These yellowish to greenish grey deposits are separated from the underlying Eocene Epoch and Cretaceous Period marine sediments by an unconformity. The Tehama Formation was deposited under floodplain conditions by rivers and streams flowing from nearby mountains in a subsiding, low relief valley. Several properties of the Tehama Formation indicate a western and northwestern origin. Mineral composition and rock type of Tehama deposits are identical to those in the Coast Ranges and Klamath Mountains. Additionally, the grain size of Tehama Formation sediments decreases to the south and east, suggesting a western and northwestern origin. This formation contains fresh water.

PLIOCENE NOMLAKI MEMBER

This deposit is recognized as a member of both the Tehama and Tuscan Formations indicating simultaneous deposition. The Nomlaki Member is composed of coarse tuff breccias and white tuffs of dacitic composition and has an eastern source. This widespread deposit serves as an important stratigraphical marker in the northern part of Sacramento Valley. This formation contains fresh water.

PLEISTOCENE DEPOSITS

Terrace deposits of the Pleistocene Modesto and Riverbank Formations are composed of poorly sorted clay, silt, sand, and gravel, and form a thin veneer at the ground surface. The Riverbank Formation is distinguished from the Modesto deposits by interbedded clay layers. In the Stony Creek Fan area, these terraces are well defined, but they are absent or poorly defined along other minor streams in the study area. This formation contains fresh water.

HOLOCENE DEPOSITS

Quaternary alluvium, the most recent deposit, is found along major rivers and is composed of unconsolidated unweathered clay, silt, sand, and gravel. Fine-grained flood plain deposits include silt with minor amounts of sand. The basin deposits are composed of fine-grained sediments and are found in flood basins and near streams. The coarse-grained sediments of the alluvial fan include sand and gravel. This formation contains fresh water.

HYDROGEOLOGY

The Stony Creek Fan deposits include Pleistocene and Holocene upper, unconfined aquifer deposits. As Stony Creek meandered across the fan, channels were created, abandoned, and then buried, creating a complex system of coarse- and fine-grained sediments. The variable nature of this fluviatile, depositional environment causes difficulty in defining groundwater aquifers within the fan.

The Stony Creek alluvial fan sediments form a thin veneer over the Tehama Formation. During the Pleistocene, the surface of the Tehama Formation was intensely eroded, then backfilled with both coarse- and fine-grained deposits of the Stony Creek Fan. The resulting uneven contact between the geologic units makes it difficult to determine the contact between the Stony Creek Fan deposits and the underlying Tehama Formation. The nature and extent of groundwater interaction between these deposits is uncertain due to the channelized nature of both formations.

Typical Tuscan deposits are coarser than those of the Tehama Formation. Simultaneous deposition of these extensive formations onto a broad valley surface resulted in the interfingering of Tuscan and Tehama sediments near the center of the valley. In general, the grain size of the Tehama Formation becomes finer to the east, and the Tuscan Formation grades into volcanic gravels, sands, and clays where the deposits overlap. The nature of groundwater interaction where these formations merge is uncertain.

The aquifer system of the Stony Creek Fan Area includes a freshwater aquifer overlying a saline aquifer. The freshwater alluvial aquifer system in the study area is composed of late Tertiary to Quaternary continental deposits. The aquifer system includes an upper unconfined alluvial aquifer consisting of Quaternary deposits overlying a confined aquifer system composed of Quaternary and Tertiary continental deposits of fluvial and volcanic origin. The saline aquifer system composed primarily of Tertiary and older marine deposits.

FRESHWATER AQUIFER SYSTEM

The freshwater aquifer system is composed of an unconfined aquifer overlying a confined aquifer as described below.

Unconfined Aquifer

The upper unconfined aquifer consists of Quaternary deposits, including Holocene alluvium, flood plain, alluvial fan, and basin deposits, and the Pleistocene Riverbank and Modesto Formations. The unconfined aquifer system is important to local groundwater users, but the potential for significant groundwater storage is limited due to insufficient thickness.

Recharge Areas

The unconsolidated, highly permeable Quaternary alluvium deposits are important recharge areas. These deposits are generally located along major rivers and facilitate groundwater recharge from rivers. Highly permeable alluvial fan deposits, specifically of the Stony Creek Fan, are also important recharge areas. The moderately permeable basin deposits and floodplain deposits are less important recharge areas.

In addition to the Holocene deposits, the highly permeable terrace deposits of the Pleistocene Modesto and Riverbank Formations are significant recharge areas. Water bearing capabilities of these formations are limited by their thickness.

Confined Aquifer

The confined aquifer is composed of Tertiary Deposits, including the Pliocene and Pleistocene Tehama Formation and the Pliocene Tuscan Formation. These widespread and thick formations are important in aquifer storage and well water supply.

Tehama Formation

The Tehama Formation is the primary water source of the study area. Groundwater in this formation occurs under semi-confined to confined conditions. The widespread occurrence and relatively higher thickness allow this formation to supply water to most of the wells in the study area. Moderately compacted, thickly bedded sandstone and siltstone layers derived from the Coast Ranges result in characteristically low to moderate permeability. However, thinner lenses of sand and gravel result in local, high permeability zones.

Potential for groundwater recharge and storage is limited by the geographic irregularity of these permeable lenses. Well yields are typically moderate for deeper wells. However, well yields vary from high to low due to variable permeability zones. Generally, wells located near the Stony Creek Fan have higher yields than those located to the south. The Tehama Formation has a higher concentration of more permeable coarse material in the vicinity of the alluvial fan deposits. Variations in well yields indicate the north to south decrease in grain size.

Tuscan Formation

The Tuscan Formation serves as the primary source of groundwater on the east side of the Sacramento River. In the study area, these deposits occur at depths in excess of the depths of the most of the existing domestic and irrigation wells.

Moderately permeable to highly permeable volcanic sediments are hydraulically confined by layers of tuff breccias and clays within the Tuscan formation. The low permeability lahar deposits of Unit C serve as confining beds for the underlying older Tuscan Units A and B. Although Unit C contains permeable volcanic sandstone and conglomerate interbeds, this unit is characterized by an overall low yield of water to wells. Units A and B are much more coarse-grained than the overlying Unit C, causing them to be the primary water-bearing zones of eastern Sacramento Valley.

Saline Aquifer System

The saline aquifer system lies beneath the fresh water aquifer. The base of the fresh water aquifer is defined by the contact between continental deposits and pre-Pliocene marine

deposits. The marine deposits present in the study area subsurface include the Miocene Neroly Formation, the Miocene and Oligocene Upper Princeton Valley Fill, the Eocene Lower Princeton Submarine Valley Fill, and the Cretaceous Great Valley Sequence.

HISTORIC GROUNDWATER CONDITIONS

DWR Bulletin 118-6 provided historic water level contours for 1912 and 1961 in the Sacramento Valley. The 1912 pre-development conditions water level in the study area varied from 80 feet to 300 feet above mean sea level. The direction of groundwater flow was generally in southeast direction. Bulletin 118-6 also provided a water level difference map between the years 1961 and 1912, which showed no difference in almost the entire study area except a 10 feet rise in groundwater level near the town of Orland.

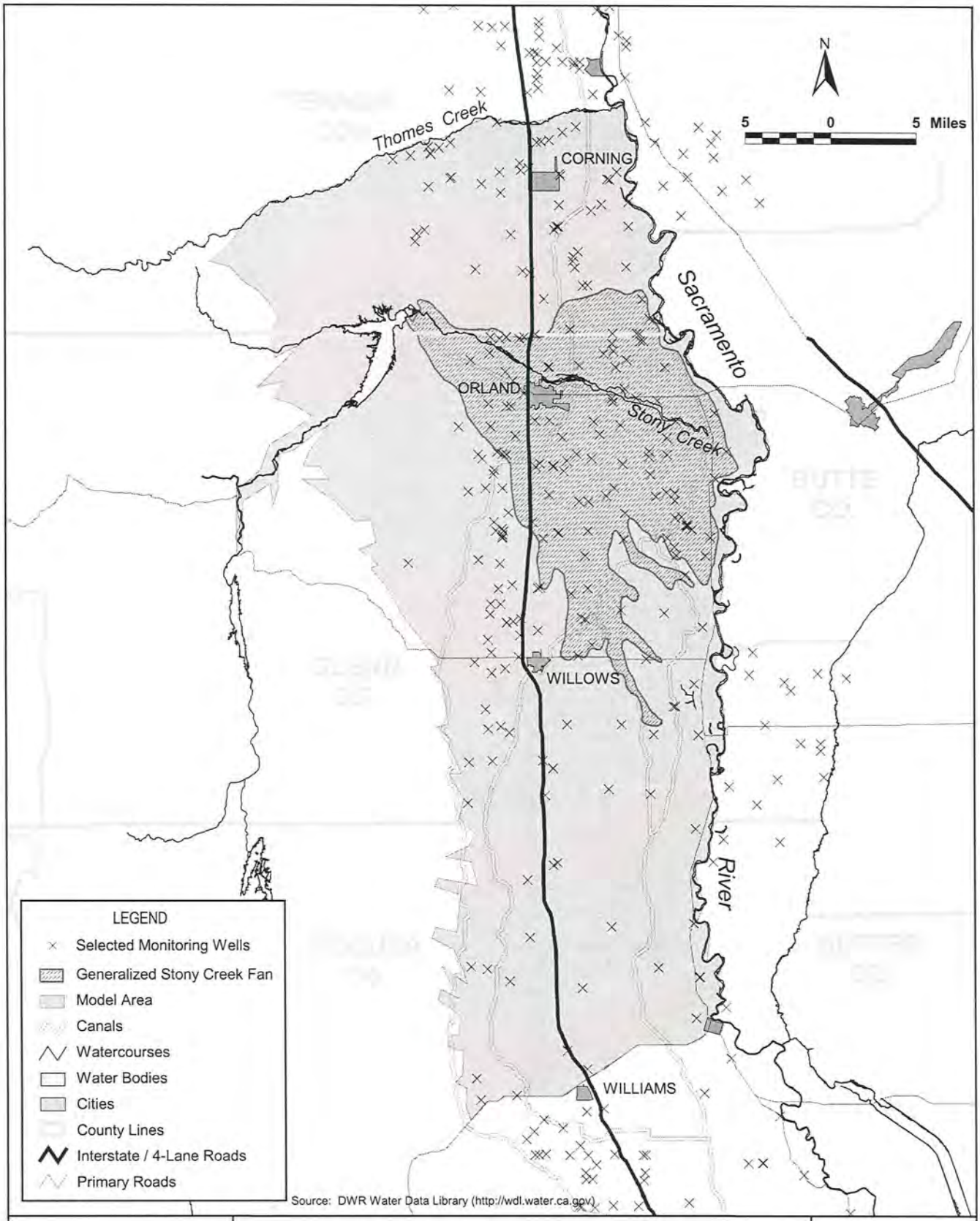
DWR has been collecting water level data at different monitoring wells in the study area for a number of years. The locations of selected past and current monitoring wells in the study area are shown in Figure 2.2. There are about 191 wells (18N–22N) in the Glenn County, 40 wells (15N–18N) in the Colusa County, and 203 wells (23N–25N) in the Tehama County that are monitored intermittently. The period of record spans from 1921 to current. Table 2.2 shows the frequency of water level measurements at wells for the 3 counties in the study area. This data is used to develop historic groundwater level contours for different periods and are presented in Figures 2.3 to 2.12. It should be noted that there are few monitored wells in the area northwest of Willows.

The fall of 1969 water surface elevation is shown in Figure 2.3. The recorded data for October 1969 were used to develop this contour map. During the month of October, the water surface elevations are at their lowest following high groundwater pumping in summer months and prior to aquifer recharge during rainy winter months.

The contour map for March 1974 (Figure 2.4) shows water level conditions prior to 1976-77 drought and prior to Tehama-Colusa Canal deliveries. In general, there is little change from the October 1969 groundwater levels, except small decreases in groundwater levels in some areas.

The contour map for March 1977 (Figure 2.5) map shows water level conditions during a historical dry period. Water levels show a decrease in elevations across the study area in response to the drought conditions. The October 1977 water level contour map (Figure 2.6) shows the impact of dry conditions compounded by increased groundwater pumping during the summer months.

Following the 1976 to 1977 drought conditions, additional surface water was delivered to the model area via the Tehama-Colusa Canal. This, along with a historical wet period, enabled



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Monitoring Well Locations

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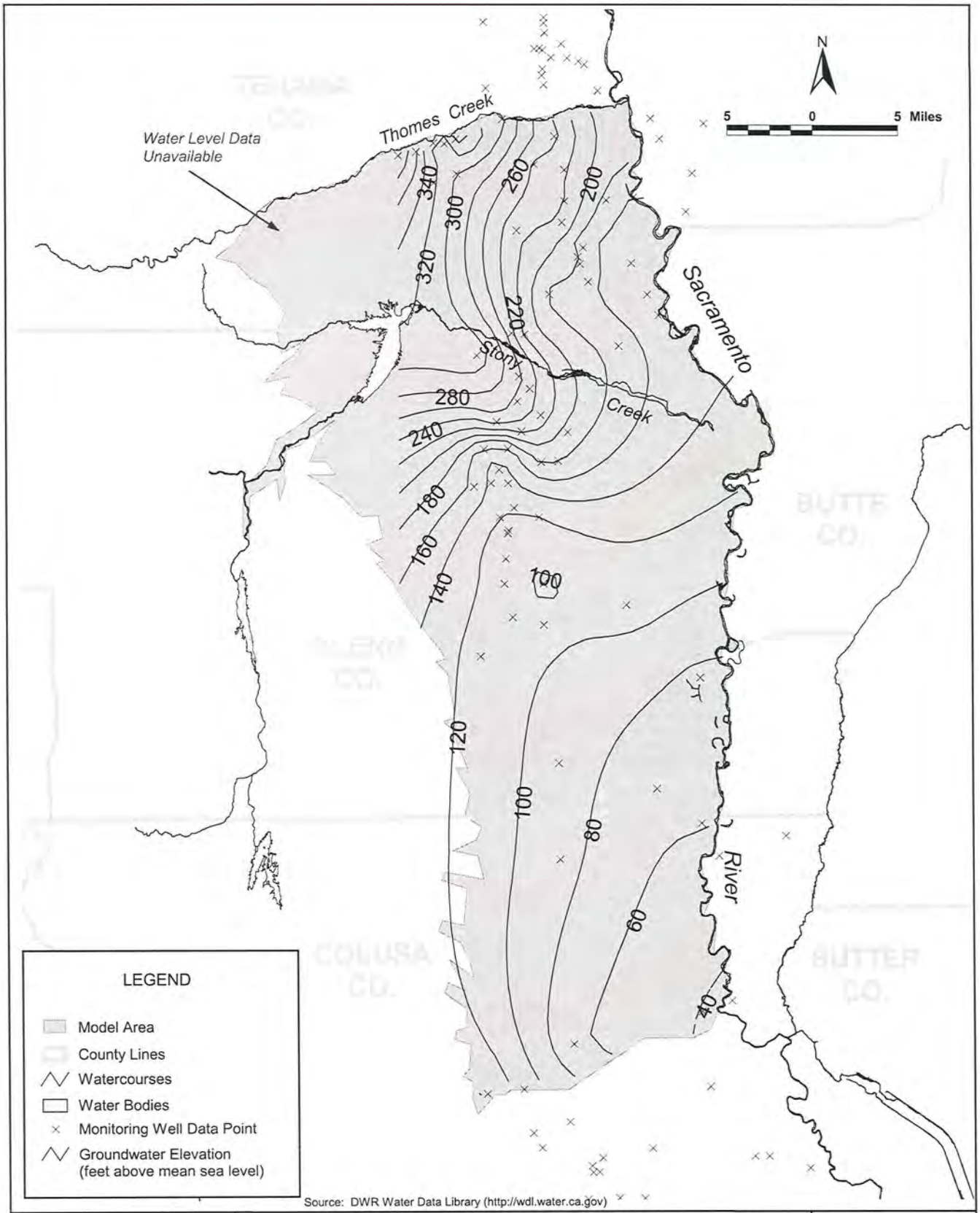
FIGURE 2.2

Table 2.2
Monitoring Well Measurements per Year

Year	Number of Wells Measured	Number of Measurements
1921	2	2
1922	1	1
1923	9	127
1924	7	134
1925	7	165
1926	10	159
1927	10	163
1928	12	167
1929	42	200
1930	43	200
1931	42	201
1932	37	177
1933	39	183
1934	35	35
1935	0	0
1936	33	33
1937	31	31
1938	1	1
1939	32	32
1940	27	27
1941	31	79
1942	29	347
1943	30	253
1944	30	269
1945	30	118
1946	44	512
1947	99	399
1948	121	476
1949	100	295
1950	115	247
1951	142	267
1952	159	430
1953	176	714
1954	158	457
1955	114	365
1956	115	333
1957	140	249
1958	174	536
1959	191	611
1960	191	620
1961	197	624
1962	204	765

Table 2.2
Monitoring Well Measurements per Year

Year	Number of Wells Measured	Number of Measurements
1963	220	832
1964	223	918
1965	254	948
1966	256	1069
1967	268	1129
1968	261	1149
1969	257	1154
1970	255	1138
1971	252	1169
1972	249	976
1973	278	1019
1974	246	869
1975	268	953
1976	279	1028
1977	279	1072
1978	281	1060
1979	284	816
1980	281	789
1981	276	802
1982	270	784
1983	265	766
1984	261	695
1985	260	821
1986	260	814
1987	262	775
1988	274	785
1989	272	853
1990	281	943
1991	281	1320
1992	286	897
1993	288	983
1994	286	989
1995	274	953
1996	290	766
1997	259	541
1998	250	505
1999	249	640
2000	277	527



Source: DWR Water Data Library (http://wdl.water.ca.gov)

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Fall 1969 Groundwater Elevation Contour Map

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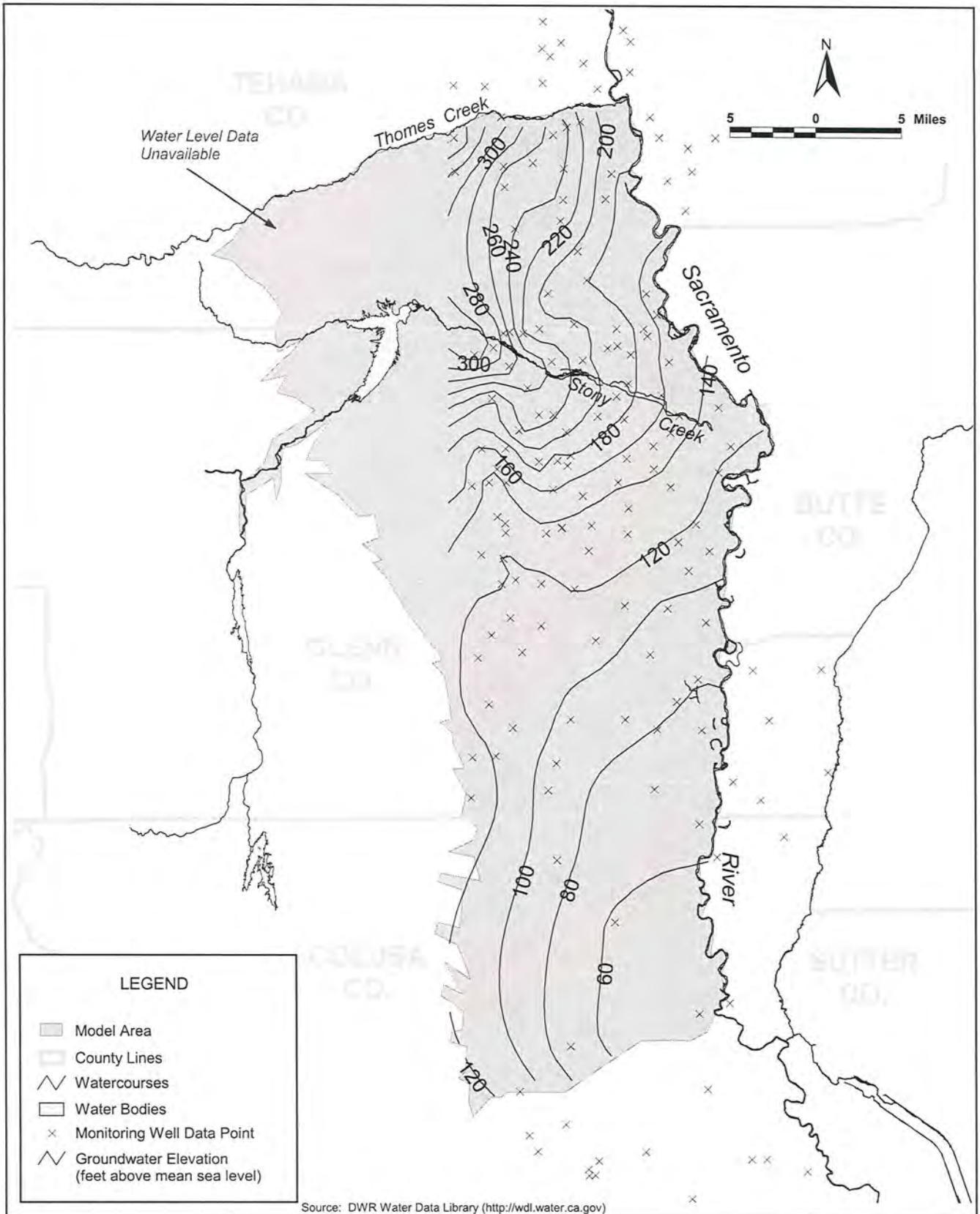
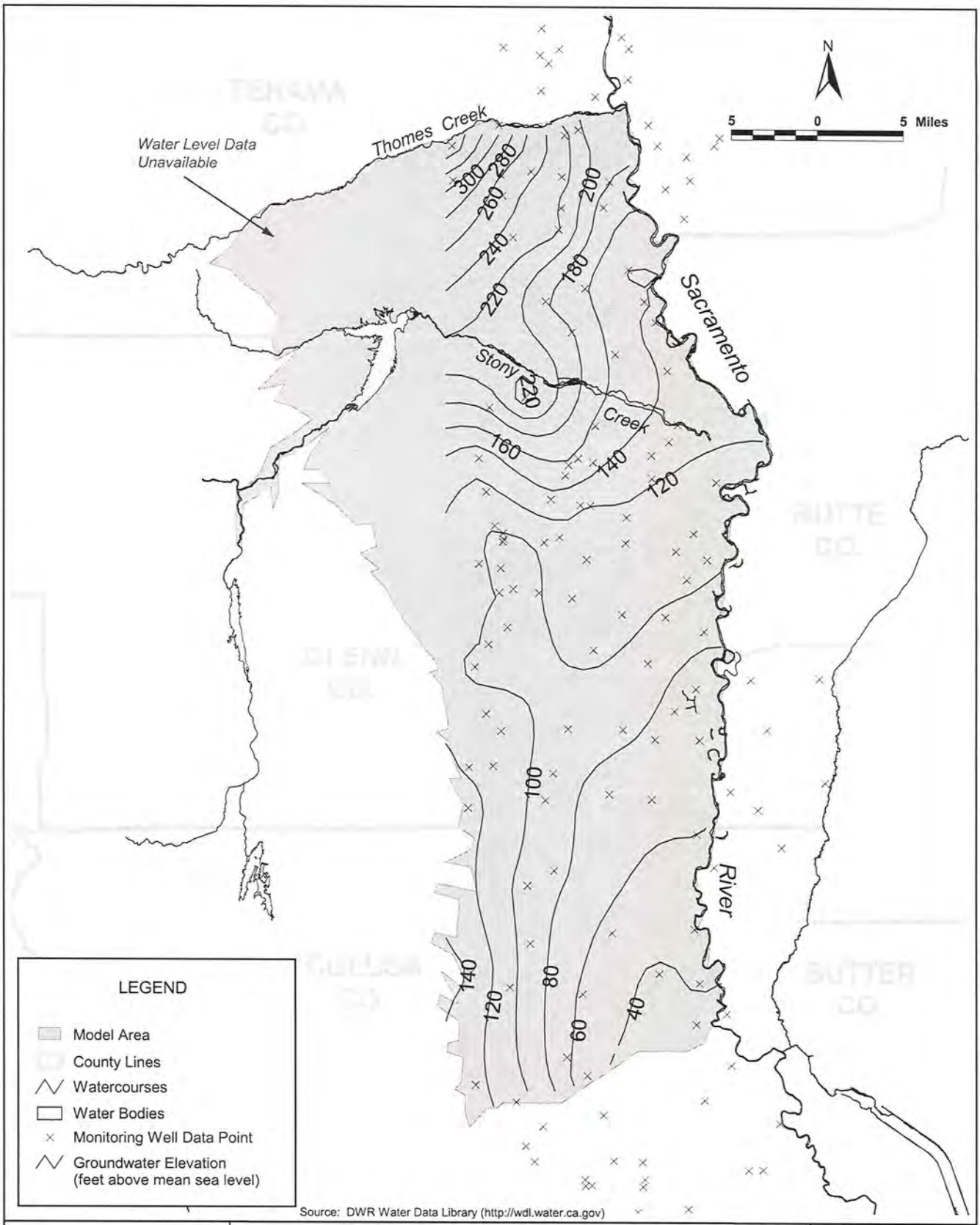
FIGURE 2.3



Source: DWR Water Data Library (http://wdl.water.ca.gov)

WRIME Water Resources & Information Management Engineering, Inc.	STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM **Spring 1974 Groundwater Elevation Contour Map** **DRAFT**	MARCH 2003 FIGURE 2.4



Source: DWR Water Data Library (http://wdl.water.ca.gov)

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Spring 1977 Groundwater Elevation Contour Map

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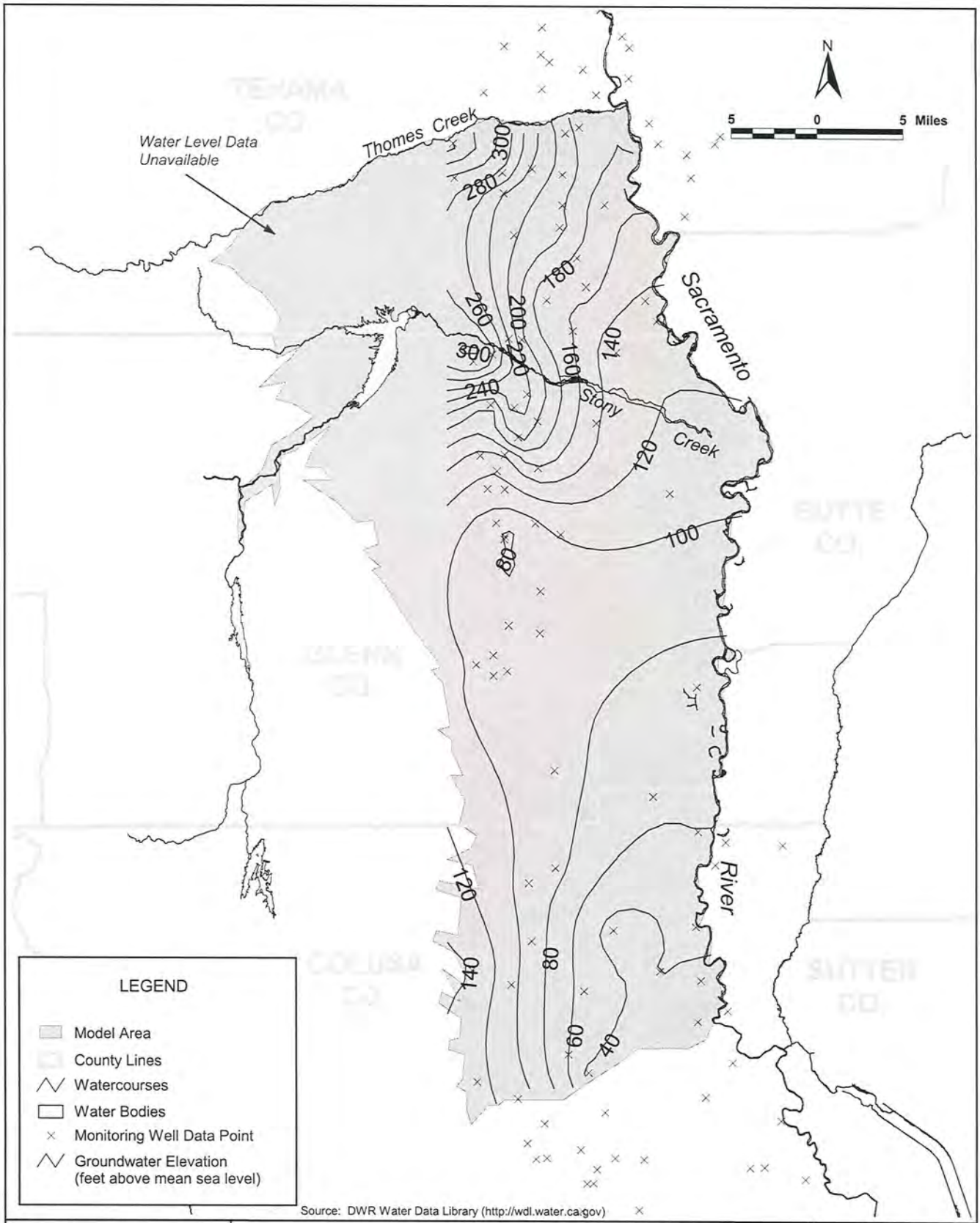
FIGURE 2.5



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Fall 1977 Groundwater Elevation Contour Map

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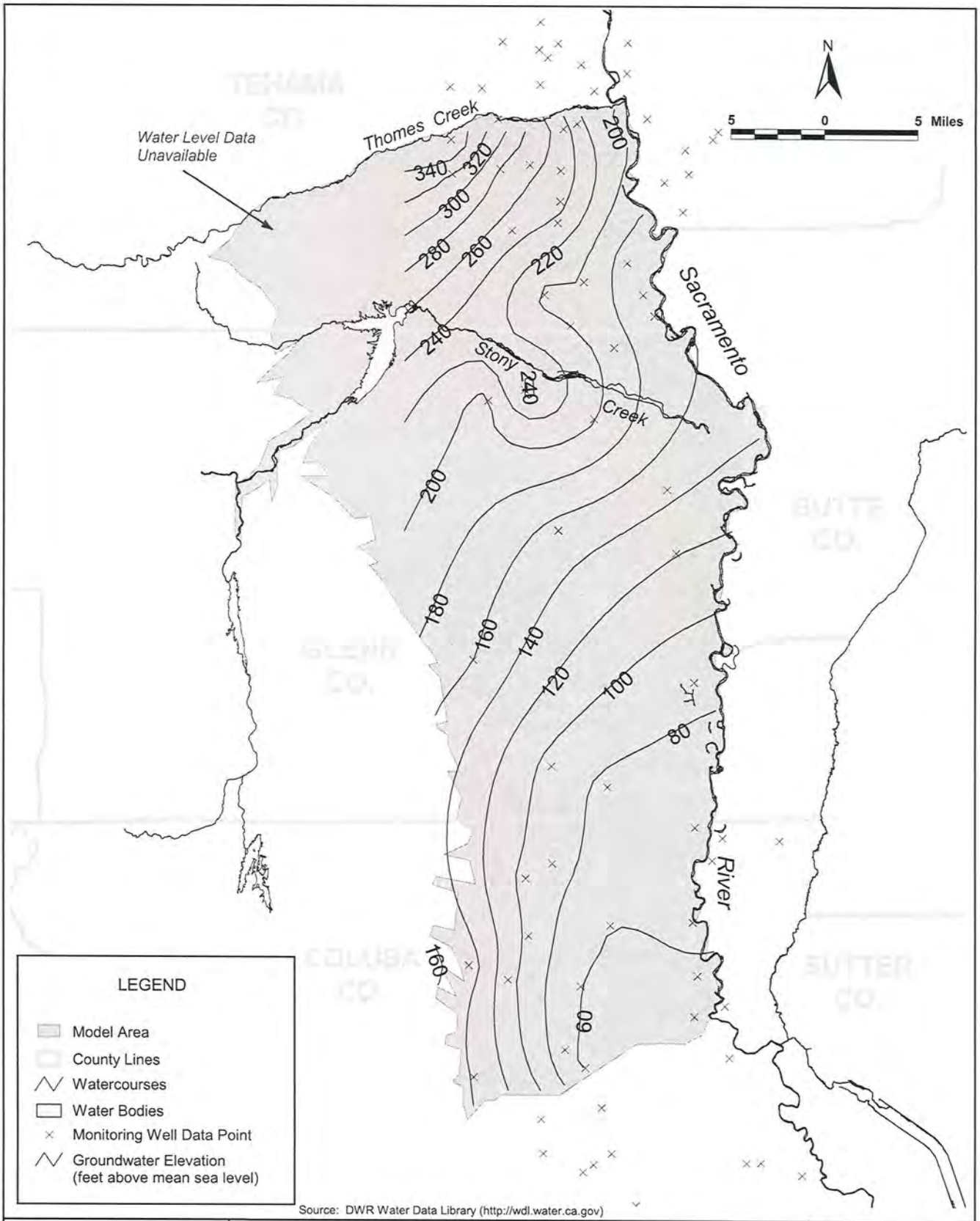
FIGURE 2.6



Source: DWR Water Data Library (http://wdl.water.ca.gov)

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Spring 1983 Groundwater Elevation Contour Map

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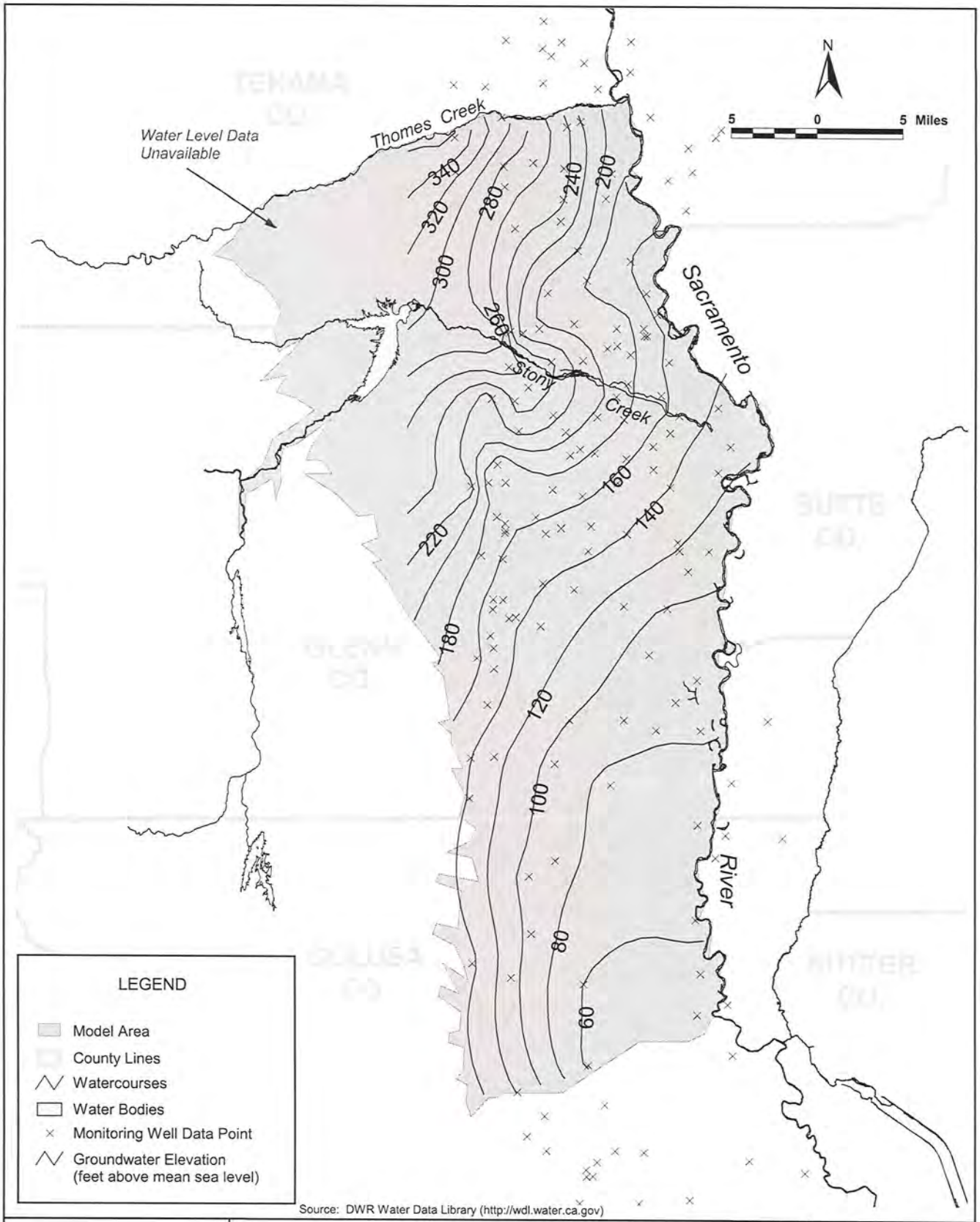
FIGURE 2.7



Source: DWR Water Data Library (http://wdl.water.ca.gov)

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Spring 1986 Groundwater Elevation Contour Map

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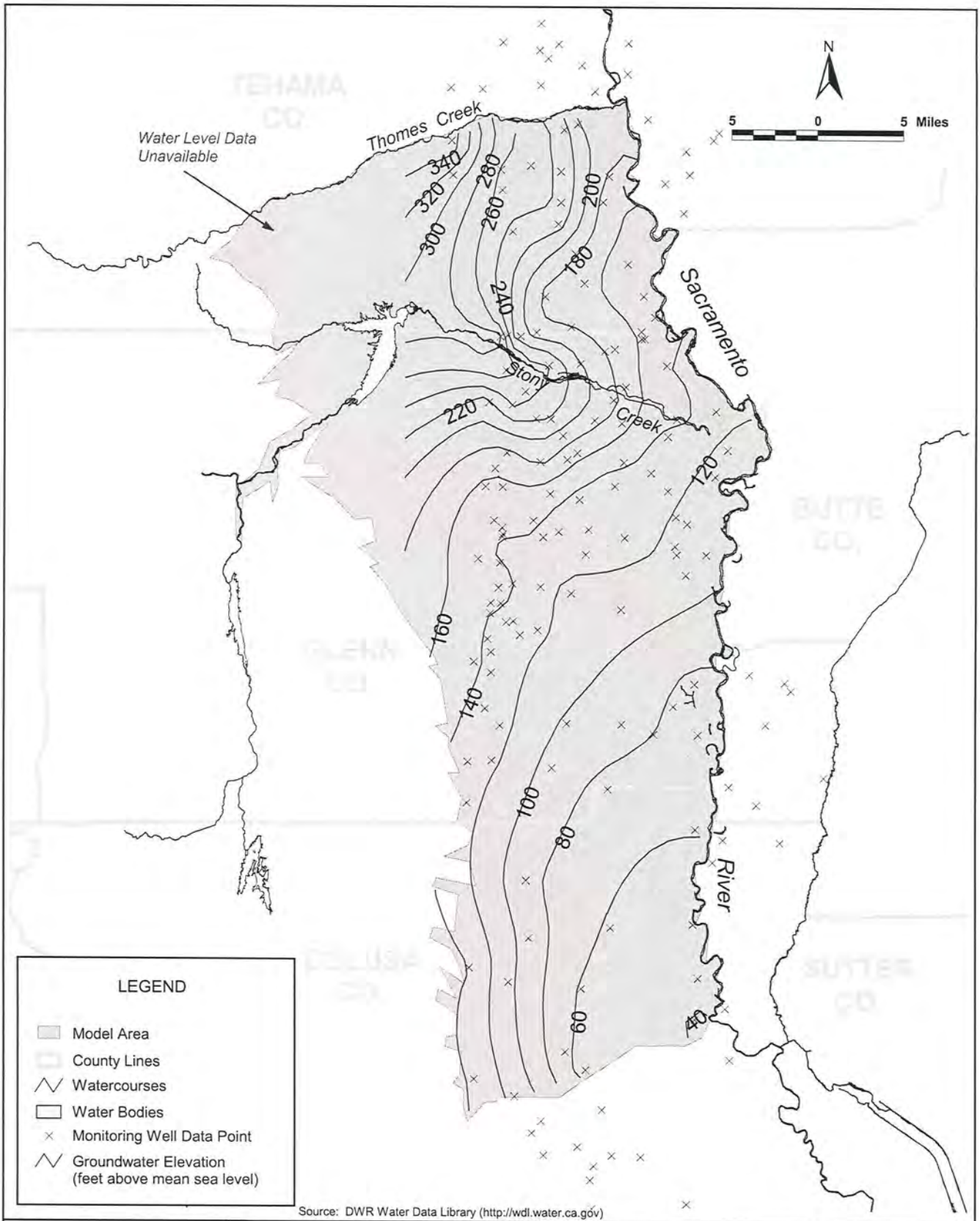
FIGURE 2.8



Source: DWR Water Data Library (http://wdl.water.ca.gov)

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Spring 1992 Groundwater Elevation Contour Map

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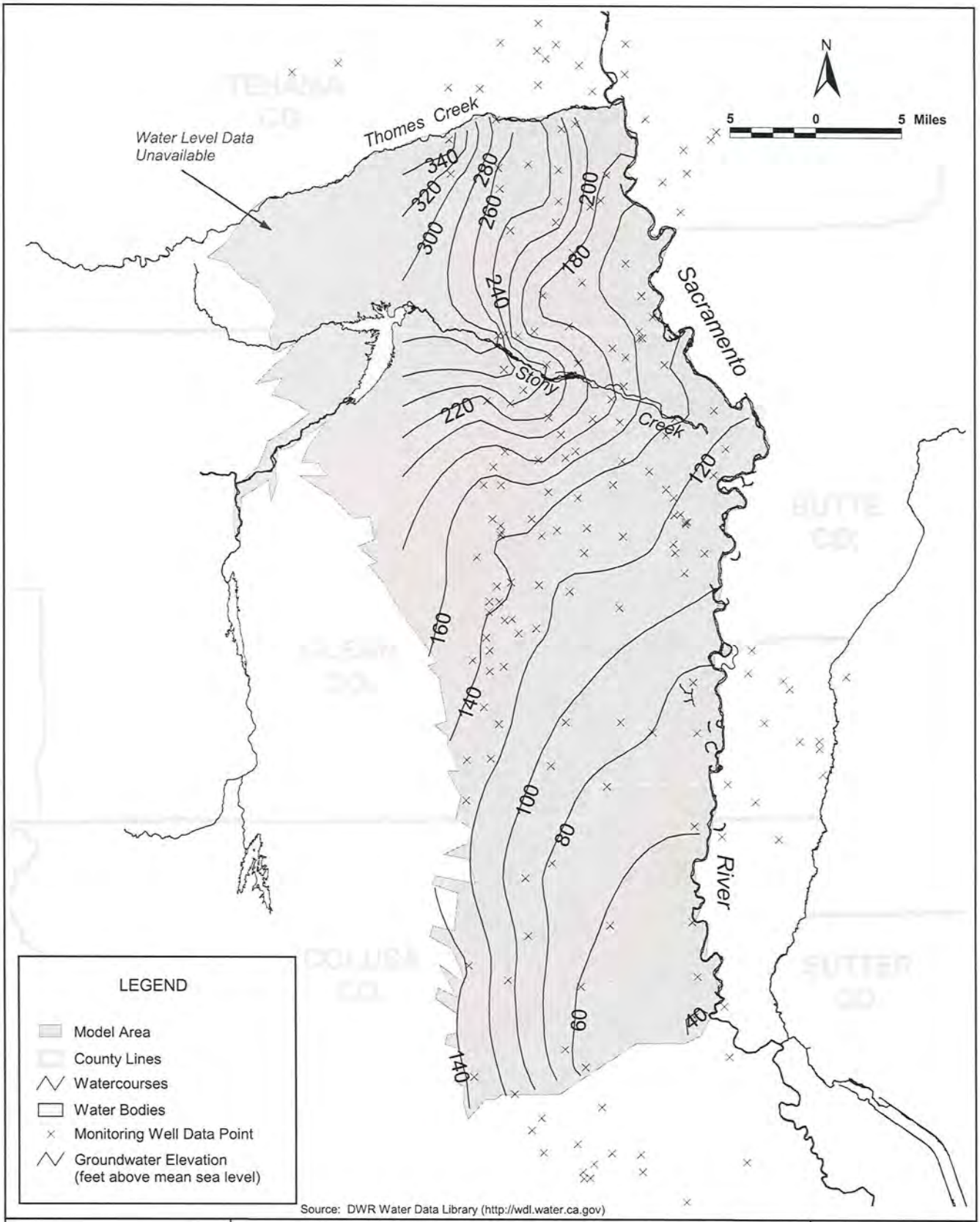
FIGURE 2.9



Source: DWR Water Data Library (http://wdl.water.ca.gov)

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STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM

Fall 1992 Groundwater Elevation Contour Map

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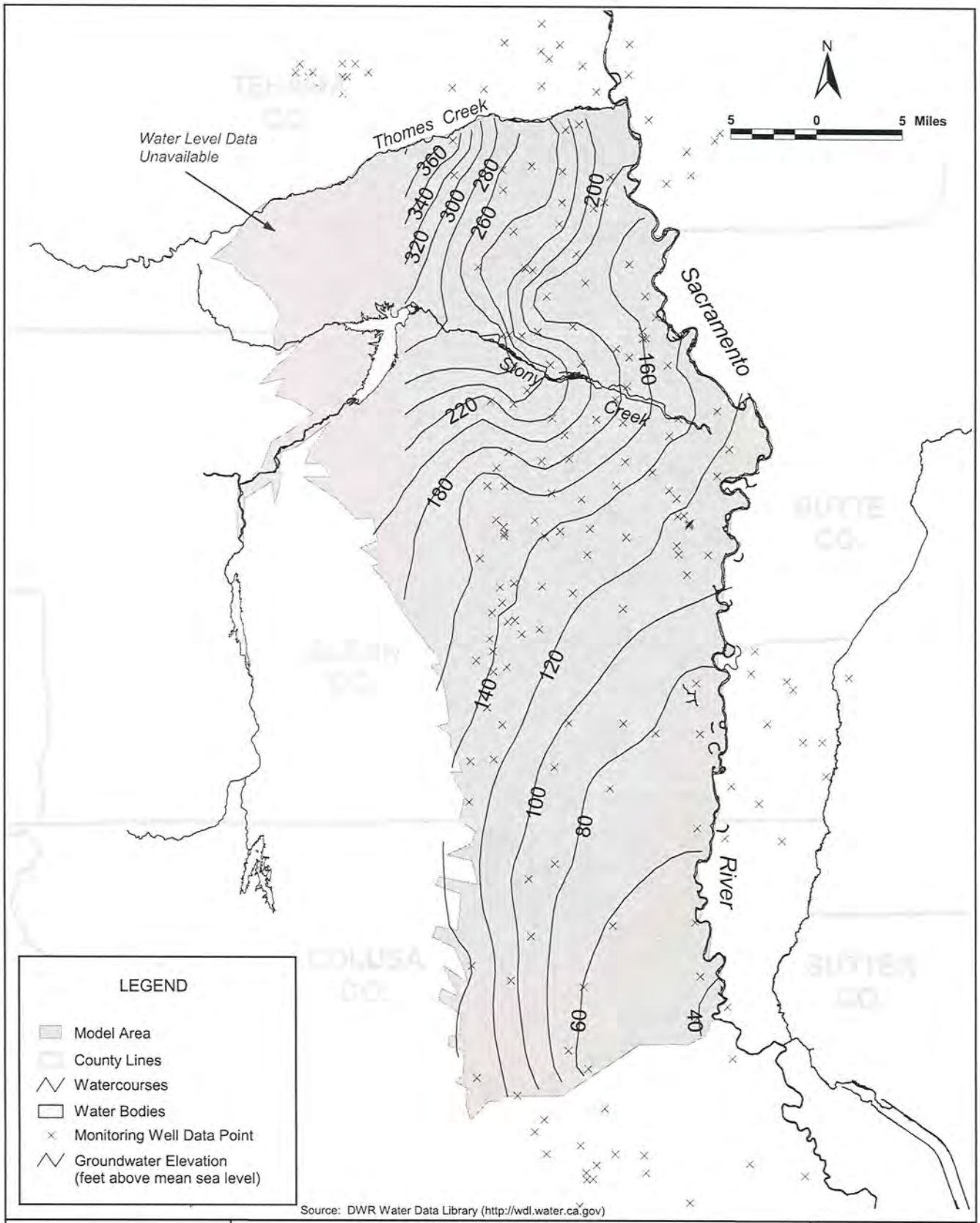
FIGURE 2.10



Source: DWR Water Data Library (http://wdl.water.ca.gov)

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STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM

Spring 1994 Groundwater Elevation Contour Map

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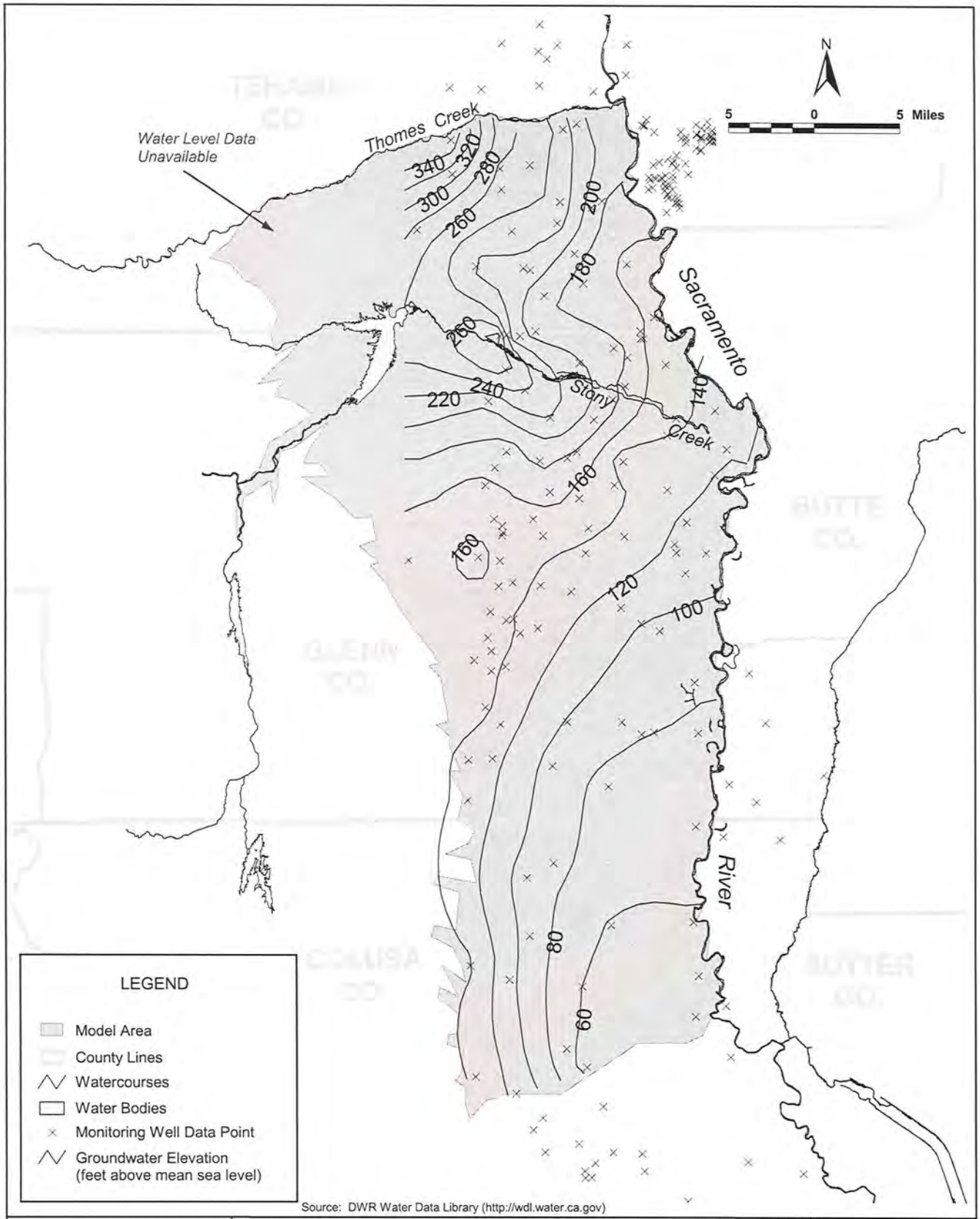
FIGURE 2.11



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Spring 2000 Groundwater Elevation Contour Map

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FIGURE 2.12

groundwater surface elevations to increase substantially. The March 1983 water level contour map (Figure 2.7) shows significant increases in elevations as compared to the 1977 maps. The 1983 map also shows increases in elevations as compared to the October 1969 contour map indicating full recovery of the aquifer to pre-drought conditions.

The March 1986 water level contour map (Figure 2.8) shows a slight decrease from the 1983 conditions. This map was constructed to evaluate water level conditions previous to the 1987-1992 drought.

The March 1992 water level contour map (Figure 2.9) shows water level conditions at the end of the 1987-1992 drought. Groundwater surface elevations decreased in response to the drought conditions. The October 1992 water level contour map (Figure 2.10) shows additional decreases resulting from increased summer groundwater pumping.

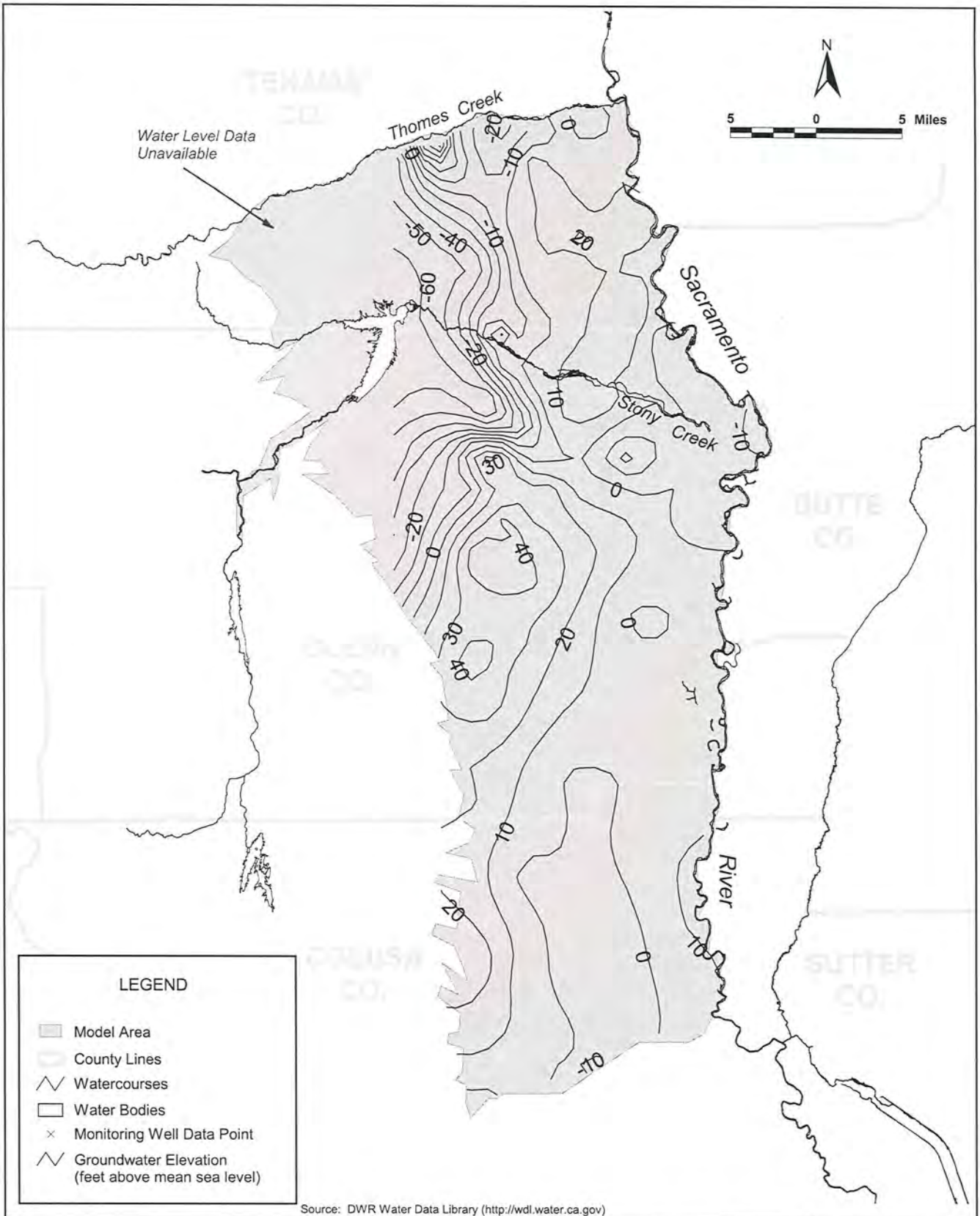
The March 1994 water level contour map (Figure 2.11) shows recovery of the aquifer with increasing groundwater surface elevations.

The March 2000 water level contour map (Figure 2.12) shows current groundwater surface elevation conditions. This map shows a slight increase in elevations compared to the March 1994 conditions.

The overall trend of the groundwater conditions is relatively stable. Although the groundwater surface elevation maps show declines in response to drought conditions, the contour maps demonstrate full aquifer recovery. This general trend is demonstrated by the groundwater surface elevation difference contour map (Figure 2.13) showing the change in elevations from the October 1969 conditions to the March 2000 conditions. In many of the areas of the basin, there is little or no change, while other portions, specifically in the area of the Stony Creek fan, groundwater levels increased by as much as 30 feet. This trend also holds true when comparing the 1969 map with the March 2000 map.

Well Hydrograph Analysis

In addition to evaluating contour maps, individual well hydrographs were analyzed for groundwater level trends. Specific well information was obtained from the Department of Water Resources, Northern District, Sacramento Valley Groundwater Basin groundwater level monitoring program. Historical water surface elevations are available in published county reports and DWR website postings. Data contained in this database is current through water level measurements made in the Fall of 2002. Six wells, as shown in Figure 2.14, are chosen to illustrate historical groundwater level trends in the model area. These trends are discussed in the following section.



Source: DWR Water Data Library (http://wdl.water.ca.gov)

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Groundwater Elevation Difference Contour Map
Spring 2000 Minus Fall 1969
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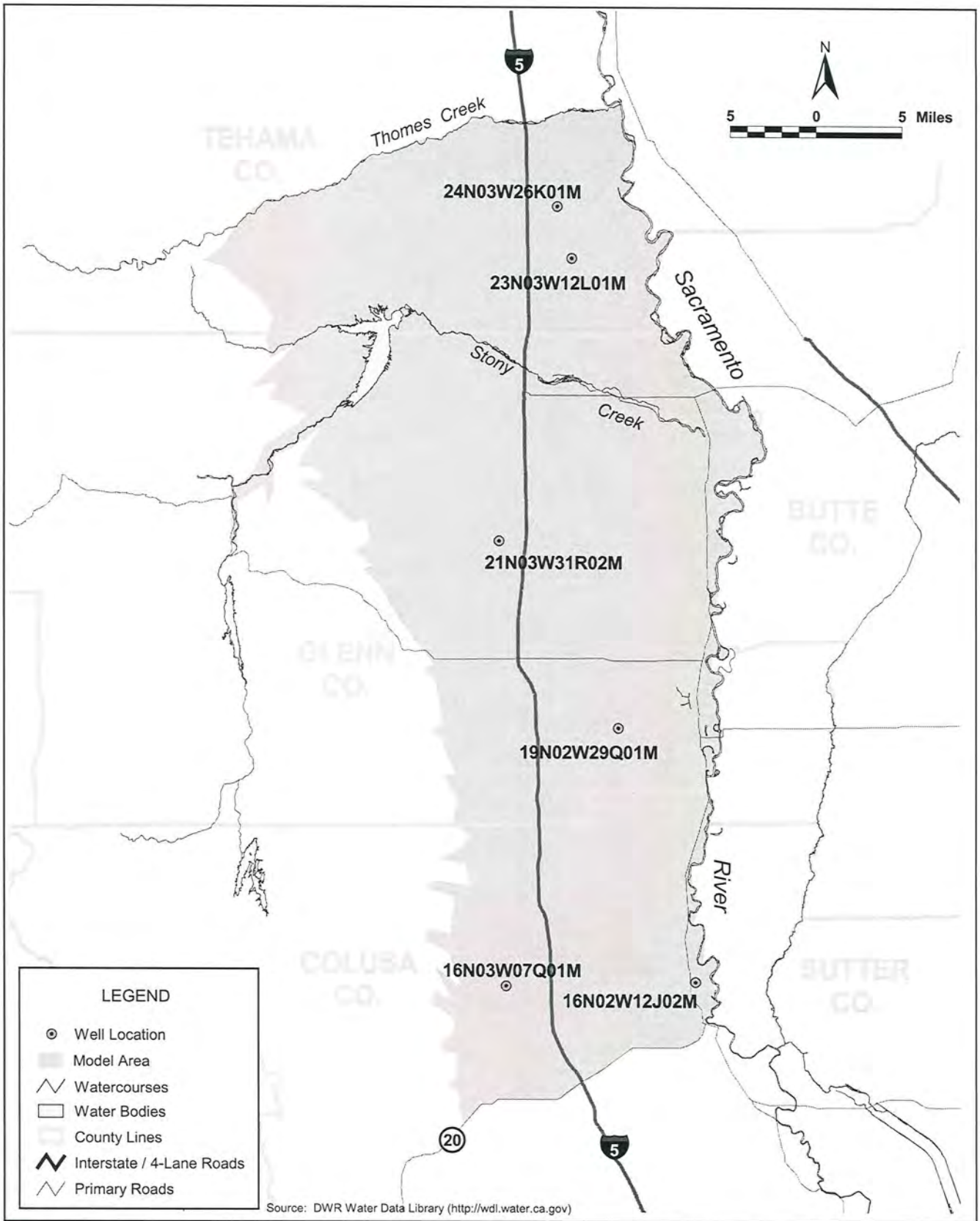
MARCH 2003

FIGURE 2.13



WRIME Water Resources & Information Management Engineering, Inc.	STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM **Well Locations of Selected Hydrographs** **DRAFT**	MARCH 2003 FIGURE 2.14

Tehama County

DWR and USBR have been collecting groundwater level data on 138 wells beginning in the late 1920's through the Tehama groundwater monitoring program. The information collected previous to 1993 is summarized in *Groundwater Levels in the Sacramento Groundwater Basin, Tehama County*. Of the 138 wells in the Tehama County monitoring program, 43 wells are located within the model area

In general, the historical groundwater level in Tehama County is constant. This is depicted in hydrographs for wells 23N03W12L01M and 24N03W26K01M, shown respectively in Figure 2.15 and Figure 2.16. Some wells in the area may show groundwater level declines reflecting the 1976-77 and 1987-92 drought periods. However, all water levels in Tehama County recovered from these droughts.

Glenn County

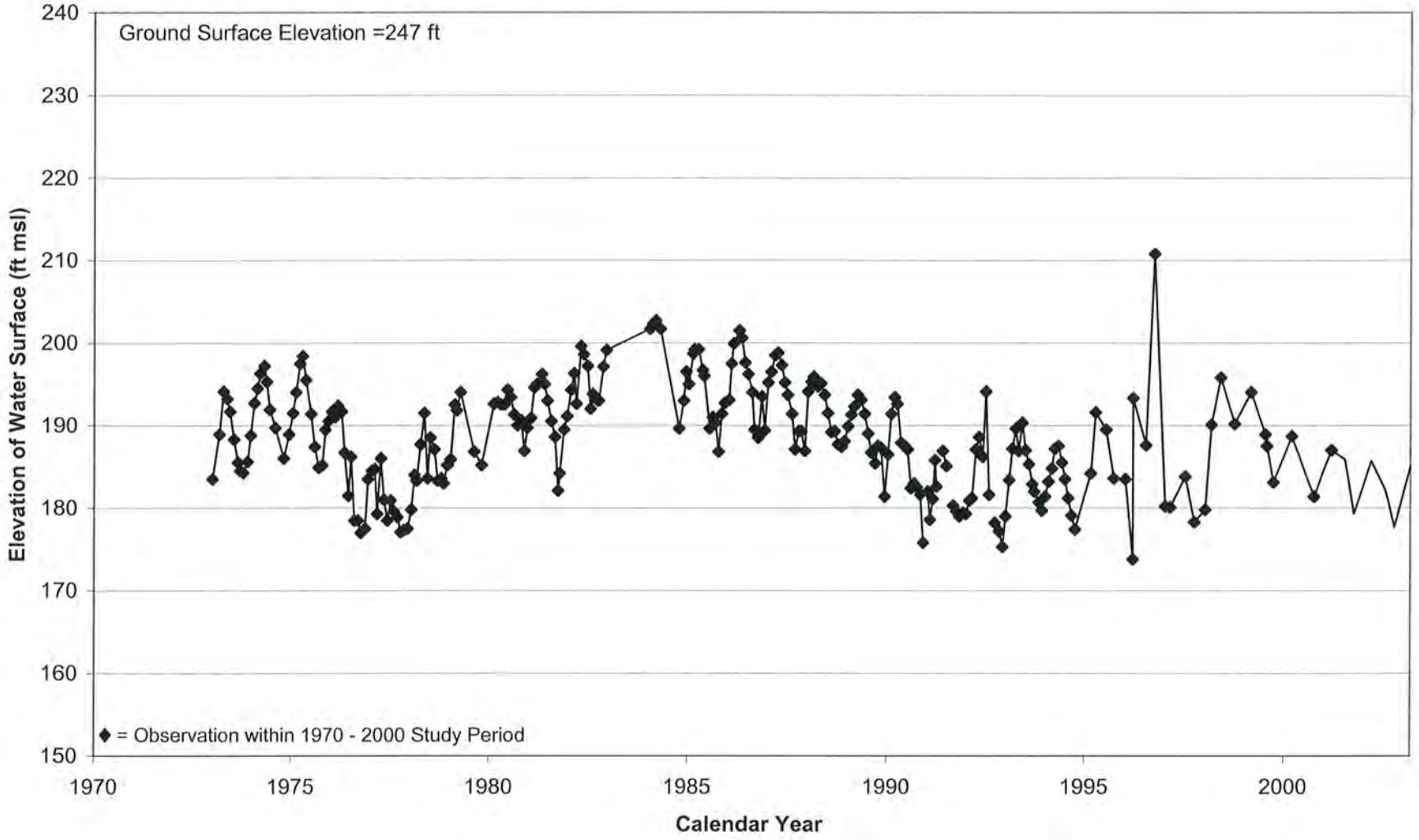
There are two groundwater monitoring programs in Glenn County. The first is similar to the groundwater monitoring program in Tehama County. Under this program, groundwater levels in Glenn County have been collected by DWR and USBR since the mid 1920's and continuing to 1997 and are summarized in *Groundwater Levels in the Sacramento Valley Groundwater Basin, Glenn County*. This study monitors 174 wells in Glenn County. The second groundwater monitoring program is the Basin Management Objective program. The information collected in this study is summarized in *Basin Management Objective (BMO) For Groundwater Surface Elevations in Glenn County, California*. There are 50 wells in this program, 42 monitored by DWR and 8 monitored by independent water districts.

In general, the current groundwater level for Glenn County is unchanged from historical groundwater levels, depicted in the well hydrograph for 19N02W29Q01M shown in Figure 2.17. The 1976-777 and 1987-92 droughts are reflected in many hydrographs in the area, both droughts followed by a recovery of the aquifer to pre-drought conditions. Surface water supplied by the Tehama-Colusa Canal was introduced to many parts of Glenn County near the end of the 1976-77 drought. This reduced the need for groundwater pumping as reflected in the rise in groundwater level around this time at well 21N03W31R02M (Figure 2-18).

Colusa County

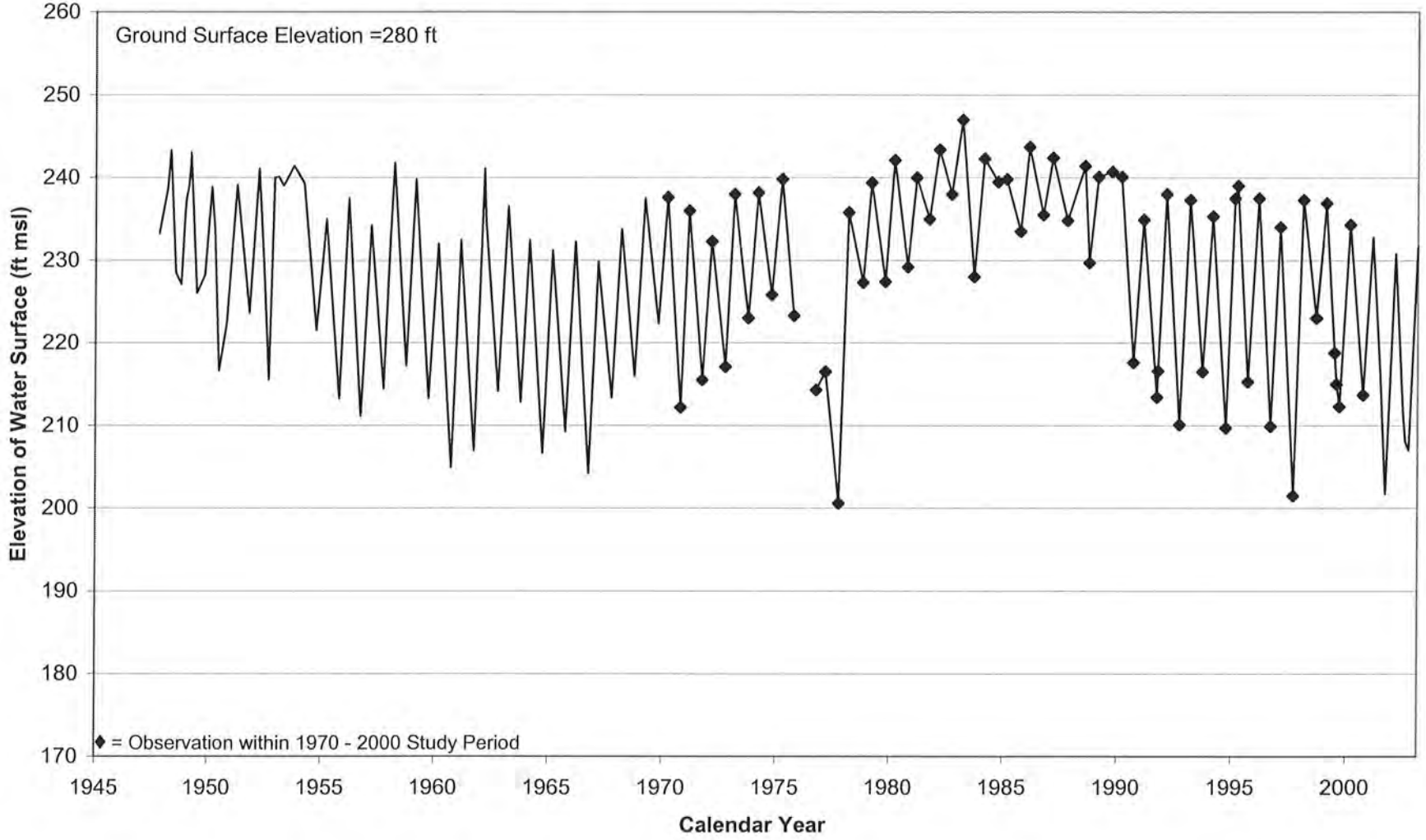
The report *Groundwater Levels in the Sacramento Valley Groundwater Basin, Colusa County*, summarizes the data collected by DWR and USBR in Colusa County from the late 1920's to

Figure 2.15
Hydrograph for Well 23N03W12L01M



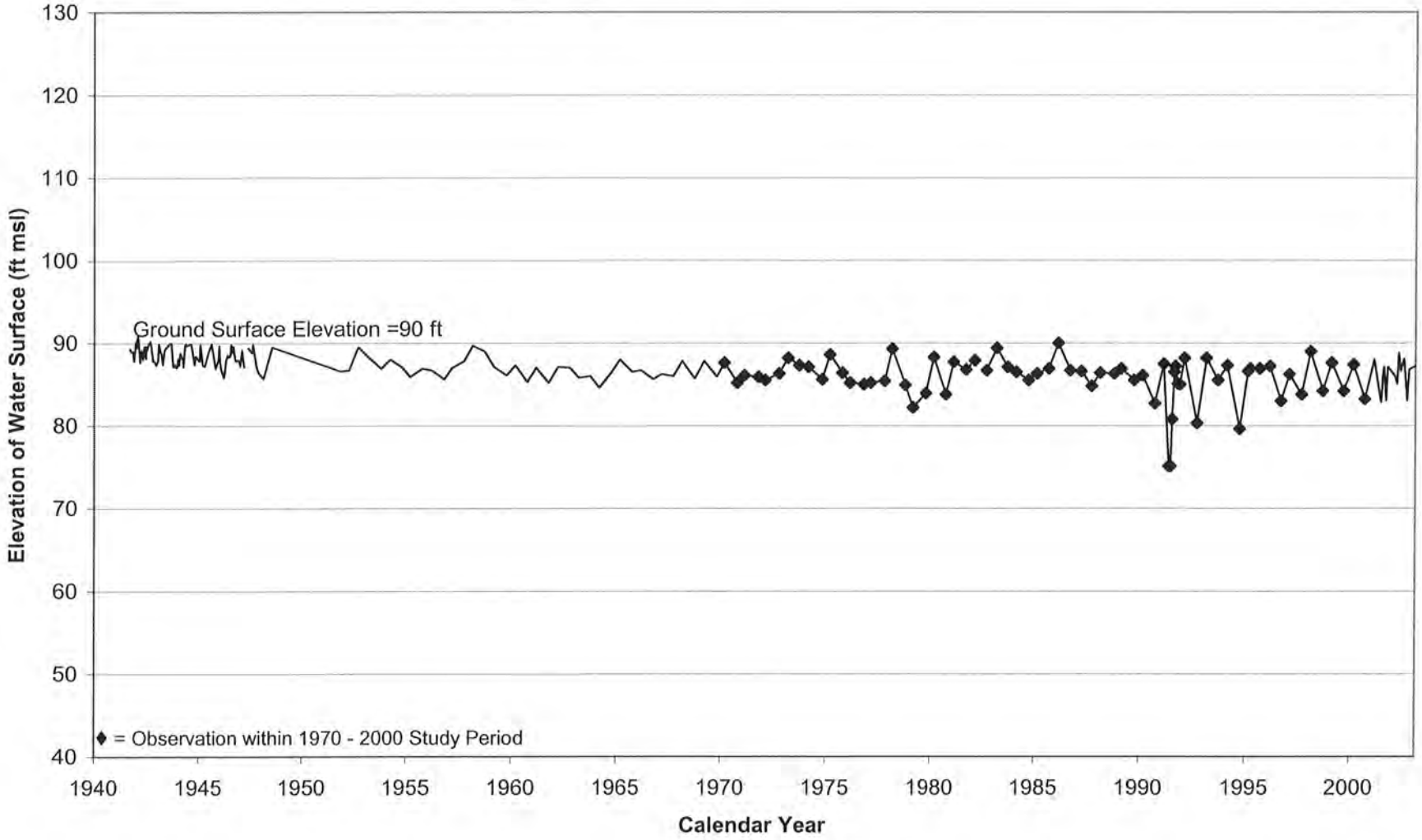
Source: DWR Water Data Library

Figure 2.16
Hydrograph for Well 24N03W26K01M



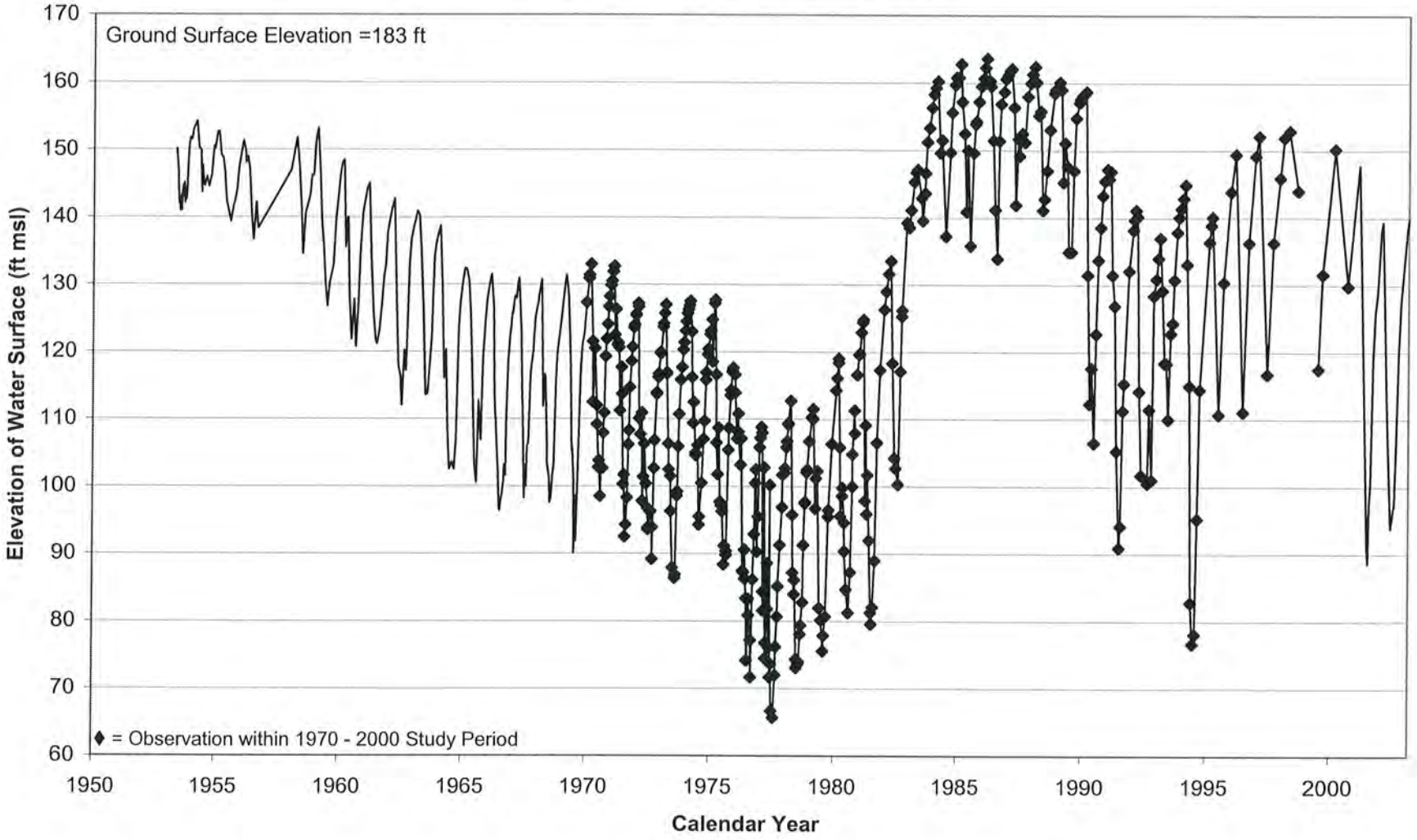
Source: DWR Water Data Library

Figure 2.17
Hydrograph for Well 19N02W29Q01M



Source: DWR Water Data Library

Figure 2.18
Hydrograph for Well 21N03W31R02M



Source: DWR Water Data Library

1995. There are 114 wells in this groundwater monitoring program, 23 of which are located within the model area.

The historical groundwater level trend in Colusa County is constant, as depicted in the hydrographs for wells 16N02W12J02M and 16N03W07Q01M, shown respectively in Figure 2.19 and Figure 2.20. Some wells in the county may reflect the 1976-77 and 1987-92 drought periods demonstrated by declines in water level, followed by full recovery.

SOILS

The processes that control the percolation of precipitation, runoff, and applied water are tied to soil properties. Published soil surveys for Glenn County, Colusa County, and Tehama County by the NRCS were reviewed for the Stony Creek Fan model area. The information contained in these surveys provides data necessary to classify the model elements based on hydrologic soil type. Inclusion of this information into the SCFIGSM enables the model to capture the influence of the ground surface and the soil horizon on aquifer recharge.

The National Resource Conservation Service (NRCS), formerly the Soil Conservation Service, has published three soil surveys in the study area for Colusa County (1907), Glenn County (1965), and Tehama County (1967). These soil surveys are compilations of a series of aerial photographs containing soil type boundaries, and tables and text detailing the soil types.

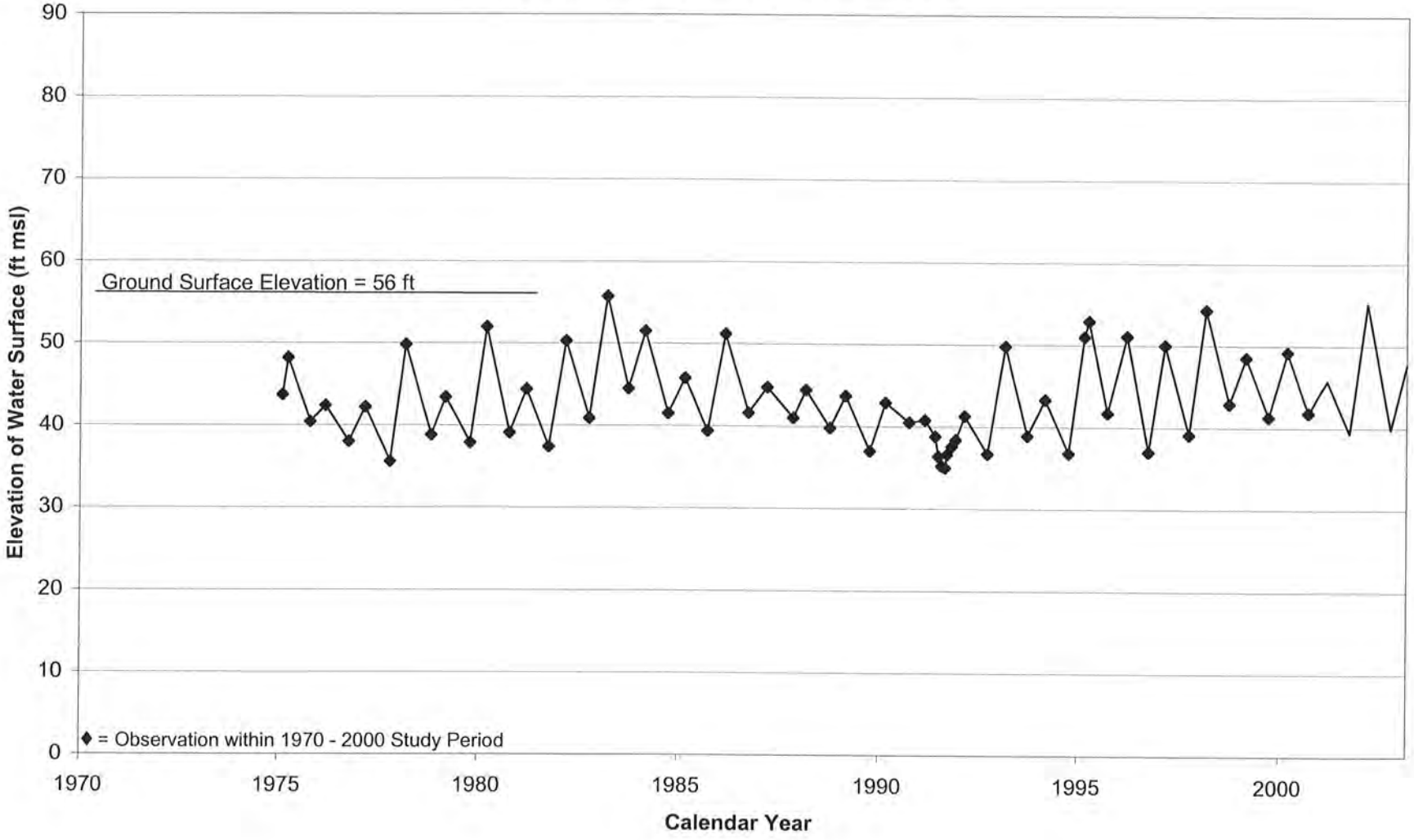
The NRCS is developing a Soil Survey Geographic Database (SSURGO) containing digital copies of original soils survey maps. The SSURGO mapping scales generally range from 1:12,000 to 1:63,000. A SSURGO database for Colusa County is available. Tehama County and Glenn County do not have a SSURGO database at this time.

HYDROLOGIC SOIL GROUPS

For the purposes of hydrologic analysis, soil types can be classified into four hydrologic soil groups, Groups A-D. This categorization system is based on estimates of runoff potential, infiltration rates, water intake, and water transmission of a saturated soil profile, with Group A having the lowest runoff potential and D having the highest.

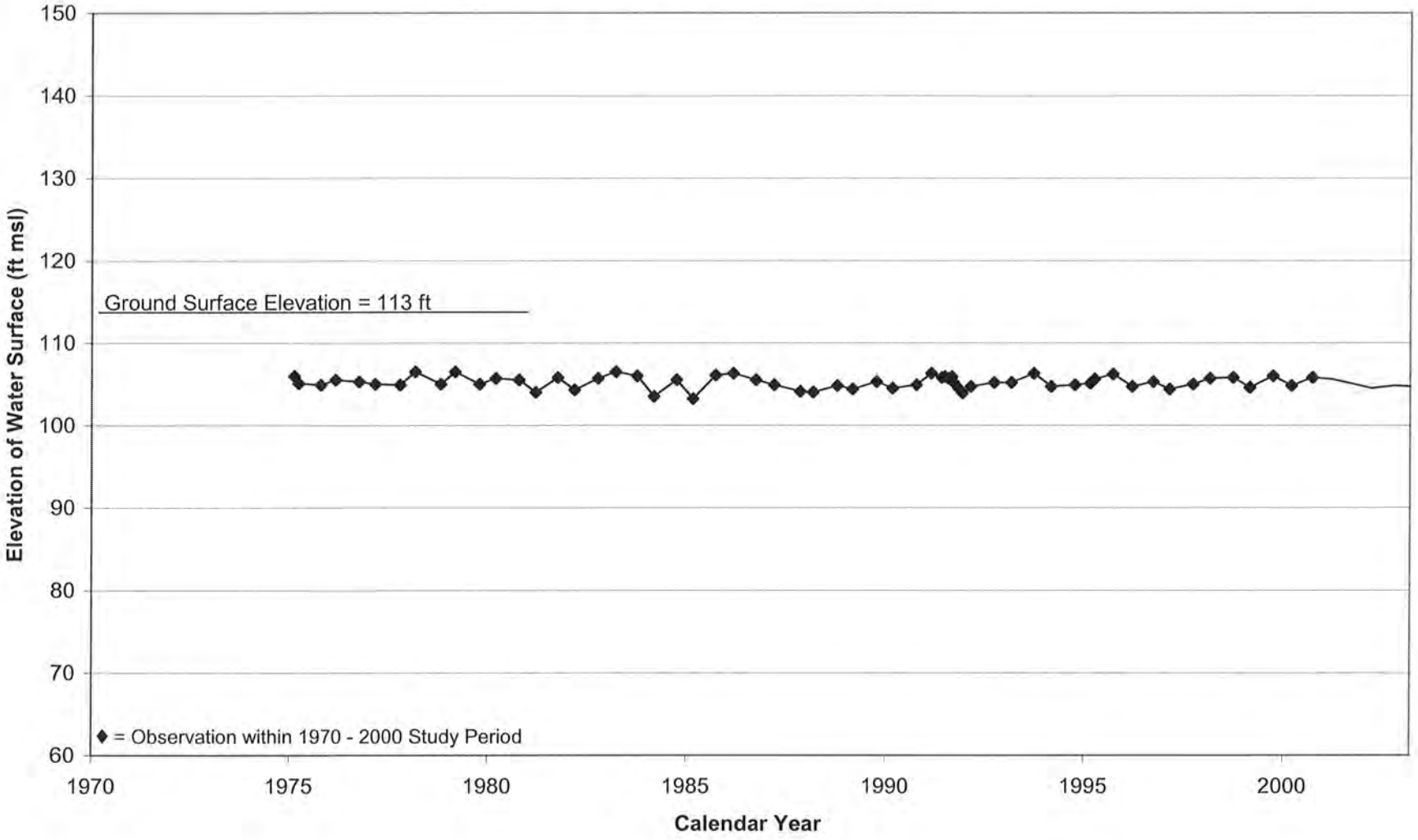
Predominant soil group and geomorphic feature associations of the study area are summarized in Table 2.3 along with the corresponding hydrologic soil groups. Typical hydrologic soil groups are discussed for the following geomorphic features: foothills, low terraces and older alluvial fans, more recent alluvial fans and flood plains, and basin deposits. These associations are demonstrated in Figure 2.21, which shows the hydrologic soil type distribution by element.

Figure 2.19
Hydrograph for Well 16N02W12J02M



Source: DWR Water Data Library

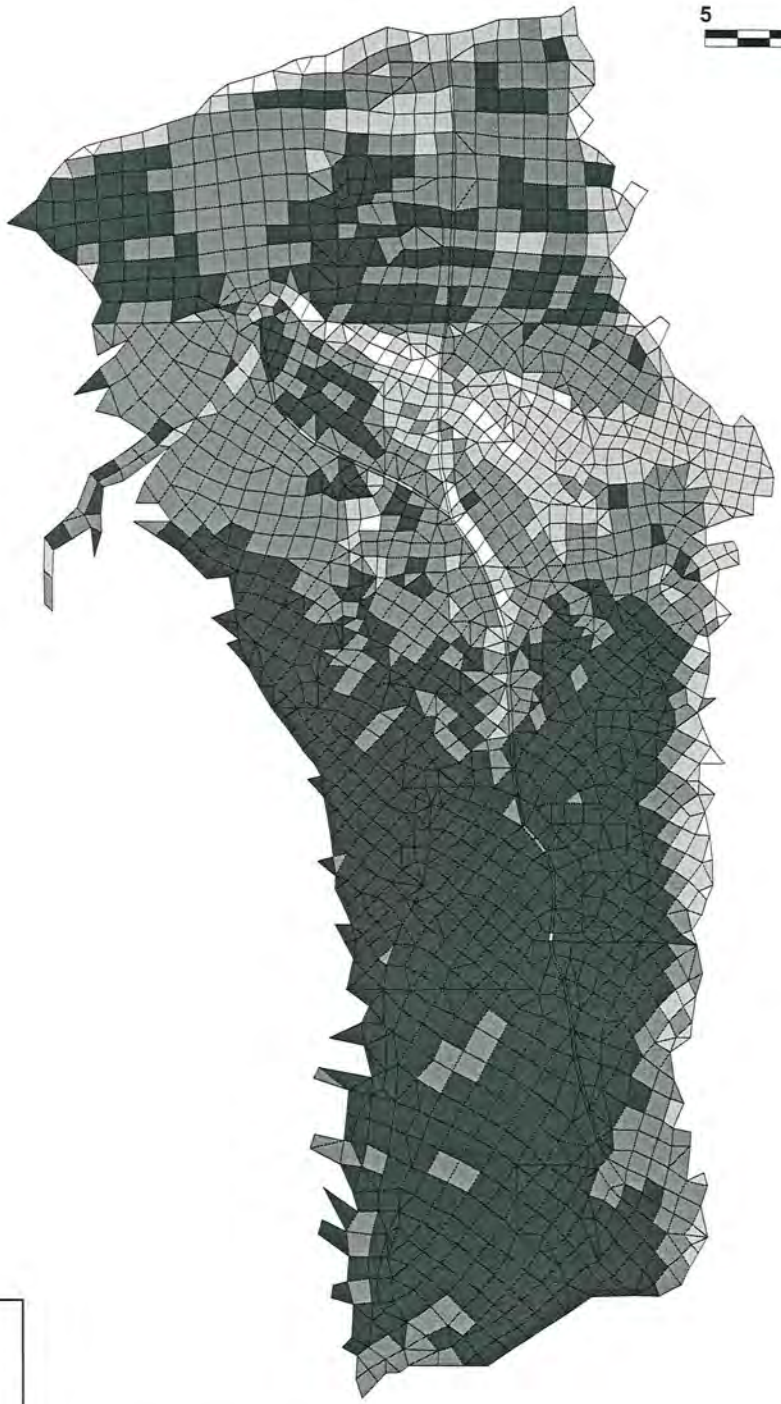
Figure 2.20
Hydrograph for Well16N03W07Q01M



Source: DWR Water Data Library

Table 2.3
Predominant Soil Types

Soil Location	Soil Name	Hydrologic Soil Group
Soils of the Foothills		
	Millsholm	C
	Altamont	D
	Newville	C
Soils of Older Alluvial Fans and Low Terraces		
	Arbuckle	B
	Kimball	C
	Hillgate	D
Soils of the More Recent Alluvial Fans and Flood Plains		
	Cortina	A
	Orland	B&C
	Columbia	B
Soils of the Basins		
	Landlow	D
	Stockton	D



Source: NRCS
Soil Survey, Tehama County, California (1967)
Soil Survey, Glenn County, California (1965)
2001 Colusa County SSURGO Dataset (http://soils.usda.gov/soil_survey/main.htm)

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Hydrologic Soil Types

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FIGURE 2.21

Soil groups C and D are the predominant soil groups of the study area and are associated with foothills, low terraces and basin deposits. More permeable soil groups A and B are associated with major hydrologic features such as the Sacramento River and the more recent alluvial fans and flood plains, such as the area of the Stony Creek alluvial fan deposits.

DRAFT

This section summarizes the general hydrology of the Stony Creek Fan study area based on the information compiled during the Data Collection and Assessment Task of this project. The hydrology of a groundwater basin is the primary driving force for groundwater flow and quality. Therefore, it is essential to understand the hydrologic characteristics of the model area in order to develop a sound conceptual model.

SURFACE WATER SUPPLIES

RAINFALL

The hydrology of the Stony Creek Fan model area is typical of a California inland basin characterized by dry summers and moist winters. Annually, the area receives an average of 24 inches of rainfall. The typical rainfall pattern is that of little to no rainfall in the summers with most of the precipitation occurring during the winter months. Figure 3.1 shows the monthly distribution of rainfall at a gaging station near the town of Orland. Figure 3.2 shows the accumulative departure from the mean precipitation for the same gauging station. This graph represents the climatic trends in the study area for the period from 1951 to 2000.

The long-term annual average rainfall distribution in the study areas is presented in Figure 3.3. This isohyetal map is developed by DWR using one hundred years of precipitation data from various raingages in the study area.

STREAMFLOWS

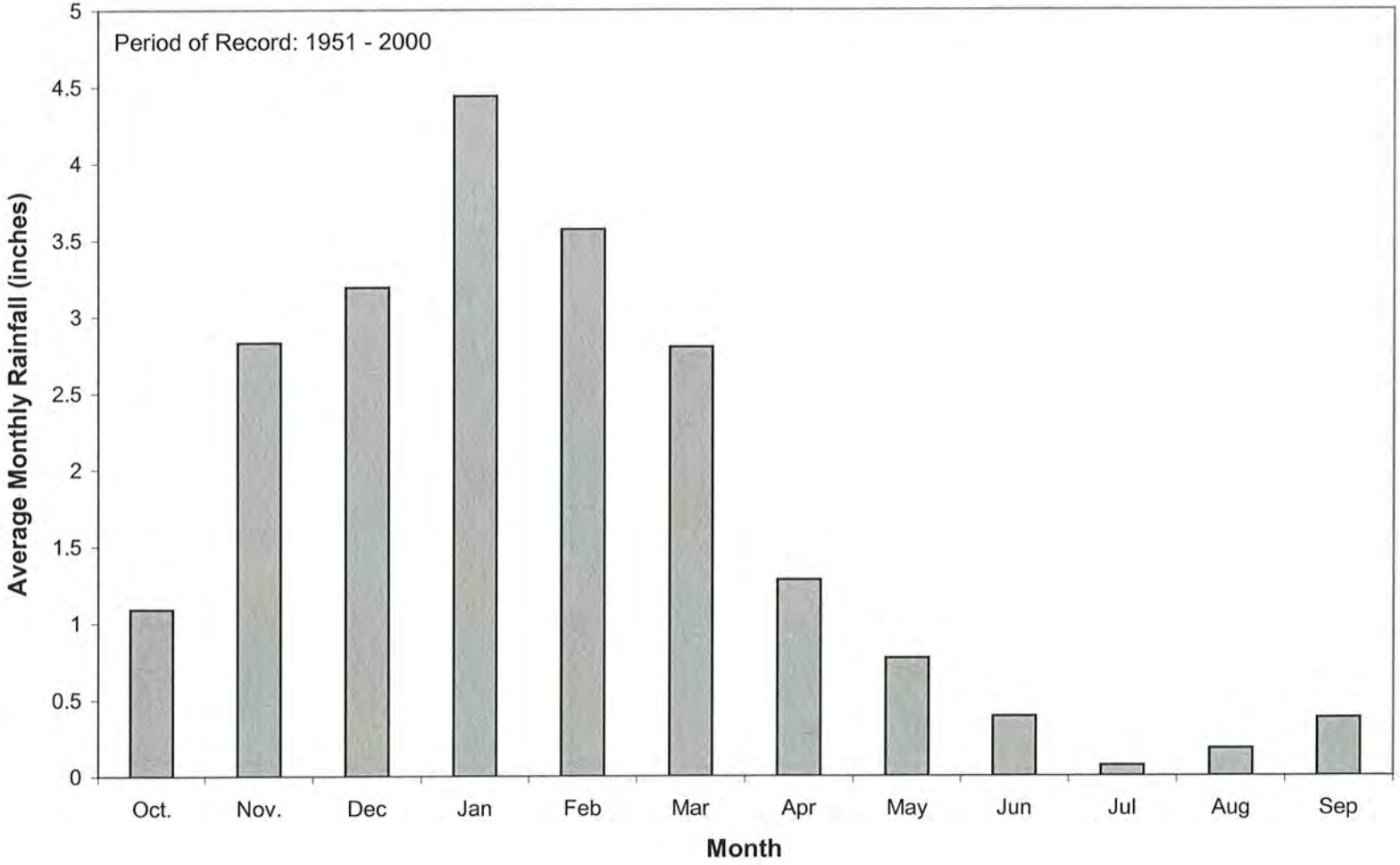
There are three major streams in the model area:

- **Thomes Creek** that coincides with the northern boundary of the model area
- **The Sacramento River** that coincides with the eastern boundary of the model area, and
- **Stony Creek** that is located within the model area.

The average annual inflows from these streams are presented in Figure 3.4 to 3.6.

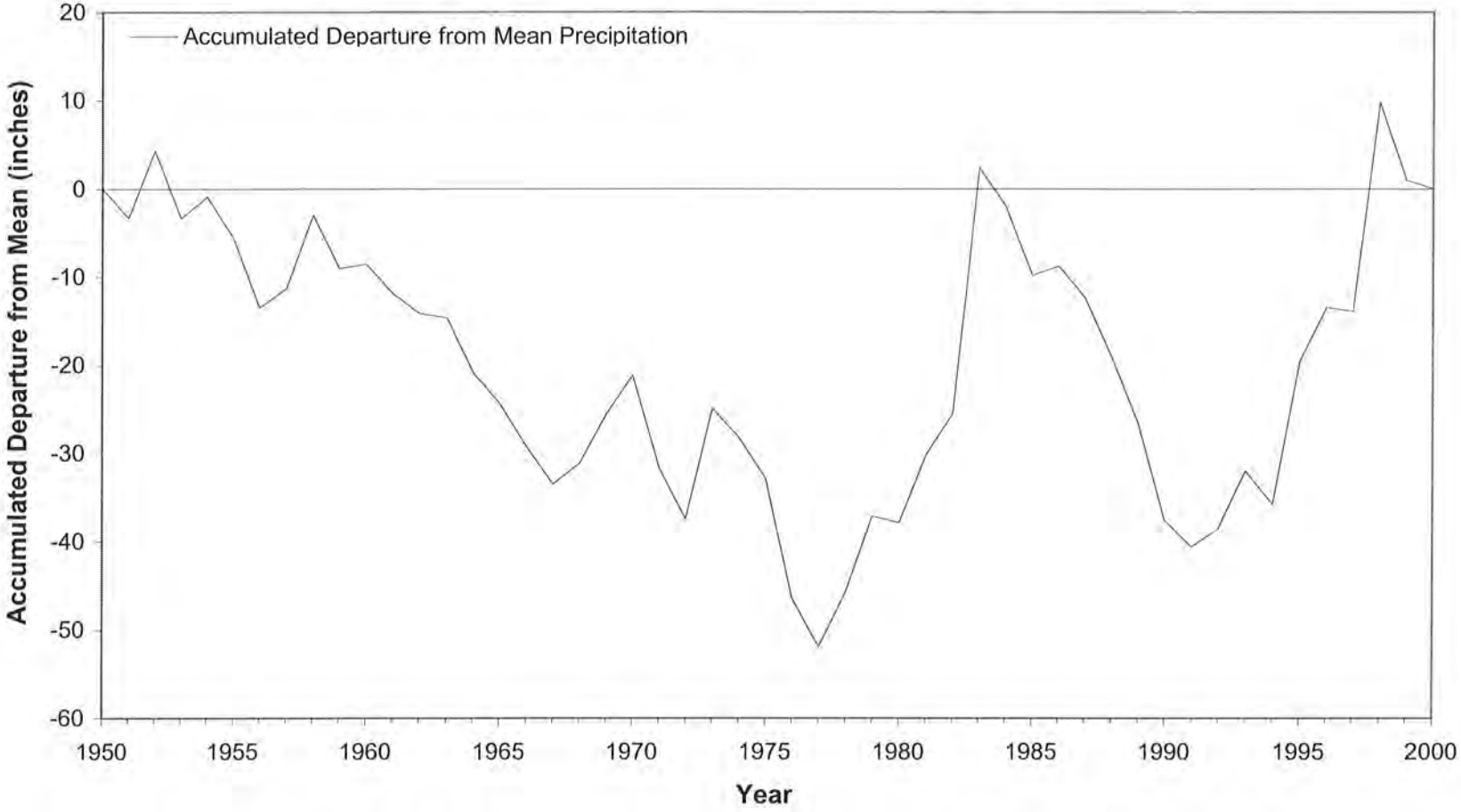
There are other tributaries of the Sacramento River on the east; these eastside streams are outside the model area, but they contribute inflows at the model boundary.

Figure 3.1
Average Monthly Rainfall (Orland)

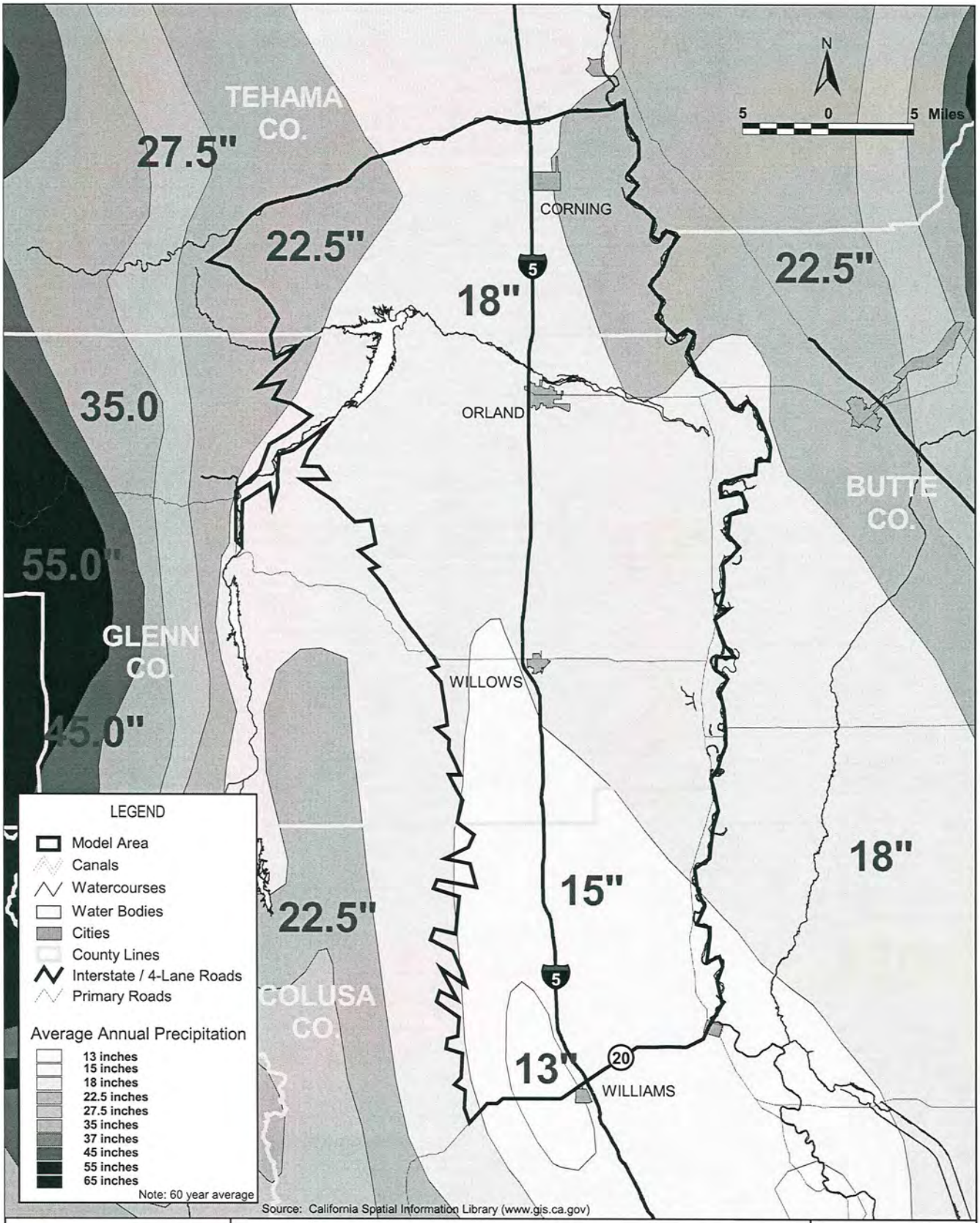


Source: National Climate Data Center (Station 6506)

Figure 3.2
Orland Accumulated Departure from Mean Precipitation (1951-2000)



Source: National Climate Data Center (Station 6506)



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Isoheytal Map

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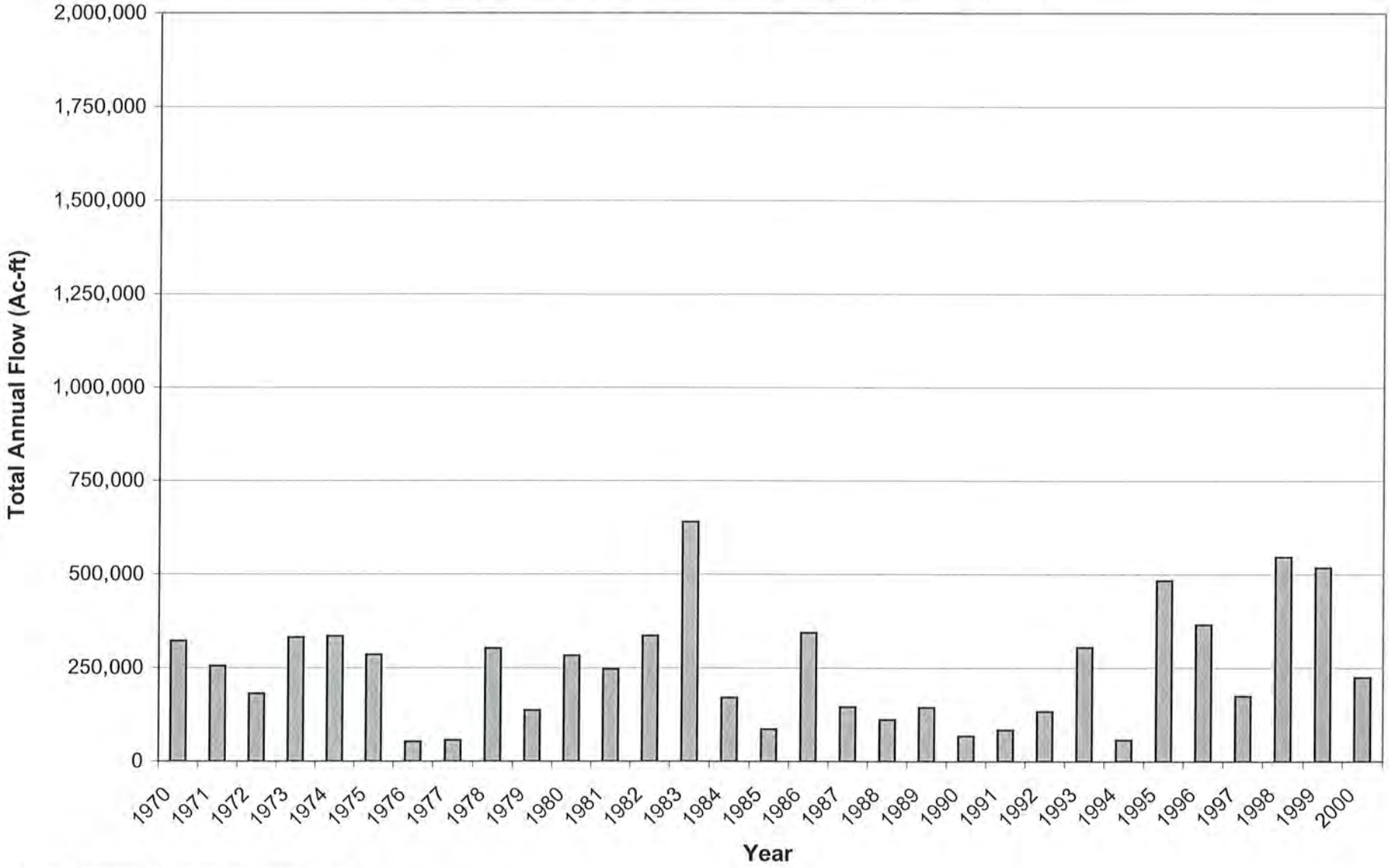
FIGURE 3.3

Figure 3.4
Stream Inflow to SCFIGSM from Thomes Creek



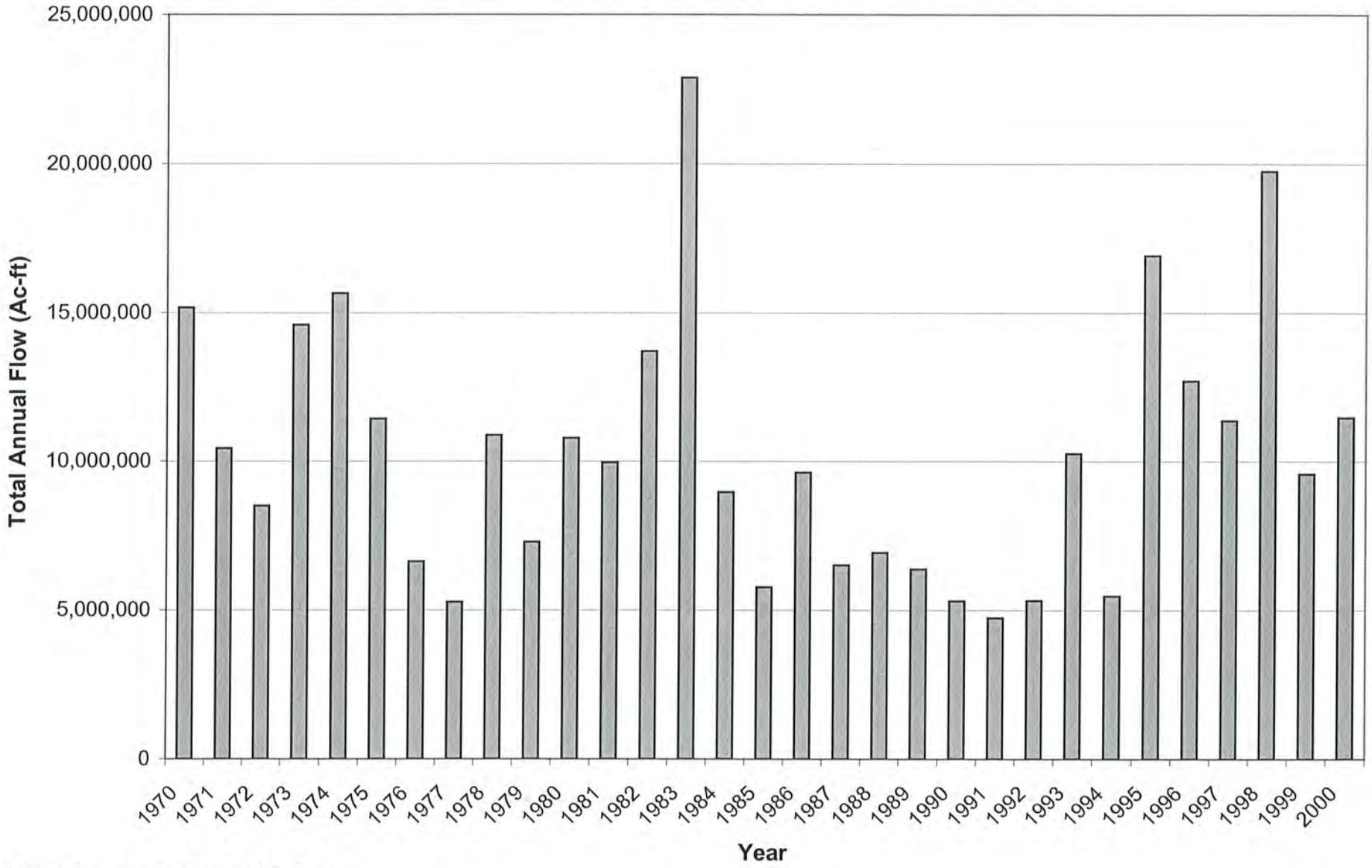
Source: Thomes Creek at Paskenta Gage

Monitored by USGS (gage 11382000) from 1970 - 1996

Monitored by DWR (gage A03500) from 1920 - 1999

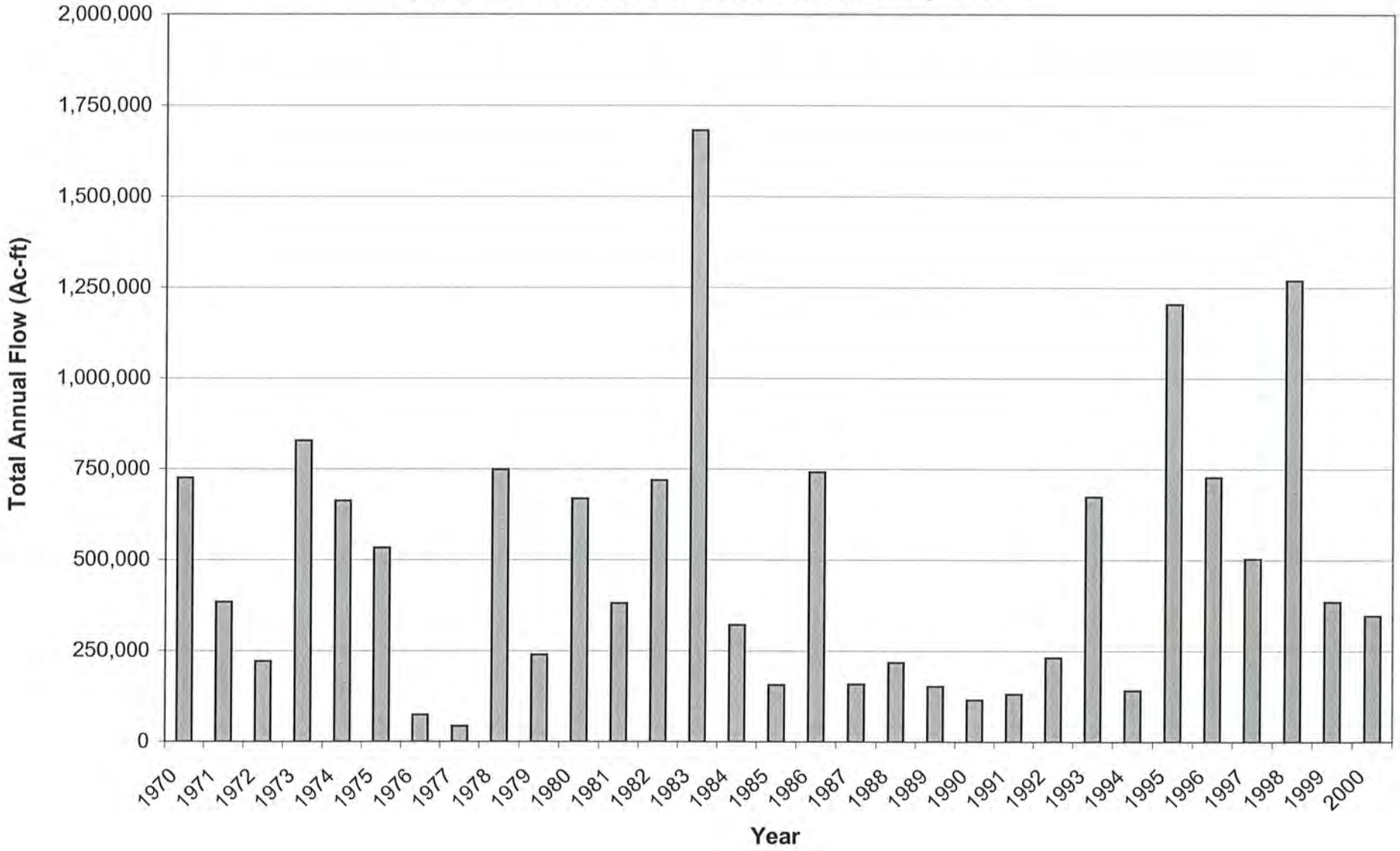
Data for 1997 and 2000 and partial data from 1998 and 1999 was estimated using the monthly flow correlation between the Thomes Creek at Paskenta gage and the Elder Creek near Paskenta gage (USGS 11379500)

Figure 3.5
Stream Inflow to SCFIGSM from Sacramento River



Source: Sacramento River at Vina Gage
Monitored by USGS (gage 11383730) from 1945 - 1978
Monitored by DWR (gage A02700) from 1978 - 2001
Partial missing data from 1983-1989 was estimated using the daily flow correlation between the Sacramento River at Vina gage and the Sacramento River at Old Ferry gage (USGS 11383730).

Figure 3.6
Stream Inflow to SCFIGSM from Stony Creek



Source: Stony Creek at Black Butte Reservoir (Operations Data)
Monitored by US Corps of Engineers from 1963 - 2001 (Water Control Data System Report, US Corps of Engineers, www.spk/wc.usace.army.mil)

Two primary sources of stream flow data are the USGS and the DWR. The USGS data is obtained from the web site (http://water.usgs.gov/usa/nwis/sw) and the DWR data is obtained from the Northern District. There are several stream gauging stations in the study area, some of which are now discontinued.

Small Watersheds

There are several small ungauged intermittent streams along the western boundary of the model area. Flow along these streams are not significant to be modeled as streams; however, the surface run off associated with these streams is a source of aquifer recharge. Estimation of inflow along these streams can be conducted by specifying the small watershed drainage areas and precipitation rates. Inflows can be set as an input to the groundwater node at which the streams enter the model area.

Surface Water Diversions and Delivery

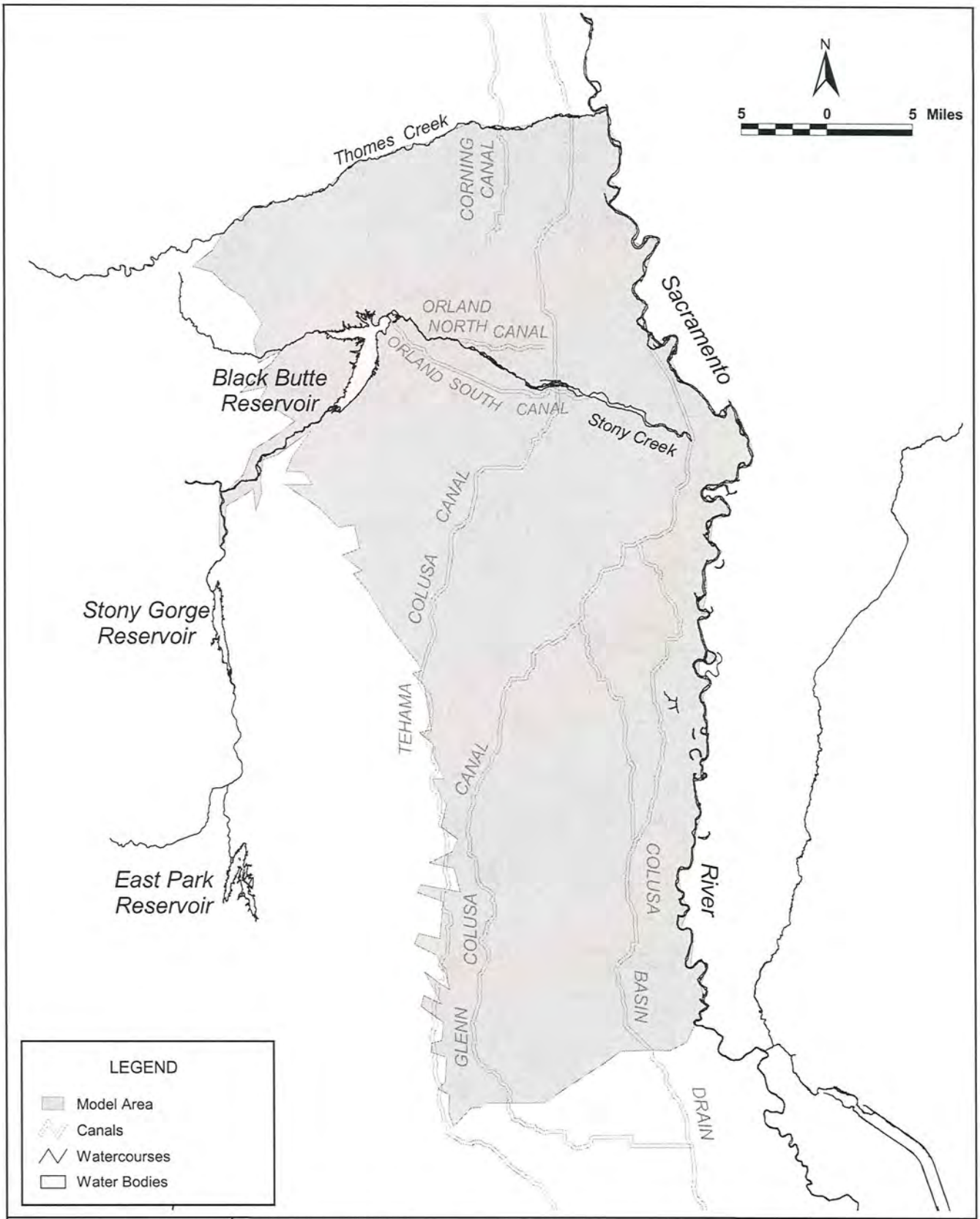
The agricultural land in the model area is irrigated by surface water from adjacent rivers and reservoirs and by groundwater pumping.

The Stony Creek system includes East Park, Stony Gorge, and Black Butte Reservoirs. Water is primarily supplied from Black Butte Reservoirs to Orland Unit Water Users Association (OUWUA). During spring, some water is diverted from Stony Creek to the Glenn-Colusa Canal.

The Sacramento River does not include any storage facilities within the model area. There are five major diversion locations along the river. These diversion locations are for the following water districts:

- Glenn-Colusa Irrigation District,
- Provident Irrigation District,
- M&T Chico Ranch, (outside model area)
- Princeton-Corado-Glenn Irrigation District, and
- Maxwell Irrigation District.

The irrigation water is brought into the model area using a network of lined and unlined canals and pipelines. There are six major canals and drains within the model area; these are shown in Figure 3.7 and listed below:



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	Locations of Major Canals and Drains	FIGURE 3.7
	DRAFT	

- **Corning Canal** - the southern extent of this canal extends about 5 miles into the northern boundary of the model area.
- **Orland North and South Canals** are entirely within model area; they deliver water from Black Butte reservoir to Orland Unit Water User Association (OUWUA).
- **Tehama Colusa Canal** is a concrete lined canal that traverses the model area from north to south along the western edge; it diverts water from Sacramento river outside of the model area .
- **Glenn-Colusa Irrigation District Main Canal** is an unlined canal, which diverts water from Sacramento river inside the model area.
- **Colusa Basin Drain** is an unlined canal that is used as a major irrigation drain in the Glenn Colusa Irrigation District.

The Corning Canal provides water to districts within the Tehama County. There are two water districts within the model boundary that receive water from the Corning Canal. These districts are Thomes Creek Water District and Corning Water District.

The Tehama-Colusa Canal provides water to over fifteen districts within Tehama, Glenn, and Colusa counties. Within in the model area, the Glenn-Colusa Irrigation District is largest recipient of water supplied by the Tehama-Colusa Canal.

The Glenn-Colusa Canal provides water to the Glenn-Colusa Irrigation District. It should be noted that the national wildlife refuges located in the GCID also receive water from the Glenn-Colusa Canal.

Water in the Colusa Basin Drain consists of return flow from GCID and other water districts that divert directly from the Sacramento River. GCID and Colusa Basin Water Users Association divert water from the Colusa Basin Drain.

The surface water diversion data is obtained from three different sources: DWR Northern District (*Sacramento Valley Westside Data*, 1970-1992), USBR, and GCID.

Table 3.1 shows the average annual surface water diversions from these sources into the model area.

Table 3.1
Summary of 1970 to 2000 Average Annual Diversions

District	Total Diversion by District	Diversion Amount Applied within SCFIGSM
North Canal		
1 - Orland Unit Water Users Association deliveries from Black Butte Reservoir via North Canal	32100[1,2]	32,100
South Canal		
2 - Orland Unit Water Users Association deliveries from Black Butte Reservoir via South Canal	63800[1,2]	63,800
Corning Canal		
3 - Corning WD delivery from Corning Canal	15900[1,2]	18,500
4 - Thomes Creek WD delivery from Corning Canal	4700[1,2]	1,800
Tehama-Colusa Canal		
5 - Ritchfield WD delivery from Tehama-Colusa Canal	100[1,2]	100
6 - Tehama W.D. delivery from Tehama-Colusa Canal	100[1,2]	100
7 - Kirkwood W.D. delivery from Tehama-Colusa Canal	400[1,2]	400
8 - O'Connel Mutual M.W.C. delivery from Tehama-Colusa Canal	20[1,2]	20
9 - Orland Water Users delivery from Tehama-Colusa Canal	2800[1,2]	2,800
10 - Orland-Artois delivery from Tehama-Colusa Canal	36400[1,2]	36,400
11 - Glide W.D. delivery from Tehama-Colusa Canal	8700[1,2]	8,700
12 - Kanawha W.D. delivery from Tehama-Colusa Canal	21300[1,2]	19,300
13 - Glenn-Colusa I.D. delivery from Tehama-Colusa Canal	87800[1,2]	87,800
14 - Holthouse W.D. delivery from Tehama-Colusa Canal	900[1,2]	800
15 - 4-M W.D. delivery from Tehama-Colusa Canal	1600[1,2]	100
16 - Glenn Valley W.D. delivery from Tehama-Colusa Canal	3500[1,2]	800
17 - La Grange W.D. delivery from Tehama-Colusa Canal	600[1,2]	600
18 - Davis W.D. delivery from Tehama-Colusa Canal	2500[1,2]	2,500
19 - Westside W.D. delivery from Tehama-Colusa Canal	20000[1,2]	5,800
Sacramento River		
20 - Glenn-Colusa ID Diversion from Sacramento River	719500[3]	649,600
21 - Glenn-Colusa ID Diversion from Glenn-Colusa Canal - Glenn County	337400[4]	337,400
21 - Glenn-Colusa ID Diversion from Glenn-ColusaID Canal - Colusa County	312200[5]	312,200
22 - Provident ID diversion from Sacramento River to Subregion 13	42000[1,2]	33,600
22 - Provident ID diversion from Sacramento River to Subregion 16		9,500
23 - Princeton-Codora-Glenn ID diversion from Sacramento River to Subregion 13	54600[1,2]	29,500
23 - Princeton-Codora-Glenn ID diversion from Sacramento River to Subregion 16		25,100
24 - Fred Cannell diversion from Sacramento River at RM 106 to Subregion 16	700[1,2]	700
25 - Maxwell ID diversion from Sacramento River to Subregion 16	5900[1,2]	5,900
26 - Odysseus Farms diversion from Sacramento River at RM 93.15 to Subregion 17	400[1,2]	400
27 - Roberts Ditch Company diversion from Sacramento River at RM 90.7 to Subregion 16	2300[1,2]	2,300
28 - M&T Chico Ranch left bank diversion from Sacramento River	23700[1,2]	23,700

[1] DWR Northern District Westside Data Report 77, 2000

[2] USBR Central Valley Operations Annual Report, 1976 - 2000

[3] Glenn-Colusa Irrigation District Annual Report, 1970 - 2000

[4] Davids Engineering Water Balance Model

[5] Estimated based on data provided by Source 3 and following equation:

Diversion from Sacramento River + Tehama-Colusa Canal Delivery - GCID (Supply to Glenn County) - GCID (Delivery to outside model area) = GCID (Deliveries to Colusa County within model area

GROUNDWATER

SOURCES OF RECHARGE

Groundwater elevation in the Stony Creek Fan area are directly affected by the volumes of water that recharges the underlying groundwater basin. Recharge of the model area consists of the following hydrologic components:

- Deep percolation of precipitation and applied water
- Stormflow recharge
- Recharge from unlined agricultural drains
- Recharge from ponded rice fields
- Steam aquifer interactions
- Subsurface inflow from adjacent groundwater basins;

Estimates of these hydrologic components will be developed using the SCFIGSM.

GROUNDWATER OUTFLOW

Groundwater pumping data in the study area is not generally recorded except for special pumping program undertaken by a water purveyor. Annual pumping data from 1994 to 1999 and 2001 were collected from GCID for 107 wells. These wells are located in the areas between the Glenn-Colusa Canal and the Sacramento River. No other records of historic groundwater pumping could be found. It appears that historic groundwater pumping will need to be estimated using applied water demand, surface water deliveries and irrigation efficiencies. Groundwater pumping has varied over time due to variations in climate, land use, and the availability of alternative sources of water.

Urban water supplies in the study area are entirely from the groundwater source. A water duty of 2 acre-feet per acre is used to estimate the groundwater pumping for urban use. This amounts to an average of 19,000 ac-ft. This amount of pumping is insignificant when compared to the groundwater pumping for agricultural use. Agricultural pumping can be estimated as the difference between agricultural water demand and surface water supply. The surface water supply data are measured data. The agricultural water demand is estimated using Consumptive Use of Applied Water (CUAW) methodology. This methodology uses antecedent soil moisture conditions, crop evapotranspiration requirements, rooting depths, crop acreages,

and irrigation efficiency. Preliminary estimates of groundwater pumping using this land-use based methodology and areally averaged rainfall show that the groundwater pumping in the model area are in the vicinity of 400,000 ac-ft to 500,000 ac-ft. These preliminary estimates will be revised as more data analysis is conducted during model development process

The historic knowledge of the groundwater conditions in the study area indicates that there are two groundwater divides (no flow boundary) in the study area: one in the north along Thomes Creek and one in the south along Highway 20. This knowledge has resulted in choosing the model boundary to be Thomes Creek and Highway 20. On the west, the geologic contact provides a no flow boundary. On the east of the model area, it is thought that groundwater flows into the model area from the east.

LAND AND WATER USE

LAND USE

Land use data for Glenn, Tehama, and Colusa counties were obtained from DWR in two formats: (a) electronic Arc View shape files for recent years; and (b) hardcopy summary tables by USGS quad sheet. The survey years for each county differ from one another. A composite map of the most recent land use patterns in the study area is developed using the most recent land use surveys and is presented in Figure 3.8.

IRRIGATED CROP ACREAGE DATA

Irrigated crop acreage data for the Glenn, Tehama, and Colusa counties are obtained from several sources, as listed below:

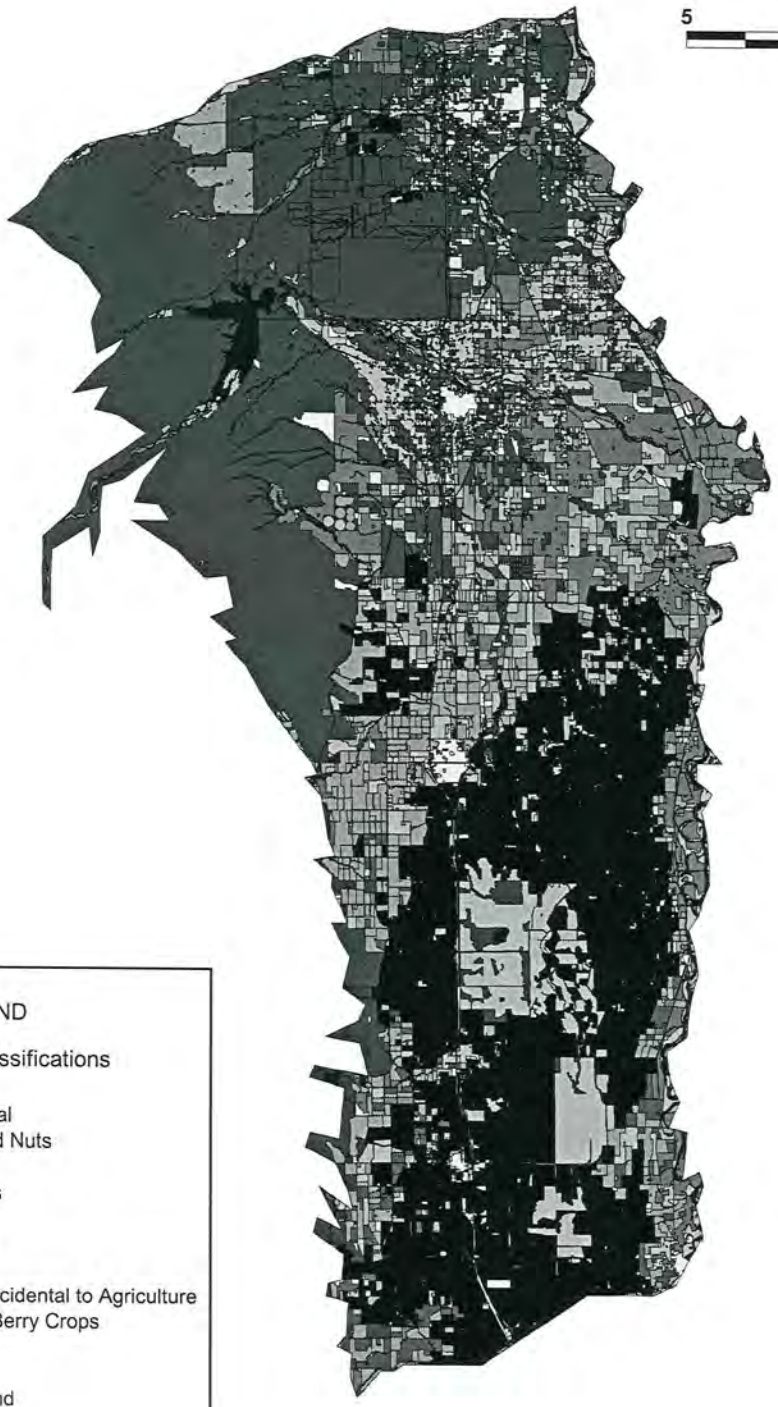
1. U.S. Bureau of Reclamation – CVP Contractors Crop Report;
2. Agricultural Commissioner – Countywide data reported annually;
3. Web Site http://www.nass.usda.gov/ca/bul/agcom/indexcac.htm for Glenn County

The historic land use trends for agricultural, urban, and rice acreage is shown in Figure 3.9.

WATER USE

The primary water use in the model area is for agriculture. Surface water comprises the major source of agricultural water supply. Groundwater is used to (a) supplement additional needs for water; and (b) to irrigate lands that do not receive surface water.

A preliminary data analysis indicates that the total amount of surface water use in the model is in the vicinity of about 1,000,000 ac-ft. It should be noted that these numbers are preliminary and provides general idea about the water use to be utilized in the development of the conceptual model.



LEGEND

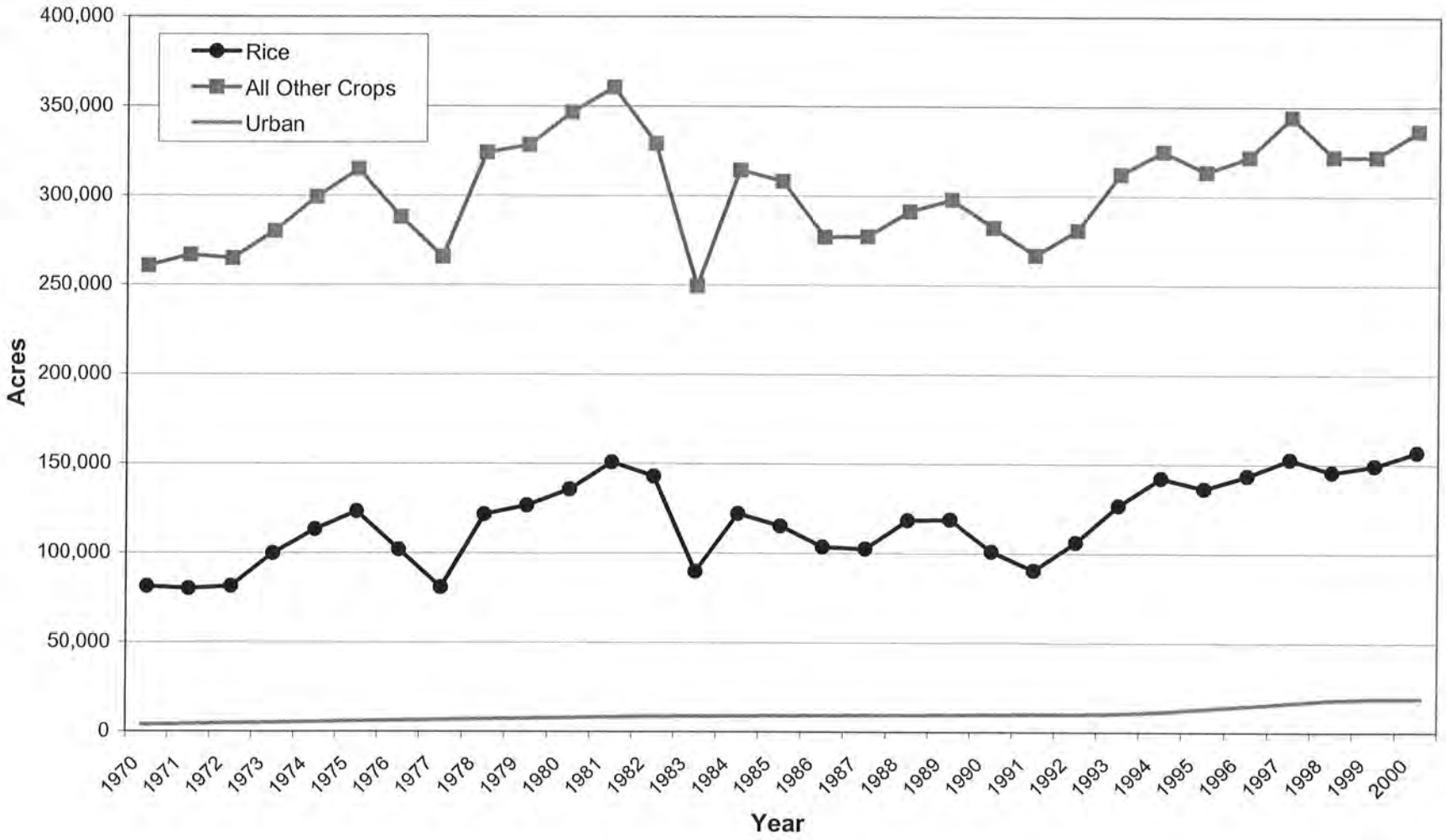
Land Use Classifications

- Citrus and Subtropical
- Deciduous Fruits and Nuts
- Field Crops
- Grain and Hay Crops
- Idle
- Pasture and Alfalfa
- Rice
- Semiagricultural & Incidental to Agriculture
- Truck, Nursery and Berry Crops
- Urban
- Vineyard
- Barren and Wasteland
- Riparian Vegetation
- Native Vegetation
- Water Surface

Source: DWR (http://www.water.ca.gov/landwateruse/landuse/ludataindex.htm)

ωRIME Water Resources & Information Management Engineering, Inc.	STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM **Land Use (1998 and 1999 Surveys)** **DRAFT**	MARCH 2003 FIGURE 3.8

Figure 3.9
Land Use Trends in the SCFIGSM Area



Source: DWR (http://www.water.ca.gov/landwateruse/landuse/ludataindex.htm)

SECTION 4 MODELING GOALS AND OBJECTIVES

It is important to consider the modeling goals and objectives during the development of the conceptual model. The choice of the features and capabilities of a model and the level of detail depends on the goals and objectives of the development of the numerical simulation model. In addition, modeling goals and objectives guides the decision regarding the inclusion, exclusion, and simplification of hydrologic processes to be considered in the conceptual model.

MODELING GOALS

The Program Sponsors have identified both common and specific goals for the Stony Creek Fan Conjunctive Water Management Program.

COMMON GOALS OF THE SPONSORS

1. Protect local surface water and groundwater resources consistent with Glenn County ordinances, specifically the Glenn County Groundwater Management Plan BMOs, and State and Federal laws;
2. Pursue opportunities to maximize Program benefits through strategic, synergistic linkages with other regional water management activities and authorities;
3. Secure water supply reliability locally and provide opportunities for improved water supply reliability for water users' elsewhere in the state; and
4. Seek ways to achieve environmental benefits that are compatible with Program operations.

INDIVIDUAL GOALS OF THE SPONSORS

Individual Goals – Orland Unit Water Users' Association

- Enhanced management of surface water resources; and
- Infrastructure improvements

Individual Goals – Orland-Artois Water District

- Secure affordable water supply reliability in all years.

Individual Goals – Glenn-Colusa Irrigation District

- Improved reliability and increased flexibility through integration of basin surface water and groundwater resources.

MODELING OBJECTIVES

In order to meet the above Program goals, it is necessary to develop a thorough understanding of:

- the groundwater basin behavior in the Program area;
- the surface water systems behavior and its interaction with underlying aquifers; and
- the interrelationships among the various operational parameters of the river/reservoir/aquifer systems.

An integrated groundwater and surface water model can be used as an analytical tool to meet the above-mentioned needs. It can also be used to determine the optimal combination of physical and operational parameters that best meet the goals of the Program Sponsors. The model will also be used to assess potential environmental and third party impacts resulting from the proposed conjunctive use Program.

In order to ensure the success of the modeling efforts in meeting the Program goals, it was decided to establish modeling objectives through discussion with key technical and managerial people involved with the Program. Several interviews and meetings were conducted in that regard and objectives, issues, concerns, and questions related to modeling were identified.

The project team members selected three modeling objectives for the Stony Creek Fan Conjunctive Water Management Program. These are:

- To develop for the Stony Creek Fan and the surrounding Glenn County area an analytical tool that can represent the groundwater and surface water flow systems and their interactions.
- To develop a planning level analytical tool that can provide quantitative information on a comparative basis to help answer different questions on the groundwater and surface water system characteristics and to evaluate alternative conjunctive water management strategies.
- To develop a tool that can be used in assessing management strategies consistent with the Program goals and objectives.

The process of selection of these objectives included interviews with the Program sponsors, assessment of the modeling needs through careful analysis of the Program goals and objectives, evaluation of the criteria for meeting the Program goals, and technical sessions among the project team members.

An effort was also made to prioritize the model capabilities and features. However, it was found that almost all of the identified model capabilities and features are needed for the evaluation and analysis of the Program. As a result, no priorities were assigned to any particular model feature.

On the basis of the required model features, Integrated Groundwater Surface water Model (IGSM) was selected as the model to be used for the Stony Creek Conjunctive Water Management Program. Several criteria were used in the model selection process, as listed below:

- A model that can meet the three modeling objectives identified by the Program Sponsors;
- An integrated hydrologic model that can simulate both the surface water and groundwater systems and their interactions;
- A model that has reservoir operations simulation capabilities;
- A model that has the built-in capability to evaluate conjunctive water management programs without development of additional elaborate program modules;
- A model that has most of the required features identified by the Program Sponsors;
- A model that can be easily modified to accommodate relevant features that may be needed for a Conjunctive Water Management Program;
- A non-proprietary model;
- A model that has a history of successful applications in California;
- A model that has the capability to share/exchange data with the regional groundwater model of the Central Valley (e.g. CVGSM - Central Valley Groundwater Surface Water Model) for boundary conditions generation;
- A model that has the capability to share/exchange data with the regional/statewide reservoir operations model, such as CALSIM, DWRSIM, and PROSIM; and

- A model that can be developed for the Program in a timely and cost effective manner.

The IGSM meets all of the above selection criteria. In addition, both the DWR staff and the project team members are familiar with the IGSM, which will ensure successful model application in a timely and cost effective manner.

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SECTION 5 CONCEPTUAL MODEL

The purpose of building a conceptual model is to simplify the modeling problem and organize the relevant field data and information so that the hydrogeologic system can be analyzed (Anderson and Woessner, 1992).

There are three key steps in developing a conceptual model, such as:

- Conceptual description of modeling of hydrologic processes;
- Delineation of hydrostratigraphic units and model grid; and
- Definition of flow systems and boundary conditions.

The conceptual model for the Stony Creek Fan Integrated Groundwater Surface water Model (SCFIGSM) is described below.

CONCEPTUAL DESCRIPTION OF MODELING OF HYDROLOGIC PROCESSES

In IGSM, the hydrologic system is divided into four major subsystems as shown in Figure 5.1. These are:

- Soil Zone;
- Stream System
- Unsaturated Zone;
- Groundwater Zone.

The hydrologic components of these physical subsystems that are considered in IGSM are shown in Figure 5.2.

SOIL ZONE

The SCFIGSM will simulate soil zone processes including evapotranspiration, direct runoff, infiltration, and deep percolation from rainfall and applied water. The computations will be performed at a finer geographical scale represented by finite element discretization. Evapotranspiration from the soil surface is computed on the basis of crop consumptive use requirement and available soil moisture. Direct runoff from rainfall and applied water is computed by using a modified Soil Conservation Service (SCS) runoff curve number method.

Figure 5.1
Hydrologic System Interactions

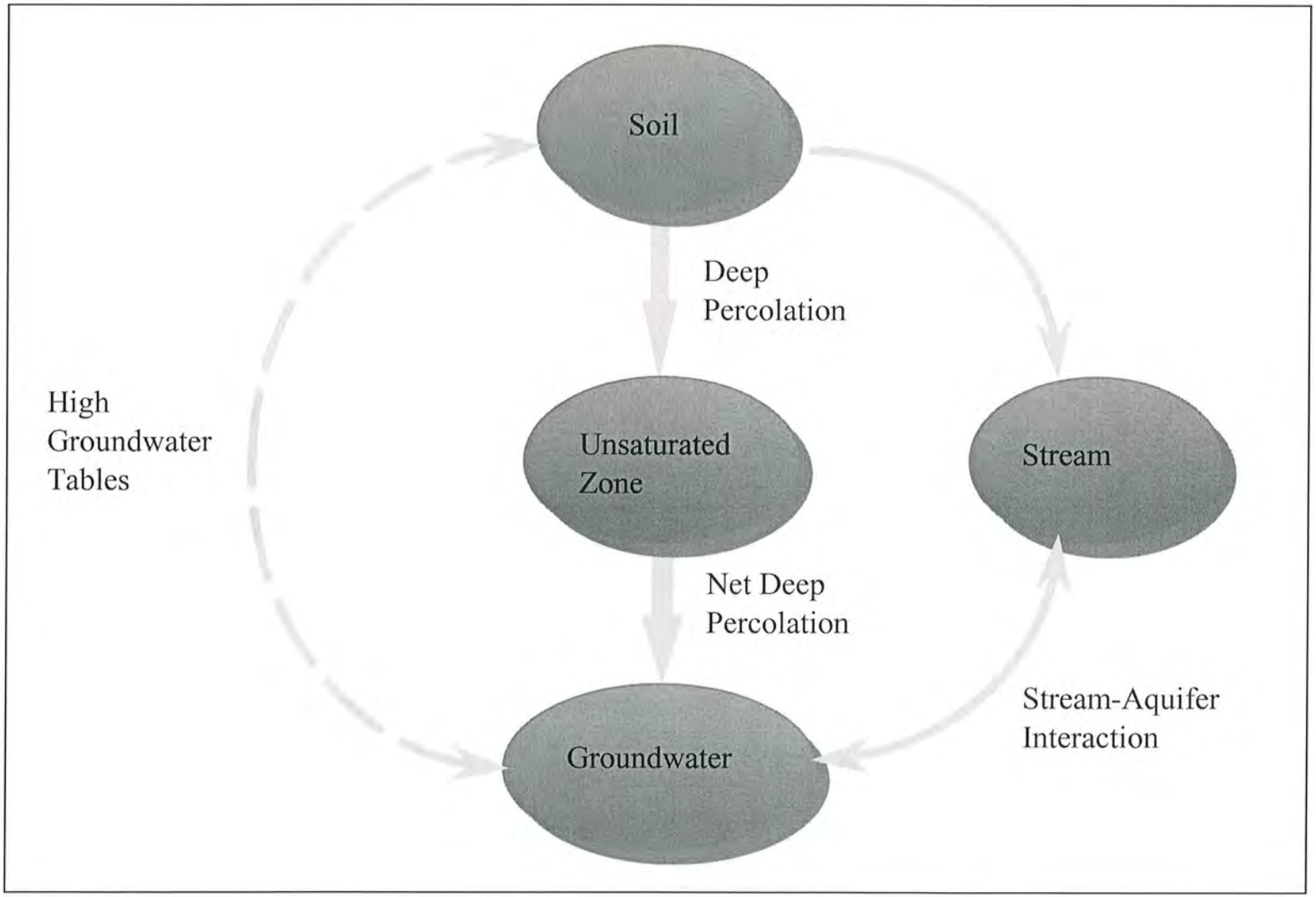
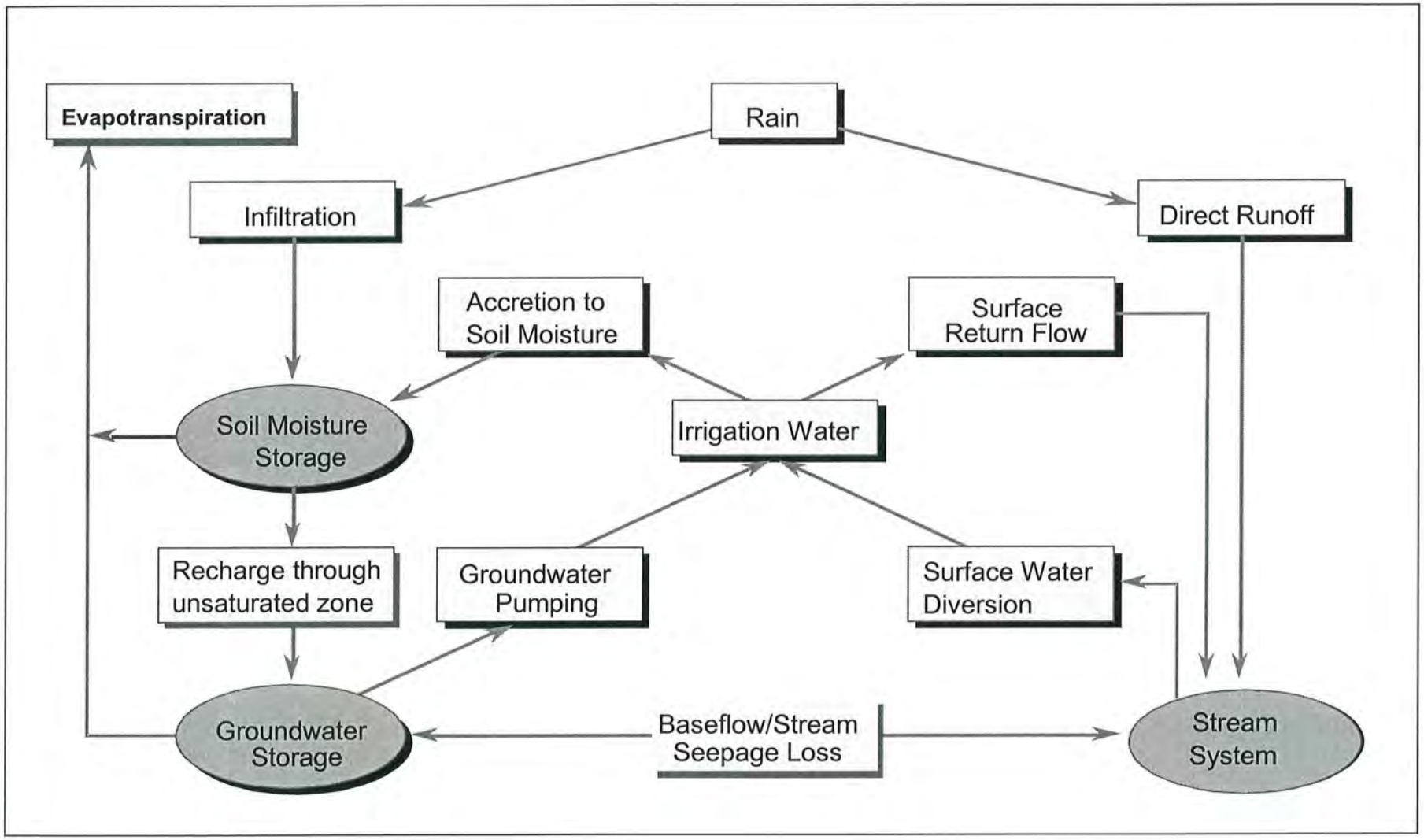


Figure 5.2
Hydrologic Components



The computed runoff from each finite element is routed to the appropriate stream node. Percolation of precipitation and applied water is added to the unsaturated zone that underlies the soil zone.

Input data for soil zone simulation includes initial soil moisture; rainfall; land use history; SCS hydrologic soil group and; minimum soil moisture requirements for:

- crop growth;
- crop consumptive use;
- root zone depth for each crop;
- surface drainage pattern; etc.

Parameter data for this submodel includes:

- SCS curve number;
- field capacity; and
- soil infiltration rate.

STREAM SYSTEM

The water balance equation is solved for each stream element to simulate streamflow in SCFIGSM. The stream elements are a series of 1-dimensional line elements that are used to describe the stream system within the model area. Each stream element is defined by two consecutive stream nodes that are coincident with the aquifer nodes. Components of water balance in a stream element of SCFIGSM are:

- inflow at upstream node of the stream element;
- direct runoff (lateral inflow);
- surface water diversions;
- wastewater discharge;
- agricultural return flow; and
- gain or loss due to interaction with the underlying aquifer.

The gain or loss due to stream aquifer interaction is computed by using mathematical equations that are based on water levels in the stream and underlying aquifer. The depth of water in the

stream is computed using stage-discharge relationships at the corresponding stream node. The solution of the water balance equation in this manner provides the downstream outflow for a stream element. This outflow is used as the upstream inflow for the stream element that is downstream of the current stream element.

The input data for the stream system simulation includes:

- stream configuration;
- stream node elevation;
- cross-section;
- stage-discharge relationship;
- stream inflows at boundary;
- tributary inflows;
- wastewater discharges to streams; and
- streamflow diversions.

The parameter data for this submodel includes hydraulic conductivity and thickness of the streambed.

VADOSE ZONE SIMULATION

Water that percolates down from the soil zone travels through the vadose zone as unsaturated flow and eventually reaches the saturated groundwater zone. The mathematical equation of unsaturated flow is solved numerically at every time step. The vadose zone is divided into a number of discrete layers of specified thickness. The one-dimensional vertical flow equation is solved layer by layer on a nodal basis. The number of vadose zone layers at any node at any time is determined by the depth to groundwater at the corresponding node. The deep percolation of applied water and precipitation that passes through the soil zone becomes the inflow to the uppermost vadose zone layer. Outflow from the overlying layer becomes inflow to the layer beneath, and so on. The outflow from the last vadose zone layer becomes inflow to the saturated groundwater zone. The effect of the rise and fall of the water table is incorporated into this submodel by keeping track of depth to groundwater and vadose zone moisture content. SCFIGSM vadose zone simulation is capable of simulating perched water table conditions resulting from the presence of low permeability zones.

The input data for vadose zone simulation includes thickness of vadose zone layers, vertical hydraulic conductivity and effective porosity.

GROUNDWATER ZONE

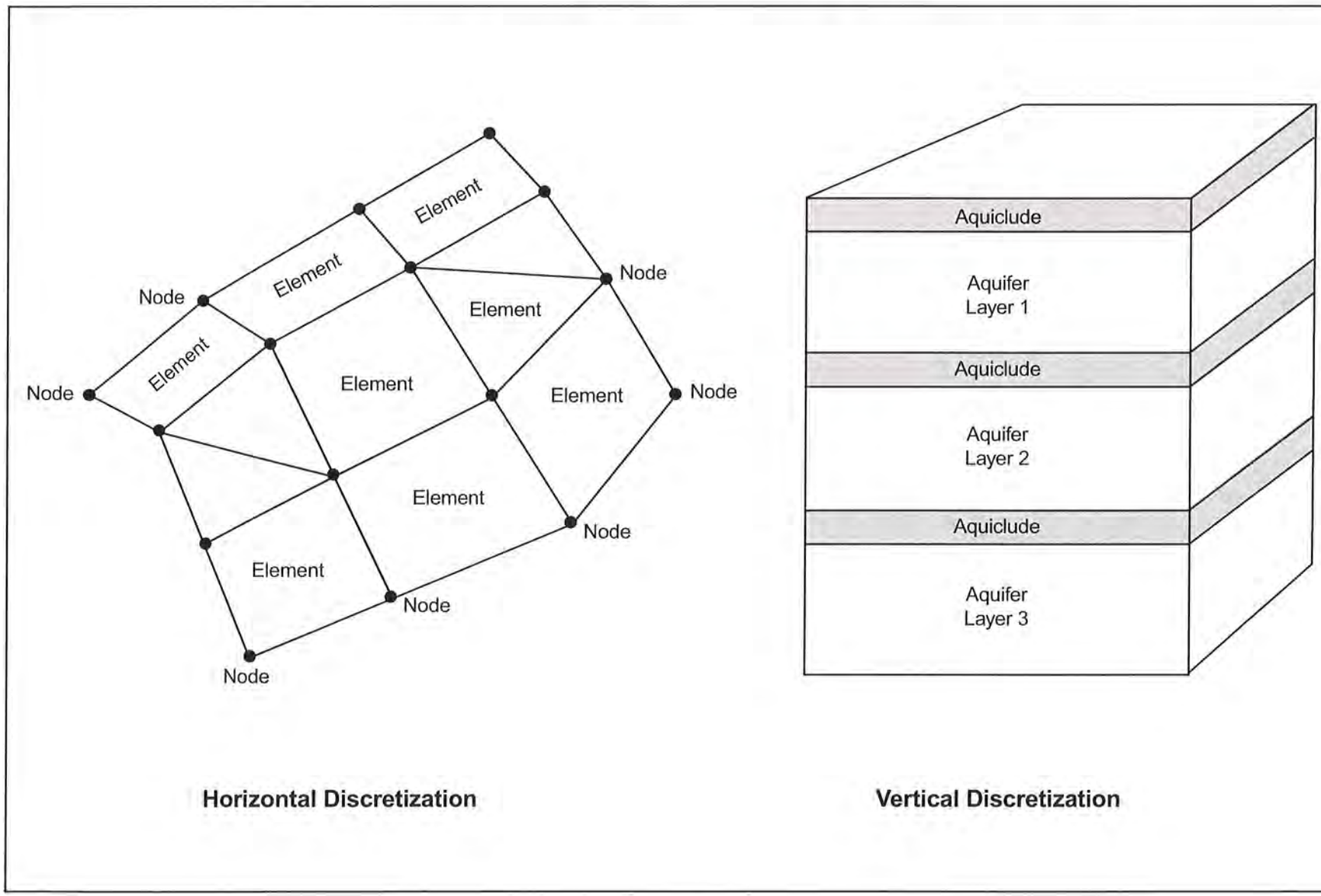
Saturated groundwater flow is simulated in SCFIGSM by solving the governing groundwater flow equation by the Galerkin finite element technique. The model flow domain has been broken down horizontally into a collection of small polygonal areas. These areas are called finite elements and they can be either three-sided or four-sided polygons. The vertices of these elements are called nodes. The network of finite elements and nodes is called a model grid. The groundwater flow domain has been broken down vertically into three discrete layers that represent the underlying groundwater aquifers. These aquifers are separated by aquicludes. A conceptual representation of horizontal and vertical discretization of the flow domain is presented in Figure 5.3.

Aquicludes limit the vertical movement of water, and are generally composed of low hydraulic conductivity materials such as silt and clay; or interbedded sequences where the hydraulic conductivity is governed by silt and clay. The aquifers are primarily composed of materials with relatively high conductivity. The predominant flow paths in groundwater aquifers are horizontal. The horizontal flow system is simulated by solving a two-dimensional groundwater flow equation. The governing differential equation is converted into a set of algebraic equations defined at the finite element nodes. This set of algebraic equations is then solved by using a matrix iterative technique until a specified convergence criterion is satisfied. The vertical flow system is simulated by solving a leakage equation based on the groundwater elevations in two adjacent aquifers.

The input data for groundwater flow simulation includes:

- well location;
- well diameter and perforation interval of wells;
- monthly pumping;
- boundary conditions at boundary nodes;
- initial groundwater elevations;
- aquifer and aquiclude thickness at each node;
- hydraulic conductivity of aquifer and aquiclude material;
- specific yield;

Figure 5.3
Horizontal and Vertical Discretization of Groundwater Flow



- specific storage; and
- leakance.

HYDROLOGIC WATER BALANCE

The primary purpose of all hydrologic modeling is to solve the water balance equation of the selected model area or watershed. The model area can be hydrologically defined, such as a watershed or drainage basin; it can also be politically or arbitrarily defined, such as water district, county, or a plot of land. Regardless of the geographic scale or time period of simulation, water balance equation should be developed as the first step of modeling to identify the appropriate components of the hydrologic cycle for a specific model area. The defining criterion for a model's reliability is how well it incorporates water balance equation for the modeled hydrologic subsystem. A model that does not explicitly generate output showing water budget at appropriate temporal and spatial scale should be used with extreme caution.

The IGSM is a unique hydrologic model that places significant emphasis on hydrologic water balance. An estimate of the net inflow of the Stony Creek Fan IGSM area can be made by summing up the appropriate hydrologic components of the physical system being modeled. This estimate is intended to ensure that the model is properly representing the key hydrologic components of the groundwater basin. As discussed above, SCFIGSM tracks the movement of all of the primary sources of water coming into and leaving the basin, including rainfall, streamflows, applied water, consumptive use, and subsurface inflows and outflows.

The model outputs are reviewed and refined during the model calibration to ensure that the primary sources of inflows and outflows in the different physical subsystems (e.g. soil zone, groundwater subsystem, stream subsystem) of the model are represented properly. This includes annual and monthly water budgets for groundwater, streamflow, soil moisture, and land and water use for the entire model area and for selected model subareas. The key components for each of these water budgets are listed in the Table 5.1 below.

Table 5.1 Water Budget Components

Budget	Components					
Groundwater	Deep Percolation	Stream Recharge	Boundary Flows	Pumping	Overdraft	
Streamflow	Upstream Flow	Rainfall Runoff	Gain from Groundwater	Diversions	Return Flows	Downstream Flow
Soil Moisture	Rainfall	Irrigation	Evapo-transpiration	Direct Runoff	Percolation	Return Flow
Water Use	Agricultural Use	Urban Use	Pumping	Diversions	Imports	Shortages

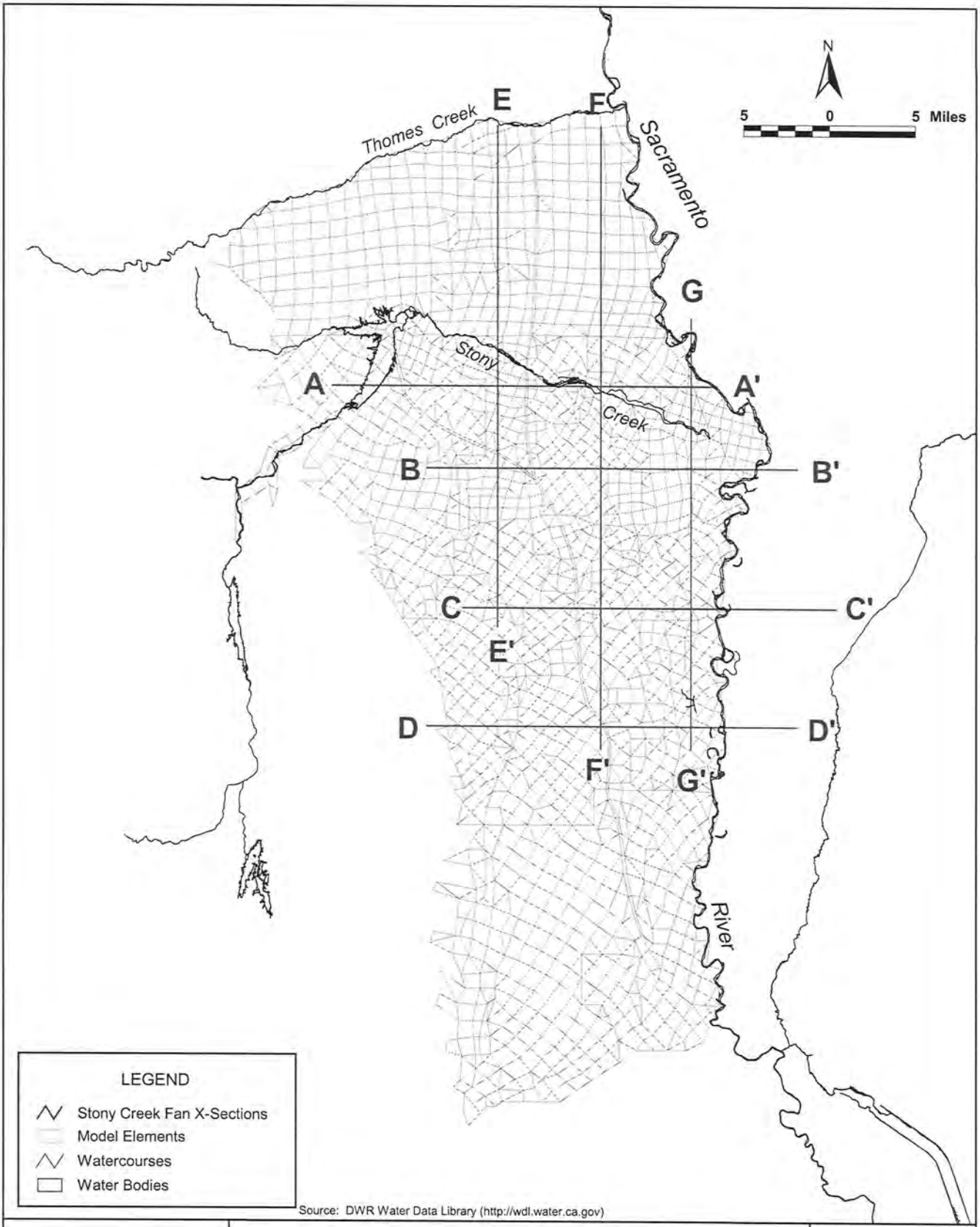
Model Simulation Period

The study period for the SCFIGSM is the 31-year period representing water years 1970 to 2000 (October 1969 to September 2000). This recent period was chosen in part because there is a relatively good set of land and water use data as well as hydrologic data such as rainfall, streamflow, and groundwater levels. This period also includes two historic drought events, 1976-1977 and 1989-1992, and two historic flood events, 1983 and 1986. This time period also includes the introduction of significant quantities of surface water to the area. This simulation period is assumed to be adequate for developing and calibrating a hydrologic model like IGSM.

The SCFIGSM will analyze the hydrologic water balance on an annual basis for this 31 years of model simulation period.

DELINEATION OF HYDROSTRATIGRAPHY

The geologic information described in Section 2 was used in conjunction with the recent geologic mapping by the DWR and well construction logs to define the hydrostratigraphic units of the SCFIGSM. Hydrostratigraphic units comprise geologic units of similar hydrogeologic characteristics and properties. Several geologic formations may be combined into one hydrostratigraphic unit or a geologic formation may be subdivided into aquifer and confining units. Seven hydrostratigraphic cross-sections from the DWR's unpublished recent geologic mapping effort were used as anchor points for developing the detail stratigraphic definition of the entire model area. These sections are shown in Figure 5.4. The number and location of these sections were selected based on the location of lithologic and geophysical data, and for stratigraphic coverage of the entire model area.



Source: DWR Water Data Library (http://wdl.water.ca.gov)

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DWR Geologic Cross Sections Used in Stratigraphic Analysis

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FIGURE 5.4

In developing hydrostratigraphic sections, ground surface elevations were obtained from the U.S. Geologic Survey Digital Elevation Model (DEM) database. The base of the aquifer system is considered to be the base of the freshwater-bearing deposits obtained from recent geologic mapping by the DWR and the past reports published by USGS.

The conceptual model is developed with four hydrostratigraphic units as presented in Figure 5.5, and summarized on Table 5.2.

SCFIGSM Layer 1

The conceptual model for SCFIGSM Layer 1 includes Pleistocene and Holocene deposits consisting of Holocene alluvium, alluvial fan, flood plain, and basin deposits, and the Pleistocene Modesto and Riverbank Formations. The highly permeable sands and gravels of Pleistocene Modesto and Riverbank Formations are only present on the Stony Creek Fan. Where Layer 1 is present throughout the model area it is exposed at the ground surface, and represents the unconfined groundwater system. Wells perforated in this layer are likely used for domestic and some agricultural water supplies.

The highly permeable sands and gravels are 50 to 80 feet thick within the Stony Creek Fan. They are not present outside the Stony Creek Fan. On the Fan, some of the highly permeable deposits are underlain by up to 50 feet of finer-grained alluvial or basin deposits. Outside the Fan, alluvial and basin deposits can reach a total thickness of 200 feet. The conceptual model stratigraphy was developed to reflect the significant difference in the characteristics of the Fan material and the other alluvial deposits present within the model area.

Inside the Fan Area

Inside the Stony Creek Fan Area, SCFIGSM Layer 1 represents the 50 to 80 foot thick highly permeable sand and gravel deposits. Any alluvial or basin deposits that may be present beneath the sands and gravels are included in Layer 2.

Outside the Fan Area

Outside the Stony Creek Fan Area, SCFIGSM Layer 1 represents the upper 80-foot thickness of the basin and alluvial deposits. Any remaining basin or alluvial deposits are considered part of SCFIGSM Layer 2.

Figure 5.5
Conceptual Model Stratigraphy

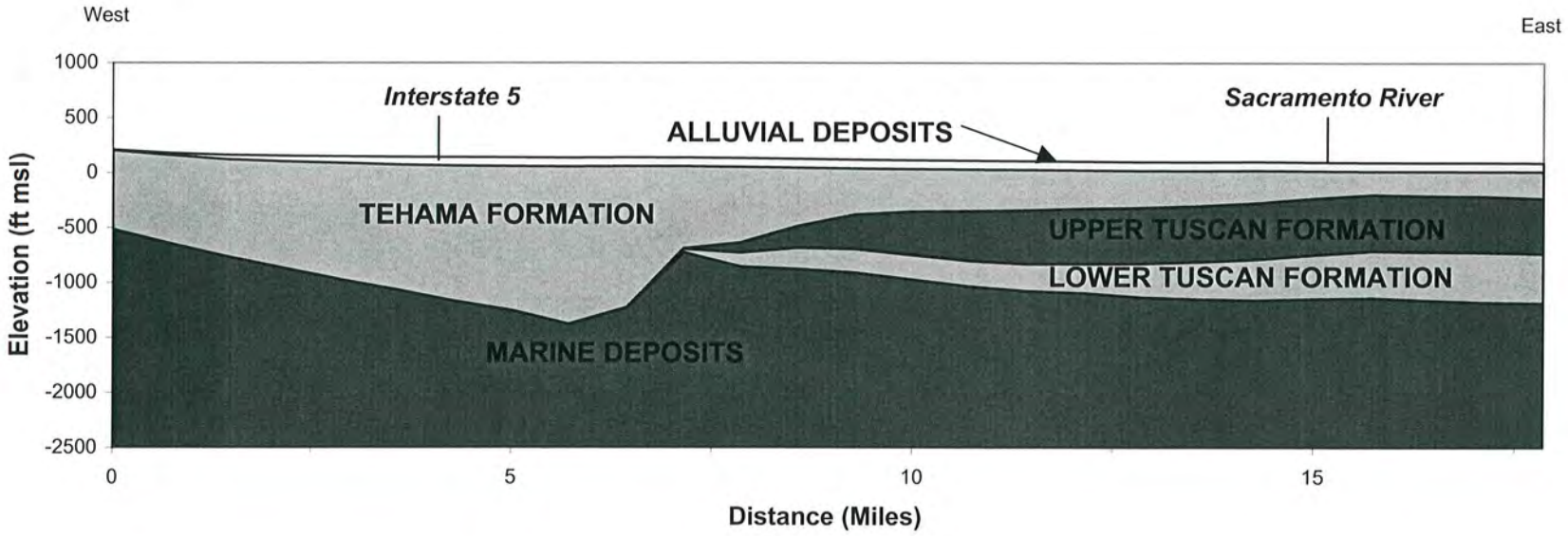


Table 5.2
Definition of SCFIGSM Stratigraphy Layers

Location within Model	Fan Material	Alluvium, Basin and Flood Plain Deposits	Tehama Formation	Upper Tuscan Formation	Lower Tuscan Formation
	Predominantly gravel and sand with minor amounts of silt and clay.	Characterized by fine-grained silts and clays.	Moderately compacted sandstone and siltstone enclosing lenses of sand and gravel; silt and gravel; and cemented conglomerate.	Characterized by massive lahar deposits.	Composed of volcanic conglomerate, sandstone, and siltstone layers interbedded with lahars.
Inside Fan Area					
Layer 1	1 ●	1			
Layer 2		2	2 ●		
Layer 3				3 ●	
Layer 4					4 ●
Outside Fan Area					
Layer 1	Not Present	up to 80 feet 1 ●			
Layer 2		greater than 80 feet 2	2 ●		
Layer 3				3 ●	
Layer 4					4 ●

■ Designates the composition of each layer in the current model using Layer 1 = 50-80 feet thick where Layer 1 is defined by the hydrogeologic properties of the material.

● Designates the composition of each layer in the alternate model which would follow the geologic cross sections exactly and classifly Layer 1 as all Quaternary alluvial deposits.

SCFIGSM Layer 2

The conceptual model for SCFIGSM Layer 2 consists primarily of the Tehama Formation (described in Section 3). The widespread distribution and thickness allow this formation to supply water to many of the agricultural wells in the study area. The Tehama Formation is present throughout the model area ranging in thickness from about 200 feet to over 2,000 feet. Model Layer 2 thickens from west to east about halfway across the model area. Model Layer 2 thins rapidly where Model Layer 3 is present (Table 5.2). As mentioned above, for modeling purposes, Layer 2 does include some basin and alluvial deposits.

Model Layer 2 generally represents groundwater systems ranging from semi-confined to confined conditions. Confinement generally increases with depth, but the actual level of confinement may vary locally due to other conditions, such as continuously perforated wells connecting different aquifer layers. Model Layer 2 is exposed at the ground surface in the northwestern portion of the model area.

SCFIGSM Layer 3

The conceptual model for SCFIGSM Layer 3 consists of the Upper Tuscan Formation (described in Section 3). Model Layer 3 is present throughout the eastern portion of the model area (Figure 5.5). Although this layer contains coarse grained sandstone and conglomerate lenses within the study area, this layer predominantly consists of fine-grained lahar deposits, so groundwater within Layer 3 represents confined aquifer conditions. Because of its overall low permeability, few wells in the model area rely on Layer 3 for groundwater supply.

SCFIGSM Layer 4

The conceptual model for SCGIGSM Layer 4 consists of the Lower Tuscan (described in Section 3). Model Layer 4 is present throughout the eastern portion of the model area (Figure 5.5). In contrast to Layer 3, it is composed of more permeable volcanic conglomerate, sandstone, and siltstone layers interbedded with lahars. It is overlain by the Upper Tuscan Formation (Layer 3), which acts as a confining layer; as a result, groundwater within Layer 4 represents confined aquifer conditions. At this time, few production wells in the model area reach Layer 4, so it currently has little groundwater production and water level data.

BASE OF THE AQUIFER SYSTEM

The base of the aquifer system is considered to be the base of the freshwater-bearing deposits (Figure 5.5). The base of the aquifer system is represented by the base of Model Layer 2 (base of the Tehama Formation) in the western half of the model area. The base of the aquifer system is represented by the base of Model Layer 4 (base of the Lower Tuscan Formation) in the eastern half of the model area.

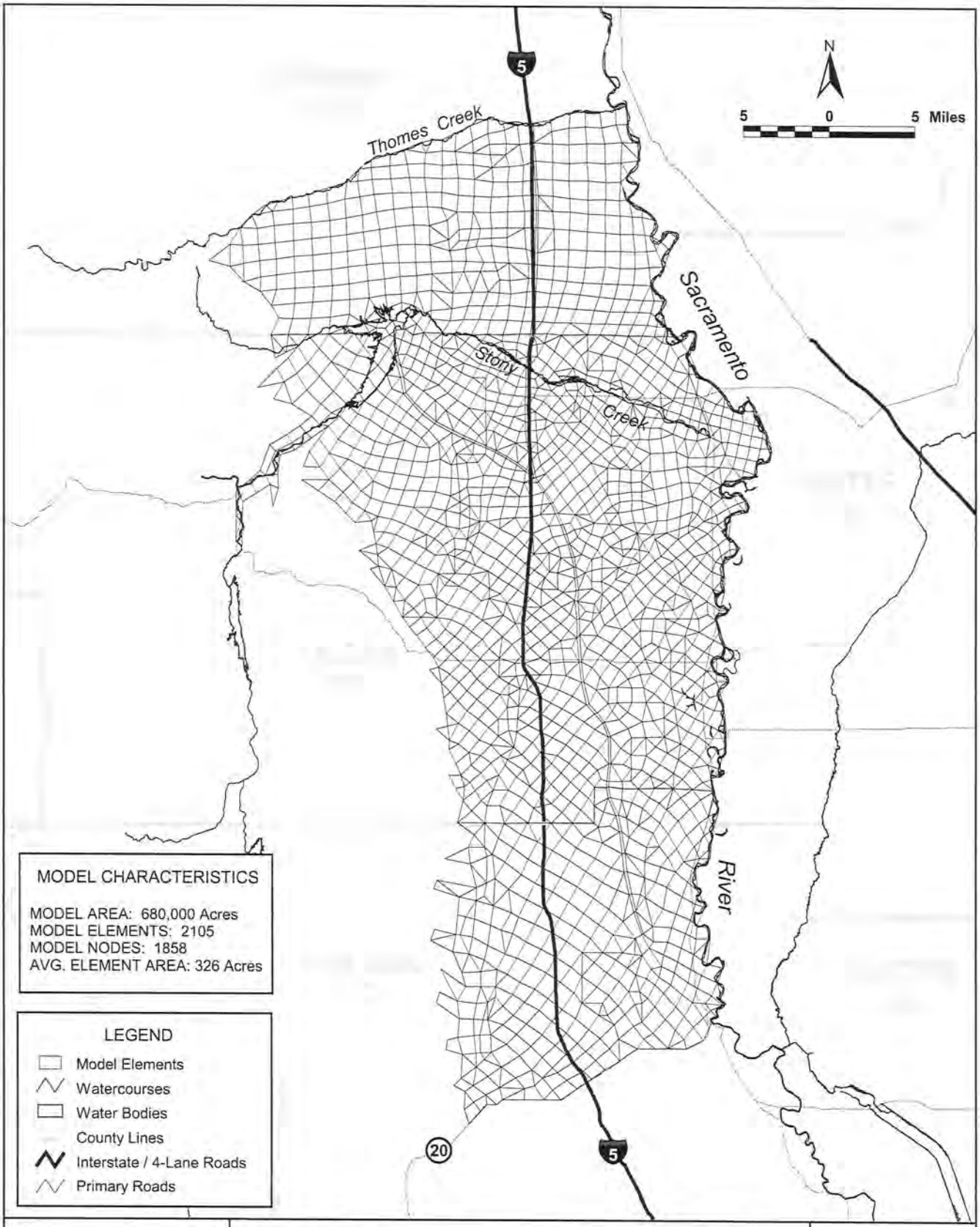
The base of freshwater is mapped in the model area on the basis of available electronic log data. In some locations the base of freshwater is identified to exist within the lower portions of the Tehama Formation or Tuscan Formation (Figure 5.5**Error! Bookmark not defined.**). The base of freshwater is not considered as a boundary between model layers because it is not a fixed location (such as the base of a formation).

SCFIGSM GRID

A two-dimensional finite element grid network was developed to model the groundwater flow in the Stony Creek Fan Area. The entire model area consists of about 1,060 square miles. The SCFIGSM model grid (shown in Figure 5.6) was divided into 2,105 elements and 1,858 model nodes. The average size of single element is about one-half square mile (316 acres). Notable features of the model grid are:

- Model boundary matches the hydrologic and hydrogeologic boundaries of the Stony Creek Fan Area;
- Grid orientation follows the regional groundwater streamlines;
- Elements are smaller in the vicinity of steep groundwater gradients; and
- Thin strips of elements are used to incorporate the discontinuities in the groundwater levels across major geologic faults and barriers.

The model grid is defined by Universal Transverse Mercator (UTM) coordinates at each model node and be the list of connecting nodes for each model element. The x-y coordinates for each model node were obtained from Geographic Information System (GIS) coverage of the model area in UTM Zone 10.5. The list of connecting nodes for each element was developed after numbering the model nodes and model elements. Two independent sets of sequential numbers were used for nodes and elements. These node and element numbers are used in specifying model input data.



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Model Grid

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FIGURE 5.6

The SCFIGSM grid was developed to reflect local conditions including:

- Geologic and Hydrogeologic Considerations,
- Hydrologic Considerations, and
- Potential Water Management Project Areas.

Each of these considerations is described below.

GEOLOGIC AND HYDROGEOLOGIC CONSIDERATIONS

The geologic and hydrogeologic information presented in Section 3 was considered during the SCFIGSM model grid development. These include:

- Geologic Contacts,
- Faults, and
- Groundwater Flow Direction.

Geologic Contacts

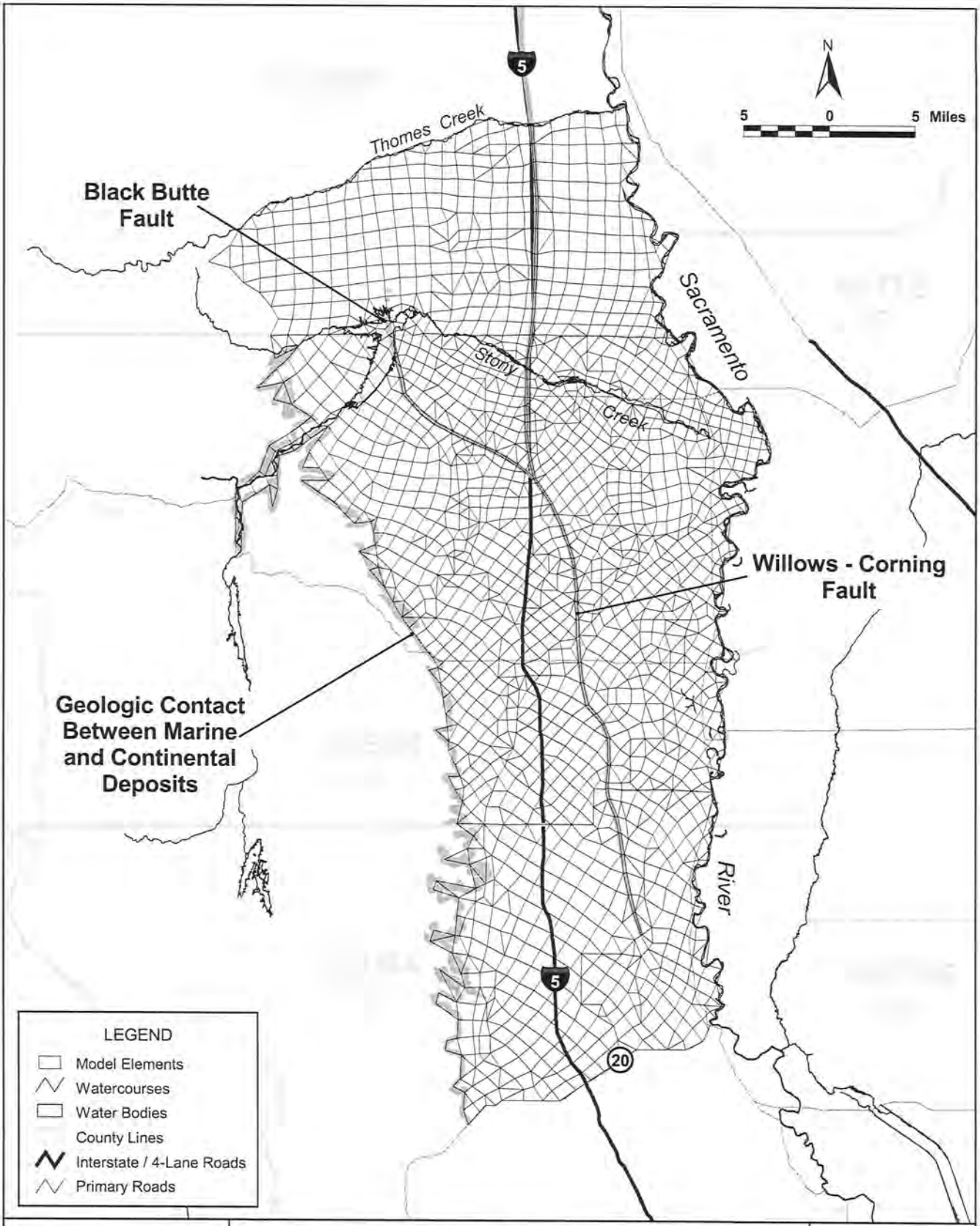
The western boundary of the SCFIGSM grid was defined as the contact between the marine basement rocks of the Coast Range and the continental and alluvial deposits of the Central Valley.

Faults

The SCFIGSM model grid was developed to reflect those faults that either may affect the flow of groundwater, or result in an abrupt change in the aquifer thickness. The SCFIGSM model grid reflects existence of faults by a narrow band of elements along the trace of the fault. After several discussions with DWR, the two faults incorporated into the model grid include the Black Butte Fault and the Willows-Corning Fault. The locations of these faults are shown in Figure 5.7.

Groundwater Flow Direction

The long-term regional groundwater flow directions were considered in the SCFIGSM grid development. Near the Stony Creek Fan, the regional groundwater flow direction is from the fan's apex to the distal portions of the fan generally in the northwest to southeast direction.



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Geologic and Hydrogeologic Considerations

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FIGURE 5.7

North and South of the Stony Creek Fan groundwater generally flows from the upland areas in the west towards the Sacramento River near the center of the Valley.

HYDROLOGIC CONSIDERATIONS

The surface water flow system is modeled by using 1-dimensional line elements along the stream courses. These line elements are defined by stream nodes that are coincident with the aquifer nodes. An independent numbering system is used to number the stream nodes. There are 266 stream nodes representing the surface water flow system in the SCFIGSM. This includes rivers, creeks, and lakes as well as major leaky water delivery canals and drains. Figure 5.8**Error! Bookmark not defined.** shows the locations of the hydrologic features simulated in the SCFIGSM model area, such as:

- Rivers and Creeks,
- Lakes, and
- Canals and Drains.

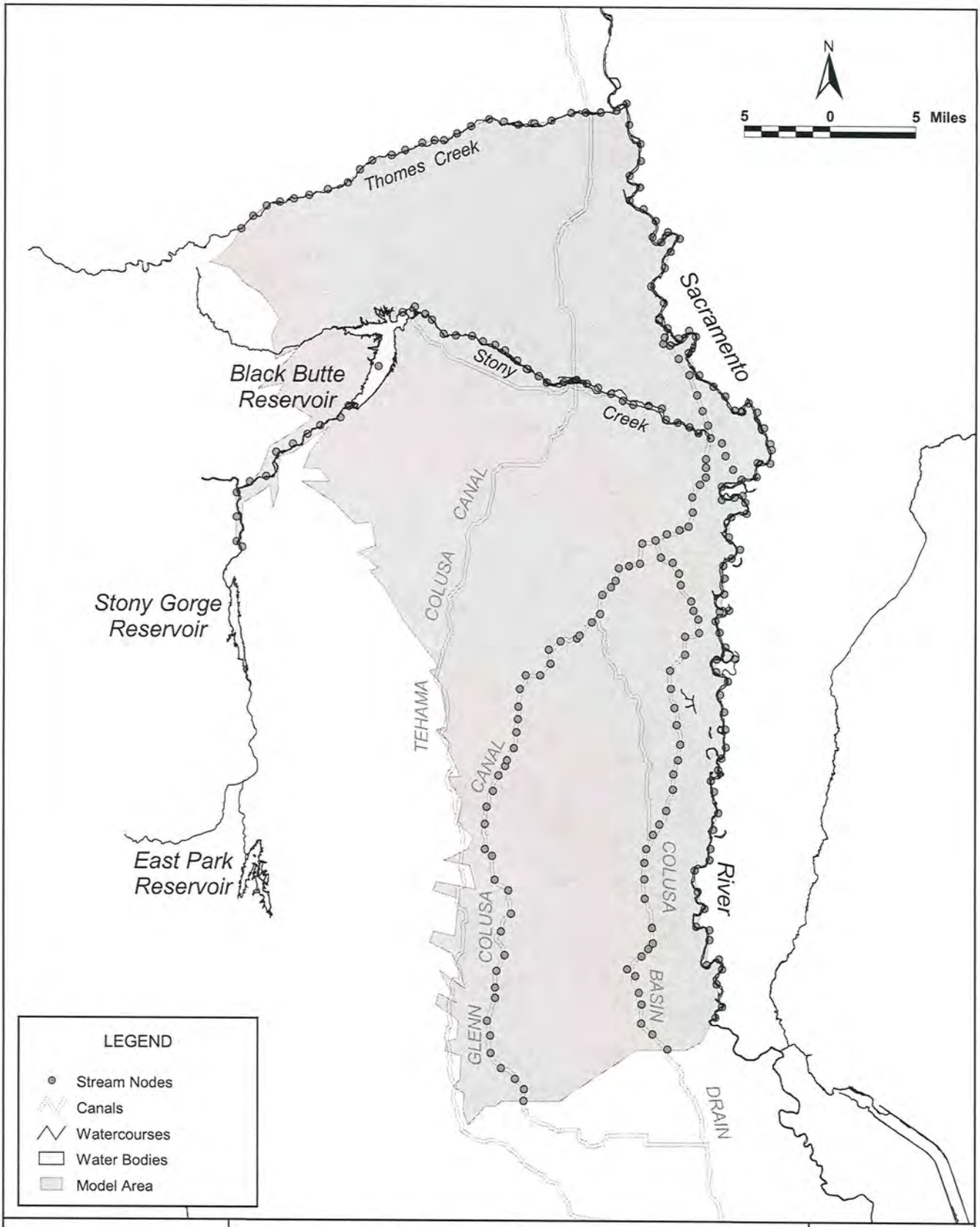
Rivers and Creeks

There are three rivers and creeks simulated in the SCFIGSM: Thomes Creek, Sacramento River, and Stony Creek.

- **Thomes Creek** coincides with the northern boundary of the SCFIGSM, and is simulated along the stream nodes shown in Figure 5.8**Error! Bookmark not defined.**.
- **The Sacramento River** coincides with the eastern boundary of the SCFIGSM, and is simulated along the stream nodes shown in Figure 5.8.
- **Stony Creek** is located within the SCFIGSM model area. It is simulated both above and below Black Butte Reservoir along the stream nodes shown in Figure 5.8.

Lakes

Black Butte Lake is located entirely within the SCFIGSM model area. The model grid was developed to represent the maximum inundation area of Black Butte Lake. The extent of the Black Butte Lake is shown in Figure 5.8.



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Location of Hydrologic Features

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FIGURE 5.8

Canals and Drains

There are two ways to model canals and drains in SCFIGSM: (1) by explicitly defining canals and drains as 1-dimensional stream elements, similar to river and streams; and (2) by specifying a series of recharge elements along the canal which recharges a portion of diverted water to the aquifer during conveyance of irrigation. The explicit definition of canals and drains require specification of canal cross section data and flow-stage rating curve at every stream node.

Two major canals and drains are modeled in the SCFIGSM by using 1-dimensional line elements; these are:

- The **Glenn-Colusa Irrigation District Main Canal** is unlined. It is simulated in the SCFIGSM along the stream nodes shown on Figure 5.8.
- The **Colusa Basin Drain** is unlined. It is simulated in the SCFIGSM along the stream nodes shown on Figure 5.8.

These canals are considered to be major water conveyance facilities that interact with the groundwater aquifer.

There are other leaky irrigation canals in the model area; such as Orland North and South Canals and Corning Canal. They will be simulated by specifying recharge elements along the canal.

The Tehama Colusa canal is concrete lined and leaks only a small amount of water. It can also be modeled by specifying recharge elements if canal seepage is determined to be of importance during the model calibration.

Potential Water Management Project Areas

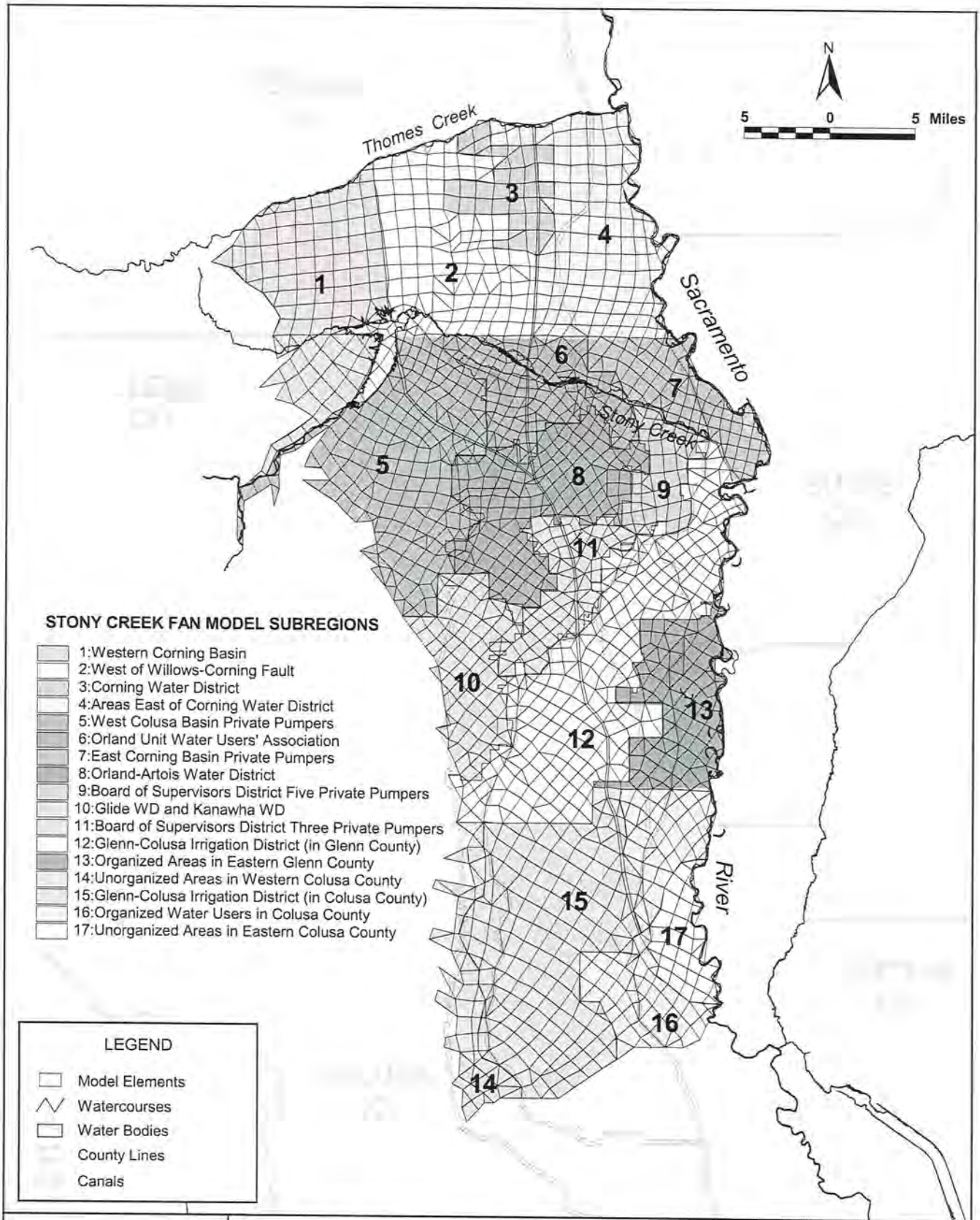
Water and land use management in the model area is represented in the SCFIGSM by subdividing the model area into 17 management areas called subregions. The criteria for the subregion delineation is described below and presented in Table 5.2. The SCFIGSM model subregions are shown on Figure 5.9.

Stony Creek Feasibility Study Subunits

Model subregions were developed to provide geographic coverage similar to the water balance subunits used in the Stony Creek Fan Feasibility Study. This criterion was utilized to define six subregions on or adjacent to the Stony Creek Fan as presented in Table 5.2 and shown in Figure 5.9. SCFIGSM Subregions 6, 7, 8, 9, 11, and 12 were defined based on this criterion.

Table 5.2
SCFIGSM Model Subregions

Stony Creek Fan Conjunctive Use Project		*Primary Criteria*	*Optional Criteria*	
Subregion Number	**Model Subregion Name**	**Stony Creek Fan Feasibility Study Water Balance Subunits**	**Glenn County BMO Basin Management Sub-Area**	**Comments**
1	Western Corning Basin	NA	1 (West Corning Basin Private Pumpers)	Includes unorganized areas in western Tehama County.
2	West of Willows Corning Fault	NA	NA	Includes the area between the northern extension of the Black Butte Fault and the Willows-Corning Fault.
3	Corning Water District	NA	NA	
4	Areas east of Corning Water District	NA	NA	
5	West Colusa Basin Private Pumpers	NA	3 (West Colusa Basin Private Pumpers)	
6	Orland Unit Water Users' Association	1 (Orland Unit Water Users' Association)		
7	East Corning Basin Private Pumpers	5 (East Corning Basin Private Pumpers)		
8	Orland-Artois Water District	2 (Orland-Artois Water District) and 4(Unorganized Pumpers embedded in OAWD)		
9	Board of Supervisors District Five Private Pumpers	6 (Board of Supervisors District Five Private Pumpers)		
10	Glide WD and Kanawha WD	NA	6 (Glide WD) and 7 (Kanawha WD) (and small portion of Sub-Area 11 west of GCID)	
11	Board of Supervisors District Three Private Pumpers	7 (Board of Supervisors District Three Private Pumpers)		
12	Glenn-Colusa Irrigation District (in Glenn County)	3 (Glenn-Colusa Irrigation District)		
13	Organized Areas in Eastern Glenn County	NA	12 (Provident ID), 13 (Willow Creek MWC), 14 (Princeton-Codora- Glenn ID)	Includes portion of Willow Creek MWC in Glenn County.
14	Unorganized Areas in western Colusa County	NA	NA	
15	Glenn Colusa Irrigation District (in Colusa County)	NA	NA	Includes portion of GCID in Colusa County north of Highway 20.
16	Organized Water Users in Colusa County	NA	NA	Includes Maxwell ID, Colusa Drain Water Users' Association
17	Unorganized Areas in Eastern Colusa County	NA	NA	



WRIME Water Resources & Information Management Engineering, Inc.

STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM

Model Subregions

DRAFT

MARCH 2003

FIGURE 5.9

Glenn County Basin Management Objectives Basin Management Sub-Areas

Additional model subregions were developed to provide geographic coverage similar to the basin management subareas used in the Glenn County Basin Management Objectives. This criterion was utilized to define four subregions within the model area in Glenn County as presented in Table 5.2 and shown in Figure 5.9**Error! Bookmark not defined.**. SCFIGSM Subregions 1 (portion in Glenn County), 5, 10, and 13 were defined based on this criterion.

Tehama County

Four subregions were defined in Tehama County based on the hydrogeologic conditions and water supply source (access to surface water). Subregions 1 (portion in Tehama County), 2, 3, and 4 were defined based on this criterion.

Colusa County

Four subregions were defined in Colusa County, primarily based on the water supply source (access to surface water). Subregions 14, 15, 16, and 17 were defined based on this criterion.

DESCRIPTION OF FLOW SYSTEMS AND BOUNDARY CONDITIONS

The groundwater flow system in the SCFIGSM area is part of the larger Central Valley groundwater basin of California. The Central Valley groundwater basin encompasses about 20,000 square miles of area. It is an almost flat alluvial plain extending more than 400 miles from near Redding in the north to near Bakersfield in the south. The width of the valley ranges from 20 to 70 miles with an average of 50 miles in most places. The Central Valley is a closed groundwater basin with an outlet into the Sacramento-San Francisco Delta where two major rivers of the Valley, the Sacramento River and the San Joaquin River, drain their outflows. The Valley is surrounded by the Klamath mountains on the north, by a volcanic plateau of the Cascade Range on the northeast, by the Coastal Ranges on the west, by the Sierra Nevada on the east, and by the Coast Ranges and the Tehachapi mountains on the south. The SCFIGSM groundwater basin is part of this larger Central Valley groundwater basin.

The underlying groundwater aquifer in the SCFIGSM model area is replenished by precipitation recharge, streams/canal seepage, and recharge of applied water over vast lands of irrigated acreage. Recent geologic investigations indicate that the SCFIGSM model area also receives groundwater from areas east of Sacramento River through relatively transmissive lower Tuscan formation which has surface outcrops in Butte County, east of the Sacramento

River. The underlying aquifer is also pumped to meet irrigation demands that cannot be met by surface water supplies. Almost all of the urban water demands in the area is also met by groundwater pumping.

The groundwater flow system in SCFIGSM model area can be defined by specifying the boundaries of the model area. IGSM requires specification of boundary conditions such as groundwater elevation or flux along the boundary of the model. The types of boundary conditions that can be handled by the SCFIGSM include:

- Prescribed flux
- Specified head
- Mixed head (rating table between heads and flows)
- General head
- Small watershed inflow

The small watershed inflow boundary condition accounts for groundwater baseflow or streamflow generated from the watershed areas adjacent to the model area. The model can simulate subsurface or surface outflows from these areas and route them as groundwater recharge or to nearby streams within the model area.

The specific boundary conditions of SCFIGSM are described below.

EXTERNAL BOUNDARIES

North Boundary

The model area is bounded on the north by the Thomes Creek. A no flux boundary condition is assumed along that boundary because of historical evidence of water level measurements and groundwater contour maps;

East Boundary

The model area is bounded on the east by the Sacramento River. A specified flux boundary condition is assumed along this boundary because of anectdotal evidence of water flowing underneath the Sacramento River through the lower Tuscan Formation. The amount of specified flux will be determined during model calibration.

South Boundary

The model area is bounded on the south by the Highway 20, which acts as a groundwater divide on the basis of historical evidence of water level measurements and groundwater contour maps.

West Boundary

The model area is bounded on the west by the geologic contact. A no flux boundary condition is assumed along this boundary.

INTERNAL BOUNDARIES

The internal boundaries are the geologic faults within the model area; they are:

A. Willows Corning Fault; and

B. Black Butte Fault.

Provisions for these internal boundaries require that the model be constructed such that barrier effects and rapid groundwater level changes across faults can be simulated. In order to simulate these internal boundaries, the model grid are kept finer spacing along these boundaries and then allowed to gradually transition to a coarser spacing away from the boundaries. These boundaries may not be vertically continuous.

SECTION 6 SUMMARY

A conceptual model for the Stony Creek Fan Integrated Groundwater and Surfacewater Model (SCFIGSMM) was presented in this report. The conceptual model was developed on the basis of hydrogeology of the model area, hydrology, land use, water use, and other relevant information and data as well as goals and objectives of the modeling.

This conceptual model will guide the development of the numerical simulation model for the Stony Creek Fan. The following section provides additional information on the potential uses and limitations of the numerical model.

MODEL USES AND LIMITATIONS

The primary intent of the Project Sponsor is to use the SCFIGSM in the formulation and development conjunctive water management strategies in the study area. This is generally a three-step process:

1. development of an calibrated model;
2. development of a baseline model; and
3. use of model in the alternatives analysis.

The definition of these model types is provided below:

Calibrated (or Historic) Model: A model that simulates the historic conditions (generally 20 to 30 years period) and is calibrated with recorded observations of groundwater levels (or other relevant variables of interest); the process of calibration (or history matching) ensures that the model is representative of the physical system being modeled.

Baseline Model: This is a revised version of the Calibrated Model with the following changes in input data: (a) the future land and water use conditions (such as 2030 build out conditions) replace the historic land and water use data; and (b) the surrogate for the future hydrology is a long sequence of historic observed hydrology. This baseline model provides the reference frame for comparison of all alternatives.

Alternatives Models: These are the versions of Baseline model with different alternative scenarios of land and water use conditions and/or conjunctive water management programs. The results of these models are used to determine the comparative impacts of different alternatives with reference to the Baseline Model results.

USE OF MODELS FOR DEVELOPMENT AND/OR REFINEMENT OF BMOS

Basin Management Objectives (BMO) are basin operational criteria developed on the basis of historic measurements of well water levels, understanding and observations of groundwater basin behavior, and other field observations. A baseline model (with existing or 2030 conditions and historic hydrologic sequence as a surrogate for future hydrology) cannot be used to evaluate/ revise/implement BMOs, because the purpose of a baseline model is to give reference frame for analyses of alternative management plans, while BMOs are real-time operational guidelines. Furthermore, a model cannot tell whether BMOs are met or not met; the compliance with BMOs can be evaluated only through monitoring of the water levels in the area. Therefore, model should not be used for implementing the Glenn County Groundwater Management Ordinance.

However, a calibrated model can be used to (a) possibly re-examine the assumptions made during the development of the BMOs; (b) enhance the information background of an existing decision or a revised decision related to the Groundwater Management Ordinance or BMOs; (c) identify sensitive areas where additional monitoring may be required to check compliance with BMOs; (d) develop general response characteristics and/or sensitivity ranges among different physical and operational elements; and (e) enhance understanding of the groundwater system behaviors, characteristics, and constraints.

The use of the calibrated model for the above purposes is contingent upon how well the model matches the historical groundwater level observations and how well the model represents physical systems to provide insights (not exact answer) into the groundwater basin response characteristics and into the inter-relationships among different physical and operational elements

USES AND LIMITATIONS OF MODELS IN MEETING THE COMMON GOALS OF THE PROGRAM SPONSORS

One of the common goals of the Program Sponsors is to pursue opportunities to maximize Program benefits through strategic, synergistic linkages with other regional water management activities and authorities. The model can help identify some opportunities or give some quantitative information to help formulate, understand, evaluate, and rank opportunities that can be specified in terms of model input data.

Another common goal of the Program Sponsors is to secure water supply reliability locally and provide opportunities for improved water supply reliability for water users' elsewhere in the state; the model can be used in a statistical mode to develop probabilistic measures of water supply reliability in the face of hydrologic uncertainties and different demand levels.

Another common goal is to seek ways to achieve environmental benefits that are compatible with project operations. A groundwater and surface water model cannot seek ways to achieve environmental benefits; also, a hydrologic model cannot determine whether environmental benefits are achieved or not. But the model can provide information on the water levels and stream flows that can be used as an indicator or measure for evaluating environmental benefits of different alternative plans.

Uses and Limitations of Models in Meeting the Individual Goals of the Program Sponsors

The Orland Unit Water Users' Association has two individual goals: (1) enhanced management of surface water resources; and (2) infrastructure improvements. A model will be able to assess on a comparative basis different alternative ways to manage surface water resources (e.g. reservoir reoperations, conjunctive use, water exchanges etc.). In addition, a calibrated model can provide general estimates of canal seepage loss ranges and help compare different alternatives of canal lining; a calibrated model also can help screen pumping well field sites or recharge sites on a preliminary basis. Both model input data and output data will be helpful in this regard.

The Orland-Artois Water District's individual goal is to secure affordable water supply reliability in all years. The hydrologic model database will have the historic water needs and water supply data and it can be used in a statistical mode to help evaluate the water supply reliability, once the quantitative measure for affordable water supply reliability is determined by the district through its planning process.

The Glenn-Colusa Irrigation District's individual goal is to improve reliability and increase flexibility through integration of basin surface and groundwater resources. As mentioned before, a calibrated model can be used in the statistical mode to help evaluate the water supply reliability, once a quantitative measure of reliability in terms of hydrology is established by the district through its planning process. In addition, an integrated surface water and groundwater model will provide insights into the interrelationships among surface water and groundwater resources to help evaluate management strategies consistent with this individual goal.

General Limitations of a Model

"Models are simplified mathematical representations of physical processes. Constructing a model that accounts for all the finest details of a process is not possible, nor is it useful or necessary." (Saquib Najmus, Water Resources Planning, AWWA Manual M50, AWWA, 2001, p.144). Thus no hydrologic model is an exact representation of the physical world. Therefore, the simulated or predicted groundwater levels from a groundwater model should never be

taken as absolute numbers to be compared against field measurements. Rather, the results of a calibrated groundwater model should be viewed as reasonable approximations of groundwater levels subject to the error ranges of history matching during calibration and also subject to the model assumptions, model set-up, and input data deficiencies.

However, it should be noted that a well-calibrated model could be used effectively in a comparative analysis mode to evaluate the relative impacts of different alternative scenarios.

Specific Limitations of the Model for the Stony Creek Fan Conjunctive Water Management Program

The specific limitations of the model for the Stony Creek Fan Conjunctive Water Management program cannot be determined a priori because they depend on (a) the model selection; (b) the conceptual model for the Stony Creek Fan; (c) the input data quality, level of accuracy, and deficiency; (c) necessary model assumptions; (d) necessary simplifications of physical system; (e) the specific performance of the calibration (history matching) for the Stony Creek Fan model application and the level of calibration, etc.

As part of the model development and documentation process the specific limitations of the Stony Creek Fan model will be evaluated and reported to help the Project Sponsors understand the modeling process as well as the model results and findings. It should also be noted that some potential uses of the model other than the specific purposes for which the model is developed, may require modifications of the Stony Creek Fan model application. However, those potential uses of the model may or may not be desirable or deemed appropriate by the Program Sponsors or stakeholders, regardless of the technical feasibility.

CONCLUSIONS

The conceptual model for SCFIGSM, described above, will serve as the foundation for the development and calibration of the numerical simulation model for Stony Creek Fan model area. The conceptual model will also guide the determination of the level of detail of model input/output data and calibration targets. It should be noted that clarification and refinements of the SCFIGSM conceptual model may be necessary during the model development and calibration process as a better understanding of the physical system is developed through more detailed data collection and analysis.

PROJECT SUMMARY

November 2, 2017

ORLAND-ARTOIS WATER DISTRICT
GROUNDWATER RECHARGE INVESTIGATION
USING 215 CONTRACT WATER

SPRING 2017 TEST

Orland-Artois Water District (OAWD) has been interested in groundwater recharge and the conjunctive use of surface and groundwater for some time. In 2002, along with the Glenn-Colusa Irrigation District and the Orland Unit Water Users Association, the Stony Creek Fan Partnership was formed to investigate the recharge capabilities of the Stony Creek Fan in Glenn County. Several dedicated monitoring wells were constructed to test the recharge of surface water in different areas of the Stony Creek Fan. Later the partnership constructed several deep wells into the Tuscan Aquifer and performed an aquifer performance test. Today most of the monitoring wells are still in use collecting data for DWR including the VanTol site in OAWD. The VanTol site is located on the Westside of County Road M about 3/4s of a mile North of Road 30. All of the monitoring wells are still there including 3 80' to 90' wells and 1 triple completion well to 420'.

In recent years there has been a move towards permanent crops on district as well as non-district lands. These crops are almonds, walnuts, pistachios, and olives which are irrigated with drip and micro-sprinkler systems. The non-district lands are using ground water and many of the district lands are also using groundwater because of the ease of filtering. The expanded use of groundwater, the recent drought years, and the replacement of rice and field crops that utilized flood irrigation with surface water have all contributed to the decline of the local aquifers. More acres are in production and even in fields using surface water the efficient irrigation systems do not allow for recharge. Even with the recent wet year, aquifer levels are considerably lower than they were in 2002. DWR has identified a depression west of Artois that is a concern to water users in that area. In 2002 the Stony Creek Fan Project revealed that the recharged water was moving to the Southeast. Today DWR and the County of Glenn are thinking that the Artois depression is drawing water from East to West towards the depression.

In 2017 OAWD acquired a Section 215 Temporary Water Contract from Reclamation. The 215 water has a lower cost than other water but is available only during times when there are high flows in the rivers and streams. The OAWD Directors felt that a recharge test using 215 Water in the old VanTol Stoney Creek Fan site would give us some new data on the recharge capabilities in the area and be cost effective. If we can recharge water in the gravels at and around the VanTol site and it moves west towards the Artois depression it would be significant. We could recharge much more water in the gravels than the heavy ground in the area of the depression. There are some areas around the depression which may be valuable for recharge but the VanTol site is already set up for a recharge test and the wells there are about 30 feet lower than in 2002.



OAWD staff started flooding the Southeast section of the VanTol property on April 20th and turned off the water on May 2nd. 102 acre-feet of water was used and the site was monitored and the wells measured. We have continued measuring the wells to date. The results show a slight rise in the wells at the end of flooding and when compared to other wells we measure in the area, the VanTol wells started dropping 2-3 weeks later. We felt this was a positive outcome for the test and hope to continue in the coming winter and spring. In the coming months the District will be working with a Chico State grad student who will be running the recharge site as part of his thesis. It will be an expanded test using a test basin and utilizing nearby drains to test their effect on recharge. We are also hoping to show the direction of flow of recharged water.

Emil Cavagnolo

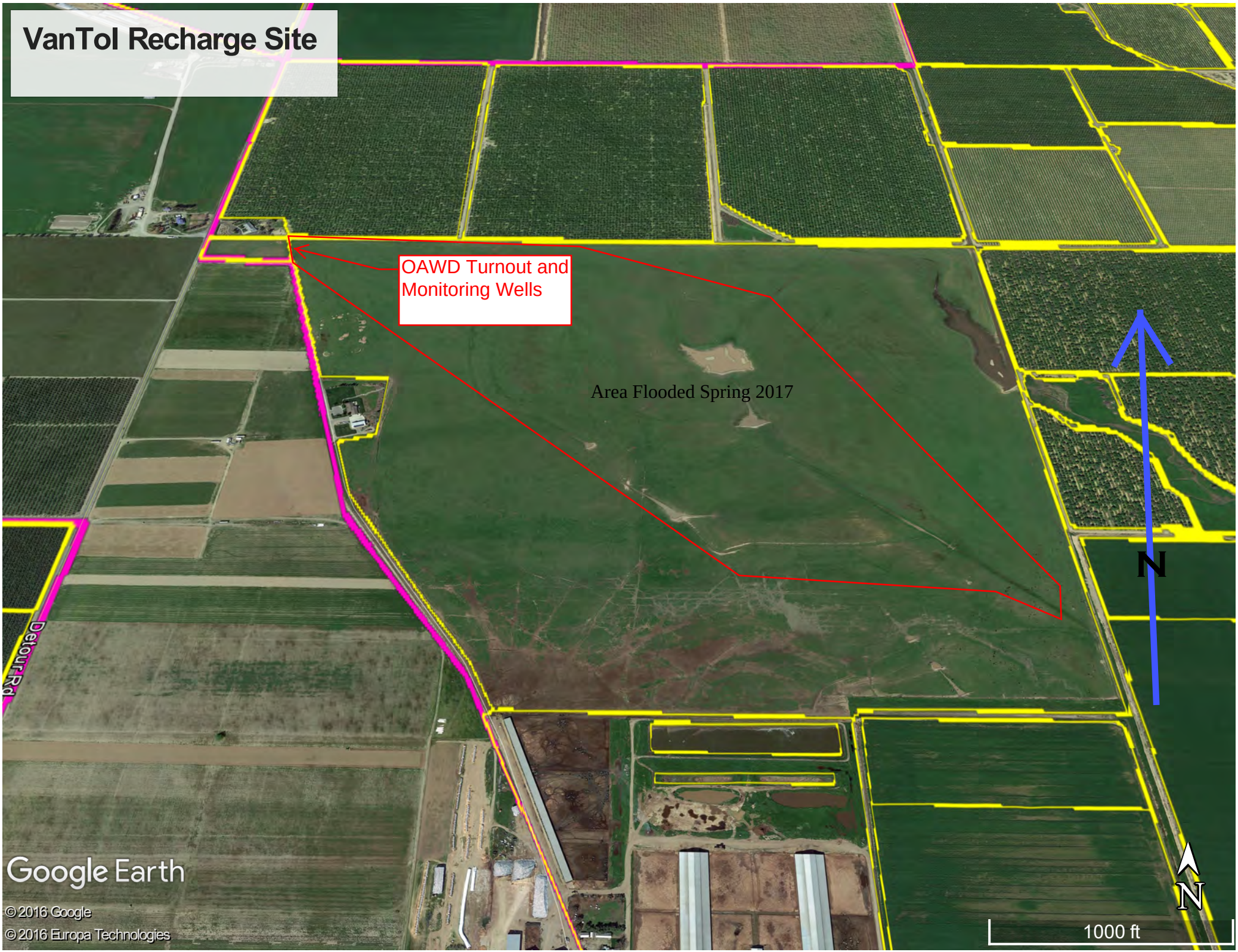
Orland-Artois Water District General Manager



Nice to have an audience.

ORLAND-ARTOIS WATER DISTRICT 2017 SPRING RECHARGE TEST

	A	B	C	D	E	F	G	H	I	J	K	L
1	DATE	TIME	VanTol Deep 21N03W23D01	VanTol Mid 21N03W23D02	VanTol Shallow 21N03W23D03	VT-01 21N03W23D05	VT-02 21N03W23D04	VT-03 21N03W23C01	TURNOUT B-26 TOTALIZER	CFS APPLIED	ACRE-FEET TOTAL	NOTES
2	04/20/17	2:00 PM	55.1	53.8	57.7	57.3	54' DRY	52.2	4322.2	2.5	0	Start Test
3	04/21/17	9:15 AM	55.5	53.1	57.2	57.3	54	52.2	4327.49	2.5	5.29	
4	04/21/17	3:00 PM	55.95	53.6	57.6	57.7	54	52.6	4328.77	2.6	6.57	
5	04/23/17	4:10 PM	55.4	52.95	56.9	56.96	54	51.93	4339.12	3	16.92	Water was at .02 miles East of
6	04/24/17	9:40 AM	55.4	53	57	57.1	54	52	4343.47	3	21.27	
7	04/24/17	3:00 PM	55.3	53	57	57.1	54	52	4344.82	3	22.62	
8	04/25/17	8:50 AM	55.7	53.35	57.4	57.5	54	52.4	4349.37	3.1	27.17	
9	04/26/17	9:10 AM	55.3	53	56.9	57	54	52	4355.47	3	33.27	Water was at .02 miles East of
10	04/27/17	9:10 AM	55.2	52.9	56.9	57	54	51.9	4361.46	3	39.26	
11	04/28/17	10:00 AM	55.2	52.9	56.8	57	54	51.9	4367.66	3	45.46	
12	05/01/17	9:50 AM	55.6	53.2	57.1	57.2	54	52.1	4385.95	3	63.75	
13	05/02/17	9:30 AM	55	52.8	56.7	56.8	54	51.7	4391.65	3	69.45	Water was at .02 miles East of
14	05/03/17	3:30 PM	55	52.8	56.6	56.7	54	51.7	4399.49	3	77.29	
15	05/04/17	5:00 PM							4405.63	0	83.43	Shut off
16	05/08/17	3:25 PM							4405.63	2.5	83.43	Re-Start
17	05/09/17	8:35 AM	54.9	53.1	56.4	56.5	54	51.4	4409.56	2.5	87.36	
18	05/11/17	10:15 AM							4419.84	2.5	97.64	
19	05/02/17	9:00 AM	54.8	52.9	56.4	56.5	54	51.4	4424.98	0	102.78	End Test/continue well measurments.
20	05/15/17	2:00 PM	54.7	53	56.2	56.3	54	51.2	4424.98	0	102.78	
21	05/23/17	7:15 AM	54.8	53.4	55.8	56	54	50.8	4424.98	0	102.78	
22	06/01/17	1:50 PM	56.4	54.4	56.8	56.9	54	51.8	4424.98	0	102.78	
23	06/14/17	9:30 AM	55.5	54.8	56.8	56.9	54	51.7	4426.02	3.5	103.82	Landowner Irrigating
24	06/27/17	10:00 AM	57.3	59.1	57.2	57.3	54	52.1	4440.91	0	118.71	
25	07/10/17	2:30 PM	57.5	60	57.3	57.3	54	52	4448.65	2.5	126.45	Landowner Irrigating
26	07/17/17	8:35 AM	57.2	58.8	57.6	57.7	54	52.4	4451.73	0	129.53	Landowner Irrigating
27	08/14/17	1:45 PM	58.9	61.2	58.7	58.7	54	53.4	4473.7	0	151.5	Landowner Irrigating
28	10/02/17	1:30 PM	58.8	58.7	59.7	59.7	54	54.4	4497.73	0	175.53	Landowner Irrigating
29	11/01/17	2:45 PM	58.9	58.4	60	60.1	54	54.7	4515.54	0	193.34	Landowner Irrigating
30	11/20/17	9:30 AM	58.9	57.9	60.2	60.3	54	55	4515.53	0	193.33	
31	12/12/17	1:52 PM	58.9	57.9	60.2	60.3	54	55.05	4515.53	0	193.33	


VanTol Recharge Site
OAWD Turnout and Monitoring Wells
Area Flooded Spring 2017
N
Detour Rd
Google Earth
© 2016 Google
© 2016 Europa Technologies
N
1000 ft

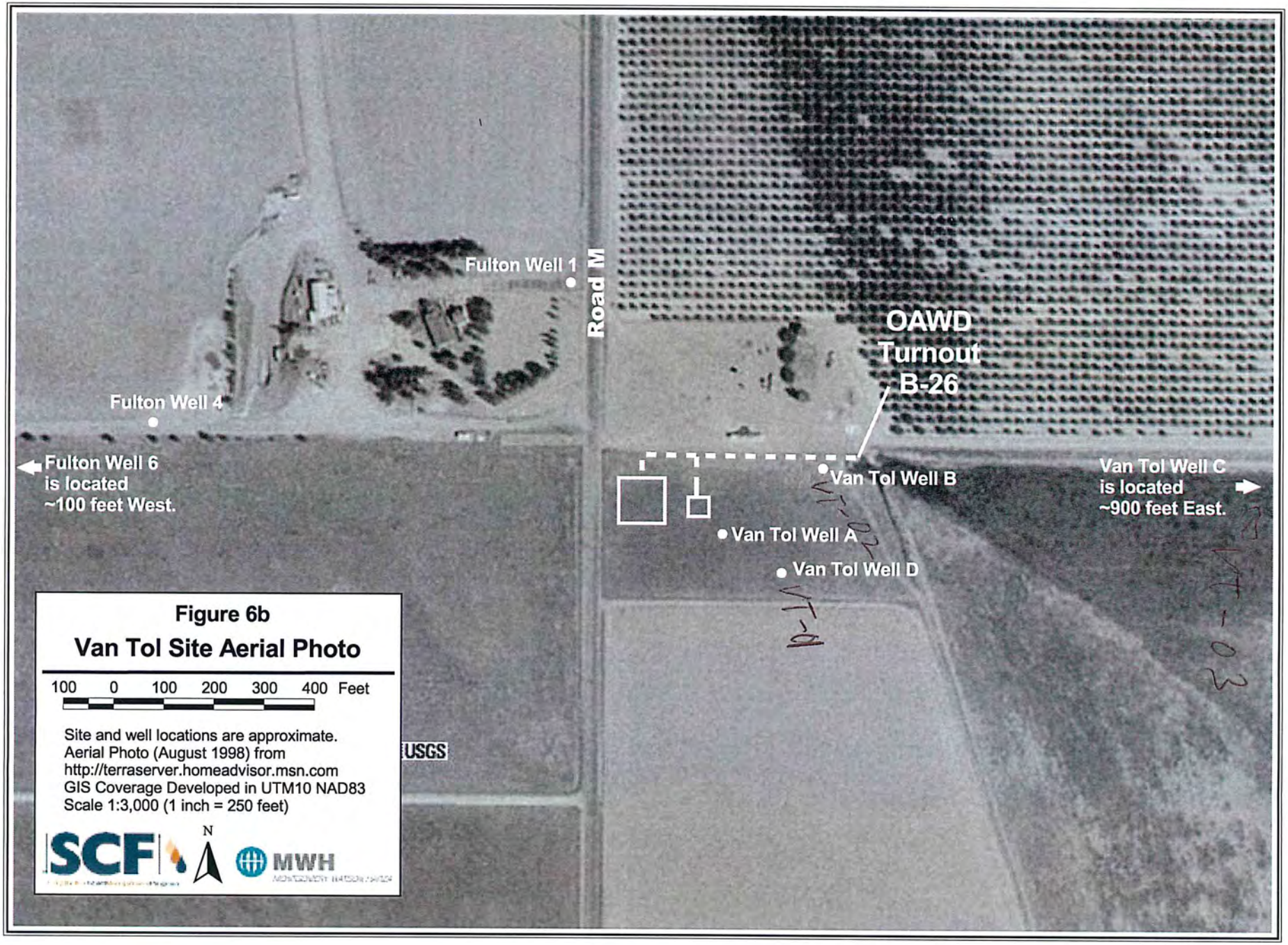


Figure 6b

Van Tol Site Aerial Photo

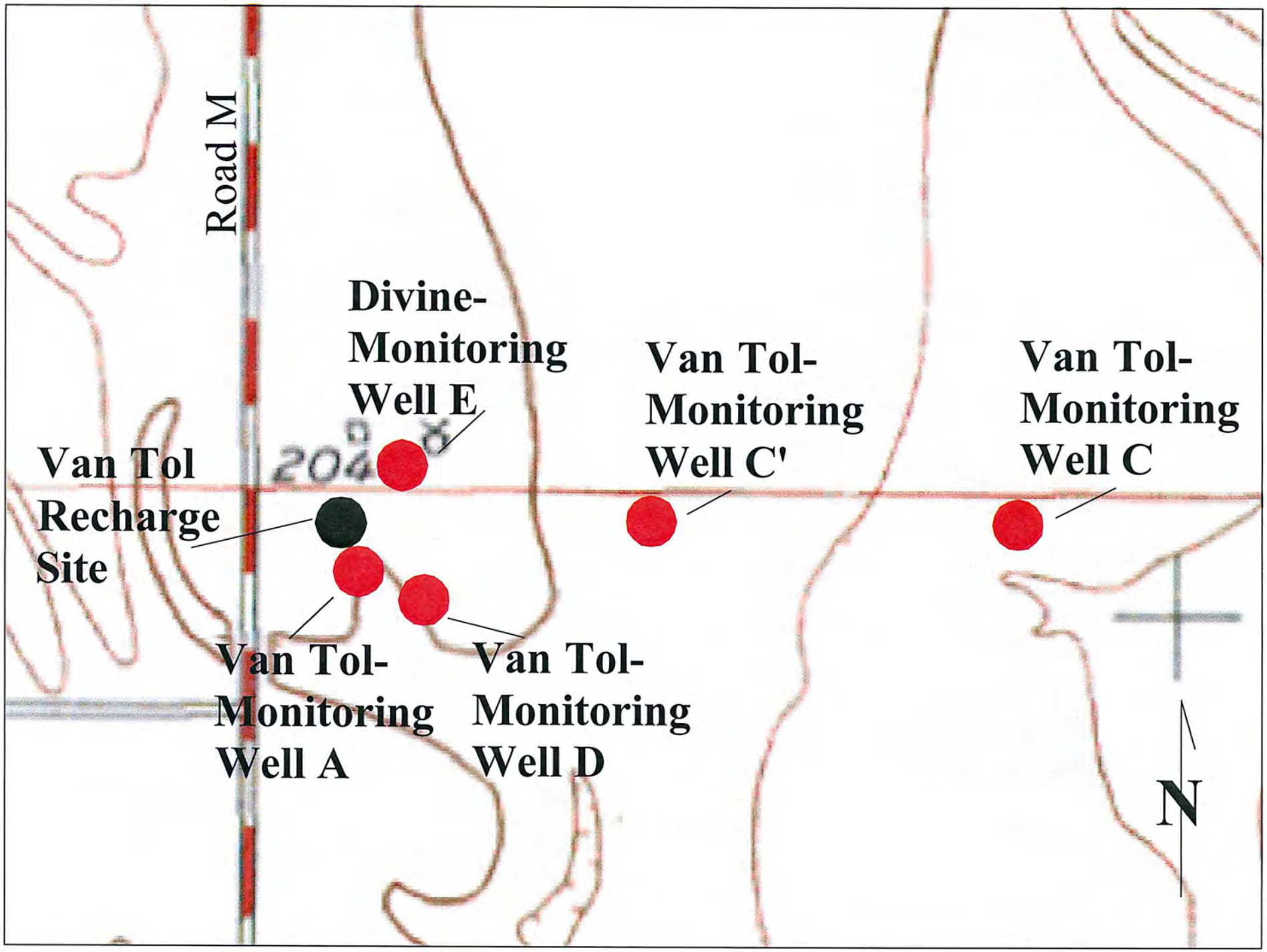
100 0 100 200 300 400 Feet

Site and well locations are approximate.
Aerial Photo (August 1998) from
http://terraserver.homeadvisor.msn.com
GIS Coverage Developed in UTM10 NAD83
Scale 1:3,000 (1 inch = 250 feet)

N

SCF

MWH


Road M
Divine-
Monitoring
Well E
Van Tol-
Monitoring
Well C'
Van Tol-
Monitoring
Well C
Van Tol
Recharge
Site
Van Tol-
Monitoring
Well A
Van Tol-
Monitoring
Well D
N

STATE OF CALIFORNIA - RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

STATE WELL NUMBERS: 21N03W23D01M-Deep Zone
21N03W23D02M-Middle Zone
21N03W23D03M-Shallow Zone

PROJECT	Stony Creek Recharge Pilot Project	HOLE NUMBER	Well A - Van Tol Site	NUMBER OF COMPLETIONS	3	CONTRACTOR	Spectrum Exploration, Inc.
FEATURE	Triple Completion Monitoring Well	TOTAL DEPTH	420 ft	TYPE OF HOLE	Direct Rotary	DRILL FOREMAN	Randy Criner
LOCATION	Glenn County, County Rd 27 and County Rd M	DATE STARTED	3/20/02	TYPE OF RIG	Ingersoll Rand	INSPECTED BY	Kelly Staton
UTM COORDINATES	UTM 10 NAD 83 570561, 4391143	DATE COMPLETED	3/29/02	COMMENTS	Test hole drilled to 500 ft.; well completed to 393 ft.		

DEPTH (ft.)	DESCRIPTION
0	Poorly graded medium sand, sub-angular to sub- rounded
20	Poorly graded gravel with fine to med. sand of metam. origin, sub-angular to sub-rounded clasts
	Gravel and sand
40	Clay
	Gravel with fine to coarse-grained sand
60	Gravel and fine to coarse-grained sand
	Gravel with minor amount of clay and sand
80	
100	Lt. brown to tan clay with gravel and sand
120	
140	Sand with gravel and clay
	Gravel and medium to coarse sand
160	Gravel and tan to brown clay
	Tan/brown clay with gravel
180	Tan/brown clay with gravel and med. sand
	Gravel with tan to brown clay
220	
240	Tan to brown clay with minor amounts of gravel
260	
280	
300	
320	Gravel with Tan/ brown clay, slightly grey
	Gravel with Tan/ brown clay
340	Tan to brown clay with minor amounts of gravel
360	Gravel w/ minor amounts of clay & sand
	Clay with minor amounts of gravel
400	
420	
440	
460	Clay with minor amounts of sand and gravel
480	
500	

Cement grout (gs to 32 ft)

#60 sand (32 ft to 36 ft)

#8 sand (36 ft to 84 ft)

Cement grout (84 ft to 127 ft)

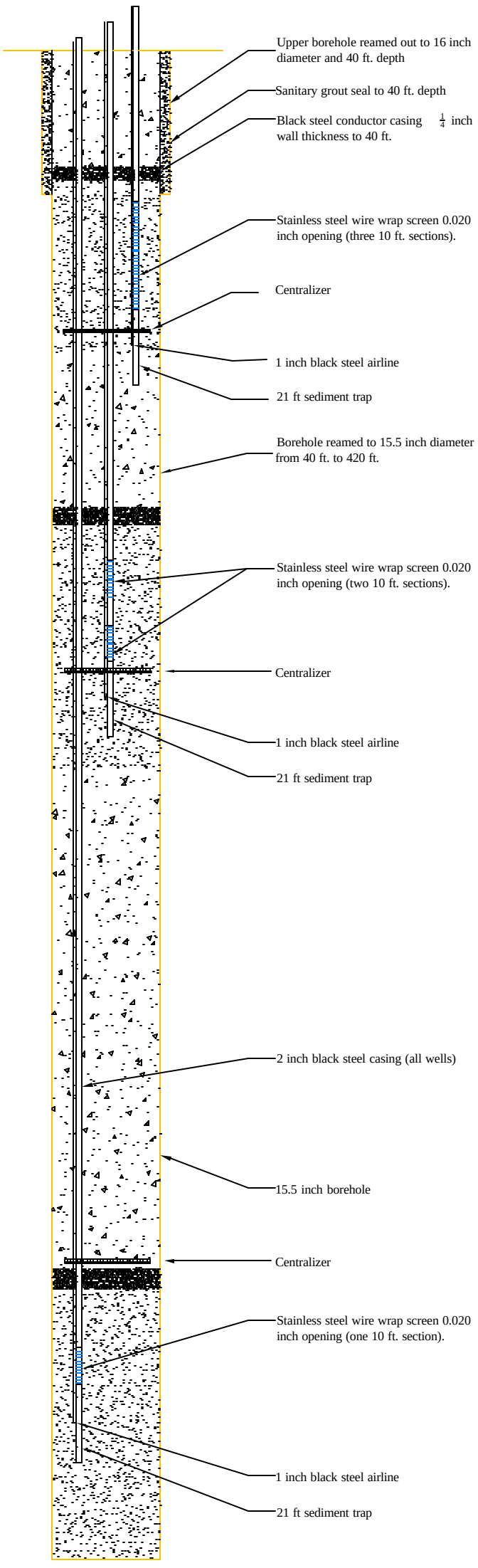
#60 sand (127 ft to 132 ft)

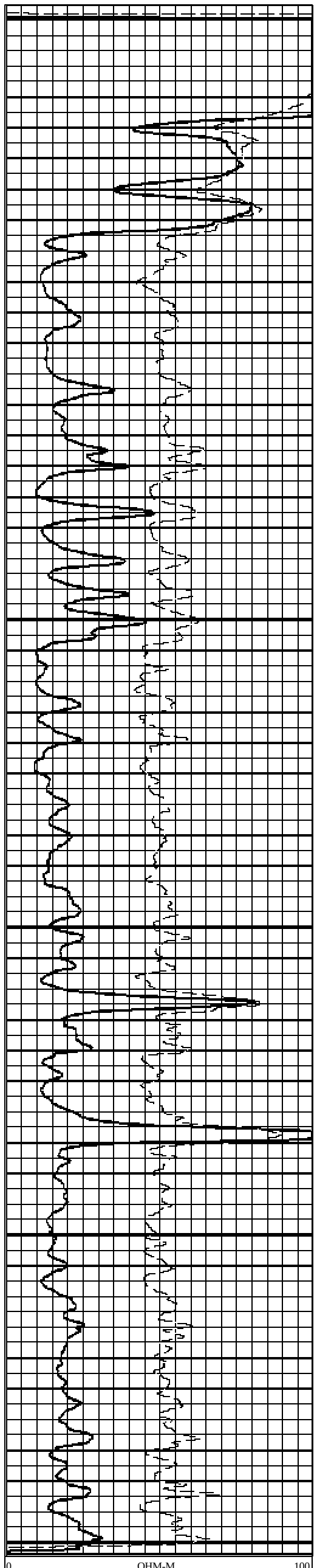
#8 sand (132 ft to 200 ft)

Cement grout (200 ft to 339 ft)

#60 sand (339 ft to 345 ft)

#8 sand (345 ft to 420 ft)





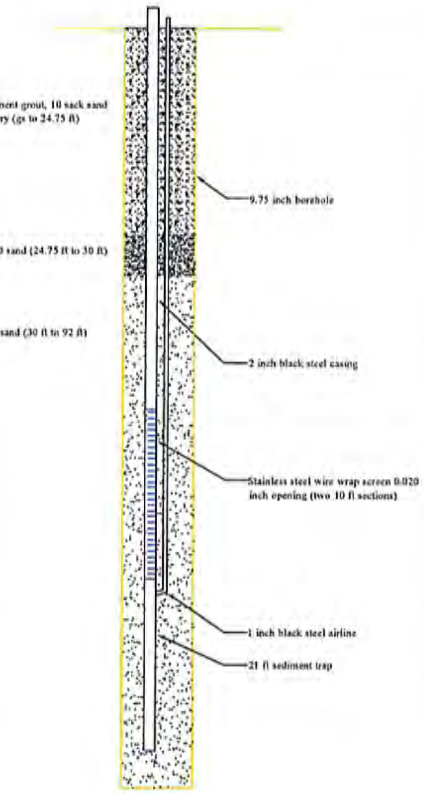
VT-01

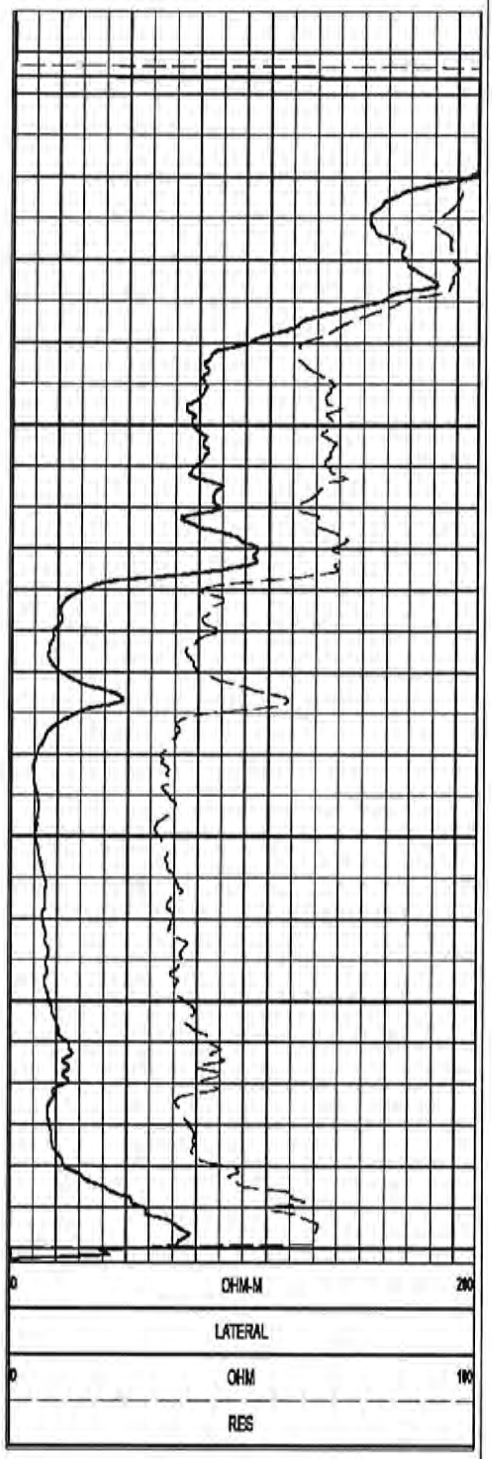
STATE OF CALIFORNIA - RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

STATE WELL NUMBER: 21N03W23D03M

PROJECT: Stony Creek Recharge Pilot Project	HOLE NUMBER: Well D - Van Tol Site	NUMBER OF COMPLETIONS: 1	CONTRACTOR: Spectrum Exploration, Inc.
FEATURE: Single Completion Monitoring Well	TOTAL DEPTH: 92 ft	TYPE OF HOLE: Direct Rotary	DRILL FOREMAN: Dan Lynch
LOCATION: Glenn County, County Rd 27 and County Rd M	DATE STARTED: 3/18/02	TYPE OF RIG: Gardner-Denver	INSPECTED BY: Seth Lawrence
UTM COORDINATES: UTM 10 NAD 83 570597, 4391120	DATE COMPLETED: 3/21/02	COMMENTS: Test hole drilled to 150 ft; well completed to 87 ft	

DEPTH (ft)	LITHOLOGY	DESCRIPTION
0		Gravel with minor amounts of sand
30		Medium to coarse sand with gravel
40		Gravel with medium to coarse sand and minor amounts of clay
60		Tan clay with fine sand and silt
65		Gravel with sand
70		Tan Clay with sand
72		Gravel with sand
75		Tan clay with sand and gravel
90		Tan to Brown clay with sand and gravel
105		Tan clay with minor amounts of sand
130		Tan clay with medium to coarse sand
145		Medium to coarse sand with clay
150		



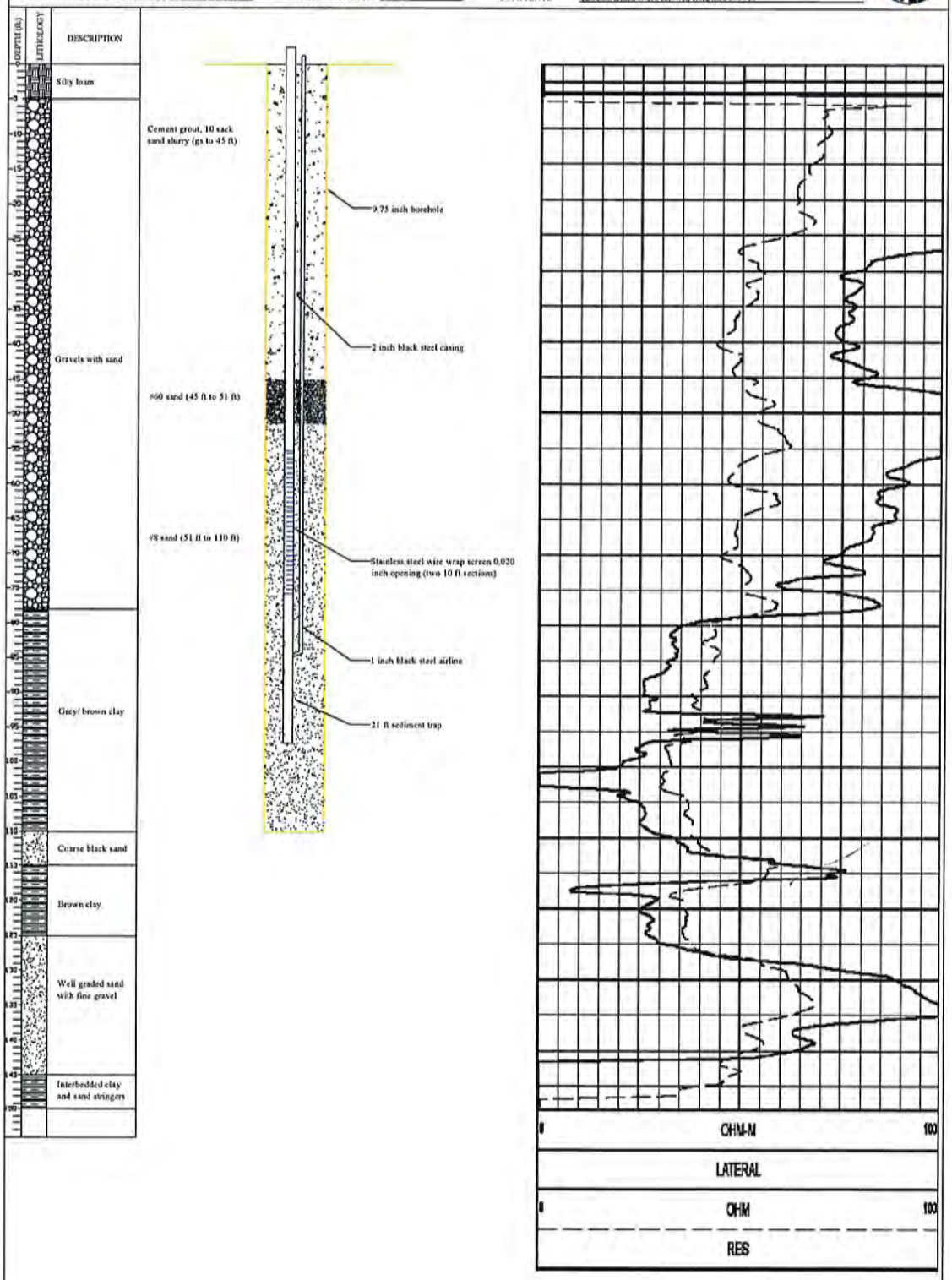


VT-03

STATE OF CALIFORNIA - RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

STATE WELL NUMBER: 21N03W23C01M

PROJECT	Stony Creek Recharge Pilot Project	HOLE NUMBER	Well C - Van Tol Site	NUMBER OF COMPLETIONS	1	CONTRACTOR	Spectrum Exploration, Inc.
FEATURE	Single Completion Monitoring Well	TOTAL DEPTH	110 ft	TYPE OF HOLE	Direct Rotary	DRILL FOREMAN	Dan Lynch
LOCATION	Glenn County, County Rd 27 and County Rd M	DATE STARTED	3/25/02	TYPE OF RIG	Gardner-Denver	INSPECTED BY	Seth Lawrence
UTM COORDINATES	UTM 10 NAD83 571213, 4391198	DATE COMPLETED	3/27/02	COMMENTS	Test hole drilled to 150 ft.; well completed to 97 ft



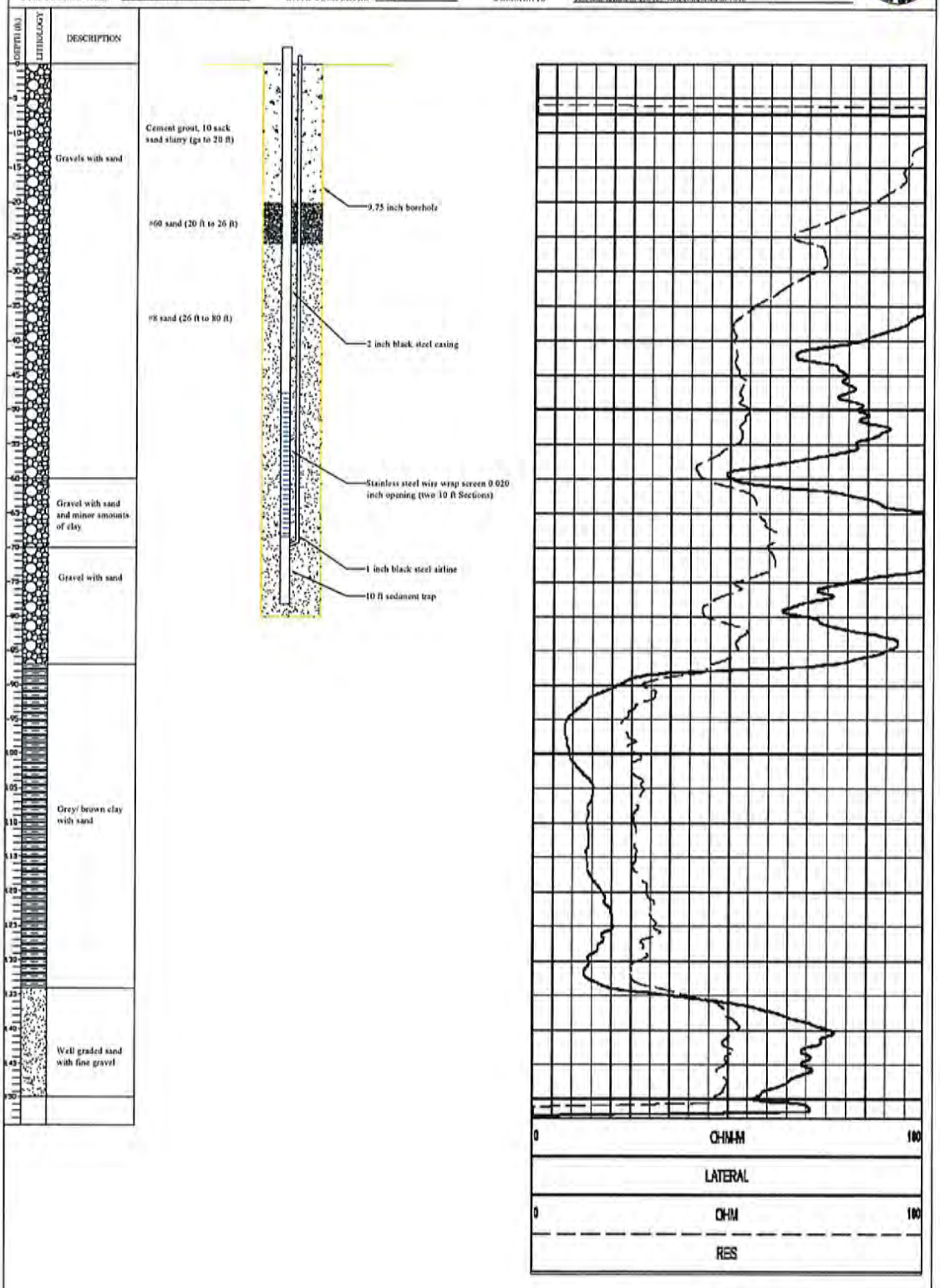
VT-02

STATE OF CALIFORNIA - RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

STATE WELL NUMBER: 21N03W23D004M

PROJECT	Stony Creek Recharge Pilot Project	HOLE NUMBER	Well B - Van Tol Site	NUMBER OF COMPLETIONS	1
FEATURE	Single Completion Monitoring Well	TOTAL DEPTH	80 ft	TYPE OF HOLE	Direct Rotary
LOCATION	Glenn County, County Rd 27 and County Rd M	DATE STARTED	3/21/02	TYPE OF RIG	Girdner-Denver
UTM COORDINATES	UTM 10 NAD 83 570672, 4391183	DATE COMPLETED	3/22/02	COMMENTS	Test hole drilled to 150 ft; well completed to 78 ft

CONTRACTOR: Spectrum Exploration Inc
DRILL FOREMAN: Dan Lynch
INSPECTED BY: Seth Lawrence



Stony Creek Pilot Recharge Monitoring Well Data (as of 5/15/02)										
Well	Screened Interval	Completed Well Depth	UTM Zone 10-NAD 83		Water Quality-Prelim Testing			Groundwater Level		
			Easting	Northing	pH	EC (microSiemens)	Temp. C	Ref. Pt. To Water Surface (ft.)	Ref. Pt. to Ground Surface (ft.)	Ground Surface to Water Surface (ft.)
Van Tol Well A-1 (deep)	362' to 372'	420'	570561	4391143	8.1	351	21.4	12.60	1.13	11.47
Van Tol Well A-2 (mid)	142' to 152'; 160' to 170'		570561	4391143	7.9	561	19.8	35.73	1.67	34.06
Van Tol Well A-3 (shallow)	42' to 72'		570561	4391143	8.1	587	18.7	38.63	2.17	36.46
Van Tol Well B (C')	48' to 68'	80'	570622	4391183	8.1	572	18.6	39.73	2.60	37.13
Van Tol Well C	55' to 75'	96'	571213	4391198	7.9	607	18.2	35.30	2.02	33.28
Van Tol Well D	46' to 66'	92'	570597	4391120	8	570	18.5	19.90	2.35	17.55
Fulton Reclamation MW-1	20' to 49'	49	570468	4391295	*	*	*	39.70	1.95	37.75
Fulton Reclamation MW-4	30' to 50'	50'	570215	4391198	*	*	*	41.23	1.88	39.35
Fulton Reclamation MW-6	none; open casing	58'	570069	4391185	*	*	*	39.93	1.56	38.37
Jasper Well A-1 (deep)	442' to 452'	490'	575379	4394921	7.9	337	21	32.20	1.50	30.70
Jasper Well A-2 (mid)	122' to 132'		575379	4394921	7.7	512	19.9	23.73	1.98	21.75
Jasper Well A-3 (shallow)	44' to 55'		575379	4394921	7.7	571	20.2	21.13	2.40	18.73
Jasper Well B	36' to 56'		575381	4394861	7.7	531	20.1	22.23	1.92	20.31
Jasper Well C (A')	30' to 35'		575378	4394918	7.7	443	19.8	19.38	2.20	17.18
Olivarez Well A-1 (deep)	390' to 400'	430'	567946	4397861	8	338	20.8	74.33	1.27	73.06
Olivarez Well A-2 (mid)	270' to 290'		567946	4397861	7.9	447	20.6	64.83	1.75	63.08
Olivarez Well A-3 (shallow)	30' to 50'		567946	4397861	7.9	416	N/A	20.57	2.30	18.27
Olivarez Well B	32' to 52'	75'	567946	4397818	7.8	451	20.1	21.03	2.30	18.73
Olivarez Ag Well	102'-104'; 128'-134'; 142-145'	200'	567838	4397766	N/A	N/A	N/A	33.70	1.30	32.40

*Data is to be faxed by Fulton Reclamation

WRIME Water Resources & Information Management Engineering, Inc.
tel. 916.564.2236 1451 River Park Drive Suite 142, Sacramento, CA, 95815
fax 916.564.1639 http://www.wrime.com • info@wrime.com

TECHNICAL MEMORANDUM

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Stony Creek Fan Conjunctive Water Management Program

SCFIGSM Hydrogeology and Model Stratigraphy

To:	Eric Hong, DWR	**CC:**	Sue King Rick Massa Van Tenney Toccoy Dudley Derrick Louie Ron Milligan Roger Putty Grant Davids
From:	Saquib Najmus Mike Cornelius	**Date:**	January 20, 2003
Subject:	**Stony Creek Fan Integrated Groundwater and Surface Water Model (SCFIGSM) Hydrogeology and Model Stratigraphy**		
Project Reference:	Contract No.: 4600000734 Task Order: WRIME-Glenn-0901-001		

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SECTION 1 INTRODUCTION

PURPOSE

The purpose of this memorandum is to document the methodology used to develop the stratigraphy data for the Stony Creek Fan Integrated Groundwater and Surface Water Model (SCFIGSM). The SCFIGSM will be used in the Stony Creek Fan Conjunctive Water Management Program (Program) to evaluate the impacts of water management scenarios on groundwater aquifer underlying the Stony Creek Fan.

The SCFIGSM is being developed in coordination with the California Department of Water Resources (DWR) and the three Project Sponsors – the Orland Artois Water District (OAWD), the Orland Unit Water User Association (OUWUA) and Glenn Colusa Irrigation District (GCID).

DWR Northern District has recently mapped the hydrogeology of the northern Sacramento Valley in great detail; this effort has resulted in the redefinition of the hydrogeologic setting of Sacramento Valley north of the Sutter Buttes. Until recently, it was believed that the northern Sacramento Valley alluvial aquifer system consisted primarily of a thick layer of interbedded sands and clays. The recent aquifer mapping by the DWR Northern District provides more detailed information about the different aquifer layers that are present in the northern Sacramento Valley. The SCFIGSM model incorporated the recent information about the northern Sacramento Valley aquifer.

The primary goals of this Technical Memorandum are to:

- Identify and summarize the available sources of geologic and hydrogeologic data in the SCFIGSM area.
- Establish the hydrogeologic setting and describe how it is used to develop the conceptual model stratigraphy.
- Discuss the SCFIGSM finite element grid.
- Document the development of the SCFIGSM stratigraphy data.

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STUDY AREA

Stony Creek Fan Conjunctive Water Management Program Study Area

The Stony Creek Fan, as shown in Figure 1.1, is a highly permeable geologic formation that extends southeast from the Black Butte Reservoir in the Glenn County. The study area for this project includes the Stony Creek Fan and the areas surrounding the Fan that may be included in the SCFIGSM (including the Counties of Tehama, Glenn, and Colusa).

The general study area, shown in Figure 1.1, extends about 30 miles from west to east and about 70 miles from north to south. The study area includes three reservoirs (the East Park Reservoir, the Stony Gorge Reservoir, and the Black Butte Lake), three major streams (the Thomes Creek, the Stony Creek, and the Sacramento River), five major water distribution canals (the Tehama-Colusa Canal, the Glenn-Colusa Canal, the Colusa Basin Drain, the Orland North Canal, and the Orland South Canal), and several small creeks.

The SCFIGSM model area (model area) is smaller than the general study area because it follows the hydrogeologic boundaries and features of the underlying groundwater aquifer. The model area is bounded on the north by Thomes Creek and on the south by Highway 20. The model area extends east from the geologic contact with the Coast Ranges Foothills to the Sacramento River.

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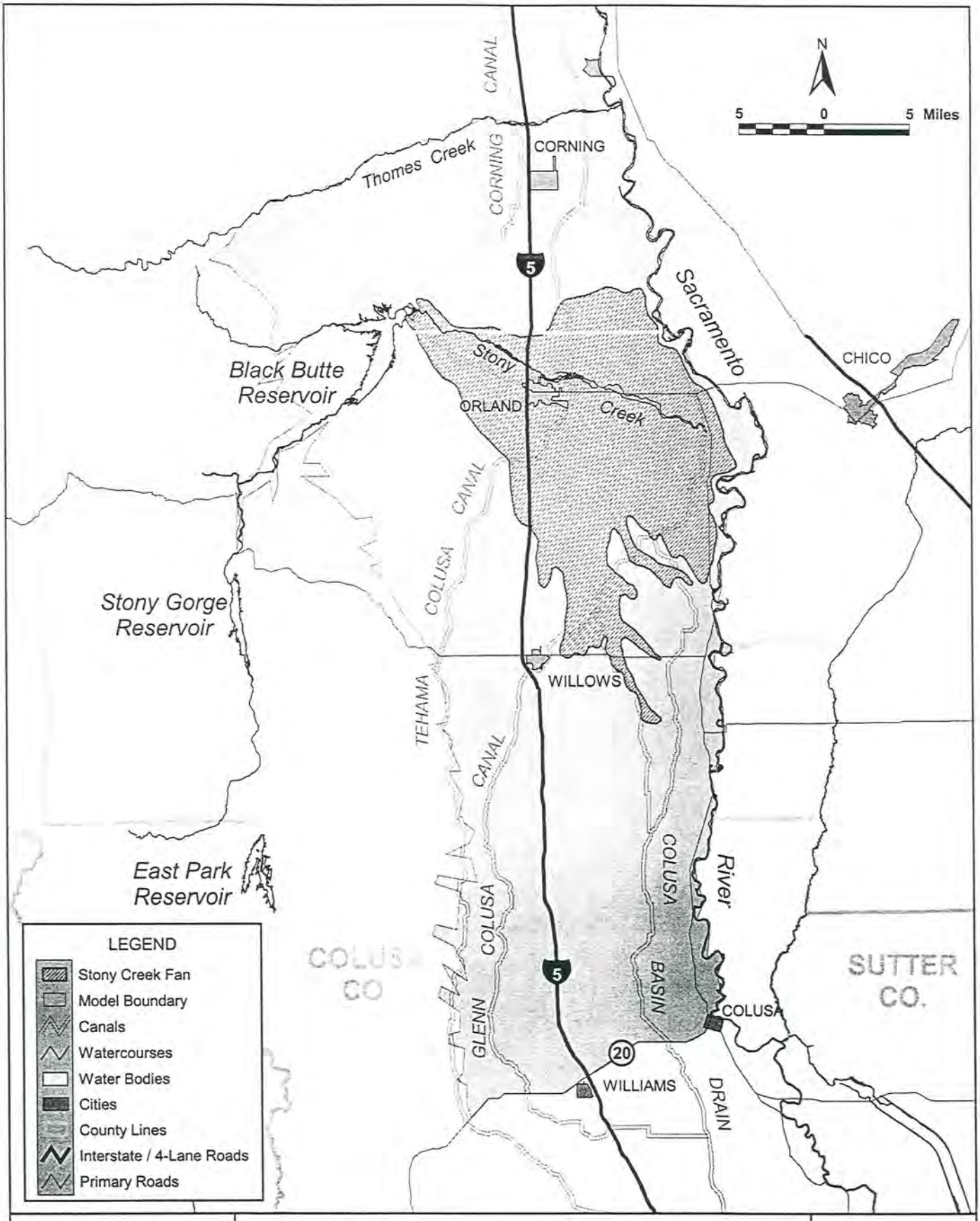
TECHNICAL MEMORANDUM OUTLINE

The SCFIGSM Hydrogeology and Model Stratigraphy Technical Memorandum is organized into the following sections:

- **Section 1: Introduction** identifies the purpose and outline of this technical memorandum.
- **Section 2: Collection and Review of Available Data** lists the available geologic and hydrogeologic data used in this analysis.
- **Section 3: Geologic and Hydrogeologic Setting of Model Area** summarizes the available data.
- **Section 4: Conceptual Model Stratigraphy for SCFIGSM** presents the conceptual model stratigraphy for the SCFIGSM.
- **Section 5: SCFIGSM Model Grid** describes the development of the SCFIGSM grid.



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STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM

Model Study Area

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FIGURE 1.1

- **Section 6: SCFIGSM Stratigraphy Data** describes the methodology used to develop the SCFIGSM stratigraphy data.
- **Section 7: Summary** presents the summary of this analysis.

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SECTION 2 COLLECTION AND REVIEW OF AVAILABLE DATA

This section describes the available geologic and hydrogeologic data that were collected and reviewed during the development of the stratigraphy data for the SCFIGSM.

The available data and information for the Program was summarized in two previous project reports:

- Integrated Groundwater and Surface Water Model (IGSM) Data Collection and Assessment Report for the Stony Creek Fan Conjunctive Water Management Program, (WRIME, Inc., August 2002), and
- Existing Data Report, Technical Memorandum 1, Stony Creek Fan Conjunctive Water Management Program (MWH/Davids Engineering, December 2002).

Other sources of information utilized to develop the SCFIGSM stratigraphy data are described below.

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PUBLISHED STUDIES AND REPORTS

The geology and hydrogeology of the Sacramento Valley has been investigated since the 1920s. The following list of reports provided regional information on the geology, hydrogeology, aquifer characteristics, and storage capacity of the aquifer system in the study area.

- Evaluation of Groundwater Resources; Sacramento Valley, Bulletin 118-6, DWR, 1978.
- Groundwater Levels in the Sacramento Valley Groundwater Basin, DWR, 1997.
- Geologic Features and Groundwater Storage Capacity of the Sacramento Valley, California, U.S. Geological Survey Paper 1497, 1961.
- Water Quality and Supply on Cortina Rancheria, Colusa County, California, USGS Water Resources Investigation 89-4004, 1989.
- Glenn-Colusa Irrigation District; Reconnaissance Evaluation of Groundwater Resources, CH2M HILL, 1978.
- Geochemistry of Groundwater in the Sacramento Valley California, Laurence C. Hull, USGS Professional Paper 1401-B, 1984.
- Base and Thickness of Post-Eocene Continental Deposits in the Sacramento Valley, California, R.W. Page in cooperation with DWR, USGS Water Resources Investigation 45-73, 1974.

- Progress Report of Groundwater Development Studies, North Sacramento Valley, DWR, 1976

RECENT/UNPUBLISHED STUDIES AND REPORTS

Some of the most recent work completed by DWR is not published yet. Two of these efforts are:

- Sacramento River Basin–Wide Water Management Plan Groundwater Hydrology Technical Memorandum, DWR Northern District, Bulletin 118-7 (Draft, unpublished, January 2000).
- California's Groundwater, Bulletin 118, Update 2002.

Sacramento River Basin–Wide Water Management Plan Groundwater Hydrology Technical Memorandum, DWR Northern District, Bulletin 118-7

The Sacramento River Basin–Wide Water Management Plan presents the results of a groundwater resource assessment for selected areas within the Sacramento Valley and Redding groundwater basins. This report emphasized areas associated with the Sacramento River Settlement Contractors, who are participating in Reclamation's development of a Basin-Wide Water Management Plan (BWMP).

As part of this project, the DWR Northern District is currently in the process of completing comprehensive geologic mapping of the Stony Creek Fan. Several geologic cross sections were developed based on analysis and interpretation of recent and E-logs, and oil and gas logs. These geologic cross-sections are not yet published but were provided as preliminary data to the project study team solely for the purpose of use in the model development.

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California's Groundwater, Bulletin 118, Update 2002

Bulletin 118–Update 2002 identifies and describes the two groundwater basins, Corning and Colusa, in the study area. Bulletin 118 briefly describes the hydrogeologic conditions of the underlying aquifers, which were taken into consideration during the development of the conceptual model hydrogeology for the SCFIGSM. This information is currently available at the Bulletin 118 website, listed below:

(http://www.waterplan.water.ca.gov/groundwater/updatemain.htm).

OTHER DATA SOURCES

Well log and construction data, and water level data are both available from DWR. This information was used to supplement the available geologic and hydrogeologic data used in developing the stratigraphic data for the SCFIGSM. Each of these data sources is briefly described below.

Well Log and Construction Data

Monitoring and production well logs for the Counties of Glenn, Tehama, and Colusa are available as hardcopy data at the DWR Northern District office in Red Bluff. About 400–500 driller's logs available at the Northern District office were reviewed and screened for geographic coverage and level of detail reported in the well log. About 154 driller's logs distributed throughout the proposed model area were selected for use in the model data development. These well log data were analyzed, interpreted, and used to supplement the existing geologic cross-section data to develop the model stratigraphy.

Historic Groundwater Levels

Historic groundwater level data for 191 wells (18N–22N) in the Glenn County, 40 wells (15N–18N) in the Colusa County, and 203 wells (23N–25N) in the Tehama County were downloaded from DWR Web site (http://www.wdl.ca.gov). A preliminary assessment of the groundwater level data shows that there are adequate data for developing the initial condition of the SCFIGSM as well as for model calibration.

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SECTION 3 GEOLOGIC AND HYDROGEOLOGIC SETTING OF MODEL AREA

The geologic and hydrogeologic setting for the model area is presented in this section to document the available information and provide the background information needed to develop the conceptual model stratigraphy (presented in Section 4), model grid (presented in Section 5), and the SCFIGSM stratigraphy data (presented in Section 6).

This section focuses on the geologic and hydrogeologic conditions of the model area; it includes discussion of the following:

- Geologic History
- Geomorphic Features
- Geologic Setting
- Hydrogeologic Setting

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GEOLOGIC HISTORY

This section presents the geologic history of the model area as it relates to the deposition of marine deposits and continental deposits. In general, the older marine deposits contain saline water and underlie the younger continental deposits which contain fresh water. The freshwater bearing continental deposits are the geologic units of interest in the Stony Creek Conjunctive Water Management Program. The geologic units and a brief description of their characteristics are presented on Table 3-1.

During the Cretaceous Period to early Miocene Epoch, the present Sacramento Valley trough was inundated by an inland sea, which deposited thousands of feet of marine sediments upon the pre-Cretaceous granitic basement rocks. After withdrawal of the marine waters occurred in the Miocene Epoch, there was a period of erosion during which time there was deposition of continental deposits.

Table 3.1
Stony Creek Fan IGSM
Geologic Units in Study Area

System and Series		Geologic Unit	Lithologic Character	Maximum Thickness[1] (ft)	Water-bearing Character
QUATERNARY	Holocene	Alluvium Qa	Unconsolidated unweathered gravel, sand, silt, and clay[1].	80	Deposits are moderately to highly permeable with high permeability gravelly zones yielding large quantities to shallow wells[2]. Although deposits along Stony, Chico, and Thomes Creeks are important recharge areas[2], extensive water bearing capacity is restricted by thickness and areal extent[1].
		Basin Deposits Qb	Unconsolidated[5] fine-grained silts and clays, locally interbedded with stream and channel deposits along the Sacramento River[1].	150	Deposits are typically saturated nearly to the ground surface[2]. The low to moderate permeability results in yields of small quantity and poor groundwater quality to domestic wells[1,2].
	Pleistocene	Modesto Formation Qm	Poorly sorted[5] unconsolidated weathered and unweathered gravel, sand, silt, and clay[3].	200	Moderately to highly permeable[1].
		Riverbank Deposits Qr	Poorly sorted[5] unconsolidated to semi-consolidated[3] pebble and small cobble gravels interlensed with reddish clay, sand, and silt[1].	200	Water-bearing capability is limited by thickness. These poorly to highly permeable deposits supply moderate groundwater amounts to domestic and shallow irrigation wells. Deeper irrigation wells may be supplied if the wells contain multiple perforation zones[1].
TERTIARY AND QUATERNARY	Pliocene and Pleistocene	Tehama Formation Tte	Fluviatile moderately consolidated pale green, gray, and tan sandstone and siltstone enclosing lenses of sand and gravel; silt and gravel; and cemented conglomerate derived from the Coast Ranges[1,3].	2,000	Local high permeability zones within this characteristically low to moderate permeability unit, widespread distribution, and deep thickness cause this formation to be the principle water bearing unit in the area. Deep well yields are typically moderate, but are highly variable[2].
TERTIARY	Pliocene	Tuscan Formation Tt	This series of volcanic flows, consolidated tuff breccia, tuffaceous sandstone, and volcanic ash derived from the Cascade Range interfingers with the Tehama Formation as it westerly grades into volcanic sands, gravels, and clays[1,2]. The formation is divided by layers of thin tuff or ash units into four lithologically similar units A-D[1].	1,500	Within this formation, moderately to highly permeable volcanic sediments are hyraulically confined by layers of tuff breccias and clays[2]. Units A and B are the primary water-bearing zones and are composed of volcanic conglomerate, sandstone, and siltstone layers interbedded with lahars. Stragraphically higher, the massive lahar deposits of unit C confine groundwater in the permeable beds of units A and B[1].
		Nomlaki Tuff Member	Tuff breccias and white tuffs of dacitic composition. This member of the Tehama and Tuscan Formations serves as an important stratagraphical marker bed in northern Sacramento Valley[5].	60[5]	Poorly permeable.
	Miocene	Neroly Formation Tn	Marine to non-marine tuffaceous andesitic sandstone interbedded with tuffaceous shales and tuff layers. Contains local conglomerate lenses[3].	500	This formation of variable permeability contains interstitial fresh water under confined conditions[4], however, deposits of the Neroly Formation are typically located below the base of fresh water.
		Lovejoy Basalt Tl	Black, dense, hard microcystalline basalt[3].	65	Largely non-water bearing.
	Miocene and Oligocene	Upper Princeton Valley Fill Tupg	Non-marine sandstone containing mudstone, conglomerate, and sandstone conglomerate interbeds[3].	1,400	Largely non-water bearing or contains saline water.
	Eocene	Lower Princeton Submarine Valley Fill Tlpg	Marine conglomerate and sandstone interbedded with silty shale[3].	2,400	Largely non-water bearing or contains saline water.
CRETACEOUS		Great Valley Sequence JKgvs	Marine siltstone, shale, sandstone, and conglomerate[3].	15,000	Largely non-water bearing or contains saline water[2].
PRE-CRETACEOUS		Basement Complex pTb	Metamorphic and igneous rocks.	n/a	May contain groundwater, mainly saline, in fractures and joints.

Notes:

[1] Department of Water Resources web page (www.wq.water.ca.gov).
[2] Department of Water Resources, Bulletin 118-6, 1978.
[3] Department of Water Resources, Bulletin 118-7 (Draft, not published).
[4] Department of Water Resources, Sacramento River Basin-Wide Water Management Plan-Draft, 2000.
[5] Department of Water Resources, Groundwater Levels in the Sacramento Valley Groundwater Basin, Glenn County, 1997.

In the Pliocene Epoch, the northern Coast Range uplift was initiated which is associated with this mountain-building episode, the Sacramento Valley began to assume its current form. Coast Range uplift and related erosion of the uplifted block resulted in deposition of the Tehama Formation onto the heavily eroded, subsiding Sacramento Valley floor. In late Pliocene time, volcanic activity on the southern Cascade Range caused the widespread deposition of the Nomlaki tuff across the northern Sacramento Valley. This extensive ash layer is found near basal deposits of the Tehama and Tuscan Formations. Continuous volcanism in the southern Cascade Range produced consecutive mudflows of basaltic and andesitic composition. These igneous deposits were reworked coincident with volcanic activity resulting in the Tuscan Formation on the east side of the Sacramento Valley.

During the Pliocene Epoch, deposition of the Tehama and Tuscan Formations occurred simultaneously. These thick, widespread deposits overwhelmed the previous topography, creating a relatively flat plain that was repeatedly dissected by meandering and braided streams.

Fluviatile sedimentation of the Tehama Formation was continuous on the west side of the Sacramento Valley throughout the Pliocene and possibly into the Pleistocene. During the middle part of the Pleistocene, mountain-building activity brought the Coast Ranges to their current structure and shape. The Tehama Formation deposits, along with older deposits, were involved in this folding and faulting event, and formed low hills and dissected uplands. Intense erosion concurrent and following this orogenic activity reworked the Tehama Formation and redeposited the sediments near the center of the Valley. Much of these sediments were carried away by the Sacramento River.

Quaternary sedimentation is represented in the deposition of broad alluvial fans and flood plains. In the vicinity of the Stony Creek Fan, the newly eroded surface of the Tehama Formation was covered with poorly sorted gravel deposits of the Pleistocene Modesto and Riverbank Formations. Gravels of these terrace deposits were partially supplied by glaciers in the Coast Ranges and Klamath Mountains and partially by continued erosion of the Coast

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Ranges. The northwest Sacramento Valley cycle of valley deposition resulting from continuous erosion in the Coast Ranges and low foothills continues to present day.

GEOMORPHIC FEATURES

Geomorphic features of the study area include the Coast Ranges, low hills and dissected uplands, alluvial fans, and flood plains (Figure 3.1). The Sacramento River and Stony Creek have significant hydrological influence on the study area.

The Coast Ranges represent the western border of the study area and extend south from the Klamath Mountains to the Cuyama River near San Luis Obispo. These north-south trending mountain ranges are predominantly composed of sedimentary deposits with minor volcanic intrusions. The sedimentary fault blocks within the ranges are complexly folded. In general, the Coast Ranges reach no higher than 6,560 feet above mean sea level.

The low hills and dissected uplands are located between the Coast Ranges and the alluvial fans of the valley. An abrupt increase in slope marks the transition between the alluvial fans and the uplands. These hills are topographic expressions of subsurface folding and faulting of the Tehama Formation and older underlying sediments.

As streams draining the Coast Ranges leave the low hills and dissected uplands, they flow out into the relatively flat valley floor. This change in slope causes them to deposit their bedload, forming broad alluvial fans. Alluvial fan deposits are an intricate system of buried channels formed by a dynamic fluviatile depositional environment. An example of an alluvial fan is the Stony Creek Fan (Figure 1.1), the focus of the current hydrogeologic investigation. This fan is the largest and most complex alluvial fan in the northwest portion of the Sacramento Valley and was deposited by Stony Creek. The apex of the Stony Creek Fan is approximately five miles northwest of the town of Orland, where Stony Creek flows out of the low hills. The Stony Creek Fan extends east to the Sacramento River flood plain, and south to the Colusa basin deposits near the town of Willows. The surface of the fan is not smooth, but rather cut by many abandoned channels. Smaller and less impressive fans

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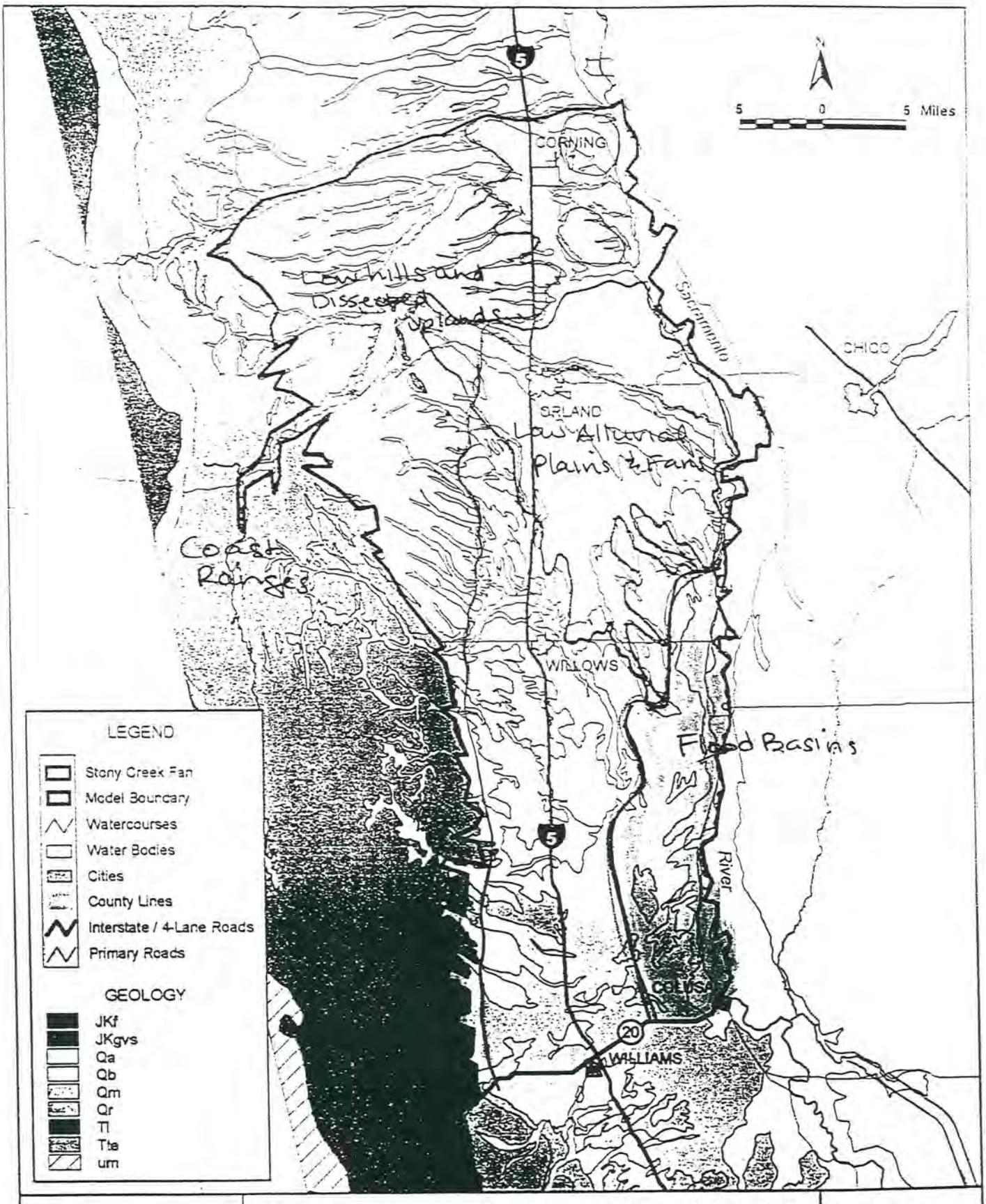

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STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM

~~Geologic Map~~

GEOMORPHIC FEATURES MAP

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FIGURE ~~X~~ 3.1

have been deposited by intermittent streams south of the Stony Creek Fan. In general, these deposits are much finer grained than the deposits of the Stony Creek Fan.

In flat, low-lying basins between the alluvial fans and the Sacramento River, distal alluvial fan sediments merge with the fine-grained flood plain and basin deposits. During flooding events along the Sacramento River, water spills over the natural river levee and accumulates in these basins. The trapped water creates temporary lakes, and the quiescent environment allows for deposition of fine-grained suspended material. The Colusa Basin is an example of this phenomenon, and extends 60 miles south of the Stony Creek Fan.

The Sacramento River and Stony Creek are responsible for depositing a large quantity of coarse material in the northwest Sacramento Valley over thousands of years. These deposits constitute the alluvial aquifer in the study area. The Sacramento River and Stony Creek are important sources of surface water to the study area.

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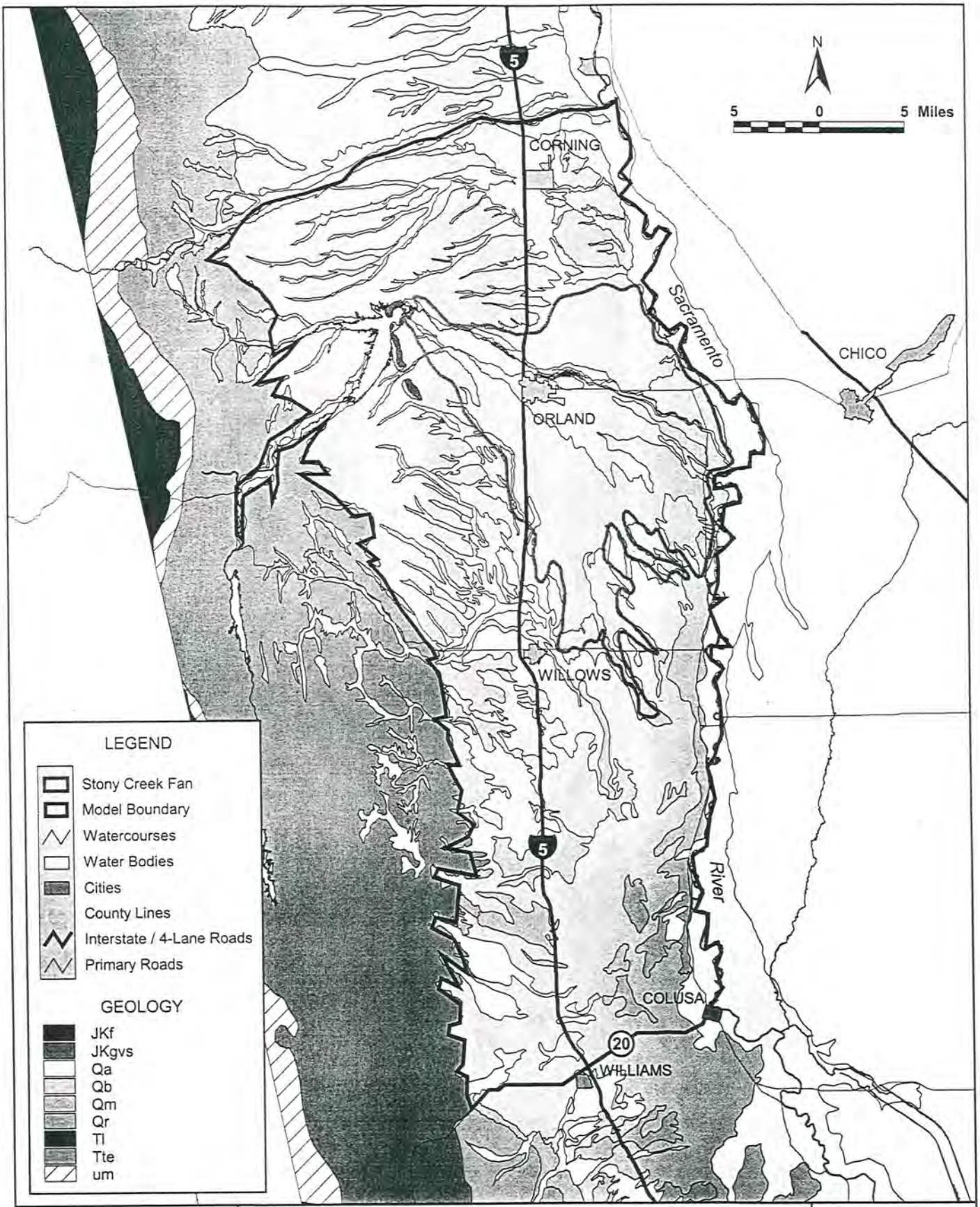
GEOLOGIC SETTING

Structure

The Sacramento Valley is an asymmetrical northward-trending syncline partially filled with sedimentary deposits. Several faulting, folding, and uplift events tilted the Sierra Nevada block relative to the Coast Ranges forming this structural basin. Latter orogenic events are expressed in folding and faulting of Pre-Middle Pleistocene basal deposits. Faults related to this activity include the Paskenta, Willows, Corning, and Black Butte Faults.

Geologic Units

This summary of the geologic units in the study area focuses on the Pliocene and younger sediments of the alluvial groundwater aquifer. These sediments include the Pliocene Tuscan Formation; Pliocene and Pleistocene Tehama Formation; Pleistocene Modesto and Riverbank Formations; and the Holocene alluvial, basin, and flood plain deposits (Figure 3.2 and Table 3.1). Little detail is given to the underlying older marine sediments.



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Geologic Map

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FIGURE 3.2

Pre-Pliocene Marine Deposits

Marine sediments in the study area include the Miocene Neroly Formation, the Miocene and Oligocene Upper Princeton Gorge Formation, the Eocene Lower Princeton Gorge Formation, and the Cretaceous Great Valley Sequence. These deposits define the subsurface freshwater aquifer boundary. In general, these largely non–water bearing deposits occur below the base of fresh water; thus they may contain small amounts of saline water. The Neroly Formation is composed of marine to nonmarine tuffaceous andesitic sandstone interbedded with tuffaceous shales and tuff layers with local conglomerate lenses. This formation generally contains saline water; however, it may contain small amounts of freshwater. The nonmarine deposits of the Upper Princeton Gorge Formation consist predominantly of sandstone containing mudstone, conglomerate, and conglomerate sandstone interbeds. Although these are continental deposits, they occur below the base of freshwater and contain saline groundwater; thus, the Upper Princeton Gorge sediments are grouped with the marine deposits. The Lower Princeton Gorge Formation is characterized by marine sandstone and conglomerate with silty shale interbeds. Sedimentary marine clastic rocks constituting the Great Valley Sequence include siltstone, shale, sandstone, and conglomerate.

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Pliocene Tuscan Formation

Tuscan deposits are characterized by their Cascade Range origin and volcanic signature. This extensive series of basaltic and andesitic volcanic flows, consolidated tuff breccia, tuffaceous sandstone, and volcanic ash is primarily located on the northeastern portion of the Sacramento Valley. The Tuscan Formation underlies much of the Valley floor and extends from the Cascades to the west side of the Valley where it grades into volcanic sands, gravels, clays, and interfingers with the Tehama Formation. Thin tuff or ash units separate the Tuscan Formation into four distinct, yet lithologically similar Units A, B, C, and D (D being the youngest). Of these units, only A, B, and C are found in the study area. Unit C is composed of massive lahar (mudflow) deposits with volcanic sandstone and conglomerate interbeds. Tuscan Formation Unit C is referred to as the Upper Tuscan Formation. Both Units A and B are largely composed of layered, interbedded lahars, siltstone, and volcanic sandstone and conglomerate. Tuscan Formation Units A and B are referred to as the Lower

Tuscan Formation. Unit A is distinguished from Unit B by the presence of metamorphic rock fragments in siltstone layers.

Pliocene-to-Pleistocene Tehama Formation

Deposits of the Tehama Formation are characterized by their fluviatile nature and origin from the Klamath Mountains and Coast Ranges. This assemblage of moderately compacted sandstone and siltstone with local coarse lenses is located in the northwest portion of the Sacramento Valley. These yellowish to greenish grey deposits are separated from the underlying Eocene Epoch and Cretaceous Period marine sediments by an unconformity. The Tehama Formation was deposited under floodplain conditions by rivers and streams flowing from nearby mountains in a subsiding, low relief valley. Several properties of the Tehama Formation indicate a western and northwestern origin. Mineral composition and rock type of Tehama deposits are identical to those in the Coast Ranges and Klamath Mountains. Additionally, the grain size of Tehama Formation sediments decreases to the south and east, suggesting a western and northwestern origin.

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Pliocene Nomlaki Member

This deposit is recognized as a member of both the Tehama and Tuscan Formations indicating simultaneous deposition. The Nomlaki Member is composed of coarse tuff breccias and white tuffs of dacitic composition and has an eastern source. This widespread deposit serves as an important stratigraphical marker in the northern part of Sacramento Valley.

Pleistocene Deposits

Terrace deposits of the Pleistocene Modesto and Riverbank Formations are composed of poorly sorted clay, silt, sand, and gravel, and form a thin veneer at the ground surface. The Riverbank Formation is distinguished from the Modesto deposits by interbedded clay layers. In the Stony Creek Fan area, these terraces are well-defined, but they are absent or poorly defined along other minor streams in the study area.

Holocene Deposits

Quaternary alluvium, the most recent deposit, is found along major rivers and is composed of unconsolidated unweathered clay, silt, sand, and gravel. Fine-grained flood plain deposits include silt with minor amounts of sand. The basin deposits are composed of fine-grained sediments and are found in flood basins and near streams. The coarse-grained sediments of the alluvial fan include sand and gravel.

Geologic Relationships

This section identifies the relationship between the geologic units in the model area. There are two specific areas of interest because of their potential affect on the groundwater in the aquifer system.

- Alluvial sediments of the Stony Creek Fan and the underlying Tehama Formation
- Tehama Formation and the Tuscan Formation

Each of these is described below.

Stony Creek Fan Area

The Stony Creek Fan deposits include Pleistocene and Holocene upper, unconfined aquifer deposits. As Stony Creek meandered across the fan, channels were created, abandoned, then buried, creating a complex system of coarse- and fine-grained sediments. The variable nature of this fluviatile, depositional environment causes difficulty in defining groundwater aquifers within the fan.

The Stony Creek alluvial fan sediments form a thin veneer over the Tehama Formation. During the Pleistocene, the surface of the Tehama Formation was intensely eroded, then backfilled with both coarse- and fine-grained deposits of the Stony Creek Fan. The resulting uneven contact between the geologic units makes it difficult to determine the contact between the Stony Creek Fan deposits and the underlying Tehama Formation. In addition, the similar lithology, variable grain size, and the channelized nature of both deposits result in questionable boundary lines.

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Tuscan and Tehama Formations Relationship

Typical Tuscan deposits are coarser than those of the Tehama Formation. Simultaneous deposition of these extensive formations onto a broad valley surface resulted in the interfingering of Tuscan and Tehama sediments near the center of the valley. In general, the grain size of the Tehama Formation becomes finer to the east, and the Tuscan Formation grades into volcanic gravels, sands, and clays where the deposits overlap. The nature of groundwater interaction where these formations merge is uncertain.

HYDROGEOLOGIC SETTING

The aquifer system of the Stony Creek Fan Area includes a freshwater aquifer overlying a saline aquifer. The freshwater alluvial aquifer system in the study area is composed of late Tertiary to Quaternary continental deposits. The aquifer system includes an upper unconfined alluvial aquifer consisting of Quaternary deposits overlying a confined aquifer system composed of Quaternary and Tertiary continental deposits of fluvial and volcanic origin. The saline aquifer system composed primarily of Tertiary and older marine deposits.

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Freshwater Aquifer System

The freshwater aquifer system is composed of an unconfined aquifer overlying a confined aquifer as described below.

Unconfined Aquifer

The upper unconfined aquifer consists of Quaternary deposits, including Holocene alluvium, flood plain, alluvial fan, and basin deposits, and the Pleistocene Riverbank and Modesto Formations. The unconfined aquifer system is important to local groundwater users, but the potential for significant groundwater storage is limited due to insufficient thickness.

Holocene Deposits

The unconsolidated, highly permeable Quaternary alluvium deposits are important recharge areas. These deposits are generally located along major rivers and facilitate groundwater recharge from rivers. Highly permeable alluvial fan deposits, specifically of the Stony Creek

Fan, are also important recharge areas. The moderately permeable basin deposits and floodplain deposits are less important recharge areas.

Pleistocene Deposits

In addition to the Holocene deposits, the highly permeable terrace deposits of the Pleistocene Modesto and Riverbank Formations are significant recharge areas. However, low permeability clay beds of the Riverbank Formation limit the water-bearing capabilities of this deposit.

Confined Aquifer

The confined aquifer is composed of Tertiary Deposits, including the Pliocene and Pleistocene Tehama Formation and the Pliocene Tuscan Formation. These widespread and thick formations are important in aquifer storage and well water supply.

Tehama Formation

The Tehama Formation is the primary water source of the study area. Groundwater in this formation occurs under semi-confined and confined conditions. The widespread distribution and high thickness allow this formation to supply water to most of the wells in the study area. Moderately compacted, thickly bedded sandstone and siltstone layers derived from the Coast Ranges result in characteristically low to moderate permeability. However, thinner lenses of sand and gravel result in local, high permeability zones.

Potential for groundwater recharge and storage is limited by the geographic irregularity of these permeable lenses. Well yields are typically moderate for deeper wells. However, well yields vary from high to low due to variable permeability zones. Generally, wells located near the Stony Creek Fan have higher yields than those located to the south. The Tehama Formation has a higher concentration of more permeable coarse material in the vicinity of the alluvial fan deposits. Variations in well yields indicate the north to south decrease in grain size.

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Tuscan Formation

The Tuscan Formation serves as the primary source of groundwater on the east side of the Sacramento River. In the study area, these deposits occur at depths inaccessible to most domestic and irrigation wells. Of the four Tuscan Units, only A, B, and C are found in the study area.

Within this formation, moderately to highly permeable volcanic sediments are hydraulically confined by layers of tuff breccias and clays. The low permeability lahar deposits of Unit C serve as confining beds for the underlying older Tuscan Units A and B. Although Unit C contains permeable volcanic sandstone and conglomerate interbeds, this unit is characterized by an overall low yield of water to wells. Units A and B are much more coarse-grained than the overlying Unit C, causing them to be the primary water-bearing zones of eastern Sacramento Valley.

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Saline Aquifer System

The saline aquifer system lies beneath the fresh water aquifer. The base of the fresh water aquifer is defined by the contact between continental deposits and pre-Pliocene marine deposits. The marine deposits present in the study area subsurface include the Miocene Neroly Formation, the Miocene and Oligocene Upper Princeton Gorge Formation, the Eocene Lower Princeton Gorge Formation, and the Cretaceous Great Valley Sequence.

SECTION 4 CONCEPTUAL MODEL STRATIGRAPHY FOR SCFIGSM

This section presents the conceptual model stratigraphy for the SCFIGSM. The conceptual model stratigraphy was presented to the Stony Creek Fan Technical Team at the August 8, 2002, Technical Team Meeting. The conceptual model stratigraphy was developed based on the hydrogeologic properties of the geologic units described in Section 3. A schematic of the four-layer conceptual SCFIGSM stratigraphy is presented in Figure 4.1, and summarized on Table 4.1.

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SCFIGSM LAYER 1

The conceptual model for SCFIGSM Layer 1 includes Pleistocene and Holocene deposits consisting of Holocene alluvium, alluvial fan, flood plain, and basin deposits, and the Pleistocene Modesto and Riverbank Formations. The highly permeable sands and gravels of Pleistocene Modesto and Riverbank Formations are only present on the Stony Creek Fan. Where Layer 1 is present throughout the model area it is exposed at the ground surface, and represents the unconfined groundwater system. Wells perforated in this layer are likely used for domestic and some agricultural water supplies.

The highly permeable sands and gravels are 50 to 80 feet thick within the Stony Creek Fan. They are not present outside the Stony Creek Fan. On the Fan, some of the highly permeable deposits are underlain by up to 50 feet of finer-grained alluvial or basin deposits. Outside the Fan, alluvial and basin deposits can reach a total thickness of 200 feet. The conceptual model stratigraphy was developed to reflect the significant difference in the characteristics of the Fan material and the other alluvial deposits present within the model area.

Inside the Fan Area

Inside the Stony Creek Fan Area, SCFIGSM Layer 1 represents the 50 to 80 foot thick highly permeable sand and gravel deposits. Any alluvial or basin deposits that may be present beneath the sands and gravels are included in Layer 2.

Figure 4.1
Stony Creek Fan IGSM
Conceptual Model Stratigraphy

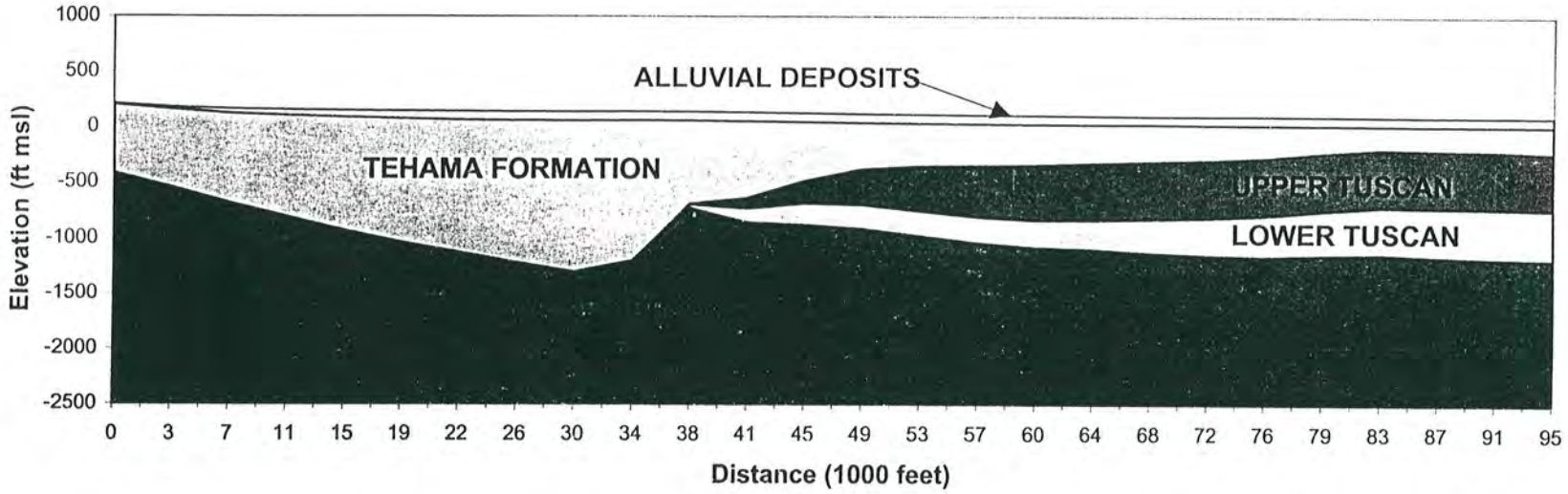

Table 4.1
SCFIGSM Stratigraphy
Definition of Layers

Location within Model	Fan Material	Alluviam, Basin and Flood Plain Deposits	Tehama Formation	Upper Tuscan Formation	Lower Tuscan Formation
	Predominantly gravel and sand with minor amounts of silt and clay.	Characterized by fine-grained silts and clays.	Moderately compacted sandstone and siltstone enclosing lenses of sand and gravel; silt and gravel; and cemented conglomerate.	Characterized by massive lahar deposits.	Composed of volcanic conglomerate, sandstone, and siltstone layers interbedded with lahars.
Inside Fan Area					
Layer 1	1 ●	1			
Layer 2		2	2 ●		
Layer 3				3 ●	
Layer 4					4 ●
Outside Fan Area					
Layer 1	Not Present	up to 80 feet 1 ●			
Layer 2		greater than 80 feet 2	2 ●		
Layer 3				3 ●	
Layer 4					4 ●

■ Designates the composition of each layer in the current model using Layer 1 = 50-80 feet thick where Layer 1 is defined by the hydrogeologic properties of the material.

● Designates the composition of each layer in the alternate model which would follow the geologic cross sections exactly and classifly Layer 1 as all Quaternary alluvial deposits.

Outside the Fan Area

Outside the Stony Creek Fan Area, SCFIGSM Layer 1 represents the upper 80-foot thickness of the basin and alluvial deposits. Any remaining basin or alluvial deposits are considered part of SCFIGSM Layer 2.

SCFIGSM LAYER 2

The conceptual model for SCFIGSM Layer 2 consists primarily of the Tehama Formation (described in Section 3). The widespread distribution and thickness allow this formation to supply water to many of the agricultural wells in the study area. The Tehama Formation is present throughout the model area ranging in thickness from about 200 feet to over 2,000 feet. Model Layer 2 thickens from west to east about halfway across the model area. Model Layer 2 thins rapidly where Model Layer 3 is present (Table 4.1). As mentioned above, for modeling purposes, Layer 2 does include some basin and alluvial deposits.

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Model Layer 2 generally represents groundwater systems ranging from semi-confined to confined conditions. Confinement generally increases with depth, but the actual level of confinement may vary locally due to other conditions, such as continuously perforated wells connecting different aquifer layers. Model Layer 2 is exposed at the ground surface in the northwestern portion of the model area.

SCFIGSM LAYER 3

The conceptual model for SCFIGSM Layer 3 consists of the Upper Tuscan Formation (described in Section 3). Model Layer 3 is present throughout the eastern portion of the model area (Figure 4.1). It consists of fine-grained lahar deposits, so groundwater within Layer 3 represents confined aquifer conditions. Because of its low permeability, few wells in the model area rely on Layer 3 for groundwater supply.

SCFIGSM LAYER 4

The conceptual model for SCGIGSM Layer 4 consists of the Lower Tuscan (described in Section 3). Model Layer 4 is present throughout the eastern portion of the model area (Figure 4.1). In contrast to Layer 3, it is composed of more permeable volcanic

conglomerate, sandstone, and siltstone layers interbedded with lahars. It is overlain by the Upper Tuscan Formation (Layer 3), which acts as a confining layer; as a result, groundwater within Layer 4 represents confined aquifer conditions. At this time, few production wells in the model area reach Layer 4, so it currently has little groundwater production and water level data.

BASE OF THE AQUIFER SYSTEM

The base of the aquifer system is considered to be the base of the freshwater-bearing deposits (Figure 4.1). The base of the aquifer system is represented by the base of Model Layer 2 (base of the Tehama Formation) in the western half of the model area,. The base of the aquifer system is represented by the base of Model Layer 4 (base of the Lower Tuscan Formation) in the eastern half of the model area,.

The base of freshwater is mapped in the model area on the basis of available electronic log data. In some locations the base of freshwater is identified to exist within the lower portions of the Tehama Formation or Tuscan Formation (Figure 4.1). The base of freshwater is not considered as a boundary between model layers because it is not a fixed location (such as the base of a formation). Also, it is unlikely to significantly interact with the water supply projects because it is located at the bottom of the aquifer system.

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SECTION 5 SCFIGSM GRID

The purpose of this section is to document the methodology used to develop the SCFIGSM grid. A two-dimensional finite element grid network was developed to model the groundwater flow in the Stony Creek Fan Area. The entire model area consists of about 1,060 square miles. The SCFIGSM model grid (shown in Figure 5.1) was divided into 2,148 elements and 1,853 model nodes. The average size of single element is about one-half square mile (316 acres). Notable features of the model grid are:

- Model boundary matches the hydrologic and hydrogeologic boundaries of the Stony Creek Fan Area;
- Grid orientation follows the regional groundwater streamlines;
- Elements are smaller in the vicinity of steep groundwater gradients; and
- Thin strips of elements are used to incorporate the discontinuities in the groundwater levels across major geologic faults and barriers.

The model grid is defined by Universal Transverse Mercator (UTM) coordinates at each model node and be the list of connecting nodes for each model element. The x-y coordinates for each model node were obtained from Geographic Information System (GIS) coverage of the model area in UTM Zone 10.5. The list of connecting nodes for each element was developed after numbering the model nodes and model elements. Two independent sets of sequential numbers were used for nodes and elements. These node and element numbers are used in specifying model input data.

The SCFIGSM grid was develop to reflect local conditions including:

- Geologic and Hydrogeologic Considerations,
- Hydrologic Considerations, and
- Potential Water Management Project Areas.

Each of these considerations is described below.

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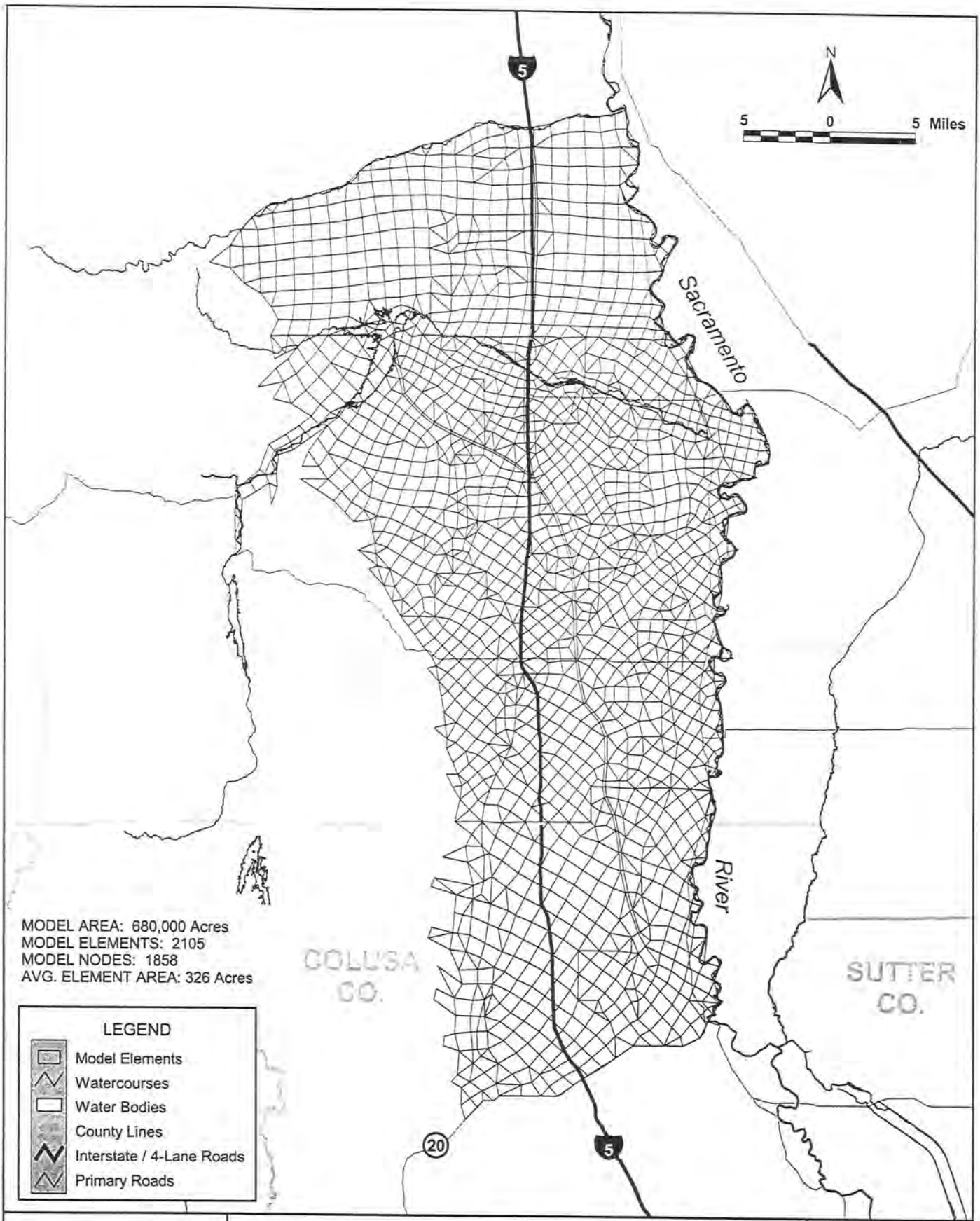

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Model Grid

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FIGURE 5.1

GEOLOGIC AND HYDROGEOLOGIC CONSIDERATIONS

The geologic and hydrogeologic information presented in Section 3 was considered during the SCFIGSM model grid development. These include:

- Geologic Contacts,
- Faults, and
- Groundwater Flow Direction.

Geologic Contacts

The western boundary of the SCFIGSM grid was defined as the contact between the marine basement rocks of the Coast Range and the continental and alluvial deposits of the Central Valley. The geologic contact between the marine deposits and the continental alluvial deposits is shown in Figure 5.2.

Faults

The SCFIGSM model grid was developed to reflect those faults that either may affect the flow of groundwater, or result in an abrupt change in the aquifer thickness. The SCFIGSM model grid reflects existence of faults by a narrow band of elements along the trace of the fault. After several discussions with DWR, the two faults incorporated into the model grid include the Black Butte Fault and the Willows-Corning Fault. The locations of these faults are shown in Figure 5.2.

Groundwater Flow Direction

The long-term regional groundwater flow directions were considered in the SCFIGSM grid development. Near the Stony Creek Fan, the regional groundwater flow direction is from the fan's apex to the distal portions of the fan generally in the northwest to southeast direction. North and South of the Stony Creek Fan groundwater generally flows from the upland areas in the west towards the Sacramento River near the center of the Valley.

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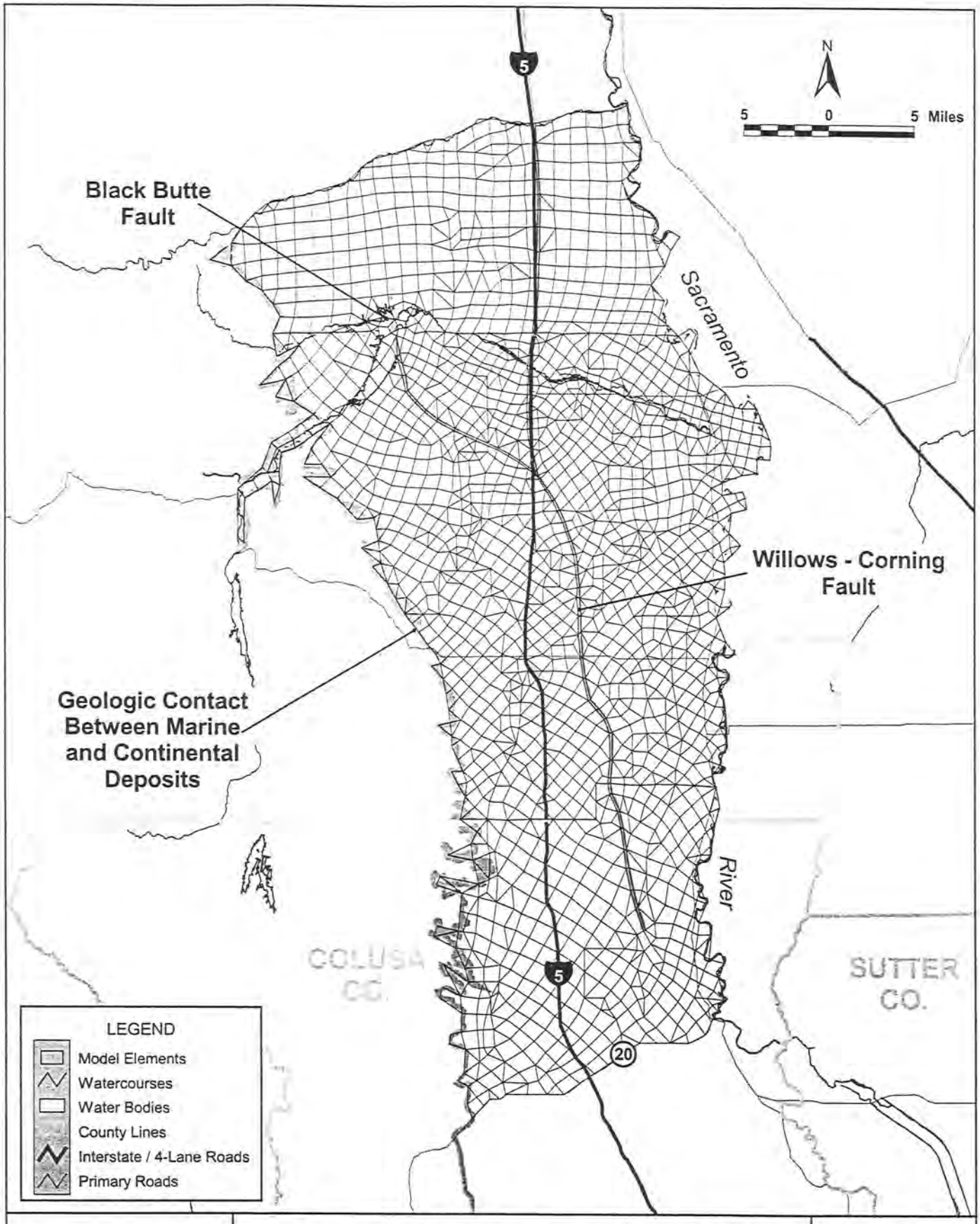

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Geologic and Hydrogeologic Considerations

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FIGURE 5.2

HYDROLOGIC CONSIDERATIONS

The surface water flow system is modeled by using 1-dimensional line elements along the stream courses. These line elements are defined by stream nodes that are coincident with the aquifer nodes. An independent numbering system is used to number the stream nodes. There are 266 stream nodes representing the surface water flow system in the SCFIGSM. This includes rivers, creeks, and lakes as well as major unlined water delivery canals and drains. Figure 5.3 shows the locations of the hydrologic features simulated in the SCFIGSM model area, such as:

- Rivers and Creeks,
- Lakes, and
- Canals and Drains.

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Rivers and Creeks

There are three rivers and creeks simulated in the SCFIGSM: Thomes Creek, Sacramento River, and Stony Creek.

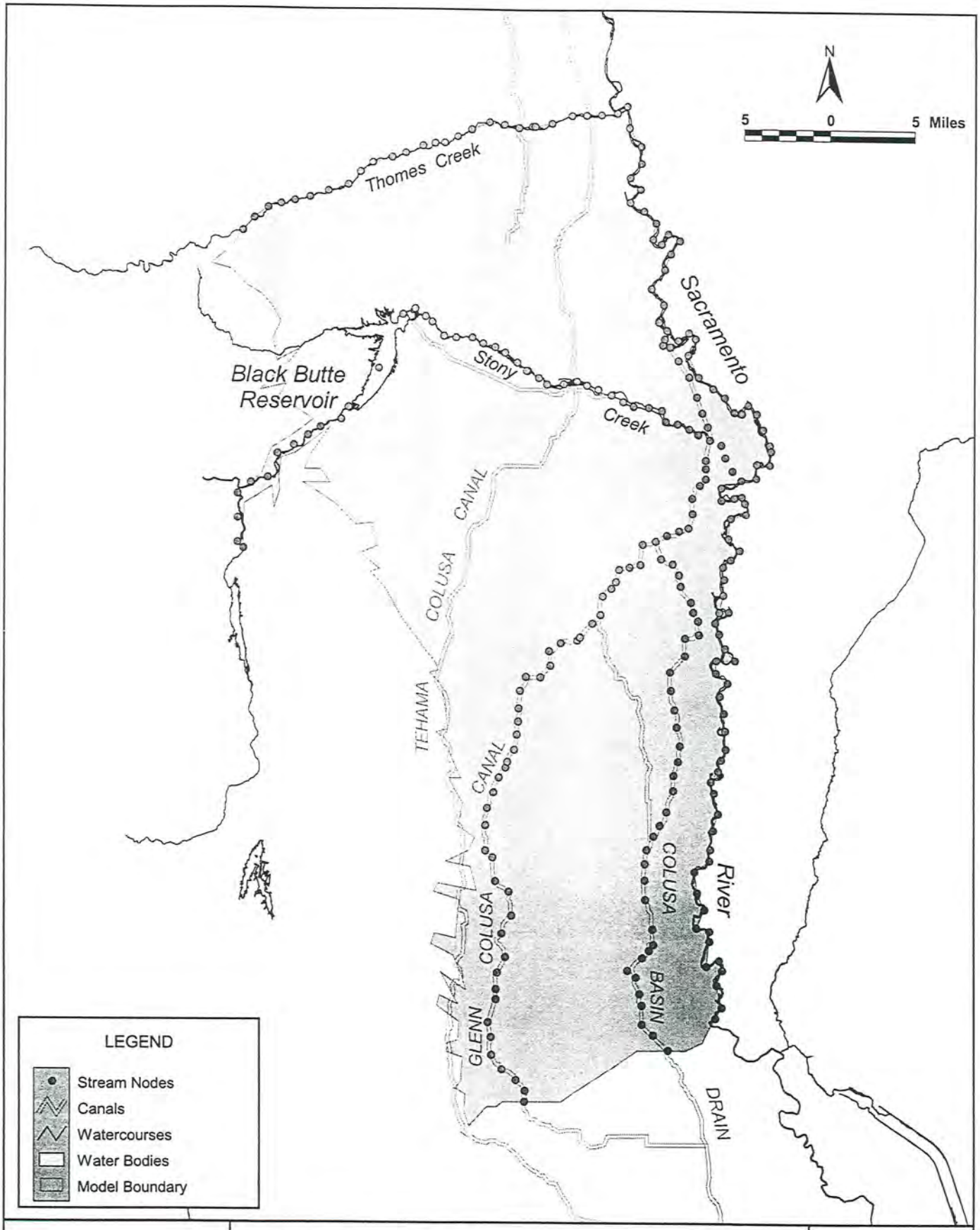
- **Thomes Creek** coincides with the northern boundary of the SCFIGSM, and is simulated along the stream nodes shown in Figure 5.3.
- **The Sacramento River** coincides with the eastern boundary of the SCFIGSM, and is simulated along the stream nodes shown in Figure 5.3.
- **Stony Creek** is located within the SCFIGSM model area. It is simulated both above and below Black Butte Reservoir along the stream nodes shown in Figure 5.3.

Lakes

Black Butte Lake is located entirely within the SCFIGSM model area. The model grid was developed to represent the maximum inundation area of Black Butte Lake. The extent of the Black Butte Lake is shown in Figure 5.3.

Canals and Drains

There are six major canals and drains within the SCFIGSM area. Each of these canals and drains was considered individually to determine if it should be simulated in the model. They are listed below:



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Location of Hydrologic Features

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FIGURE 5.3

- The southern extent of the **Corning Canal** extends approximately 5 miles south of Thomes Creek into the model area. At this time the Corning Canal is not simulated in the SCFIGSM.
- The **Orland North and South Canals** are piped, so there is limited interaction with the groundwater basin. They are not simulated in the SCFIGSM.
- The **Tehama Colusa Canal** is lined through the model area, so it is not simulated in the SCFIGSM.
- The **Glenn-Colusa Irrigation District Main Canal** is unlined. It is simulated in the SCFIGSM along the stream nodes shown on Figure 5.3.
- The **Colusa Basin Drain** is unlined. It is simulated in the SCFIGSM along the stream nodes shown on Figure 5.3.

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POTENTIAL WATER MANAGEMENT PROJECT AREAS

Water and land use management in the model area is represented in the SCFIGSM by subdividing the model area into 17 management areas called subregions. The criteria for the subregion delineation is described below and presented in Table 5.1. The location of the SCFIGSM model subregions is shown on Figure 5.4.

Stony Creek Feasibility Study Subunits

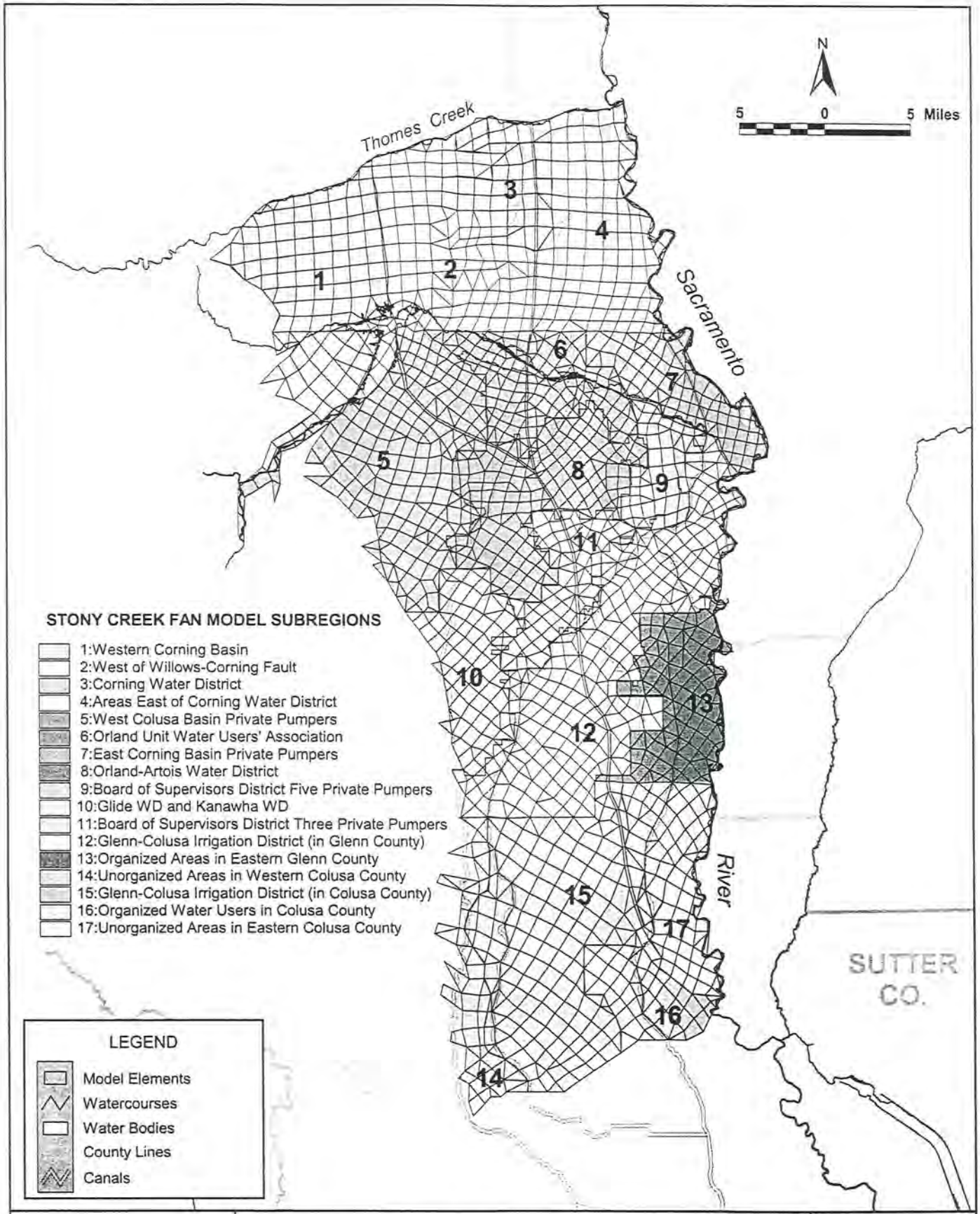
Model subregions were developed to provide geographic coverage similar to the water balance subunits used in the Stony Creek Fan Feasibility Study. This criterion was utilized to define six subregions on or adjacent to the Stony Creek Fan as presented in Table 5.1 and shown in Figure 5.4. SCFIGSM Subregions 6, 7, 8, 9, 11, and 12 were defined based on this criterion.

Glenn County Basin Management Objectives Basin Management Sub-Areas

Additional model subregions were developed to provide geographic coverage similar to the basin management subareas used in the Glenn County Basin Management Objectives. This criterion was utilized to define four subregions within the model area in Glenn County as presented in Table 5.1 and shown in Figure 5.4. SCFIGSM Subregions 1 (portion in Glenn County), 5, 10, and 13 were defined based on this criterion.

Table 5.1
Stony Creek Fan Conjunctive Use Project
SCF IGSM Model Subregions

Stony Creek Fan Conjunctive Use Project		*Primary Criteria*	*Optional Criteria*	
Subregion Number	**Model Subregion Name**	**Stony Creek Fan Feasibility Study Water Balance Subunits**	**Glenn County BMO Basin Management Sub-Area**	**Comments**
1	Western Corning Basin	NA	1 (West Corning Basin Private Pumpers)	Includes unorganized areas in western Tehama County.
2	West of Willows Corning Fault	NA	NA	Includes the area between the northern extension of the Black Butte Fault and the Willows-Corning Fault.
3	Corning Water District	NA	NA	
4	Areas east of Corning Water District	NA	NA	
5	West Colusa Basin Private Pumpers	NA	3 (West Colusa Basin Private Pumpers)	
6	Orland Unit Water Users' Association	1 (Orland Unit Water Users' Association)		
7	East Corning Basin Private Pumpers	5 (East Corning Basin Private Pumpers)		
8	Orland-Artois Water District	2 (Orland-Artois Water District) and 4(Unorganized Pumpers embedded in OAWD)		
9	Board of Supervisors District Five Private Pumpers	6 (Board of Supervisors District Five Private Pumpers)		
10	Glide WD and Kanawha WD	NA	6 (Glide WD) and 7 (Kanawha WD) (and small portion of Sub-Area 11 west of GCID)	
11	Board of Supervisors District Three Private Pumpers	7 (Board of Supervisors District Three Private Pumpers)		
12	Glenn-Colusa Irrigation District (in Glenn County)	3 (Glenn-Colusa Irrigation District)		
13	Organized Areas in Eastern Glenn County	NA	12 (Provident ID), 13 (Willow Creek MWC), 14 (Princeton-Codora- Glenn ID)	Includes portion of Willow Creek MWC in Glenn County.
14	Unorganized Areas in western Colusa County	NA	NA	
15	Glenn Colusa Irrigation District (in Colusa County)	NA	NA	Includes portion of GCID in Colusa County north of Highway 20.
16	Organized Water Users in Colusa County	NA	NA	Includes Maxwell ID, Colusa Drain Water Users' Association
17	Unorganized Areas in Eastern Colusa County	NA	NA	



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Model Subregions

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FIGURE 5.4

Tehama County

Four subregions were defined in Tehama County based on the hydrogeologic conditions and water supply source (access to surface water). Subregions 1 (portion in Tehama County), 2, 3, and 4 were defined based on this criterion.

Colusa County

Four subregions were defined in Colusa County, primarily based on the water supply source (access to surface water). Subregions 14, 15, 16, and 17 were defined based on this criterion.

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SECTION 6 SCFIGSM STRATIGRAPHY DATA

The purpose of this section is to document the data and methodology used to develop the stratigraphy data for the SCFIGSM. The stratigraphy data is assigned to each model node in the model area (total of 1853 model nodes) for each layer included in the model.

The methodology to develop the SCFIGSM stratigraphy data involved a three-step process described below:

- **Step 1. Develop Preliminary Stratigraphy Data:** The purpose of this step is to collect and analyze the available stratigraphy data for the model area and develop a preliminary set of stratigraphy data for the SCFIGSM.
- **Step 2. Refine Stratigraphy Data:** The purpose of this step is to refine the SCFIGSM stratigraphy data set developed in Step 1 to check for accuracy and reasonableness of the data.
- **Step 3. Quality Control of Stratigraphy Data:** The purpose of this step is to complete the quality control process of SCFIGSM stratigraphy data and develop the figures and tables necessary to allow efficient presentation and review of the stratigraphy data.

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STEP 1: PRELIMINARY STRATIGRAPHY BASED ON CROSS-SECTION DATA

The goal of Step 1 is to convert the available cross-section data (randomly spaced stratigraphy data) to each of the SCFIGSM model nodes. The six sub steps listed below were required to develop the preliminary SCFIGSM stratigraphy data file.

- **Step 1A. Collect Cross-Section Data Available From DWR**
- **Step 1B. Digitize Cross-Sections to Establish Control Points**
- **Step 1C. Aggregate Control Point Data to SCFIGSM Layers**
- **Step 1D. Distribute Stratigraphy Layer Data to SCFIGSM Area**
- **Step 1E. Distribute Stratigraphy Data to SCFIGSM Nodes**
- **Step 1F. Develop Model Layer Thickness by Model Nodes**

Each of these sub steps is described below.

STEP 1A. COLLECT CROSS-SECTION DATA AVAILABLE FROM DWR

Based upon the review of available geologic and hydrogeologic data described in Section 2 of this technical memorandum, it was determined that the best source of data available to develop the stratigraphy data for the SCFIGSM was the recent set of cross-sections developed by the DWR Northern District. The Northern District office completed two sets of cross-sections, one for the northern Sacramento Valley, and a second set for the Stony Creek Fan Area. Each of these sets of cross-sections is described below.

Sacramento Valley

The Northern District developed six cross-sections based on electric logs for the northern Sacramento Valley. The northern Sacramento Valley generally includes the portion of the Central Valley north of the Sutter Buttes and extending north to Redding. This includes portions of Colusa, Butte, Glenn, Tehama, and Shasta Counties.

Stony Creek Fan

More recently, the Northern District developed seven cross-sections based on electronic logs for the Stony Creek Fan Area. These were developed as part of the Department's ongoing investigation of the Stony Creek Fan Area. These sections were the primary source of stratigraphy data used to develop the model layering in the SCFIGSM.

The three cross-sections from the Sacramento Valley cross-sections were used to extend the Stony Creek Fan cross-section data to the entire SCFIGSM model area for those areas that extend beyond the Stony Creek Fan. The Northern District provided electronic files for each of the cross-sections included in their analysis. Figure 6.1 shows the sections used in this analysis.

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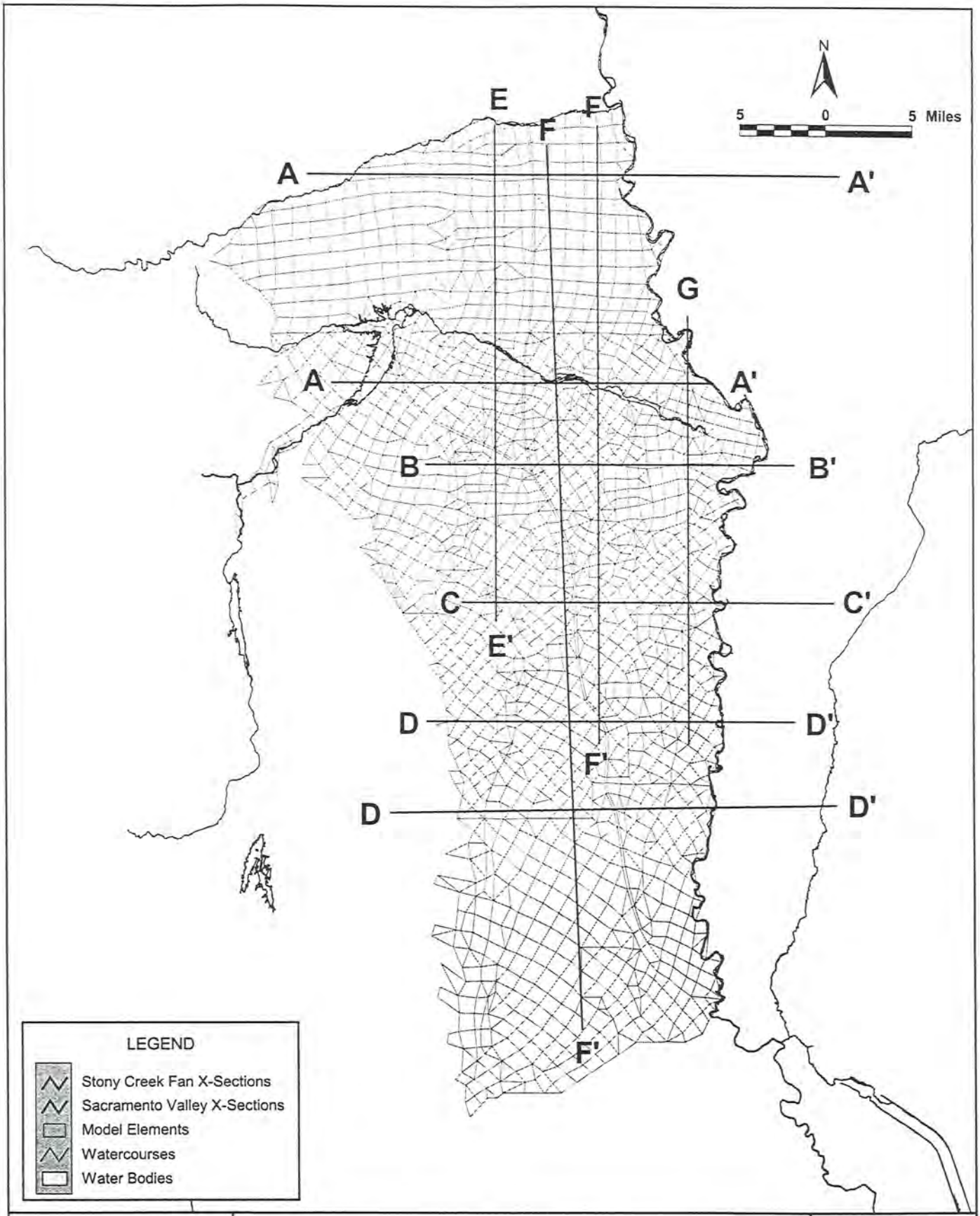
STEP 1B. DIGITIZE CROSS-SECTIONS TO ESTABLISH CONTROL POINTS

Once the selected DWR cross-sections within the SCFIGSM model area were identified, all geologic layers were digitized using Surfer 8.0 (Surfer). The digitization required carefully tracing each contact and fault as well as digitizing the minimum and maximum x and y



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DWR Geologic Cross Sections Used in Stratigraphic Analysis

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FIGURE 6.1

values from the axes of each cross section. This process established control points (points of known location and stratigraphic thickness), which would be used to develop the stratigraphic data.

STEP 1C. AGGREGATE CONTROL POINT DATA TO SCFIGSM LAYERS

This step converts the control points of the individual cross-sections developed in Step 1B to the model layers to be used in the SCFIGSM.

Approximately 500 control points were identified to represent the base for each model layer from the digitized cross-sections. This process was completed for the:

- Elevation of the Base of Model Layer 1,
- Elevation of the Base of Model Layer 2 (base aquifer system in the western portion of the SCFIGSM),
- Elevation of the Base of Model Layer 3, and
- Elevation of the Base of Model Layer 4 (base aquifer system in the eastern portion of the SCFIGSM).

The ground surface elevation was developed from digital elevation model (DEM) data developed by the USGS.

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STEP 1D. DISTRIBUTE STRATIGRAPHY LAYER DATA TO SCFIGSM AREA

The purpose of this step is to distribute the model layer elevation control point data developed in Step 1C to the SCFIGSM nodes. The irregularly spaced control points for each model layer were distributed to a finely spaced regular grid. This was completed with Surfer using a 250 by 250 mesh grid that covered the SCFIGSM area.

STEP 1E. DISTRIBUTE STRATIGRAPHY DATA TO SCFIGSM NODES

The purpose of this step is to assign the model layer elevation data from fine mesh grid (Step 1D) to SCFIGSM model nodes. This was completed using the bilinear interpolation provided in Surfer. Note the SCFIGSM grid is generally coarser than the fine mesh grid.

STEP 1F. DEVELOP MODEL LAYER THICKNESS BY MODEL NODES

The purpose of this step was to convert the model layer elevation data to model layer thickness (for input into the SCFIGSM stratigraphy data file). This was completed by determining the difference between model layers at each node. The thickness of Model Layer 1 was calculated as the difference between the ground surface and the elevation of the base of Layer 1.

The completion of Step 1 provided a preliminary stratigraphy data file for the SCFIGSM area. Any Further refinements to the stratigraphy data in Step 2 would be completed using the SCFIGSM stratigraphy model data.

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STEP 2. STRATIGRAPHY DATA REFINEMENT

The purpose of Step 2 is to review and refine the SCFIGSM stratigraphy data file to confirm there was no loss of stratigraphy data integrity due to the data processing completed in Step 1. The stratigraphy refinement was completed through the following steps:

- **Step 2A. Check Model Stratigraphy Data Accuracy**
- **Step 2B. Check Model Stratigraphy Data Reasonableness**
- **Step 2C. Check Level of Detail of Model Stratigraphy Data**
- **Step 2D. Refine Model Stratigraphy Data**

Each of these steps is described below.

Step 2a. Check Model Stratigraphy Data Accuracy

The purpose of this step is to check the accuracy of the model stratigraphy data by comparing it to known and widely accepted stratigraphy data, including knowledge of faults, formation transitions, and accepted ranges and thickness. One of the primary checks for model data accuracy was to compare the model stratigraphy data to the original DWR cross-sections. Figures 6.2a–g compare the cross-section data. This included:

Figure 6.2 a
Stony Creek Fan IGSM
Comparison of SCFIGSM Stratigraphy with DWR Cross Section Data
SCF Section A

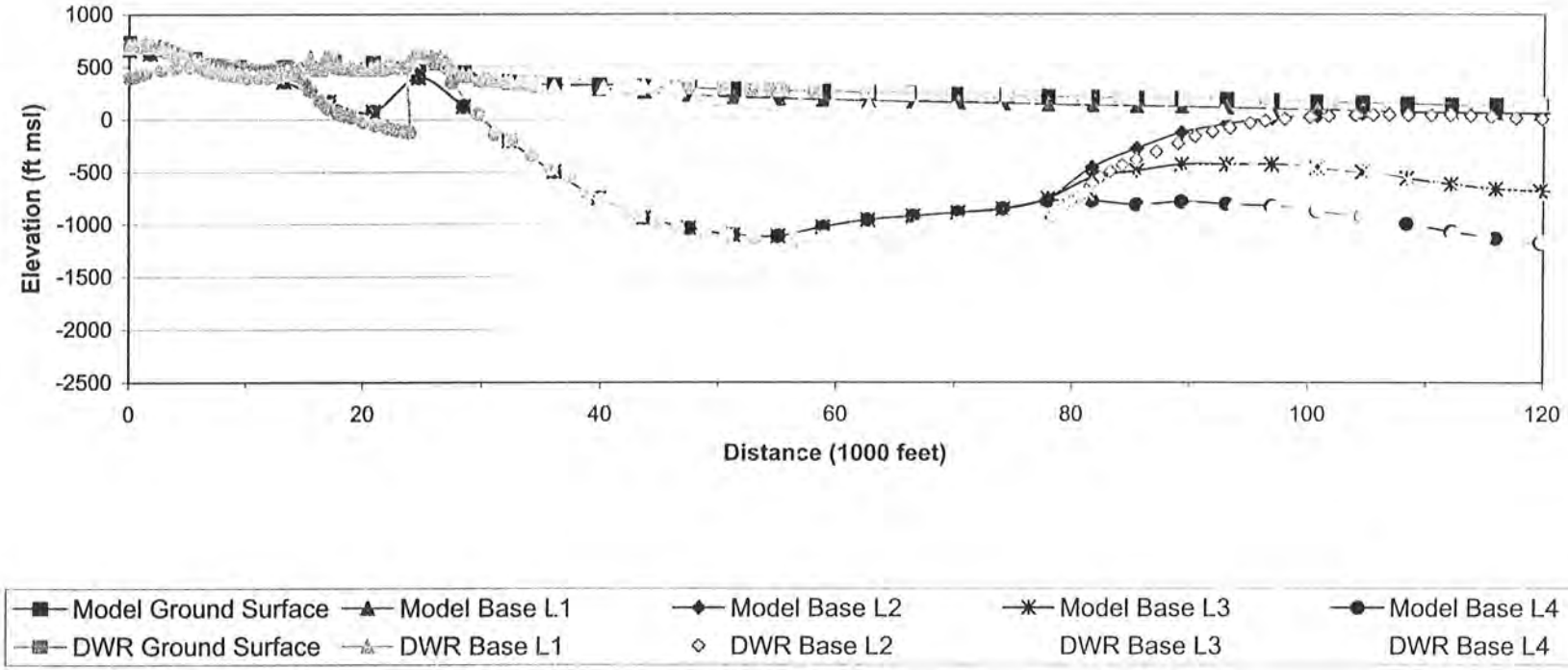


Figure 6.2 b
Stony Creek Fan IGSM
Comparison of SCFIGSM Stratigraphy with DWR Cross Section Data
SCF Section B

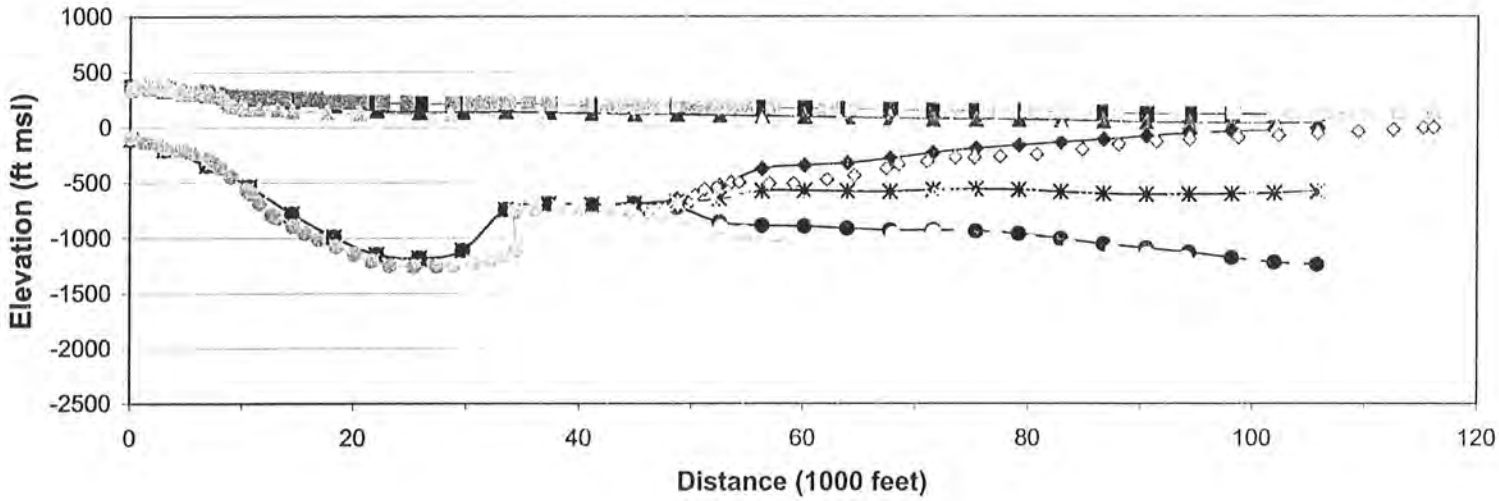


Figure 6.2 c
Stony Creek Fan IGSM
Comparison of SCFIGSM Stratigraphy with DWR Cross Section Data
SCF Section C

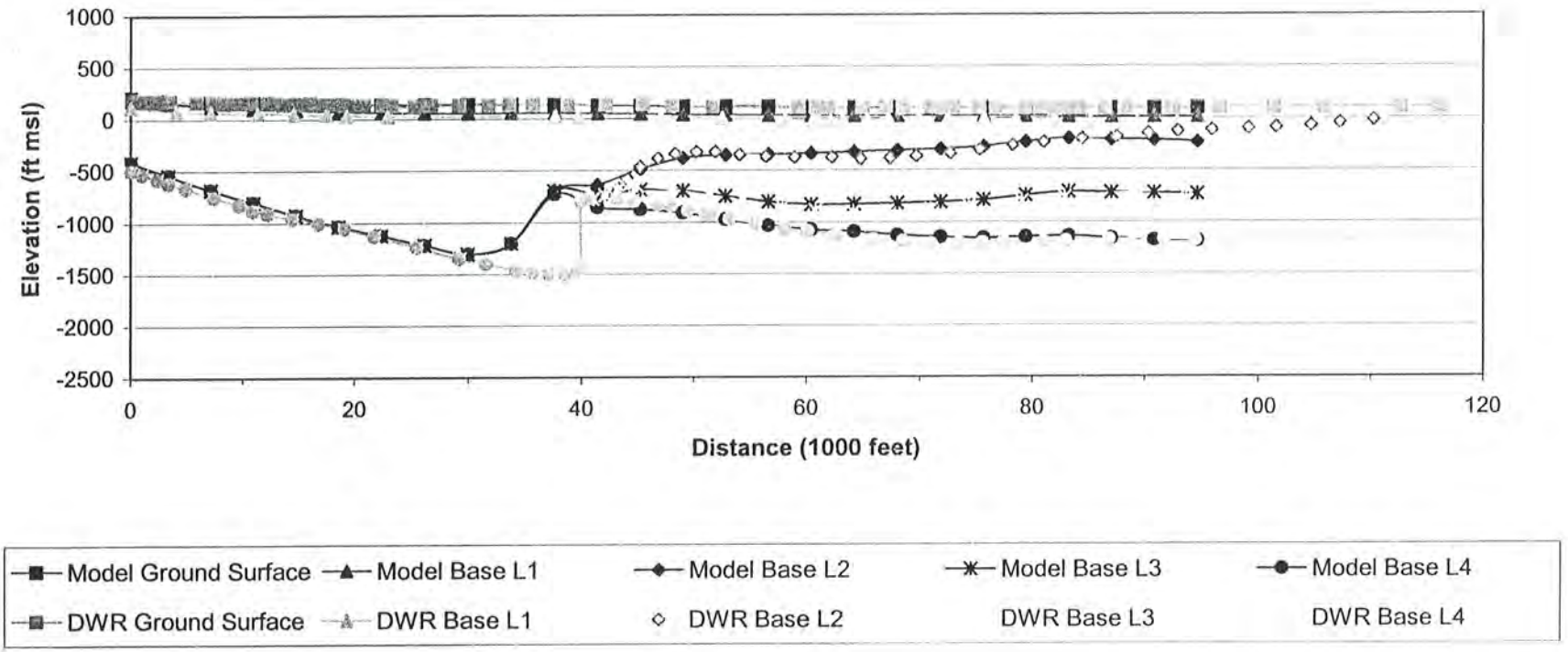


Figure 6.2 d
Stony Creek Fan IGSM
Comparison of SCFIGSM Stratigraphy with DWR Cross Section Data
SCF Section D

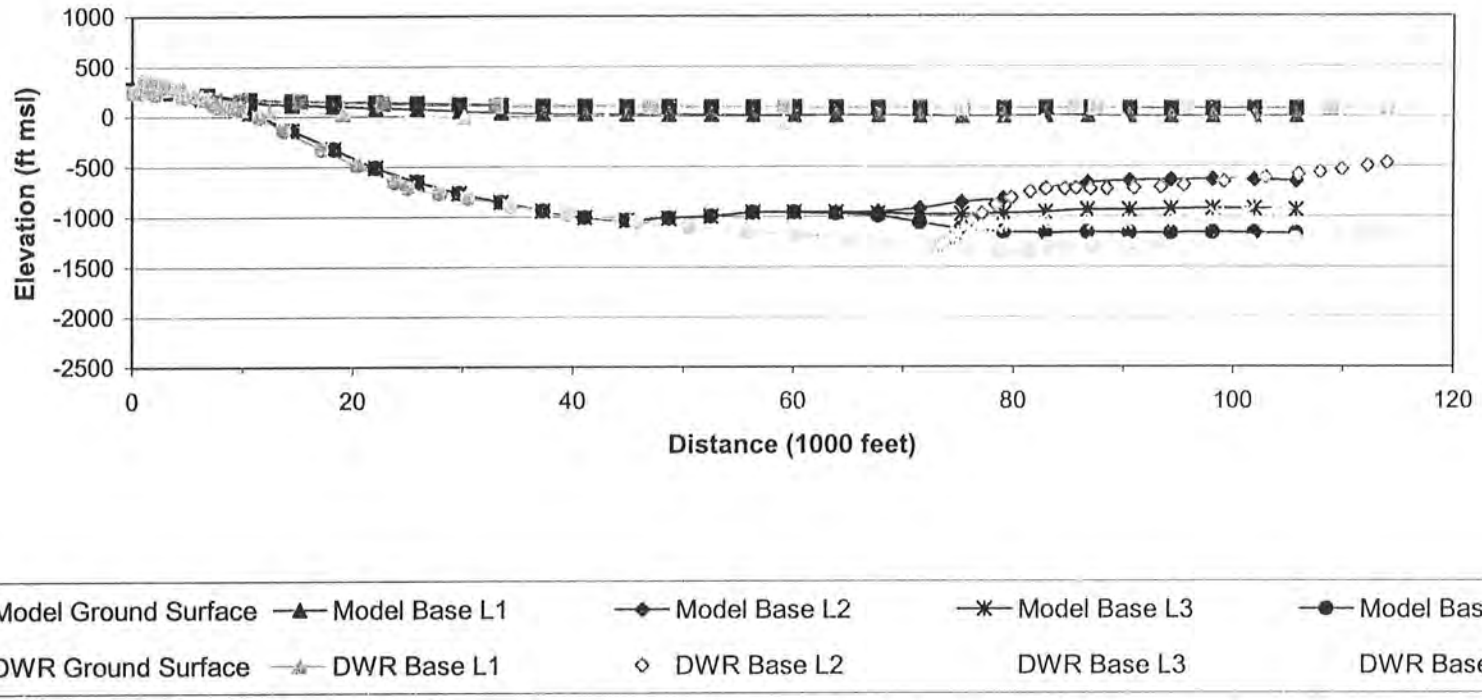


Figure 6.2 e
Stony Creek Fan IGSM
Comparison of SCFIGSM Stratigraphy with DWR Cross Section Data
SCF Section E

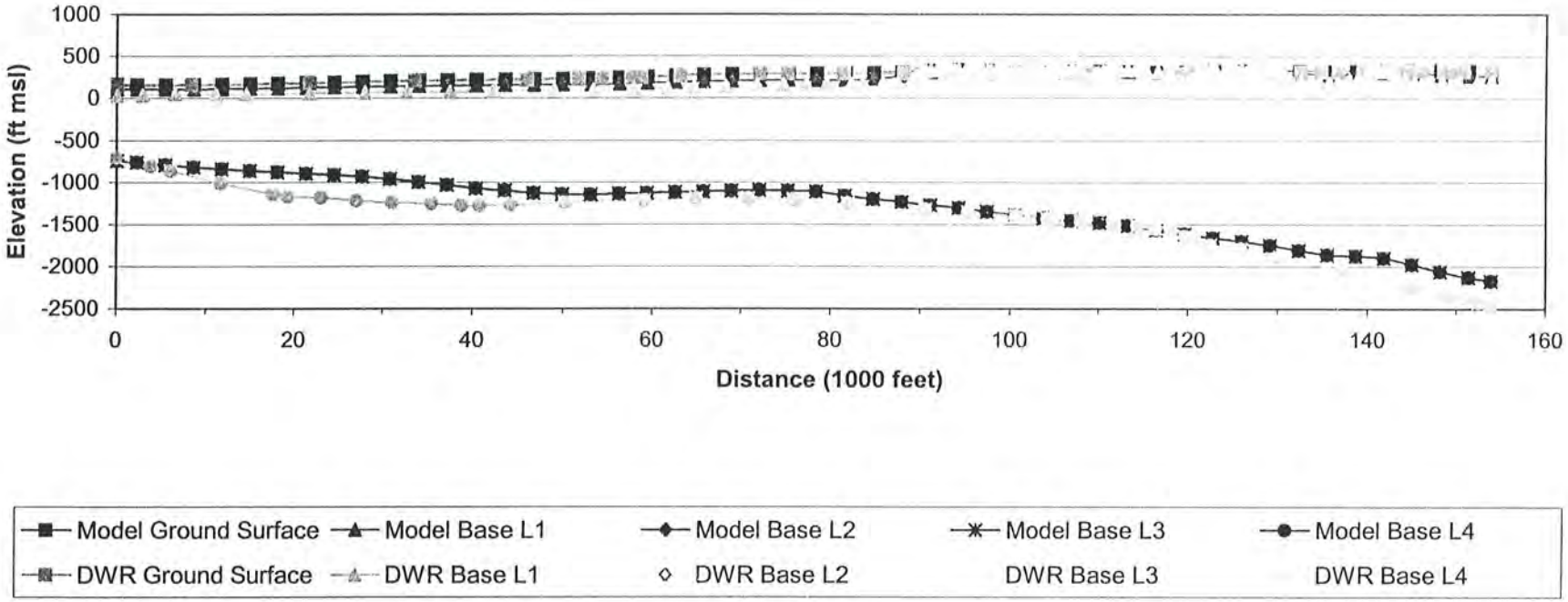


Figure 6.2 f
Stony Creek Fan IGSM
Comparison of SCFIGSM Stratigraphy with DWR Cross Section Data
SCF Section F

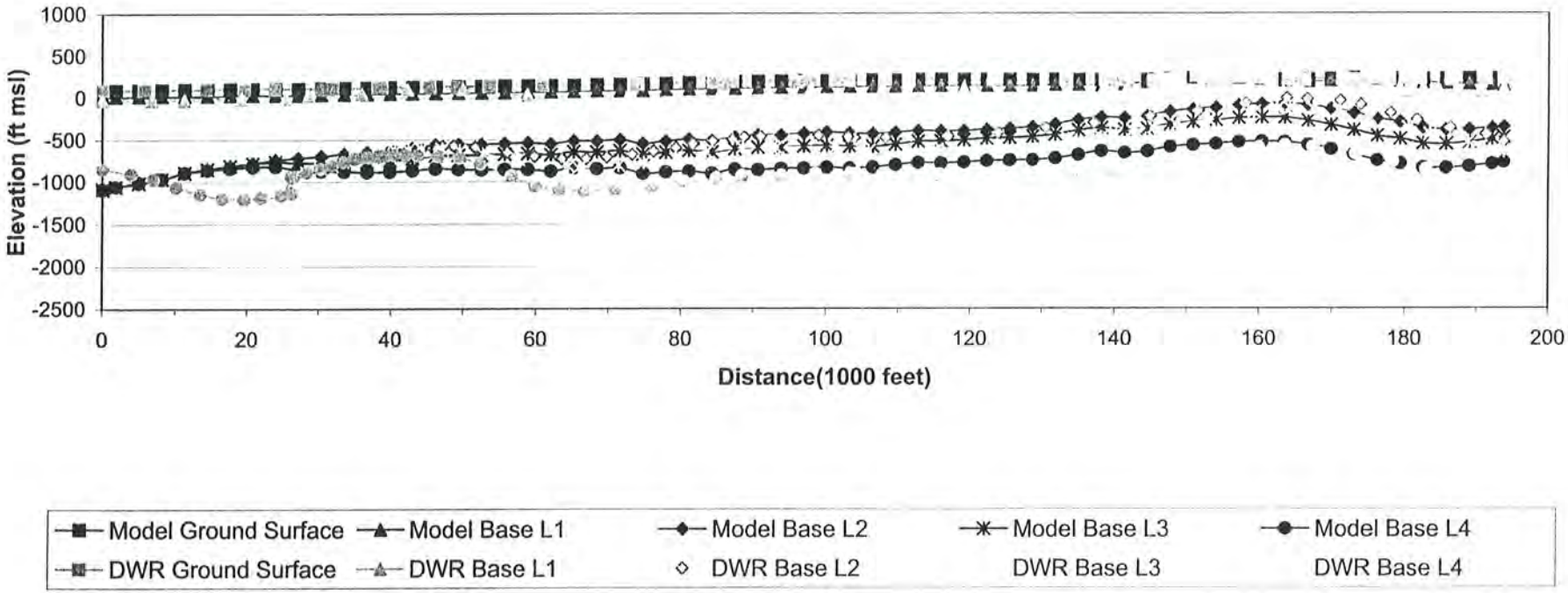
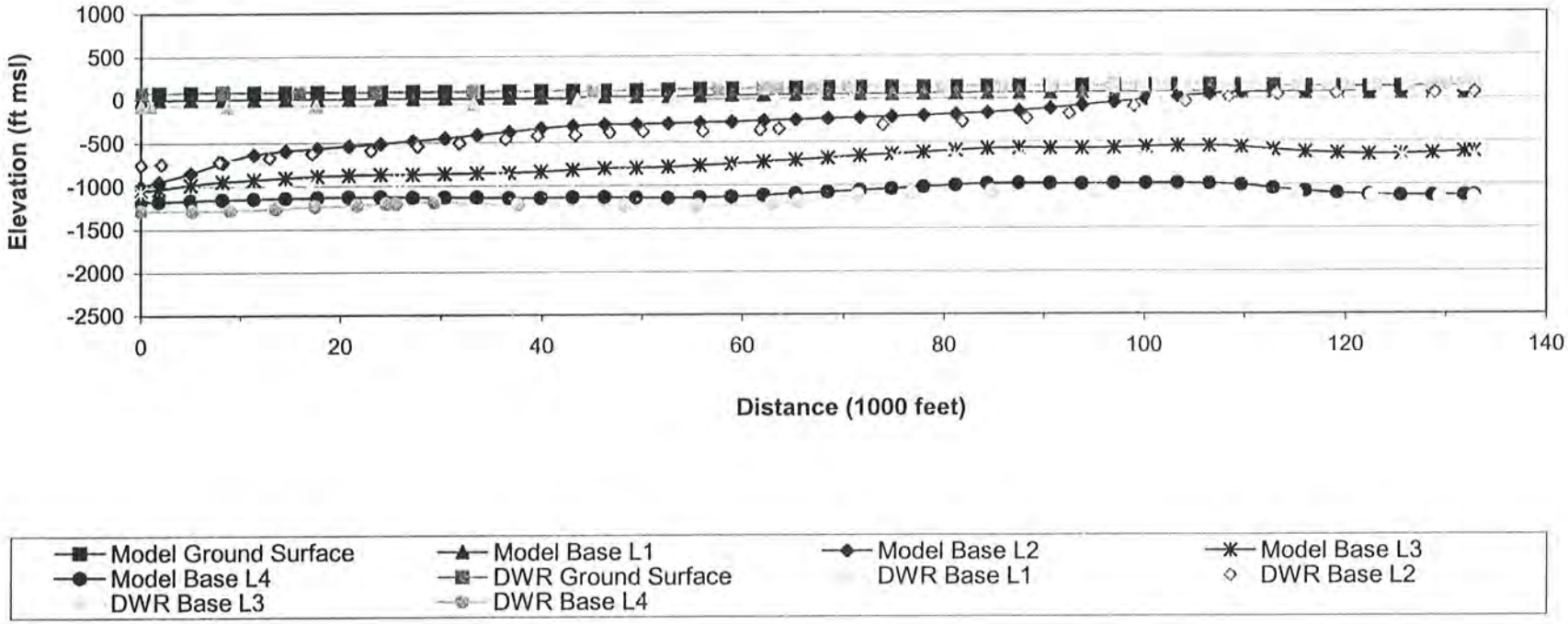


Figure 6.2 g
Stony Creek Fan IGSM
Comparison of SCFIGSM Stratigraphy with DWR Cross Section Data
SCF Section G



- Checking model data around faults to confirm location of fault and correct offset,
- Checking and modifying model data for changes in formation thickness, and
- Checking model layer thickness and comparing it to known data.

Step 2b. Check Model Stratigraphy Data Reasonableness

The purpose of this review is to confirm that the SCFIGSM stratigraphy data reflects the aquifer system identified in the hydrogeologic setting (Section 3). This step was completed by a review of model data and comparison to data not used in the stratigraphy data development process. This includes data from reports, previous studies, and expert opinions, and comparison to existing maps, aquifer thickness contours, or cross-sections.

Step 2c. Check Level of Detail of Model Stratigraphy Data

The model data should not suggest that we know information at a higher level of detail than is presented in the original source of the data. This step includes checks of the:

- Interpretation of the available (original data) to the model data; and
- Presentation of the model data.

Step 2d. Refine Model Stratigraphy Data

The stratigraphy model data is refined to reflect the information developed in Steps 2A through 2C. Stratigraphy model data refinement needs to be done carefully, recognizing that modifying the base of a model or the thickness of a model layer affects all the stratigraphic data at the corresponding model node.

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STEP 3. STRATIGRAPHY DATA QUALITY CONTROL

The purpose of Step 3 is to evaluate each SCFIGSM model layer to confirm that the model stratigraphy data accurately reflects the conceptual hydrogeology presented in Section 4 and the original available data (DWR cross-section data). Maps showing the thickness of aquifer layers and the base of elevations were used to check the model data. The quality control for each model layer is described below.

Step 3a. Check Ground Surface Elevation

The ground surface elevation data was developed from a USGS digital elevation model (DEM) for the northern Sacramento Valley. The ground surface data is shown in Figure 6.3. The model ground surface elevation was checked by comparing it to the ground surface elevation data from the USGS 1:250,000 map series.

Step 3b. Check Base of the Aquifer System

In the western half of the SCFIGSM model area, the base of the aquifer system is the base of the Tehama Formation (Layer 2). In the eastern half of the SCFIGSM model area, the base of the aquifer system is the Lower Tuscan Formation (Layer 4).

In general, the modeled aquifer system ranges from less than 50 feet thick to about 2,500 feet thick as shown in Figure 6.4. The elevation of the base of the modeled aquifer system ranges from 800 feet above sea level to 2,400 feet below sea level as shown in Figure 6.5.

Step 3c. Check Model Layer 1 (Alluvial Aquifer)

Model Layer 1 primarily represents the alluvial aquifer system. In the areas on the Stony Creek Fan, is represents the high permeability sand and gravels which generally range from 50 to 80 feet thickness (Figure 6.6). Outside the Stony Creek Fan, Layer 1 represents the upper 80 feet of alluvial and basin deposits, even in areas were the total thickness exceeds 80 feet. Layer 1 is not present in the northwest portion of the model area were the Tehama Formation is present at the ground surface, thus Layer 1 has zero thickness as shown in Figure 6.6. The elevation of the base of Layer 1 ranges from more than 900 feet above sea level in the northwest part of the model area to just below sea level in the southeast part of the model area as shown in Figure 6.7.

STEP 3D. CHECK MODEL LAYER 2 (TEHAMA FORMATION)

Model Layer 2 generally represents the Tehama Formation. As mentioned, it does include some basin and alluvial deposits. Where model Layers 3 and 4 are not present, Layer 2 is the base of the aquifer system. In this area, Layer 2 ranges in thickness from less than 100

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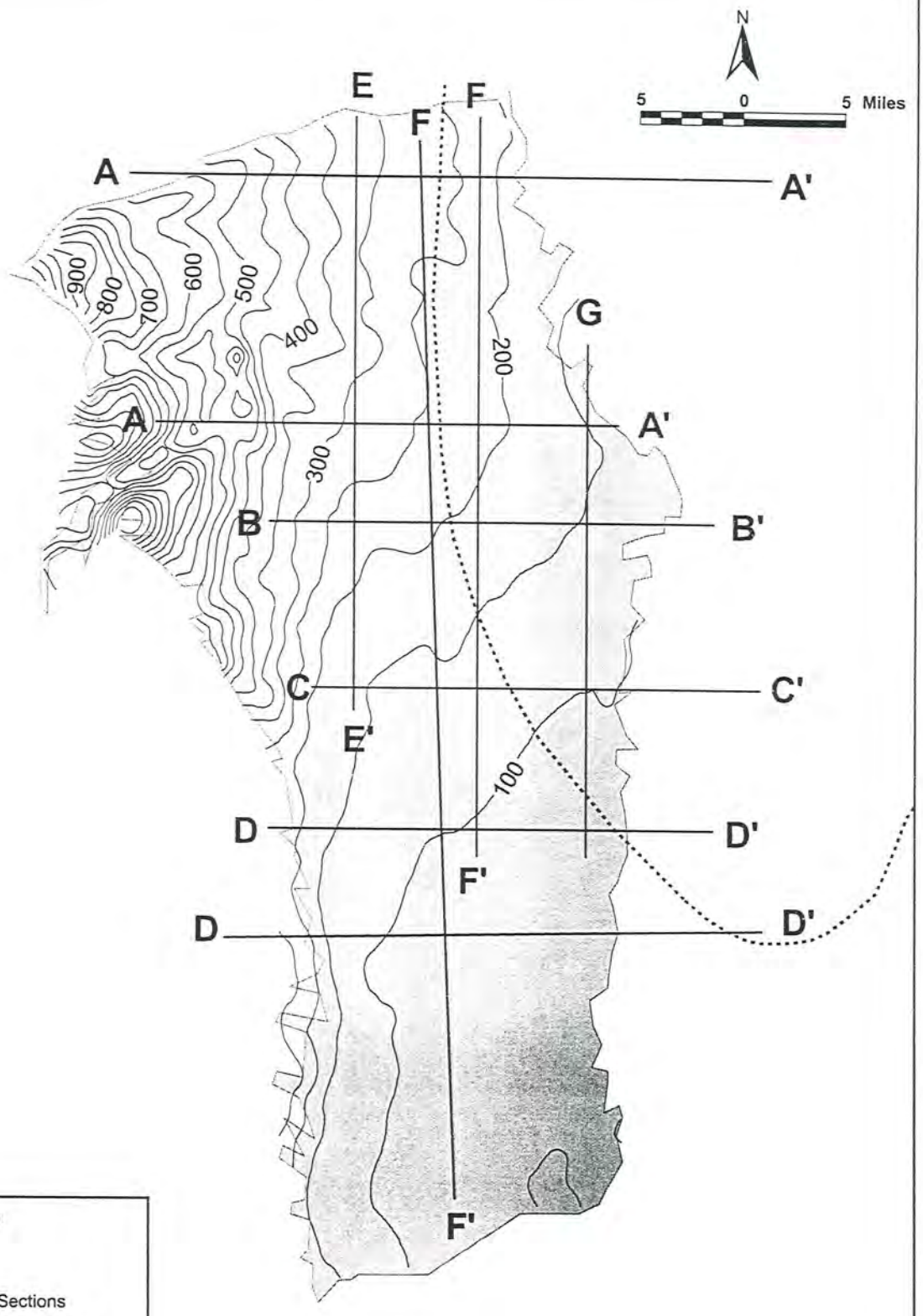
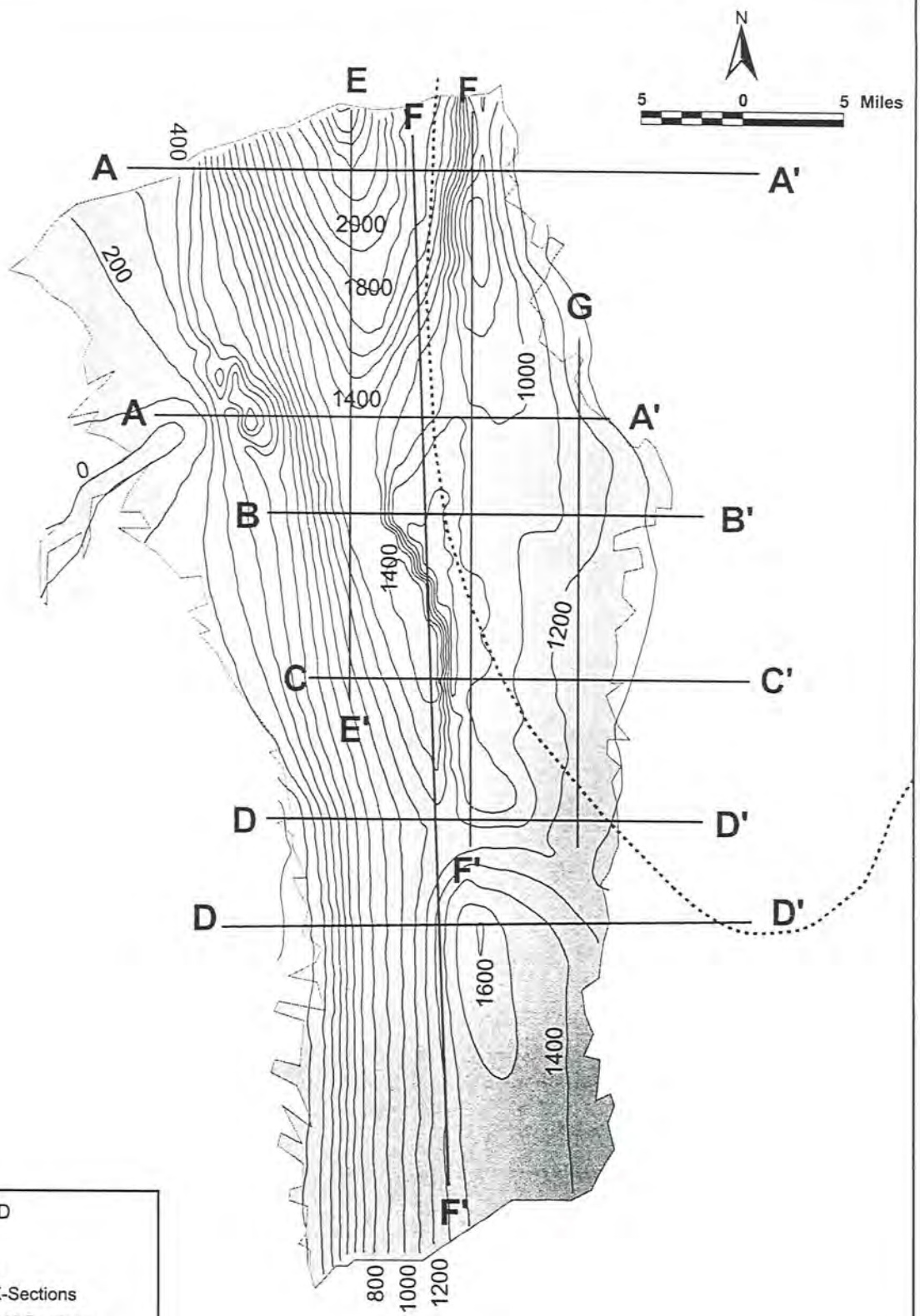


PRIME Water Resources & Information Management Engineering, Inc.	STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM **Ground Surface Elevation Contour Map** **DRAFT**	JANUARY 2003 FIGURE 6.3



LEGEND

- Contours (100 ft.)
- Stony Creek Fan X-Sections
- Sacramento Valley X-Sections
- Approx. Extent of Tuscan Formation

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STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM

Thickness of Alluvial Aquifer

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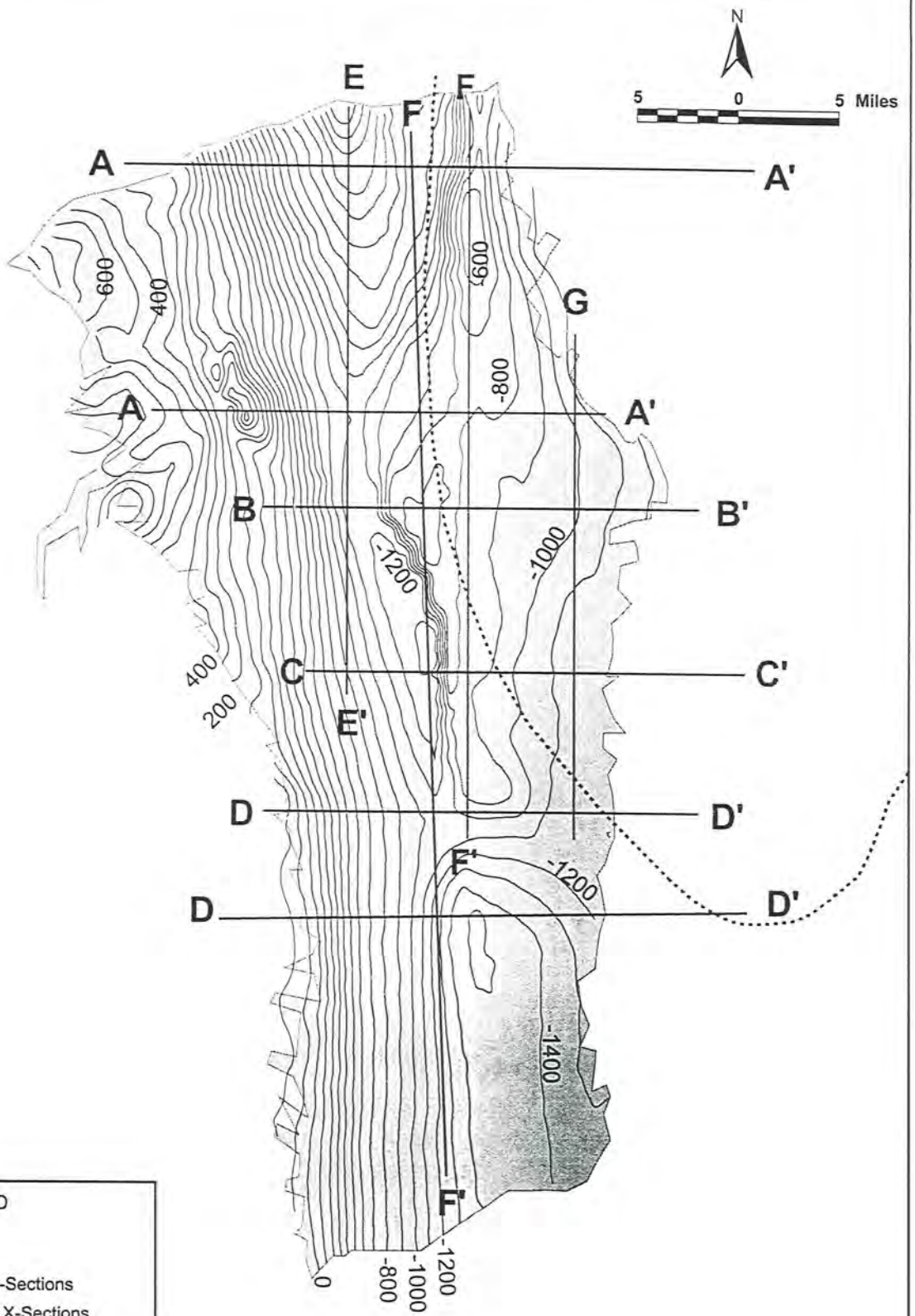
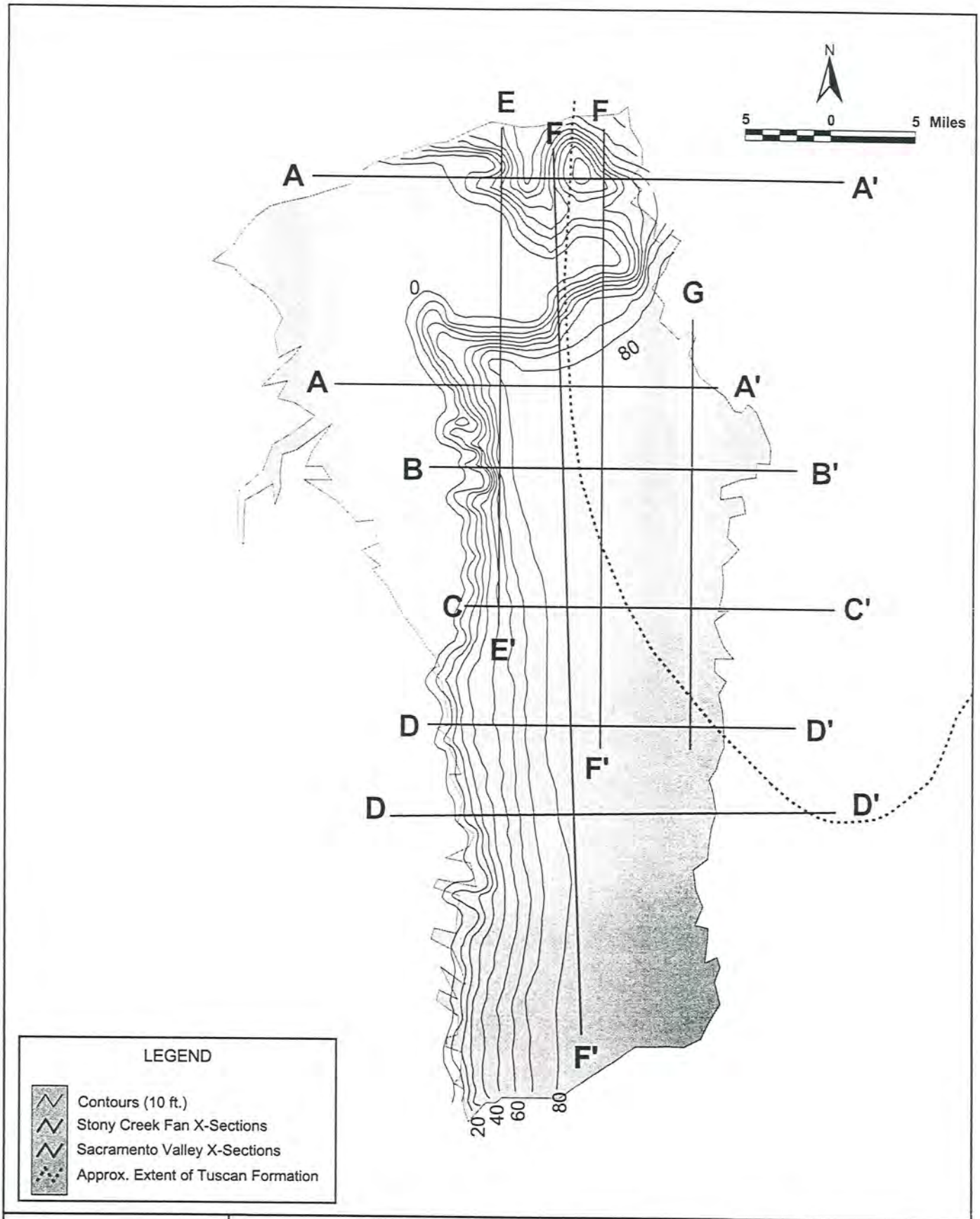
FIGURE 6.4



LEGEND

- Contours (100 ft.)
- Stony Creek Fan X-Sections
- Sacramento Valley X-Sections
- Approx. Extent of Tuscan Formation

RIME Water Resources & Information Management Engineering, Inc.	STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM **Elevation of Base of Aquifer** **DRAFT**	JANUARY 2003 FIGURE 6.5



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STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM

Thickness of Layer 1

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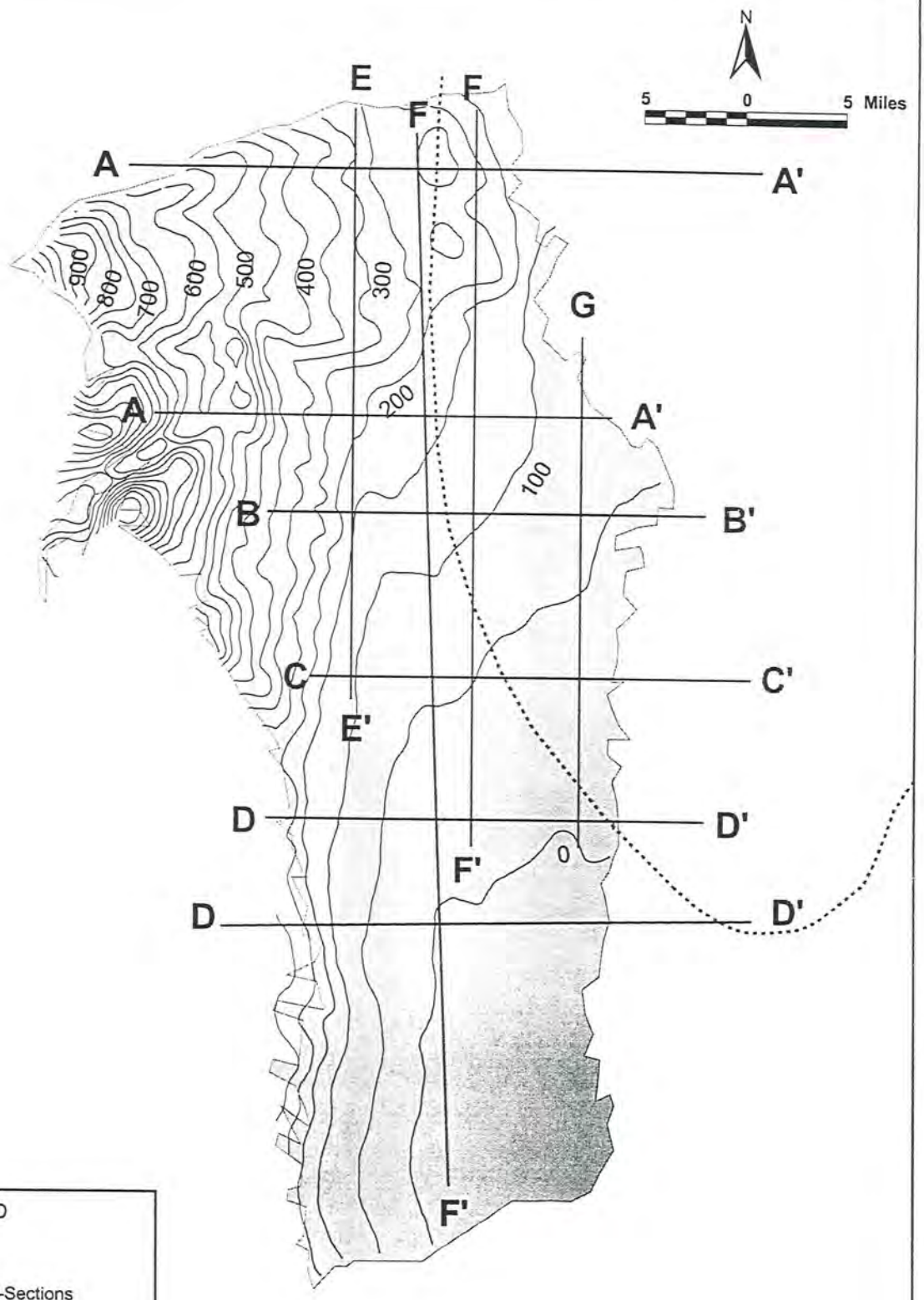
FIGURE 6.6



PRIME Water Resources & Information Management Engineering, Inc.	STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM **Elevation of Base of Layer 1** **DRAFT**	JANUARY 2003 FIGURE 6.7

feet in to more than 2,400 feet, as shown in Figure 6.8. On the western half of the model area, Layer 2 generally increases from less than 100 feet near the western edge of the model area to about 1,200 feet near the center of the model area. In the northern portion of the model area, Layer 2 achieves its maximum thickness of more than 2,400 feet.

Where Layers 3 and 4 are present beneath Layer 2, Layer 2 decreases in thickness from about 1,200 feet thick near the center of the model are zero thickness along the northeastern edge of the model boundary.

The abrupt changes in the thickness in Layer 2 are due to offset along the Corning-Willows Fault (located near the center of the model area in a north-south direction), and the presence of the Tuscan Formation (entering the model area from the east).

Figure 6.9 shows the elevation of the base of Layer 2 ranges from 800 feet above sea level to more that 2,000 feet below sea level.

STEP 3E. CHECK MODEL LAYER 3 (UPPER TUSCAN FORMATION)

Model Layer 3 represents the Upper Tuscan Formation. It extends about halfway into the model are from the northeast ranging in thickness from zero to 700 feet as shown in Figure 6.10. Layer 3 is not present in the western or southern portion of the model area. The elevation of the Base of Layer 3 ranges from near sea level in the northern area to about 1,000 feet below sea level at its southern extent as shown in Figure 6.11.

STEP 3F. CHECK MODEL LAYER 4 (LOWER TUSCAN FORMATION)

Model Layer 4 represents the Lower Tuscan Formation. It extends about halfway into the model are from the northeast ranging in thickness from zero to about 600 feet as shown in Figure 6.12. Layer 4 is not present in the western or southern portion of the model area. The elevation of the Base of Layer 4 ranges from about 500 feet below sea level in the northern are to about 1,200 feet below sea level near the eastern edge of the model area as shown in Figure 6.13 It should be noted that in that where present, Layer 4 represents the base of the aquifer system.

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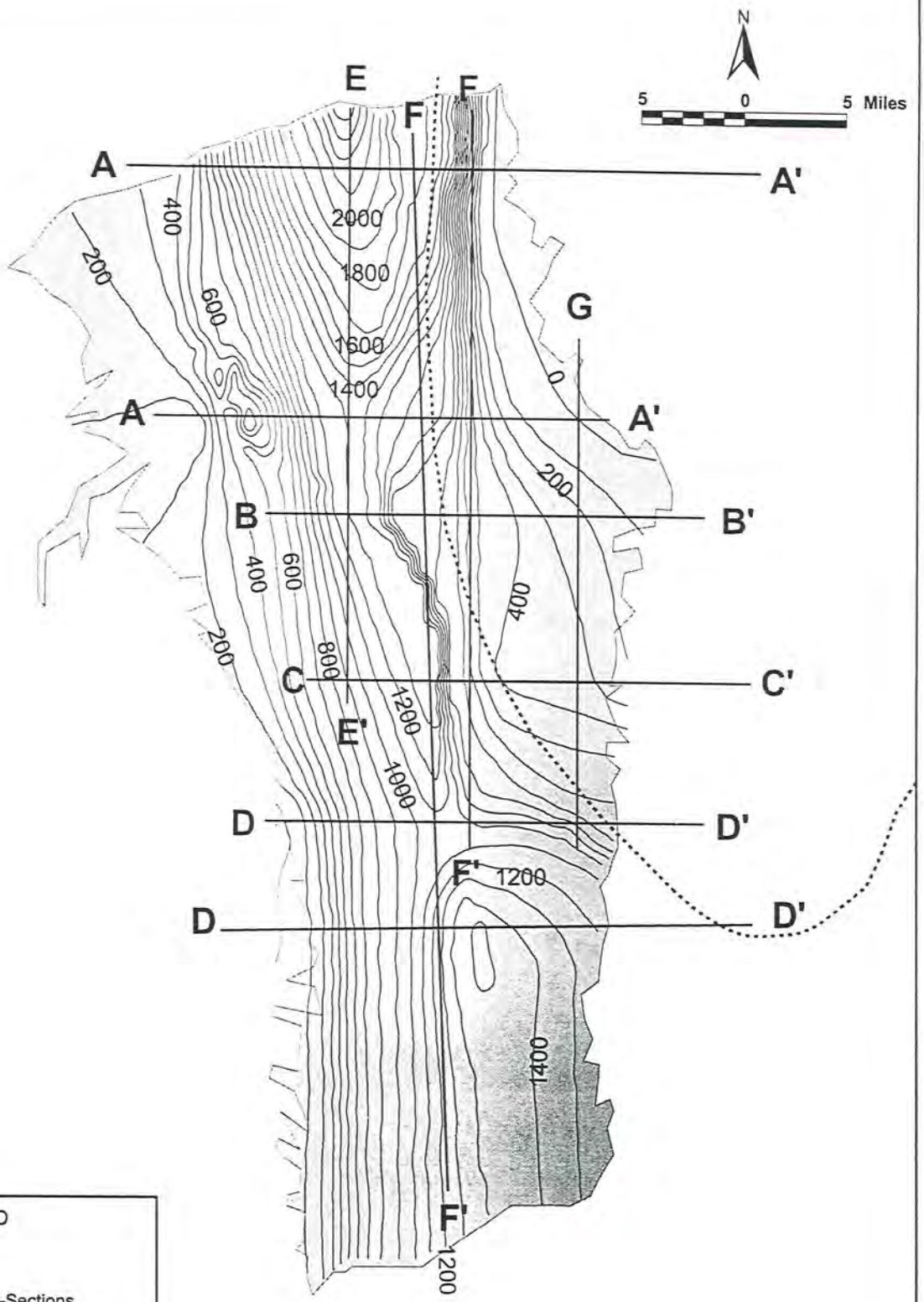
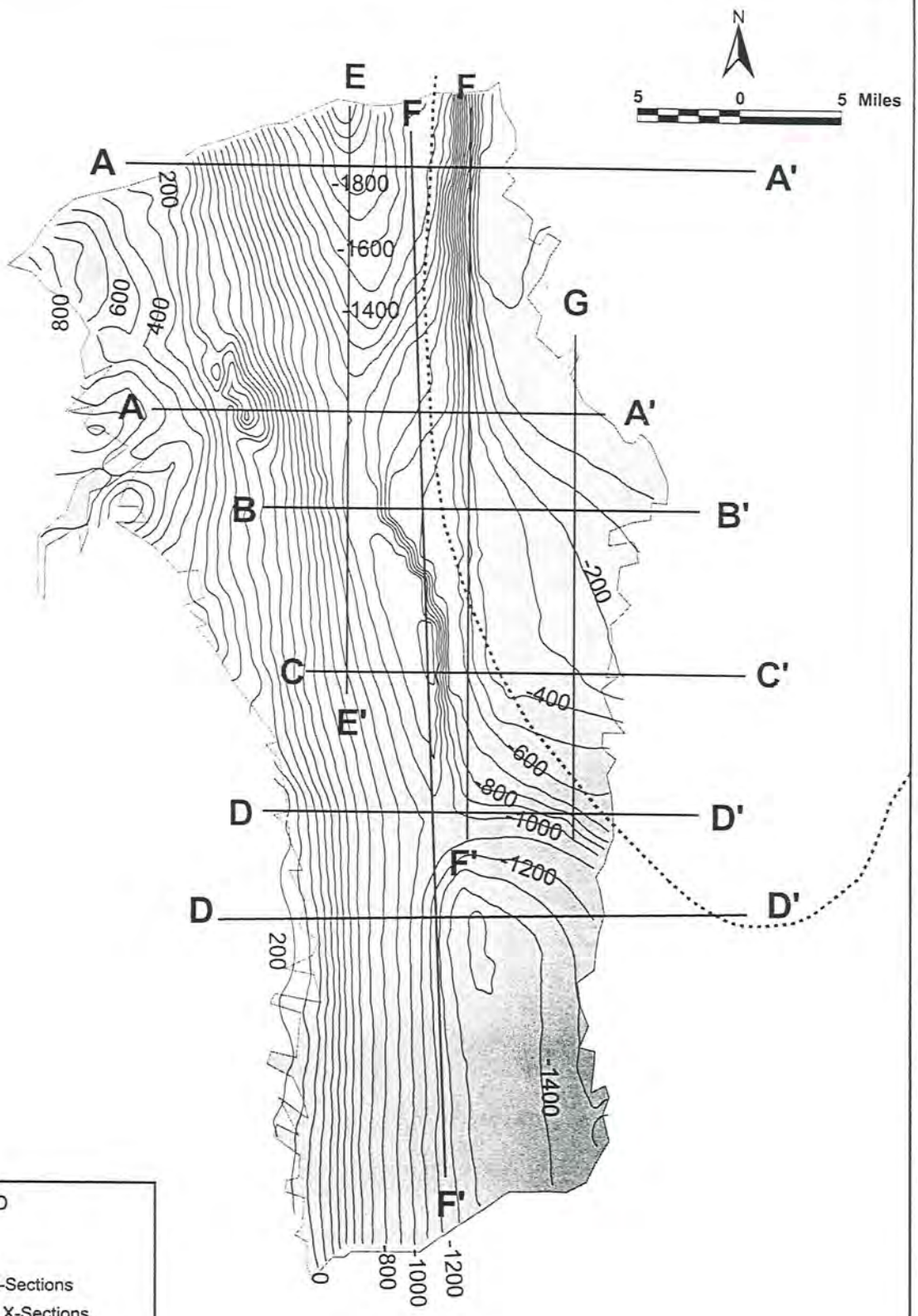


LEGEND

- Contours (100 ft.)
- Stony Creek Fan X-Sections
- Sacramento Valley X-Sections
- Approx. Extent of Tuscan Formation

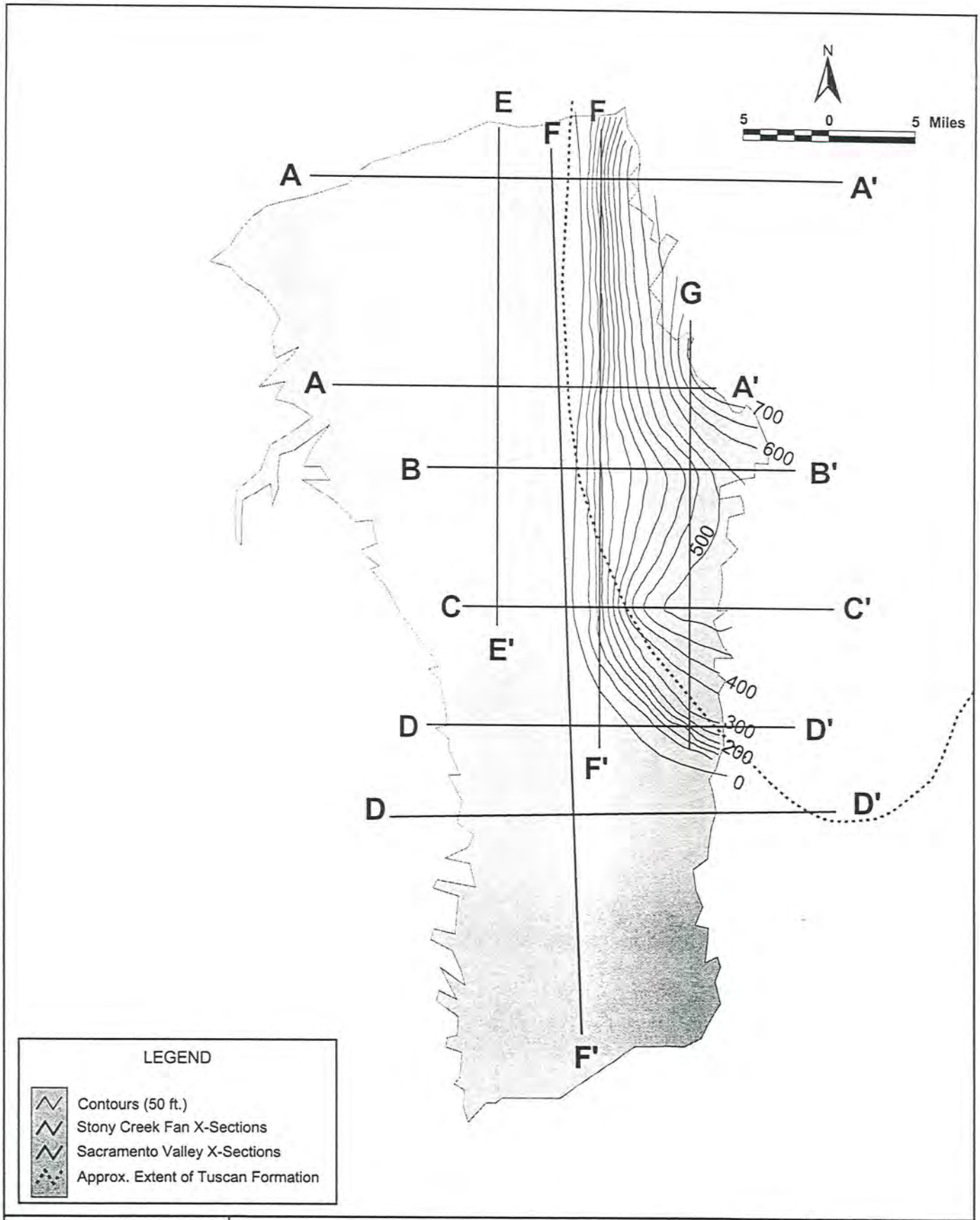
RIME Water Resources & Information Management Engineering, Inc.	STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM **Thickness of Layer 2** **DRAFT**	JANUARY 2003 FIGURE 6.8



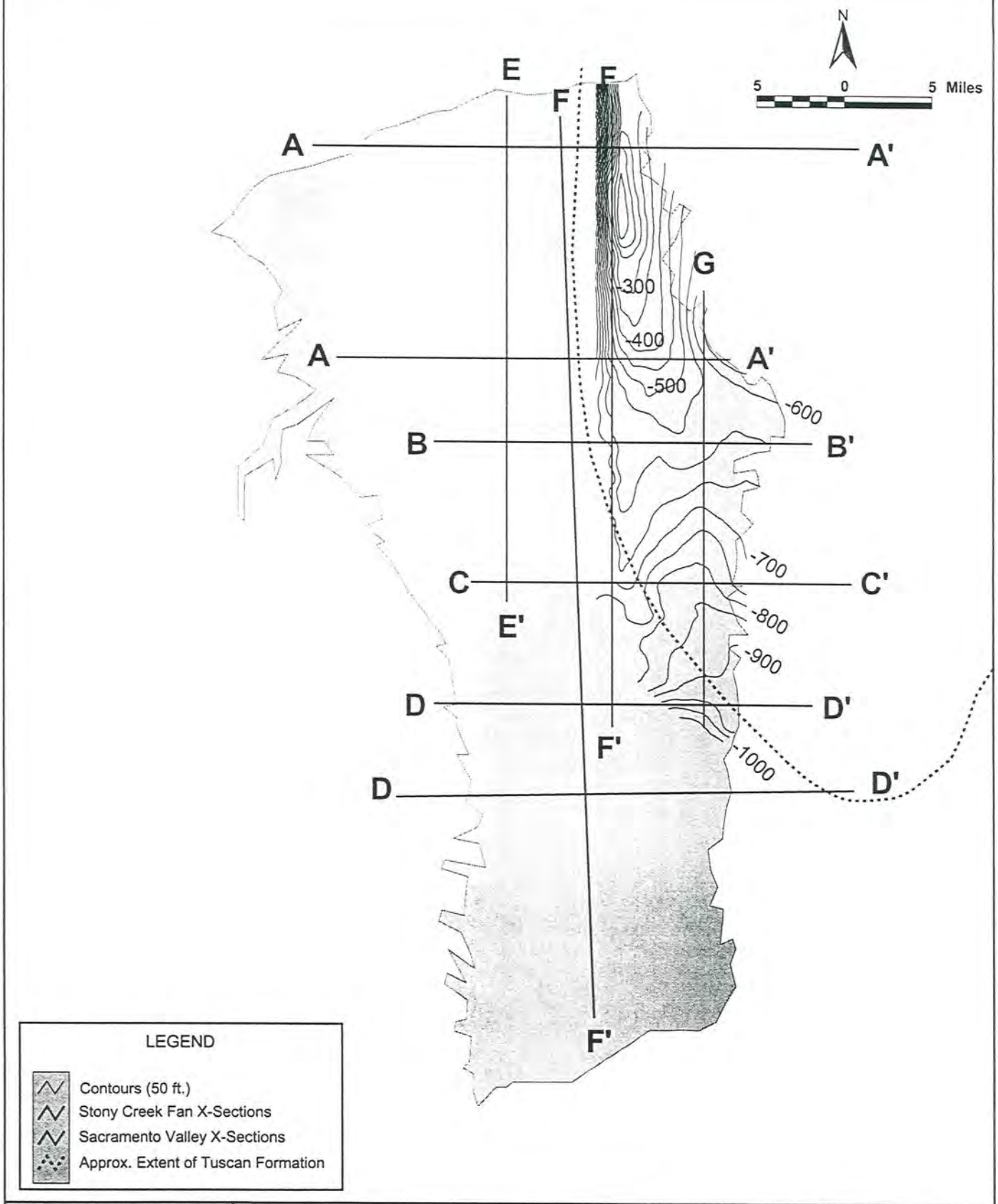
LEGEND

- Contours (100 ft.)
- Stony Creek Fan X-Sections
- Sacramento Valley X-Sections
- Approx. Extent of Tuscan Formation

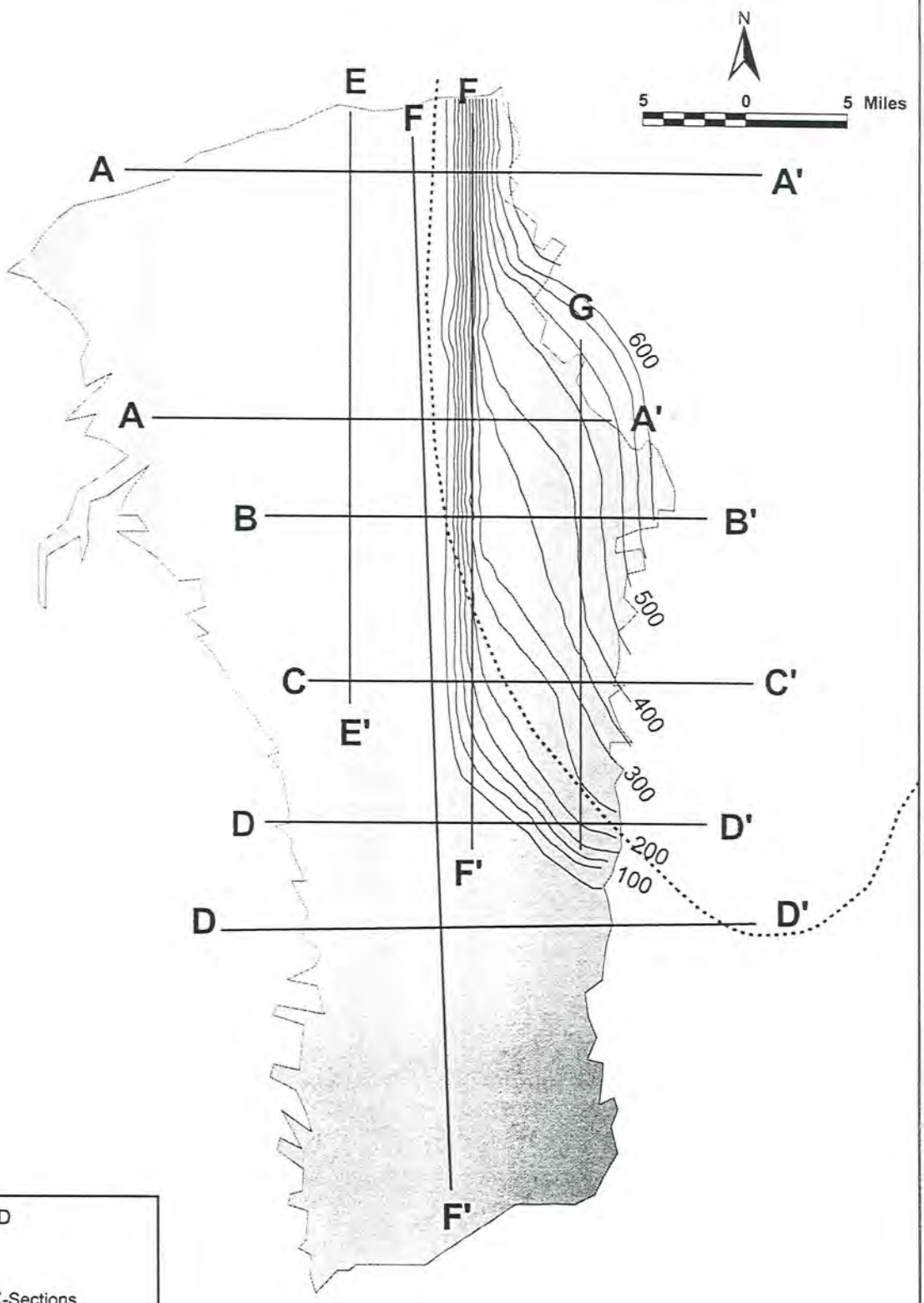
RIME Water Resources & Information Management Engineering, Inc.	STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM **Elevation of Base of Layer 2** **DRAFT**	JANUARY 2003 FIGURE 6.9



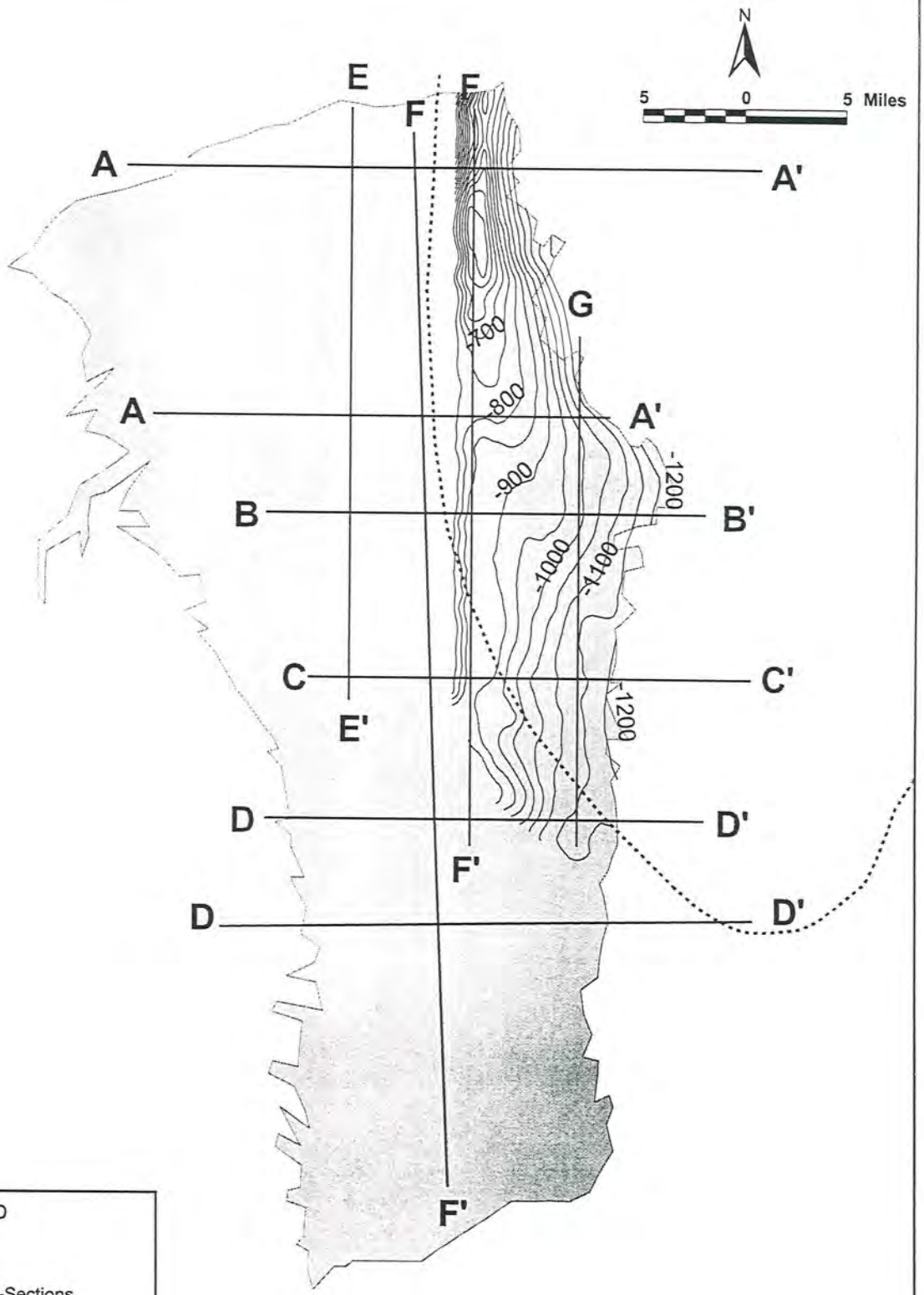
RIME Water Resources & Information Management Engineering, Inc.	STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM **Thickness of Layer 3** **DRAFT**	JANUARY 2003 FIGURE 6.10



RIME Water Resources & Information Management Engineering, Inc.	STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM **Elevation of Base of Layer 3** **DRAFT**	JANUARY 2003 FIGURE 6.11



RIME Water Resources & Information Management Engineering, Inc.	STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM **Thickness of Layer 4** **DRAFT**	JANUARY 2003 FIGURE 6.12



LEGEND

- Contours (50 ft.)
- Stony Creek Fan X-Sections
- Sacramento Valley X-Sections
- Approx. Extent of Tuscan Formation

RIME Water Resources & Information Management Engineering, Inc.	STONY CREEK FAN CONJUNCTIVE WATER MANAGEMENT PROGRAM **Elevation of Base of Layer 4** **DRAFT**	JANUARY 2003 FIGURE 6.13

SECTION 7 SUMMARY

The SCFIGSM model grid and stratigraphy data were developed using the methodology described in this technical memorandum.

SCFIGSM MODEL GRID

The SCFIGSM model grid was developed to reflect local hydrogeologic, hydrologic, and water management conditions (Section 5).

SCFIGSM STRATIGRAPHY DATA

The SCFIGSM stratigraphy data was developed after an extensive data collection and review effort (Section 2). Geologic cross-sections provided by the California Department of Water Resources Northern District Office were the primary source of data for the stratigraphy model development. The geologic and hydrogeologic setting (Section 3) was developed based on the review, analysis, and interpretation of this unpublished data. This is followed by the development of the conceptual model stratigraphy (Section 4) for the SCFIGSM. The process to develop the SCFIGSM stratigraphy data from the available data included three steps including data development, data refinement, and data quality control (Section 6).

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Colusa Groundwater Authority

Project Management Action (Proposed)

Date Proposed:	June 11, 2021
Project Title:	Colusa Drain Mutual Water Company (CDMWC) In-lieu Groundwater Recharge
Project Type:	In-lieu Groundwater Recharge
Project Proponent:	Colusa Drain Mutual Water Company
Measurable Objectives to Benefit:	Groundwater levels and groundwater storage
Water Source:	Sacramento River through CDMWC contractual rights with USBR together with annual and multi-year transfer agreements with USBR settlement contractors utilizing the Colusa Basin Drain (Drain).
Project Area:	CDMWC service area, approx 46,000 acres, Glenn, Colusa and Yolo County (see attached Map)
Brief Project Description:	The Colusa Drain Mutual Water Company(CDMWC) encompasses approximately 46,000 acres of agricultural production and environmental habitat adjacent to the Colusa Basin Drain. Shareholders in CDMWC divert water for summer irrigation from the drain under a combination of; appropriative water rights held individually by the shareholders, a long term service supply agreement with USBR and annual and multi-year transfer agreements with neighboring USBR settlement contractors. Historically, many CDMWC diverters use both groundwater and surface water for summer irrigation because physical supplies of water in the Colusa Drain are often insufficient and unreliable to satisfy those irrigation requirements. The purpose of this project is to provide a reliable and sufficient supply of water in the Drain allowing CDMWC diverters to increase their diversions of surface water while slowing or stopping their groundwater pumping.
Implementation and Termination	
Criteria for Implementation:	This project could be implemented quickly and could be ongoing. Some of the criteria required for implementation would include: • Physical supply of surface water to be introduced into the Drain. • Necessary environmental permitting to allow for transfers into the drain by settlement contractors or others.

- Necessary permitting by Department of Water Resources (DWR) and State Water Resources Control Board (SWRCB) to allow CDMWC shareholders to divert from the Drain.
- Necessary infrastructure with CDMWC and/or its shareholders to divert from the Drain.
- Necessary infrastructure on part of settlement contractors to introduce a physical supply of water into the Drain.

Much of these criteria are already being met by potential project participants. Additional participants could be added as needed and as interest for a project increased. For example, CDMWC and GCCID have completed the necessary environmental reviews and approvals with USBR for a multi-year transfer agreement between the parties. This process could be completed for other settlement contractors as well. CDMWC's long term contract with USBR provides CDMWC diverters necessary permission to divert from the drain when individual appropriative water rights would otherwise be deficient, allowing for diversion throughout the irrigation season (April 1 through Sept 30). Most of CDMWC shareholders have the necessary infrastructure already in place to divert from the drain.

Public and/or Interagency Notice Process:

While public notice may be necessary under SGMA regulations, it is not expected that Public or Interagency Notice would necessarily be required to complete a project of this nature. At least some of the necessary permitting and noticing is in place. This part of the project requires legal review and input.

Required Permitting and Regulatory Process

This project would require, at a minimum:

- Underlying appropriative water rights; licenses and/or permits held by CDMWC and/or its individual shareholders to allow for diversion of surface water from the Drain throughout the summer irrigation season.
- Environmental Permitting allowing for the transfer of surface water from USBR Settlement Contractors or others to CDMWC.
- Transfer agreements between CDMWC and settlement contractors or others to provide a physical supply of water in the Drain.

Current Status:

Several elements of this proposal are already in place and are functioning. For example:

- Several USBR Settlement Contractors have the necessary infrastructure in place to introduce surface supplies into the Drain.
- CDMWC shareholders have the necessary infrastructure in place to divert surface water from the drain.
- GCID and CDMWC currently have a transfer agreement in place that includes the necessary environmental permitting with USBR and DWR.
- CDMWC shareholders have the necessary licenses and permits in place with DWR and SWRCB to allow those diversions.
- CDMWC has a long-term supply agreement with USBR to supply water into the Sacramento River to offset shareholders diversions from the Drain that would otherwise infringe the rights of senior water right holders in the Sacramento River.

The important element of this project that does not currently exist is the adjustment of the current economic relationship between CDMWC diverters and potential participating settlement contractors that provides settlement contractors sufficient economic incentive to introduce a physical supply of surface water to the Drain, and, at the same time, CDMWC diverters sufficient incentive to access that supply in lieu of their groundwater wells.

Estimated Cost:	$1,725,000	(See attached cost estimate analysis)
Potential Funding Sources:	Primary Source:	CDMWC and its shareholders
	Secondary Source:	CGA, Settlement Contractors, NGO's(TNC & others), Prop 1 grant funding, water export fees
Anticipated Start Date:	It is expected that this project in some form could start as early as crop year 2022 (March 2022)	
Anticipated Completion Date:	This project could be ongoing	
Measurable Objectives Expected To Benefit:	Groundwater Levels, Groundwater Storage	
Serves Disadvantaged Community:	At least some of the area within the CDMWC service area is identified as a Disadvantaged Community	

Expected Yield:	Unknown at this time. However, For the subarea within the Colusa Subbasin that approximately corresponds to the CDMWC the water budget currently included in the GSP includes an average from 1990 to 2015 of 48,000 AF/yr of surface water diversions, presumably from the Drain. For the same period, groundwater pumping averages about 40,000 AF/yr. Assuming a successful project could displace 70% of this current groundwater pumping along the drain, a yield of 28,000 af of in-lieu recharge could be realized.
Benefit Evaluation Methodology:	This needs further development, however, it is expected that the combination of information available through water budgets included within the currently proposed GSP, diversion data collected under SB88 and available publicly, evaluation of transfers contemplated under the project using the HCM developed for the GSP and the specific details of any proposed transfer subject to this project would yield sufficient data to calculate the benefits realized by the project.
Next Steps	1) Present/review with TAC committee 2) Present/Review with GSP consulting team 3) Present/Review with CGA legal counsel 4) Present/Review with potential supply partners (settlement contractors & others) 5) Complete financial analysis 6) Complete benefit analysis
Summary	CDMWC and its shareholders represent an important component of the overall groundwater demand within the Colusa Subbasin. An in-lieu re-charge project that effectively partners these groundwater users with potential supply partners to reduce or eliminate groundwater pumping represents a great opportunity for improving groundwater sustainability withing the subbasin.

From: Grant Davids
To: Jim Wallace
Subject: RE: Colusa Drain Mutual Proposed Project Management Action for In-lieu groundwater re-charge
Date: Monday, June 21, 2021 7:57:00 AM

Jim,

This sounds good. Even a narrow (or "conditional") policy statemen as you describe would be useful. If that's not forthcoming, we'll just describe the physical and operational elements of the project in he GSP, and discuss the agreements that will need to be negotiated in the future. One thing to keep in mind is that if the benefits of your recharge project extend beyond the CDMWC service area, then those outside beneficiaries should pay something to facilitate the project. Simple in concept, hard to put into effect.

Grant

From: Jim Wallace <jimwallace@ecolusa.com>
Sent: Saturday, June 19, 2021 9:48 AM
To: Grant Davids <grant@davidsengineering.com>
Subject: Re: Colusa Drain Mutual Proposed Project Management Action for In-lieu groundwater re-charge

Thank you Grant. I couldn't speak with Thad on Friday but I left a message and asked for an appt. I expect both Thad and Lewis to support this project at technical level. I won't look further than that for now. But of course that is the easier discussion, objective discussion about infrastructure, quantities, timing, permitting, etc. So I am focusing on this(technical) first. To make sure that given a suitable political environment and workable economics, we can do something positive. But if you have anxiety about how the politics and economics of all this will play, then I share this anxiety. Our larger board has yet to have a productive discussion about money, priorities, fairness, public trust, and other more subjective issues. And I see a wide variety of perspective on these issues given the relatively disparate nature of key player positions(the haves and the have nots). To be blunt, I fear a policy statement that accurately reflected the position of the large SW suppliers at this point in the process would not be acceptable to many players within our community. That being said, a narrow statement from the entire board that agrees to prioritize in basin transfers for the purpose of recharge and other project management actions , for example, might be achievable. I'll ask Thad about this specifically if/when we talk. Thanks again for thinking about this and responding. Jim

> On Jun 19, 2021, at 8:13 AM, Grant Davids <grant@davidsengineering.com> wrote:
>
> Hi Jim,
>
> Thank you for the additional information. This will allow the team to prepare a detailed, compelling project description for the GSP.
>
> I don't know whether or how it would work politically, but a meeting among the larger

settlement contractors and major proposed in-lieu rechargers (CDMWC, CCWD, and OAWD) to discuss available water quantities in non-Shasta critical years would be very helpful. Most of the necessary infrastructure is in place for these projects (some new infrastructure needed OAWD), so the key is to demonstrate to DWR (in the GSP) that the SW supply is available and there is general agreement regarding increased transfers moving forward. I am encouraged that Settlement Contractors are telling you they want to more fully utilize project water within the basin in full supply years. This is key. If the Settlement Contractors could prepare a general "policy statement" to this effect that could be included in the GSP, that would be very positive. Maybe you could float this idea?

Thanks again for your thoughtful reply,

Grant

From: Jim Wallace <jimwallace@ecolusa.com>
Sent: Friday, June 18, 2021 5:33 PM
To: Grant Davids <grant@davidsengineering.com>; Jim Wallace <jimwallace@ecolusa.com>
Cc: Mary Fahey <mfahey@countyofcolusa.com>; Dave Ceppos <dceppos@ccpcsus.edu>
Subject: RE: Colusa Drain Mutual Proposed Project Management Action for In-lieu groundwater re-charge

Hi Grant, Thanks for your encouragement and feedback on this proposal. I appreciate it.

1. You asked for a copy of CDMWC/USBR contract. Here is a link for that contract.
    a. https://drive.google.com/file/d/14Ab3TJDp5kC5cY000h0887iGoiyYH6yA/view?usp=sharing
2. You asked for a copy of CDMWC/GCID 2021 transfer agreement (note: this copy is a draft but I believe was the final draft for this years agreement. I will upload an executed copy when I put my finger on it.). Here is a link for that contract:
    a. https://drive.google.com/file/d/14Cw6I7NGhvdzOErv356Ot3gYWNzJFlGj/view?usp=sharing
3. You asked is more water available under this contract with GCID? I think the answer is yes, but I have not reviewed this project proposal with Thad to see if or where it fits in GCID's strategy for recharge projects. I am hoping to do that next week.
4. You asked which settlement contractors are most likely to be the source of transferred water. My answer is:

a. GCID first because:
    i. we are currently working with them
    ii. they have the largest supply
    iii. they have the most infrastructure on the drain that is relevant to a project like this
b. Maxwell Irrigation,
    i. we have worked with Maxwell in the past
    ii. they can divert and deliver directly to the drain and are upstream from much of our shareholder base
    iii. I have not reviewed this project with Maxwell
c. Princeton/Provident
    i. same reasons as Maxwell, we have worked with them previously and they have relevant infrastructure.
    ii. I have not reviewed this project with Princeton/Provident
d. RD108
    i. RD108 is located further down the drain and their ability to deliver to the drain is slightly less convenient than some of the upstream diverters (once diverted from the river, RD108 has to lift the water over their back levee to get the water into the drain. But CDMWC has executed this maneuver with RD108 successfully in the past and so I believe is a viable option.)
    ii. Direct diversion and delivery to the drain is the best option to work with RD108, in my opinion. But a second option is for RD108 to be a supplier of transfer water but have the water wheeled through another upstream diverter into the Drain.
    iii. I met today with Bill V at RD108 to review this proposal and get feedback. In general, I would describe the discussion as positive and I expect RD108 would support this project.
e. Davis Ranch. CDMWC has not worked with them before, however:
    i. They have the ability to divert from the river and deliver directly into the drain with their existing infrastructure
    ii. They have the added benefit to CDMWC of being able to deliver into the Drain below the Davis weir. This is an important distinction because a major challenge with the operations on the Drain is lack of flow below the Davis Weir and significant of CDMWC service area is below the Davis Weir.
    iii. They have a demonstrated interest in recharge in general and so might be interested in participating in a project like this
    iv. I have not reviewed this project with Davis

5. You asked about validating whether 83,000 af was reliably available from

settlement contractors to meet demands of multiple recharge projects. In Shasta Critical years I expect one could not validate that this quantity is available, especially, to the extent that settlement contractors have already committed project water to other transfers both in and out of basin. In full supply years, however, I believe the answer is yes. In speaking with Settlement Contractors I am consistently told that better (more complete or fuller) usage of project water within the basin during water flush years is a top priority with respect to groundwater sustainability. Review of settlement contractors prior year project water scheduling with USBR would give a good idea of the total quantity of water likely available for transfer to any proposed project. I have not seen any of the detail included in the other recharge projects proposed for inclusion in the GSP, but I am guessing that much of this work has already or is currently being done.

6. You asked about how could this new demand for recharge water affect prices? Simple answer is I don't know. But, for the purposes of my proposal I estimated that CDMWC would pay approx. double the amount we are currently paying for transfer water for the additional 28,000 af.
7. You asked about the current cost of groundwater pumping in CDMWC service area. This information is not readily available, however, I have some information from my own farm operations within CDMWC and I will reach out to some other shareholders to see if I can put some information together and send it over. I expect this cost to be in the range of 75-100/af for direct electric charges for pumping.
8. You asked about current transfer cost. Please reference the contract in the above link.
9. You asked about the cost estimate analysis that I referenced in the proposal. This is not complete, but as soon as I have something I will send it over.

Thanks again for looking at this project. JIM

Jim Wallace
jimwallace@ecolusa.com
mobile 530.218.1396

From: Grant Davids
Sent: Thursday, June 17, 2021 9:39 AM
To: Jim Wallace
Cc: Mary Fahey; Dave Ceppos
Subject: RE: Colusa Drain Mutual Proposed Project Management Action for In-lieu groundwater re-charge

Hi Jim,

This is an excellent project, one reason being that it can be implemented at some level with existing infrastructure and expanded gradually as additional infrastructure is constructed.

Some follow up comments/questions/requests:

1. Please send a copy of CDMWC's contract with USBR, or a summary of key terms.
2. Please send a copy of CDMWC's transfer agreement with GCID, or a summary of key terms. Is more water available under this agreement than has been used historically?
3. Other that GCID are any of the "multi-year transfer agreements with USBR settlement contractors" already in place or to be negotiated?
4. Which settlement contractors are most likely to be the source of transferred water (e.g., GCID, PCGID, PID, others???)
    a. Note that the OAWD and CCWD projects are also counting on transfers to supply their in-lieu recharge projects: 25,000 AF/yr for OAWD and 30,000 AF/yr for CCWD
    b. What suggestions do you have for validating that 83,000 AF/yr (25,000+30,000+28,000) are reliably available from settlement contractors to meet these needs?
    c. How could this new demand for surface water affect prices?
5. I will forward your project description to Duncan MacEwan, the team economist, and get him thinking about financial incentives to get CDMWC shareholders to divert SW rather than pump GW. These incentives are a key element of the project.
    a. What is the current, approximate cost to pump groundwater within the CDMWC service area, energy only, not including amortization of capital?
    b. What is your best estimate of average SW costs under transfer agreements?
6. The cost estimate analysis referenced in your document was not attached; please send.

Thank you,

Grant Davids, P.E. | President/Principal Engineer **|** Davids Engineering, Inc.
1772 Picasso Avenue Suite A Davis, CA 95618**|** office 530.757.6107 x104 **|** mobile 530.304.8655
<image001.jpg>

From: Jim Wallace <jimwallace@ecolusa.com>
Sent: Wednesday, June 16, 2021 9:15 PM
To: Grant Davids <grant@davidsengineering.com>; Mary Fahey <mfahey@countyofcolusa.com>; Dave Ceppos <dceppos@ccpcsus.edu>
Subject: Colusa Drain Mutual Proposed Project Management Action for In-lieu groundwater re-charge

Hello Mary, Grant, Dave,

Please find attached a Proposed Project Management Action for In-lieu groundwater recharge proposed by Colusa Drain Mutual Water Company. I would like to add this project to the list presented at last weeks joint TAC meeting. I would also like to include this project as an agenda item at our next TAC meeting with possible action.

With the exception of the direct recharge project on Sycamore Slough, I have not yet seen any of the other projects under consideration. For this project proposal I used the project elements detailed on slide 27 of Grant and Ken's June 11 presentation to the TAC. Let me know if you have questions or comments.

Thanks, JIM

Jim Wallace
jimwallace@ecolusa.com
mobile 530.218.1396

COLUSA SUBBASIN

Colusa Subbasin GSP Projects and Management Actions (PMAs) Submittal Form

Overview

The purpose of this form is to gather ideas for potential projects and management actions (PMAs) that could be evaluated and ultimately included in the Colusa Subbasin GSP. Once ideas are gathered, an initial screening and evaluation process will be conducted, followed by ranking of potential PMAs for more detailed evaluation and inclusion in the initial GSP.

Potential PMAs may fall under several categories, including but not limited to the following:

- Recharge projects
- Supply augmentation projects
- Water conservation projects
- Projects to reduce non-beneficial consumptive use
- Groundwater pumping allocations
- Monitoring programs (groundwater pumping, water levels, stream flows, etc.)

Please provide supporting documentation and/or links to that documentation for each question, if available. **NOTE: It is recognized that much of the requested information may not be available at this time. Please provide as much information as you can.**

Project Name and Contact

Project or Management Action Name:

COR artificial recharge

Contact Person:

Brad Samuelson, Water and Land Solutions on behalf of California Olive Ranch (COR)

Organization/Affiliation (Project Proponent):

California Olive Ranch

Contact Phone:

(209) 658-8487

Contact Email:

bsamuelson@waterandlandsolutions.com

Project or Management Action Description and Status

Project or Management Action Description:

Artificial recharge is proposed at the California Olive Ranch property in Artois. Potential sources of water for recharge are flood flows from White Cabin Creek and Sheep Corral Creek, as well as Section 215 water through Orland-Artois Water District (OAWD). Potential sites for recharge include a retired drainage ditch that borders the property, as well as recharge within the streambed.

Project or Management Action Location (please provide a map if available):

See attached. As shown, the proposed recharge location is within the Orland-Artois Water District.

Which Sustainability Indicator(s) does this Project or Management Action address:

1. Groundwater levels
2. Groundwater Storage
3. Groundwater Quality
4. Land Subsidence
5. Surface Water Interaction

Groundwater levels would be addressed by this project. As shown in draft Figure 3-23 of the Colusa Subbasin GSP, this area showed the greatest decline in groundwater elevations from spring 2006 to spring 2017.

Project or Management Action Status (Conceptual, In Design, Ready for Implementation):

Conceptual

Has a feasibility assessment been conducted? If so, please list the agency and provide the documentation (or provide web link to download).
A feasibility study is currently being scoped and engineering firms are writing proposals to prepare the feasibility study.

Estimated Cost:
TBD

Potential Funding Sources:
TBD

Management Action or Project Yield (e.g. water contributed to the groundwater system, acre-feet per year):
TBD. It is envisioned that recharge would take place in wet years when flood flows are available.

Please describe any required Permitting and Regulatory Process and status of permitting and CEQA/NEPA compliance:
Water rights would need to be acquired if flood flows from White Cabin Creek or Sheep Corral Creek are used.

Does this Management Action or Project serve a disadvantaged community? If so, which one(s)?
N/A

Additional Information Sources:

Other Information:

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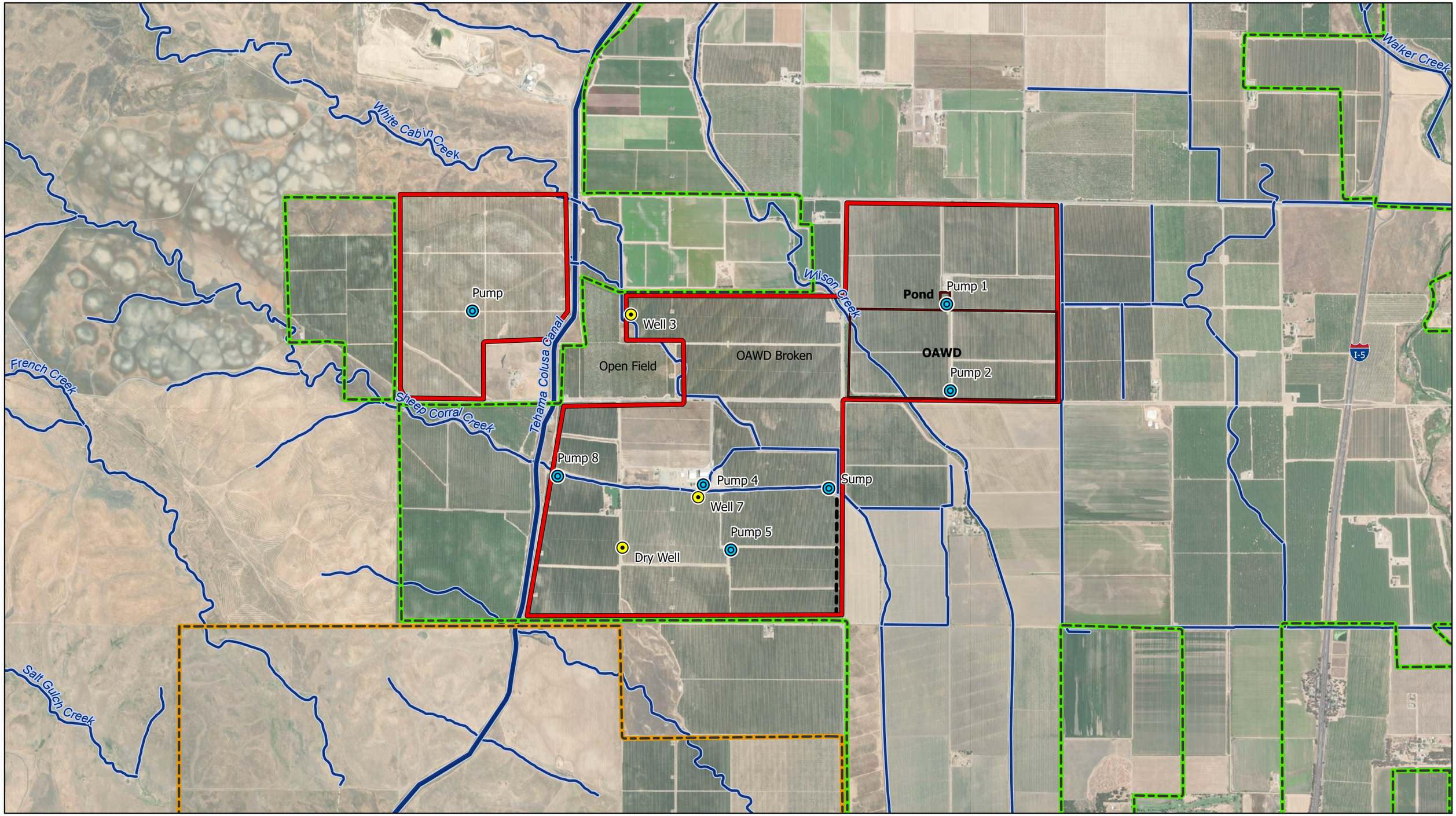

COR 2 Ranch (2,065 ac)
Well
Pump (OAWD)
Drainage Ditch Potential Recharge
Glide Water District
Orland - Artois Water District

N
Scale: 1:25,000
0 0.13 0.25 Miles



California Olive Ranch
COR 2 Ranch

Spatial Reference: NAD 1983
CA State Plane Zone II

Created by: Water & Land Solutions
Date exported: 6/17/2021

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From: Sugar, Sarah@Waterboards
To: Michael Doherty
Cc: Mary Fahey; Kim Vann (kvann@frontiernet.net); Lee, Katherine@Waterboards
Subject: RE: ground water recharge
Date: Wednesday, April 05, 2017 11:53:12 AM
Attachments: image001.png

Hi Michael,

It sounds like an interesting project. Below, I've included: 1) information on the different possible avenues for your project, 2) additional detail on temporary permits for groundwater recharge, 3) some initial thoughts on your proposal, and 4) the next steps for honing in on a clear project description. The e-mail includes a lot of information, so feel free to let me know if you have questions.

1) The first step would be to decide what type of water right permit you're applying for: temporary or standard. A temporary permit application can usually be processed more quickly, but only lasts 180 days and needs to meet certain criteria (urgent need for the water, no injury to downstream users, no unreasonable effects to fish and wildlife). A standard permit application can take several years to process, but generally lasts as long as the water is put to beneficial use. (More information on groundwater recharge and water rights can be found on our webpage: http://www.waterboards.ca.gov/waterrights/water_issues/programs/applications/groundwater_recharge/)

2) Right now, the Division of Water Right filing fees for temp. permit applications for these types of projects have been reduced to $100+, depending on how much water is diverted. One thing to note, however, is that both standard and temporary permits are subject to environmental review under the California Environmental Quality Act (CEQA), which can take some time to complete. CEQA is currently suspended for some temporary permits for recharge projects by local or state agencies while the Drought State of Emergency is in effect, but not for projects by private entities. However, a private entity may be able to partner with a public agency to qualify for the CEQA suspension.

   We have a webpage that outlines the temporary permit process and gives tips on how to avoid potential delays: http://www.waterboards.ca.gov/waterrights/water_issues/programs/applications/groundwater_recharge/tips_for_filing.shtml.

3) When applying for a temporary or standard permit, you will need to specify:
   a. the point of diversion (where you would set up the pump)
   b. a diversion season (when you'll pump water from the creek)
   c. the maximum diversion rate (one option is to propose the capacity of the pump)
   d. the maximum amount of water you would divert each season
   e. the area that will be used for recharge (the gravel excavation sites)
   f. the place of use and purpose of use of the water: groundwater recharge is a type of storage, not a beneficial use, so the application will need to specify how the recharged water will ultimately be used. If you already use groundwater on your ranch, the place of use might be the ranch itself, and the purpose(s) of use could be irrigation, domestic use and/or stockwatering, for example.

   Other questions that could come up during our review are:
   a. When were you planning to start diversions (this spring, next winter, or later)?
   b. How high are "high flows", how was that determined, and how will you know flows are high enough to start diverting?
   c. Are there existing water rights for the ponds at the gravel excavation site?
   d. If the gravel excavation site is close to Sand Creek, how does the groundwater basin interact with Sand Creek? Depending on water table levels and gradients, there is a possibility of recharged water returning to the stream as flow, rather than remaining available in the groundwater basin. Or, during high flows, water levels in Sand Creek may already contribute water to the gravel ponds.
   e. Is there information on water table depth or groundwater movement near the recharge site?
   f. Are there downstream water users with a right to the water, or fish and wildlife species that might be affected?

4) If you'd like, we could start by discussing your basic project and initial questions by phone, then set up an in-person meeting or site visit when the project description is fleshed out. We also strongly recommend looping in the California Department of Fish and Wildlife early in the process, in case changes to the project description are necessary to reduce impacts on fish and wildlife. The water rights contact for Department of Fish and Wildlife for Colusa County is Lauren Mulloy, available at (916) 358-2909, or lauren.mulloy@wildlife.ca.gov.

Again, I'm happy to answer any questions on process, fees, or your particular project be e-mail or phone.

Regards,

Sarah Sugar
Environmental Scientist
Division of Water Rights
State Water Resources Control Board
Office: (916) 341-5426
Sarah.Sugar@waterboards.ca.gov



From: Michael Doherty [mailto:mike@chamisalcreek.com]
Sent: Monday, April 03, 2017 5:22 PM
To: Sugar, Sarah@Waterboards
Cc: Mary Fahey; Kim Vann (kvann@frontiernet.net)
Subject: ground water recharge

Sarah,

My name is Michael Doherty and I am a farmer/landowner in Arbuckle, south western Colusa County. I am very interested in pursuing a small scale ground water recharge project that I believe has great merit and could be a template for more projects in Northern California. My ranch is adjacent to Sand Creek which during the winter can have high flows of drain water that make it to the Colusa Basin Drain and eventually to the Sacramento River. My thought is to divert water during these high flows and hold the water so it can percolate into the groundwater basin. I would hold the water in some ponds on my property that are gravel bottomed. These ponds are really old gravel excavation sites from the previous landowner. They are not currently farmable and would be perfect for this use. There is a product called a Riverscreen pump that only needs 4 inches of water depth to function. I would put the pump into the creek at high flows and remove it when the flows are too low.

I understand the Governor himself is very interested in projects such as this and has encouraged them.

I would love to speak with you in person about this project. I am also available to show or set up a tour when needed.

Looking forward to hearing from you.

Chamisal Creek Ranch LLC.

Michael F. Doherty
1167 Cortina School Road
P.O. Box 157
Arbuckle, Ca 95912
Home 530-476-3538
Fax 530-476-3168
Cel 530-681-8204

Ephemeral Stream Recharge Field Notes

Date: 11/19/19
Participants: Mary Fahey, Bill Vanderwaal, Halbert Charter, David Henriques (Charter Oaks), Steffen M. (Chico State), Jeff Davids

General notes

1. Two different scales and approaches to managed aquifer recharge are described below. In both cases, the potential water sources are the same:
    a. Imported surface water (e.g. 3F or 215 USBR water (surplus water))
    b. Locally generated runoff in ephemeral streams and swales
    c. Mixture of the two
2. Regardless of the water supply or project conceptualization, it is critical to understand:
    a. Availability of water for recharge (in space and time)
    b. Ability to recharge available water (limited by infrastructure, land area, and infiltration rates)
3. There are also important policy and legal questions including:
    a. How will credits for groundwater recharge work?
    b. Are there any water rights concerns over impacts to downstream water users?
    c. What is the permitting process for agricultural managed aquifer recharge?

Sand Creek Project(s)

On Sand Creek, there appears to be two basic long-term project concepts, which are not mutually exclusive (i.e. the first could be part of the second):

1. Diversion of Salt Creek water during storm events (or runoff from agricultural fields or CCWD water) and application to nearby lands
    a. Michael Doherty's gravel pit to the north of Sand Creek and east of Cortina School Road may be a good place to start.
    b. Currently, runoff from field(s) to the west of Cortina School Road is diverted into the gravel pit.
    c. It may be possible to fill portions of the gravel pit with Colusa County Water District (CCWD) water from the delivery point near the northwest portion of the gravel pit.
        i. There may be some water rights issues to utilizing CCWD water for recharge
    d. In the long run, infrastructure to move water from Salt Creek into the gravel pit would be necessary and could involve either:
        i. A gravity diversion from Salt Creek upstream of Cortina School Road, an open channel to convey water to the gravel pit, and a spillway/return flow to Salt Creek from the southeastern corner of the gravel pit or
        ii. A pumped diversion from Salt Creek along with an appropriate screening facility and pipeline.
    e. Suggested next steps:

i. Determine area of agricultural lands currently draining to the gravel pit
ii. Measure runoff from these lands to the gravel pit
    1. Depending on the range of flows, either a weir box (like the one that Hal is using) on the end of the pipe can be used for measurements (this works for low flows). If higher flows are anticipated, the weir box is still helpful to keep a full pipe, but a hydroacoustic meter (e.g. SonTek IQ) should be installed.
iii. Measure infiltration capacity of several different locations within the gravel pit with:
    1. Large scale USBR ponding seepage tests
    2. Small scale double ring infiltrometer tests
iv. Perform detailed topographic survey of gravel pit and Sand Creek to facilitate conceptual design of necessary diversion and conveyance infrastructure
v. Measure rainfall and runoff from Sand Creek
vi. Draft a conceptual plan for increased utilization of the gravel pit for groundwater recharge
    1. This would include more accurate estimates of recharge potential
    2. Cost estimates for different configurations (i.e. gravity diversion vs. pumped)
vii. If these steps are of interest to the group, CSU Chico could prepare a more detailed proposal for the Agricultural Research Institute funding, and willing partners could help provide the necessary match (i.e. 25% cash and 100% total (in-kind + cash).
viii. We would also need to find a partner/student to investigate the identified policy

2. Lower Salt Creek River Restoration, Grade Control, and Recharge Project
    a. This would be a significantly larger and more complicated project involving multiple partners with multiple objects (objectives?).
    b. Objectives
        i. Decreased gravel migration and stream incision
        ii. Reduced flood flows
        iii. Restored channel grade and riparian corridor
        iv. Increased groundwater recharge
    c. Methods
        i. Construction of additional grade control structures similar to the Sand Creek Road low water crossing approximately 2.5 miles west of Cortina School Road.
        ii. Restoration of streambed materials and grade in incised locations
        iii. Diversion of runoff outside of Sand Creek for application to areas with high recharge potential (like)
        iv. The stair-stepped grade control structures would service the purposes of:
            1. Slowing water velocities in the channel
            2. Reducing gravel migration and associated downstream impacts
            3. Increasing water storage and residence time, thus decrease peak flood flows

4. Increasing recharge upstream of grade control structures
5. Allowing gravity diversions from Sand Creek to adjacent recharge projects (e.g. Michael Doherty's sand pit described above)

d. Possible partners
   i. Caltrans
   ii. Railroad
   iii. Colusa County (water resources, public works)
   iv. Colusa Basin Drainage District
   v. TNC, EDF, or ???
   vi. CSU Chico
   vii. Colusa GSA
   viii. Colusa County RCD
   ix. Landowners
e. Possible next steps
   i. Pitch the idea to potential project partners to gauge interest
   ii. Caltrans and the railroad might be the most interested because of the impact to their operations from ongoing flooding and gravel migration issues that cause the roadways/railways to be closed.
   iii. CSU Chico could play a role in understanding the hydrology, geomorphology, and recharge potential from the project, but this would require a longer term project and ongoing monitoring and investigation.

Smaller Distributed Landowner-Led Recharge Projects

1. In addition to larger publicly funded recharge projects, there may also be opportunities for landowners to construct and operate smaller recharge projects. (This could be done with incentives from the GSAs)
2. Water source
   a. Imported surface water (e.g. 3F or 215 USBR water (surplus water))
   b. Locally generated runoff in ephemeral streams and swales
   c. Mixture of the two
3. Design
   a. Constructed within existing drainage ways or in other higher permeability areas
   b. Open to the atmosphere (i.e. spreading basin) or closed (e.g. infiltration pit)
4. Water Quantity Monitoring
   a. It is critical that incremental recharge (i.e. before and after the project(s)) be measurable.
   b. Generally, directly measuring recharge will not be possible, so a water balance approach involving measuring all other inflows and outflows needs to be used to solve for recharge (i.e. recharge = inflows - outflows)
   c. If possible, inflows and outflows should be measured with a standard flow device, as described in the USBR Water Measurement Manual.
      i. Smaller full-pipe flows can be reliably measured with magnetic meters (e.g. Seametrics)

ii. Larger open channel flows can be measured with critical flow devices (e.g. weirs or flumes) and measurement of water level (e.g. Seametrics pressure transducers). For flumes and weirs, it is best to have a low range sensor (e.g. 2.3 feet or 1 PSI) with high accuracy ± 0.01 feet, such as the low pressure range Seametrics PT2X pressure transducer.

iii. When insufficient head is available, or if the range of possible flows is too great, an Acoustic Doppler Velocimeter (e.g. SonTek) can be used.

iv. If the recharge facility is open to the atmosphere, evaporation losses should be accounted for, especially if they are operated during the hot and dry summer months (see USGS Estimation of evaporation from open water).

5. Water Quality Monitoring
    a. The quality of recharged water should be measured to understand potential water quality impacts from additional recharge.

May 10th, 2021

Halbert W. Charter

6682 Greenbay Rd.

Arbuckle, Ca. 95912

Cell: 530-867-4003

Email: hcharter69@gmail.com

To Whom It May Concern:

H&A Charter Farms successfully completed construction of a ground recharge project in the fall of 2019. This pilot project recharges water at a rate of 30-40 gallons per minute (gpm). The idea of this project was to realize proof of concept for implementing larger scaled projects of similar design at different locations on the ranch. We feel confident that after recharging nearly 1.5 million gallons of water to date, that the concept is sound and the next project will be scaled to recharge at least 150-250 gpm. The basic concept is to copy the design of a residential leach field, but supersize it.

Much of the area we farm in the Southwest corner of Colusa County, consists mostly of low foothills. It is widely known that many of these ridges are well drained and deep in gravel alluvium. With careful design, I now know that we can capture storm water runoff that flows through our orchards and allow the water to recharge back into the aquifer. When it is not raining outside, I can meter district water into the recharge structure. Currently, I am paying Colusa County Water District rates for this water. If the expectation is to meet groundwater sustainability, there is going have to be consideration to figure out a way to get the cost of recharge water at a reduced rate. I do imagine a day where the fee structure developed for the water being extracted helps offset the cost of recharge water. I hope this day is coming sooner rather than later.

This idea, and ideas like it, that capture storm water runoff and utilize surface water for groundwater recharge show benefits that cannot be denied. What is needed to move forward, is an acknowledgement of the benefit and the policy that provides assurance that the water that is recharged into the ground will be able to be utilized on our farm at a later date, like a savings account. If you have any questions, please contact me.

Thank You,



Halbert W. Charter















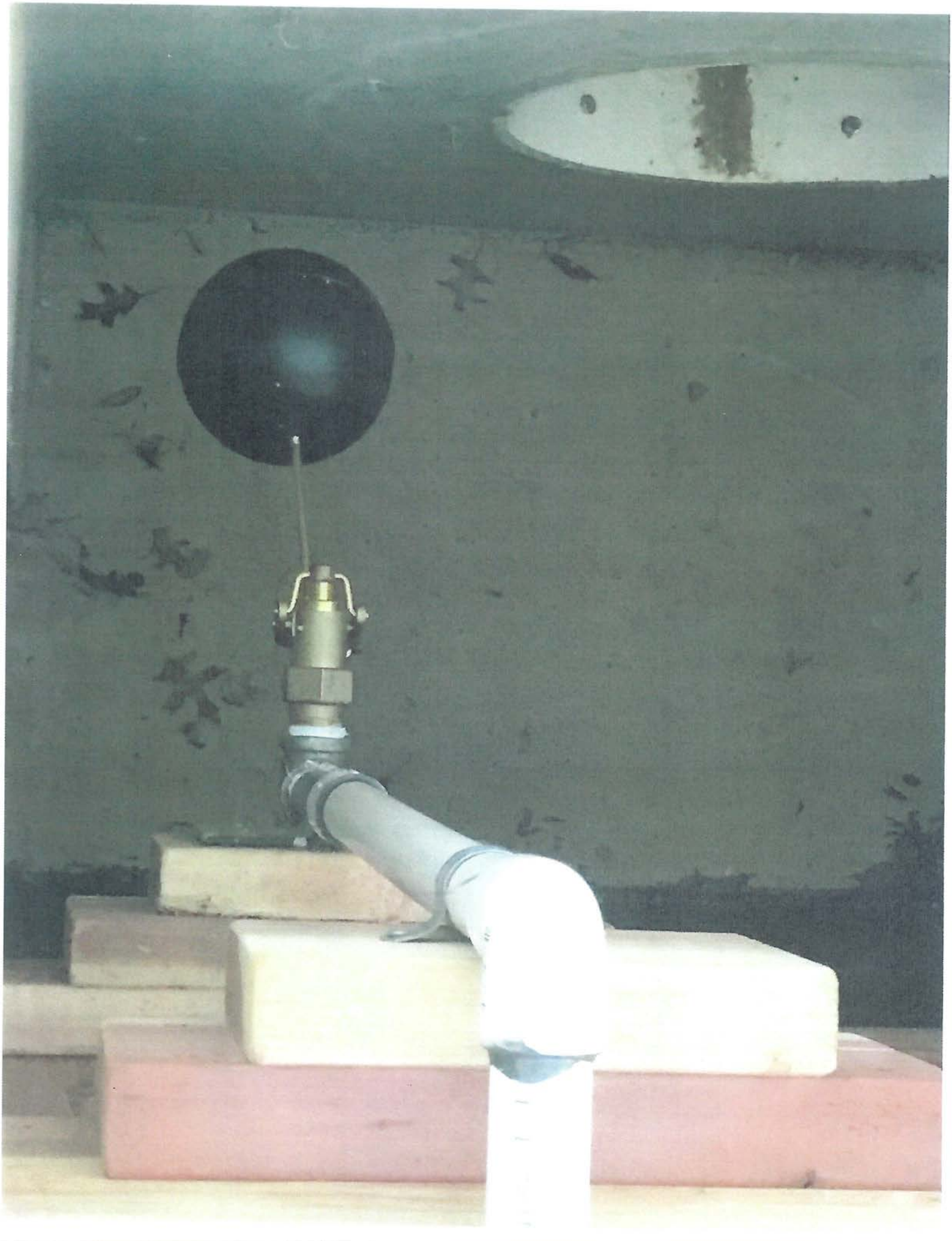









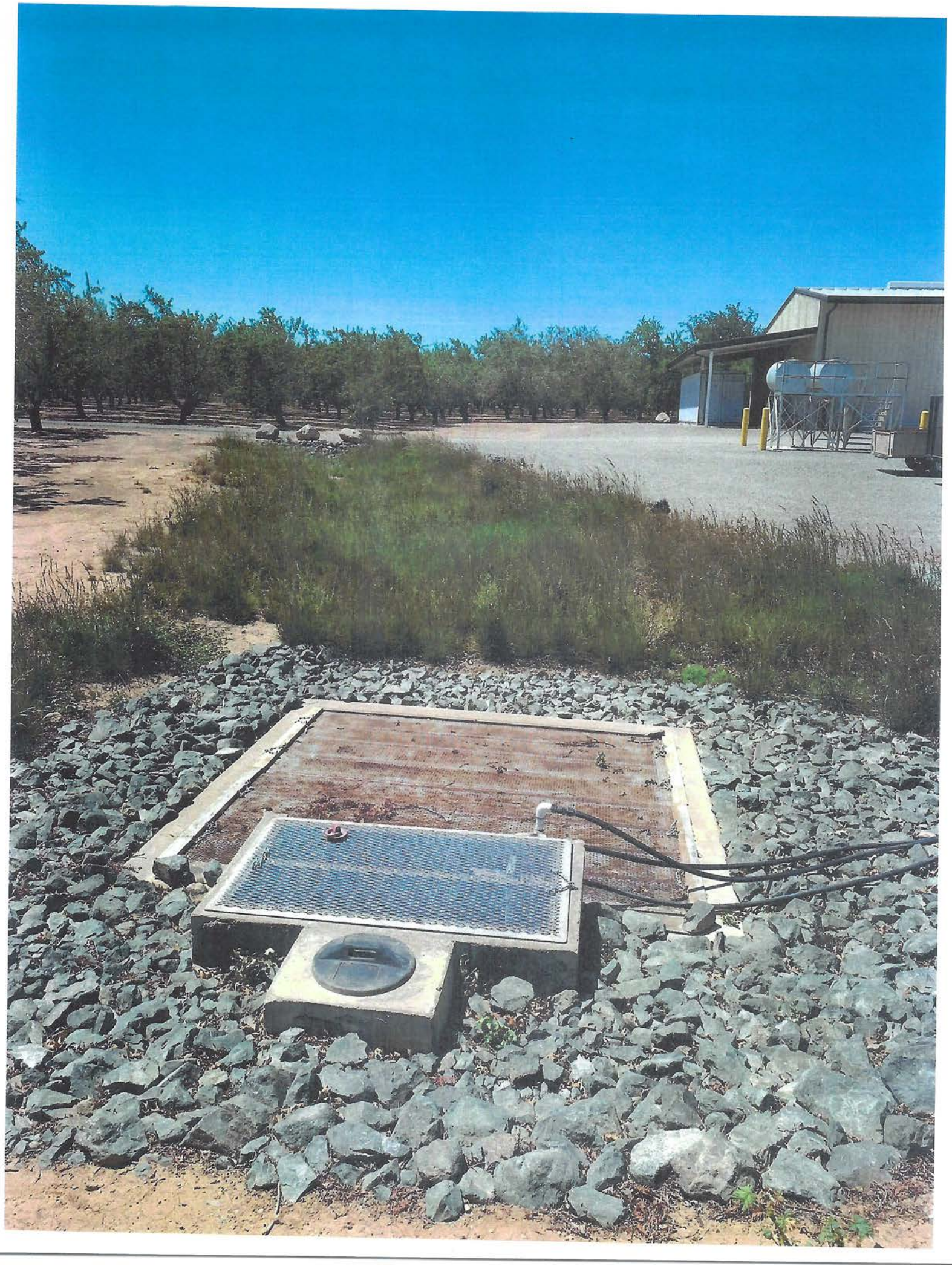

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Byron Clark

From: Mary Fahey <mfahey@countyofcolusa.com>
Sent: Friday, January 22, 2021 7:31 AM
To: DeBow, Danaka N; Ceppos, David M; Byron Clark
Cc: Lisa Hunter
Subject: FW: Colusa County Water Filtration Plant
Attachments: Colusa County Water Filtration Plant.pdf

Follow Up Flag: FollowUp
Flag Status: Flagged

FYI – our first project submittal for CGA. Do we have a depository set up for PMAs?
Thank you,
Mary

From: Ben King [mailto:bking@pacgoldag.com]
Sent: Thursday, January 21, 2021 11:28 AM
To: Mary Fahey <mfahey@countyofcolusa.com>
Cc: Ben King <bking@pacgoldag.com>; Susan Meeker <susan@colusacountynews.net>
Subject: Colusa County Water Filtration Plant

CAUTION: This email originated from outside of the organization. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Hi Mary,

Attached is a Colusa Basin GSP Project recommendations.

I believe that Colusa County needs a fresh water supply from the Sacramento River to guarantee the residents of Colusa County the human right to fresh drinking water, to preserve housing values and promote economic sustainability through growth that will come with future sustainable fresh water supplies. As you know the City of Davis and City of Woodland just installed a filtration plant and this project would give the residents of Colusa County the same access that the State and other policy makers facilitated for Yolo County residents.

As you know the public water systems of Grimes and Princeton have arsenic contamination above EPA standards. The City of Colusa has abandoned two wells due to arsenic contamination and faces future contamination from arsenic and diminished potability due to salt water intrusion into the public water system of Colusa. Williams faces a very uncertain future because it water supply aquifer is surrounded by no potable salt water and faces the risk of future deterioration in potability due to over pumping cased by groundwater substitution and contamination from future recharge projects which could harm potability or lead to contamination from nitrates and other man made contaminants. Arbuckle faces a lack of supply of fresh groundwater and faces the specter of contamination of its public supply due to over pumping and recharge projects necessary to prevent future subsidence.

My proposal is to coalesce around a filtration plant for the County while funding is available and interest rates are low. This timing of this effort may be urgent because it will need political support to benefit from likely Federal infrastructure program.

I will have two more Project recommendations – can you tell me the deadline for submittals?

Thank you for your consideration.

Best Regards,

Ben

COLUSA SUBBASIN

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- Recharge projects
- Supply augmentation projects
- Water conservation projects
- Projects to reduce non-beneficial consumptive use
- Groundwater pumping allocations
- Monitoring programs (groundwater pumping, water levels, stream flows, etc.)

Please provide supporting documentation and/or links to that documentation for each question, if available. **NOTE: It is recognized that much of the requested information may not be available at this time. Please provide as much information as you can.**

Project Name and Contact

Project or Management Action Name: Sycamore Slough Colusa Basin Drain Multi-benefit Recharge Project

Contact Person: Ben King

Organization/Affiliation (Project Proponent): Stakeholder

Contact Phone: (530) 723-3119

Contact Email: bking@pacgoldag.com

Project or Management Action Description and Status

Project or Management Action Description: Voluntary Landowner participation in restoring stretches of the Sycamore Slough as part of a newly formed water storage district. The Sycamore Slough ran parallel on the east side of the Colusa Basin Drain from slightly north of Tule Road all the old Farnsworth Ranch before running more east west towards the Sacramento River. Excess flows winter natural flows could be diverted from the Colusa Basin Drain for recharge as part of a water storage district and restoration could include a multi-benefit focus

for monarch butterfly and other pollinator habitat restoration. Other multi-benefits could also be included.

Project or Management Action Location (please provide a map if available): East of the Colusa Basin Drain from approximately .5 miles north of the intersection of the Colusa Basin Drain northward. Basically south end of old Balsdon Ranch north to old Farnsworth Ranch. See attached Map

Which Sustainability Indicator(s) does this Project or Management Action address:

1. Groundwater levels Yes – winter recharge
2. Groundwater Storage Yes – natural levee of Sycamore Slough has high recharge capacity
3. Groundwater Quality Yes - this will provide fresh water recharge – new deep wells are being constructed with likely long term groundwater degradation due to the present of salt water and possibly arsenic from the Sutter Buttes Rampart.
4. Land Subsidence – Yes – this area was part of a fresh water lake during the lacustrine period of the Sacramento Valley and may have Corcoran like clay stratas that may dewater due to the deep wells being drilled in the area.
5. Surface Water Interaction

Project or Management Action Status (Conceptual, In Design, Ready for Implementation): Conceptual

Has a feasibility assessment been conducted? If so, please list the agency and provide the documentation (or provide web link to download). No – will take landowner involvement and participation

Estimated Cost: Unknown but not prohibitive - some areas of the Sycamore Slough are still in place and existing diversion infrastructure from the Colusa Basin Drain could be used.

Potential Funding Sources: State Water Bonds if Multi-benefit projects could be included.

Management Action or Project Yield (e.g. water contributed to the groundwater system, acre-feet per year): 1000 to 5000 acre feet

Please describe any required Permitting and Regulatory Process and status of permitting and CEQA/NEPA compliance: Yes – application to the SWRCB similar to the Yolo County Flood District Project

Does this Management Action or Project serve a disadvantaged community? If so, which one(s)? Yes – Grimes/College City environs

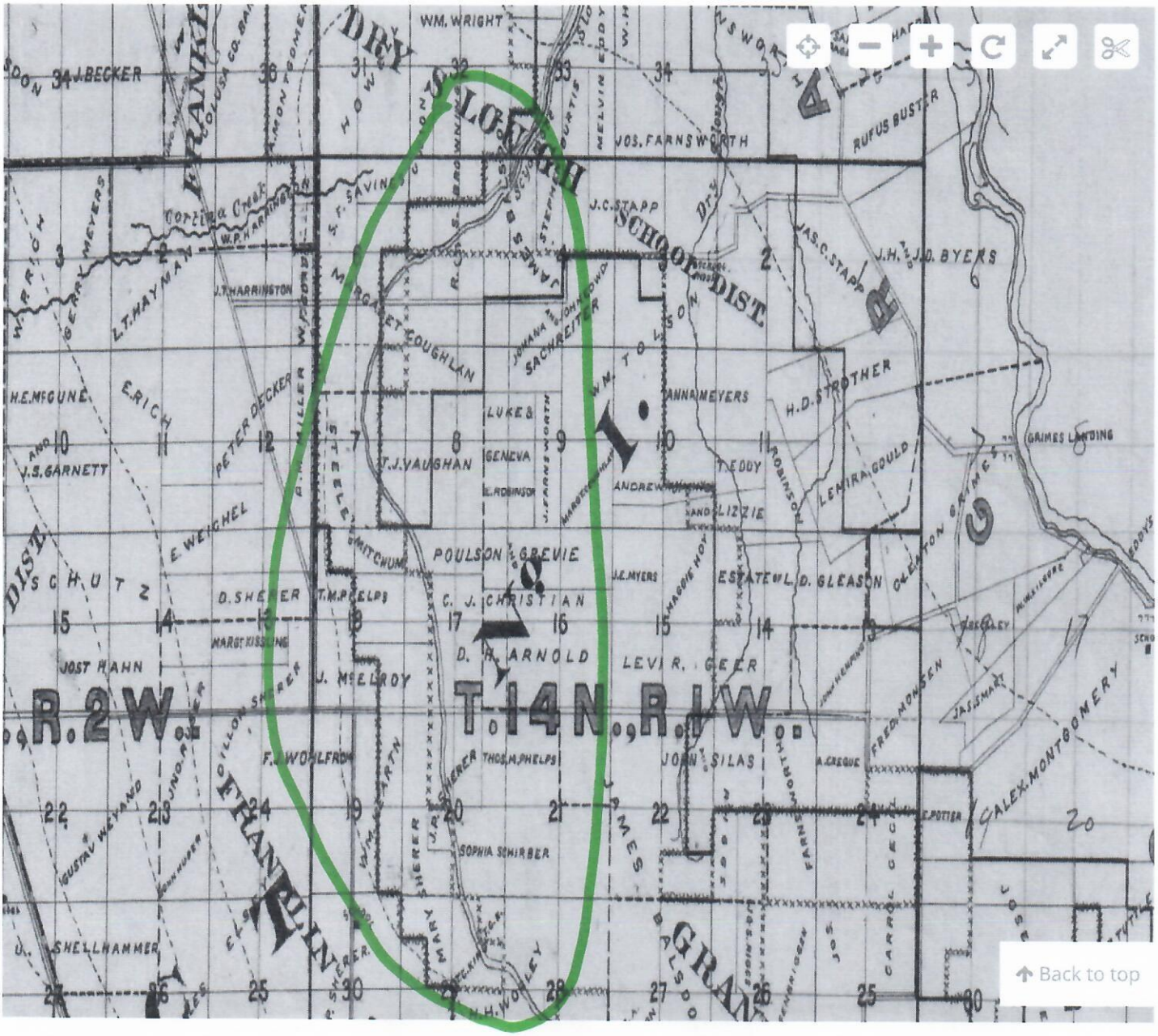
Additional Information Sources: Landowner Group should engage UC Davis Hydrology Department and Ag Extension.

Other Information:

MAP

Official map of Colusa County, California. : compiled and drawn from official surveys and records Copy 1

« About this Item



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Please provide supporting documentation and/or links to that documentation for each question, if available. **NOTE: It is recognized that much of the requested information may not be available at this time. Please provide as much information as you can.**

Project Name and Contact

Project or Management Action Name: Colusa County Public Water System Water Filtration Plant

Contact Person: Ben King

Organization/Affiliation (Project Proponent): Stakeholder

Contact Phone: (530) 723-3119

Contact Email:bking@pacgoldag.com

Project or Management Action Description and Status

Project or Management Action Description: Build a water filtration plant on the Sacramento River between Colusa and Grimes to provide fresh drinking water to public water supply systems in Colusa and possibly Sutter and Yolo Counties.

Project or Management Action Location (please provide a map if available): Near Grimes with access to Colusa and Princeton on Hwy 45 access or old railroad easement. Access to Williams, Arbuckle, Maxwell and Dunnigan across Hahn Road, Tule Road or through Colusa and west via Lurline Road and then north/south via old Hwy 99 easement. Possible extension across river to

Meridian and Sutter. This is just conceptual with no discussion but the perfect site probably COLUSA SUBBASIN 12/22/2020 2

would be to work with Davis Ranches and purchase water rights from Sycamore Mutual or other Settlement Contractors. Use the Conway JPA as the proto-type

Which Sustainability Indicator(s) does this Project or Management Action address:

1. Groundwater levels **Arbuckle & potentially Dunnigan face loss of well supply**
2. **Groundwater Storage**
3. Groundwater Quality **Fresh Drinking water is a human right. Grimes and Princeton have arsenic contamination – Colusa has abandoned wells and faces the risk of arsenic contamination. Williams has elevated levels of dissolved solids and faces an uncertain future for a potable water supply**.
4. Land Subsidence **Groundwater Recharge and therefore potential contamination needed to mitigate Subsidence near Arbuckle**.
5. Surface Water Interaction

Project or Management Action Status (Conceptual, In Design, Ready for Implementation):

Conceptual

Has a feasibility assessment been conducted? If so, please list the agency and provide the documentation (or provide web link to download).
No

Estimated Cost:
$250 to $ 400 million

Potential Funding Sources:
Prop 1, Prop 218, EPA Funding – new Federal Infrastructure Bill.

Management Action or Project Yield (e.g. water contributed to the groundwater system, acre-feet per year): Recharge projects west of Arbuckle and Williams probably are not feasible without a safe supply of drinking water since these projects at higher elevations would likely contaminate the public supply. Settlement Contractor groundwater substitution pumping near Colusa, Princeton and Grimes are likely causing arsenic to move upward into the aquifers of the public supply systems – this system will mitigate that risk and the risk of recharge projects near the public supply systems.

Please describe any required Permitting and Regulatory Process and status of permitting and CEQA/NEPA compliance: YES

Does this Management Action or Project serve a disadvantaged community? If so, which one(s)? Yes – some of this area is/are SDACs.

Additional Information Sources:

See USGS Circular 1358 "Water Quality in Basin-Fill Aquifers of the Southwestern United State: Arizona, California, Nevada, New Mexico and Utah, 1993 by Susan A. Thiros, Angela P. Paul, Laura M. Bexfield and David W. Anning 2014. https://pubs.usgs.gov/circ/1358

USGS predictive model validates empirical evidence of arsenic contamination highlighted in the Sutter County GMP, EPA remediation site at Robbins, Grimes and Princeton. Arsenic desorbs from volcanic rock such as the Sutter Buttes into groundwater in both anoxic and high PH environments.

Dissolved soild issues likely to increase for Williams public supply system due to increase groundwater substitution pumping. 6/16 GCID wells are pumping brackish water near the William supply aquifer. Proposed recharge projects that will be integrated into the TC Canal – Sites interconnect will also lead the lateral movement of nitrates and higher concentrations of dissolved solids into the public supply systems for Williams and Arbuckle.

Other Information: Documents previously sent to Mary Fahey.

See- "Sutter-Yuba Counties Investigation "SWRCB Bulletin No. 6 September 1952 See Table 20 Page 36 for multiple brackish groundwater observations made from 1931 to 1947. See last paragraph on Page 38 regarding fresh water aquifer contamination caused by groundwater pumping. This is empirical evidence of the presence of brackish groundwater for over 100 years in groundwater flow path from volcanic geologic structure of the Sutter Buttes. Robbins is an intuitive discharge site for arsenic due to its location south of the Buttes and because the significant lower elevation due to the natural slope of the Valley.

See- "Hydrogeology Of The Sutter Basin, Sacramento Valley, Calfornia by George Curtin 1971. Discussion regarding the presence of connate or anoxic seawater in the volcanic geologic structure of the Sutter Buttes and the uncertain vertical depths of the fresh water aquifer overlying the Colusa Dome adjoining formation. See page 49 – 2nd Paragraph regarding the mound of saline water between the Buttes and the City of Colusa.

See -Sutter County Groundwater Management Plan. See general discussion concerning movement of arsenic on top of the stratigraphy of the Sutter Buttes Rampart and Figures 5 and 19 regarding the location of the Willows Fault and observed EC and Arsenic levels. Observed arsenic as high as 370 ug/L south of Sutter Buttes.

COLUSA SUBBASIN

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- Projects to reduce non-beneficial consumptive use
- Groundwater pumping allocations
- Monitoring programs (groundwater pumping, water levels, stream flows, etc.)

Please provide supporting documentation and/or links to that documentation for each question, if available. **NOTE: It is recognized that much of the requested information may not be available at this time. Please provide as much information as you can.**

Project Name and Contact

Project or Management Action Name: **Sycamore Marsh Farm Recharge Project**

Contact Person: **Charles Marsh**

Organization/Affiliation (Project Proponent): **Sycamore Marsh Farm**

Contact Phone:**530 682 9881**

Contact Email: **sycamoremarshfarm@gmail.com**

Project or Management Action Description and Status

Project or Management Action Description:

Sycamore Marsh Farm has been in process of developing a groundwater recharge plan to store water in our aquifer by several different methods. The plan provides for 205 acres of year round recharge basins and 163 additional acres of winter recharge areas.

The fall/winter program entails impounding winter runoff in basins on our farm to eliminate or minimize runoff during winter rain events. In addition, we will supplement the rainfall with surface water supplies from the 2047 Canal to flood fields the Colusa Drain Mutual Water

Company and impound that water for recharge. This recharge program begins soon after crops are harvested.

Both methods of recharge have multiple benefits in addition to recharge. First, the recharge basins will provide habitat for waterfowl and migratory shorebirds. For many years, there has been an effort by multiple agencies to encourage these "pop up wetlands". These man made habitats provide additional winter bird food and resting sites. In addition, these sites spread out the migrating birds, potentially minimizing disease pressure among the bird populations.

Our summer program utilizes the same basins and fields as the winter program, however, recharge is obtained by use of surface water to irrigate crops or provide recharge whenever possible.

In addition, any runoff is captured in basins located in the lowest elevation of the farm and held in order to percolate into the aquifer. We are also exploring the use of post harvest application of surface water to the fields whenever possible to add to seasonal recharge.

Enclosed are maps of the proposed recharge areas. The maps show the diversion points of the 2047 canal for surface water and proposed capture basins.

Additional benefits of the project:

Greenhouse gas reduction

Reduction of sediment loading in the Colusa Basin Drain and the Sacramento River

Project or Management Action Location (please provide a map if available):

Sycamore Marsh Farm, see attached map.

Which Sustainability Indicator(s) does this Project or Management Action address:

1. Groundwater levels
2. Groundwater Storage
3. Surface Water Interaction

Project or Management Action Status (Conceptual, In Design, Ready for Implementation):

The project is ready for implementation.

Has a feasibility assessment been conducted? If so, please list the agency and provide the documentation (or provide web link to download).
No

Estimated Cost:
Pipeline from Diversion Point 2 to Recharge Basin 2 $200,000
Additional operational and maintenance expenses unknown at this time

Potential Funding Sources:
Landowners, CGA, NGO's (The Nature Conservancy and other), Prop 1 grant funding

Management Action or Project Yield (e.g. water contributed to the groundwater system, acre-feet per year):
Unknown at this time.

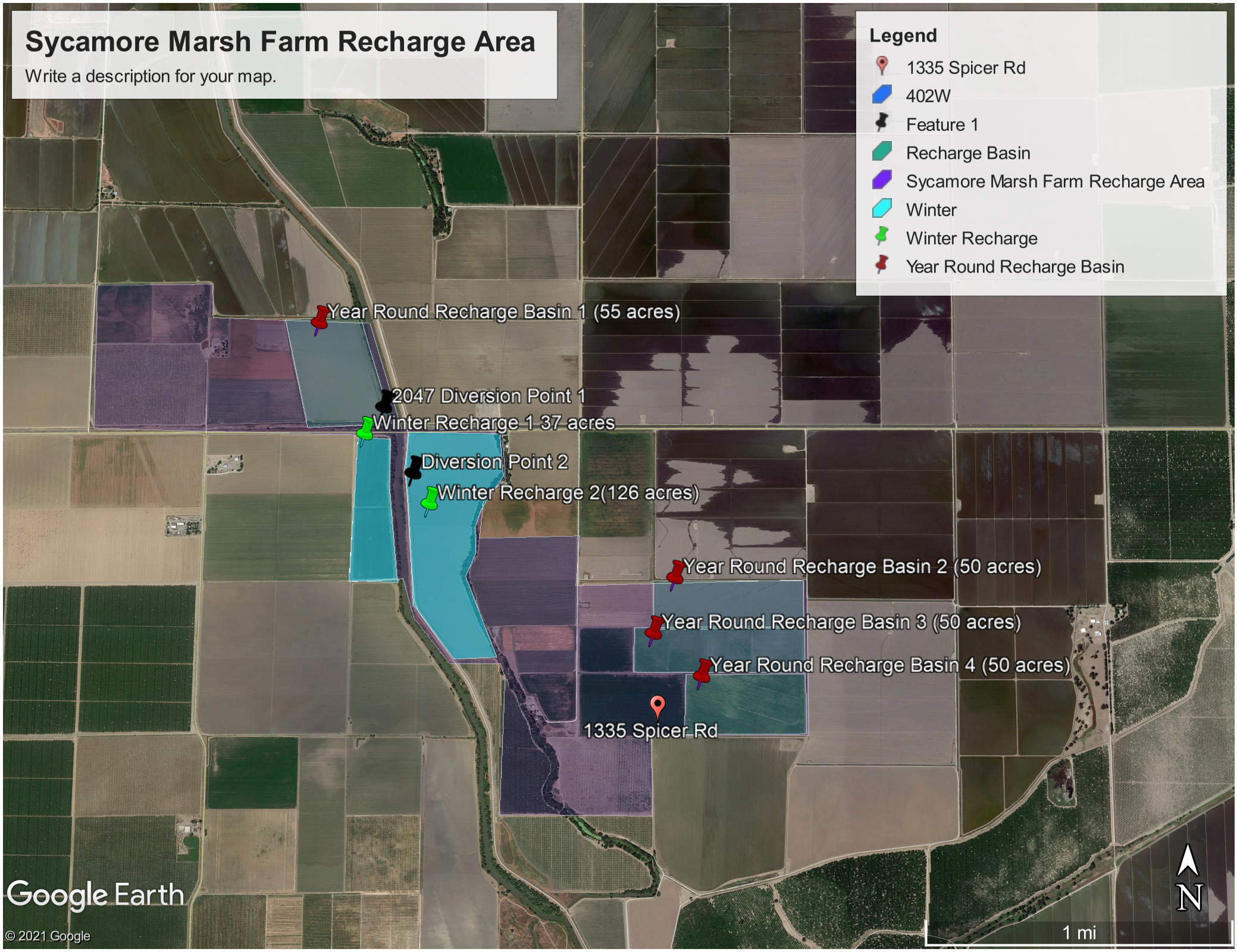
Please describe any required Permitting and Regulatory Process and status of permitting and CEQA/NEPA compliance:
Unknown at this time, but a supplemental permit for water storage from State Water Resource Control Board will be needed.

Does this Management Action or Project serve a disadvantaged community? If so, which one(s)?
No.

Additional Information Sources:

Other Information:

This project provides many benefits in addition to groundwater recharge/storage. Potential benefits include reduced sediment loading into the 2047 Canal and Sacramento River, increased habitat for migratory shorebirds, and reduced greenhouse gas emissions from reduced pumping from Reclamation District 479.


Sycamore Marsh Farm Recharge Area
Write a description for your map.
Legend
1335 Spicer Rd
402W
Feature 1
Recharge Basin
Sycamore Marsh Farm Recharge Area
Winter
Winter Recharge
Year Round Recharge Basin
Year Round Recharge Basin 1 (55 acres)
2047 Diversion Point 1
Winter Recharge 1 37 acres
Diversion Point 2
Winter Recharge 2(126 acres)
Year Round Recharge Basin 2 (50 acres)
Year Round Recharge Basin 3 (50 acres)
Year Round Recharge Basin 4 (50 acres)
1335 Spicer Rd
Google Earth
© 2021 Google
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COLUSA SUBBASIN

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- Water conservation projects
- Projects to reduce non-beneficial consumptive use
- Groundwater pumping allocations
- Monitoring programs (groundwater pumping, water levels, stream flows, etc.)

Please provide supporting documentation and/or links to that documentation for each question, if available. **NOTE: It is recognized that much of the requested information may not be available at this time. Please provide as much information as you can.**

Project Name and Contact

Project or Management Action Name: **Sycamore Marsh Farm Recharge Project**

Contact Person: **Charles Marsh**

Organization/Affiliation (Project Proponent): **Sycamore Marsh Farm**

Contact Phone:**530 682 9881**

Contact Email: **sycamoremarshfarm@gmail.com**

Project or Management Action Description and Status

Project or Management Action Description:

Sycamore Marsh Farm is in process of developing a in lieu groundwater recharge plan.

Sycamore Marsh Farm encompasses approximately 420 acres in the Colusa Drain Mutual Water Company (CDMWC) and has an additional 449 acres that could potentially be annexed into the CDMWC. The acreage is composed of agricultural production and environmental habitat.

Sycamore Marsh Farm can divert water from the CDMCW to provide in lieu groundwater recharge.

Greenhouse gas reduction from reduced groundwater pumping

Project or Management Action Location (please provide a map if available):

Sycamore Marsh Farm, see attached map.

Which Sustainability Indicator(s) does this Project or Management Action address:

1. Groundwater levels
2. Groundwater Storage

Project or Management Action Status (Conceptual, In Design, Ready for Implementation):

The project is ready for implementation.

Has a feasibility assessment been conducted? If so, please list the agency and provide the documentation (or provide web link to download).
No

Estimated Cost:
Additional operational and maintenance expenses unknown at this time

Potential Funding Sources:
CGA, NGO's (The Nature Conservancy and other), Prop 1 grant funding, landowners

Management Action or Project Yield (e.g. water contributed to the groundwater system, acre-feet per year):
Unknown at this time.

Please describe any required Permitting and Regulatory Process and status of permitting and CEQA/NEPA compliance:

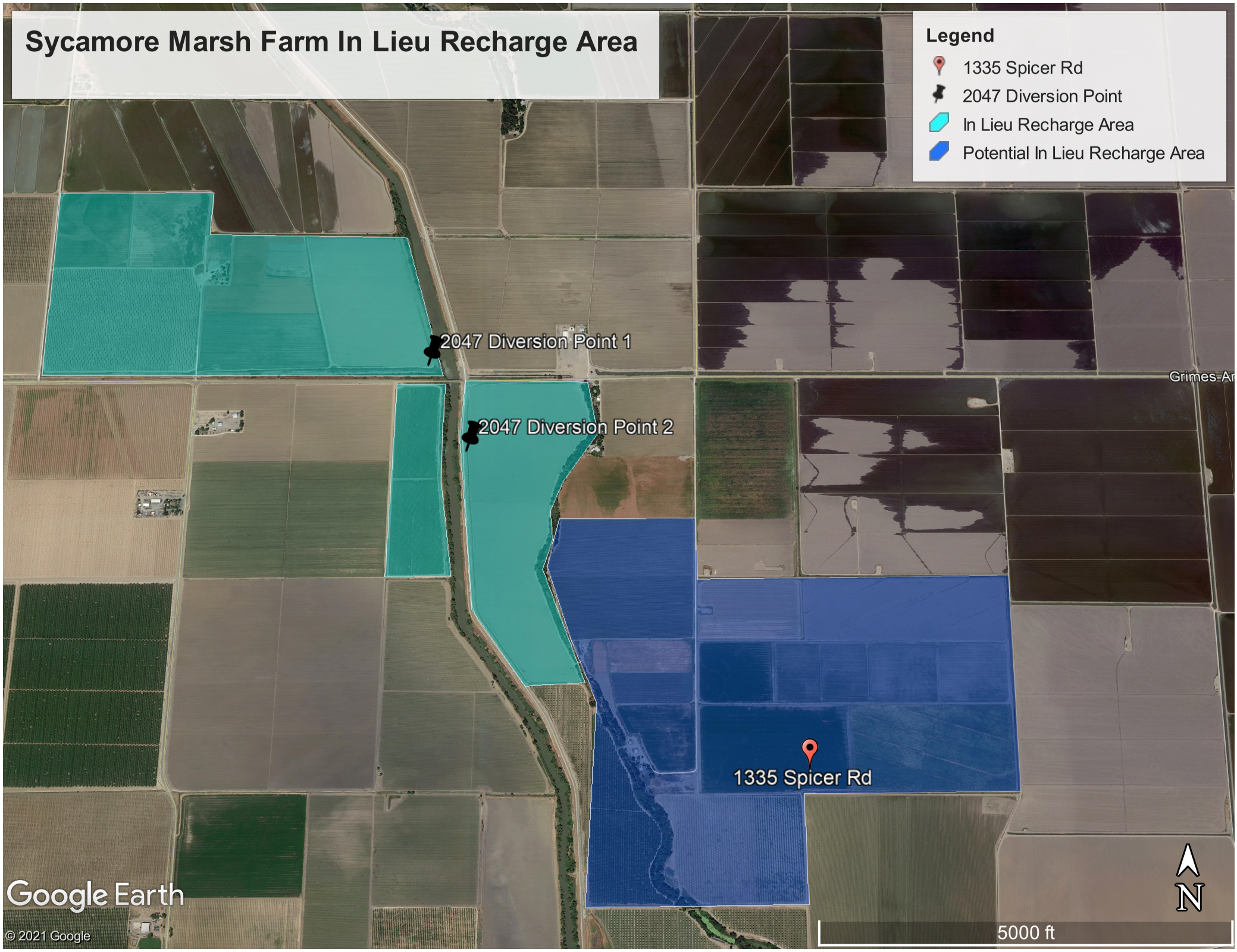
Unknown at this time, but a supplemental permit for water storage from State Water Resource Control Board will be needed.

Does this Management Action or Project serve a disadvantaged community? If so, which one(s)?
No.

Additional Information Sources:

Other Information:

This project provides many benefits in addition to groundwater recharge/storage. Potential benefits include reduced sediment loading into the 2047 Canal and Sacramento River, increased habitat for migratory shorebirds, and reduced greenhouse gas emissions from reduced pumping from groundwater wells.


Sycamore Marsh Farm In Lieu Recharge Area
Legend
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2047 Diversion Point
In Lieu Recharge Area
Potential In Lieu Recharge Area
2047 Diversion Point 1
2047 Diversion Point 2
1335 Spicer Rd
Grimes-Ar
Google Earth
© 2021 Google
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5000 ft

Colusa Subbasin GSP Projects and Management Actions (PMAs) Submittal Form

Project Name and Contact

Project or Management Action Name: Colusa Subbasin In-lieu Recharge & Banking Program

Contact Person: Scott Hamilton

Organization/Affiliation (Project Proponent): South Valley Water Resources Authority

Contact Phone: (661) 303 1540

Contact Email: Scott@ResourceEconomics.net

Project or Management Action Description and Status

Project or Management Action Description: The purpose of the project is to incentivize landowners to take surplus contract surface water in-lieu of pumping groundwater by providing financial incentives (subsidizing surface water costs) to make surface water less expensive than groundwater. If needed, South Valley would subsidize the cost of new distribution systems to facilitate the delivery of additional surface water or provide funds to districts to implement other programs. The magnitude of such payments would depend on the size of the banking project but could exceed $100,000 per year per district.

A predetermined portion of the additional water brought into the districts would be dedicated to achieving local groundwater sustainability and some portion of the remaining quantities would be available for delivery, directly or by exchange, to South Valley members. Additional facilities may need to be constructed to enable recovery. Such facilities would be paid for by South Valley but located and constructed in coordination with local districts.

Project or Management Action Location (please provide a map if available): The project would be located within any districts willing to participate.

Which Sustainability Indicator(s) does this Project or Management Action address:

1. *Groundwater levels*
2. *Groundwater Storage*
3. *Groundwater Quality*
4. *Land Subsidence*
5. *Surface Water Interaction*

As an in-lieu recharge and banking project, groundwater levels would be expected to increase as a result of using surface water rather than groundwater. Groundwater storage would increase because of the groundwater not pumped. If the incentives to take surface water were strongest in the areas of subsidence, then the impacts of subsidence would also be reduced. Studies would need to be conducted to determine the impact on groundwater quality – we have not tried to assess these impacts yet.

Project or Management Action Status (Conceptual, In Design, Ready for Implementation): The project is conceptual at this time. Before proceeding to the design stage, we would need to meet with managers of districts willing to participate to really understand their concerns and objectives. The program can be structured in a variety of ways to meet the needs of the districts.

Has a feasibility assessment been conducted? If so, please list the agency and provide the documentation (or provide web link to download). Our consultants, Woodward Curran have developed an operational model for the program where inputs and parameters can be changed to consider varying circumstances and district requirements. However, it is necessary to understand the water districts goals and objectives before such a model can produce meaningful output.

Estimated Cost: It is not possible to estimate the cost of the project without understanding what size projects would best fit the water districts' needs. However, the projects are intended to generate income for participating districts without them having to pay any up-front capital costs. South Valley would also cover any increased O&M costs the districts might incur.

Potential Funding Sources: South Valley would fund projects through assessments on its members and perhaps through issuance of bonds where South Valley members would be responsible for the debt. We have not considered public grants or loans.

Management Action or Project Yield (e.g. water contributed to the groundwater system, acre-feet per year): The contribution to the groundwater would vary by district but, at the upper end, would be the difference between current deliveries and the minimum of: available but unused water, and the district irrigation demand.

Please describe any required Permitting and Regulatory Process and status of permitting and CEQA/NEPA compliance: We have not initiated any approval, permitting or environmental processes and would not do so without your consent.

Does this Management Action or Project serve a disadvantaged community? If so, which one(s)? There are ways the program can be structured to aid disadvantaged communities and we would be interested in exploring those options with you.

Other Information: South Valley members have extensive experience in water banking both as hosting agencies and project participants. These programs have provided funds, financed infrastructure and improved groundwater conditions. While we do not pretend to understand your circumstances, we would be interested in learning more and to see if this, or some other program can help achieve your objects without increasing your water costs. Financially, a program like this makes sense to us because our dry year water supplies are very expensive and a program like this could help lower those costs.

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Project Name and Contact

Project or Management Action Name: Urban Water Conservation in Willows

Contact Person: Evan Markey

Organization/Affiliation (Project Proponent): California Water Service Willows District

Contact Phone: 530-934-4735

Contact Email: infoWIL@calwater.com

Project or Management Action Description and Status

Project or Management Action Description:
Water waste prevention ordinances, Metering, Conservation pricing, Public education and outreach, Programs to assess and manage distribution system real loss, Water conservation program coordination and staffing support, and other demand management measures

Project or Management Action Location (please provide a map if available):

Willows

Which Sustainability Indicator(s) does this Project or Management Action address:

1. Groundwater levels
2. Groundwater Storage

Project or Management Action Status (Conceptual, In Design, Ready for Implementation):

Ready for Implementation

Has a feasibility assessment been conducted? If so, please list the agency and provide the documentation (or provide web link to download).

Urban Water Conservation in Willows is ready for implementation and described in Cal Water's Urban Water Management Plan Chapter 9.

Estimated Cost:

The cost of these activities is covered by the rate structure set by Cal Water for it's service areas.

Potential Funding Sources:

Collaboration and coordination with local entities is possible to extend the value of these activities.

Management Action or Project Yield (e.g. water contributed to the groundwater system, acre-feet per year):

Table 9-2 in Cal Water's 2020 Urban Water Management Plan (attached) shows the estimated water conserved from 2016-2020. From 2016-2020 an average annual savings of 2 AF was achieved.

Please describe any required Permitting and Regulatory Process and status of permitting and CEQA/NEPA compliance:

None

Does this Management Action or Project serve a disadvantaged community? If so, which one(s)?

No

Additional Information Sources:

Attached is Chapter 9 from the 2020 California Water Service Willows District Urban Water Management Plan which details the conservations activities currently in place and available in the future.

Other Information:

Chapter 9
Demand Management Measures

☑ ***CWC § 10631 (e)***

Provide a description of the supplier's water demand management measures. This description shall include all of the following:

(1) (A) For an urban retail water supplier, as defined in Section 10608.12, a narrative description that addresses the nature and extent of each water demand management measure implemented over the past five years. The narrative shall describe the water demand management measures that the supplier plans to implement to achieve its water use targets pursuant to Section 10608.20.

(B) The narrative pursuant to this paragraph shall include descriptions of the following water demand management measures:

(i) Water waste prevention ordinances.

(ii) Metering.

(iii) Conservation pricing.

(iv) Public education and outreach.

(v) Programs to assess and manage distribution system real loss.

(vi) Water conservation program coordination and staffing support.

(vii) Other demand management measures that have a significant impact on water use as measured in gallons per capita per day, including innovative measures, if implemented.

This chapter provides a summary of past and planned demand management measure (DMM) implementation in the Willows District (also referred to herein as the "District"), as well as an overview of the expected water savings.

This chapter contains the following sections:

9.1 Demand Management Measures for Wholesale Agencies

9.2 Demand Management Measures for Retail Suppliers

9.3 104Implementation over the Past Five Years

9.4 Implementation to Achieve Water Use Targets

9.5 Water Use Objectives

9.1 Demand Management Measures for Wholesale Agencies

Because the District is a retail water supplier, this section does not apply.

9.2 Demand Management Measures for Retail Suppliers

California Water Service Company (Cal Water) centrally administers its conservation programs for all the districts it operates. For purposes of this section, these programs have been grouped in accordance with the DMM categories in California Water Code (CWC) §10631(e). These categories are:

(i) Water waste prevention ordinances
(ii) Metering
(iii) Conservation pricing
(iv) Public education and outreach
(v) Programs to assess and manage distribution system real loss
(vi) Water conservation program coordination and staffing support, and
(vii) Other demand management measures

Following are descriptions of the conservation programs Cal Water operates within each of these DMM categories. The District's Conservation Master Plan, provided in Appendix I, contains additional information on Cal Water's conservation programs.

9.2.1 Water Waste Prevention Ordinances

Cal Water's enforcement of water waste prevention and water use restrictions is authorized and overseen by the California Public Utilities Commission via Rule 14.1 or Schedule 14.1. Local government in districts operated by Cal Water may also adopt ordinances regulating water use. Cal Water coordinates its efforts to prevent water waste with the appropriate local governmental entities.

Rule 14.1 defines the District's Water Shortage Contingency Plan (WSCP, Chapter 8), including its prohibitions on water waste and restrictions on water use. Prohibitions include:

- Use of potable water through a broken or defective plumbing fixture or irrigation system when Cal Water has notified the customer in writing to repair the broken or defective plumbing fixture or irrigation system, and the customer has failed to effect such repairs within seven (7) business days of receipt of such notice.
- The application of potable water to landscapes in a manner that causes runoff such that water flows onto adjacent property, non-irrigated areas, private and public walkways, roadways, parking lots, or structures.

- The use of a hose that dispenses potable water to wash vehicles, including cars, trucks, buses, boats, aircraft, and trailers, whether motorized or not, except where the hose is fitted with a shut-off nozzle or device attached to it that causes it to cease dispensing water immediately when not in use.

Restrictions on water use during shortages include, but are not necessarily limited to:

- Outdoor irrigation restrictions in terms of time of day and weekly frequency.
- Obligations to fix leaks, breaks, or malfunctions within five (5) business days of written notification by Cal Water.
- Application of potable water to driveways and sidewalks.
- The use of potable water in a water feature, except where the water is part of a recirculating system.
- The application of potable water to outdoor landscapes during and within 48 hours after measurable rainfall.
- The serving of drinking water other than upon request in eating or drinking establishments.
- Irrigation of ornamental landscape on public street medians.
- Irrigation outside of newly constructed homes and buildings with potable water in a manner inconsistent with regulations or other requirements established by the California Building Standards Commission and the Department of Housing and Community Development.
- Operators of hotels and motels shall provide guests with the option of choosing not to have towels and linens laundered daily. The hotel or motel shall prominently display notice of this option in each guest room using clear and easily understood language.
- Limits on filling ornamental lakes or ponds.
- Use of potable water for street cleaning with trucks, except for initial wash-down for construction purposes.
- Use of potable water for construction purposes, such as consolidation of backfill, dust control, or other uses unless no other source of water or other method can be used.

9.2.2 Metering

☑ ***CWC § 526 (a)***

Notwithstanding any other provision of law, an urban water supplier that, on or after January 1, 2004, receives water from the federal Central Valley Project under a water service contract or subcontract … shall do both of the following:

(1) On or before January 1, 2013, install water meters on all service connections to residential and nonagricultural commercial buildings constructed prior to January 1, 1992, located within its service area.

(2) On and after March 1, 2013, or according to the terms of the Central Valley Project water contract in operation, charge customers for water based on the actual volume of deliveries, as measured by a water meter.

☑ ***CWC § 527 (a)***

(a) An urban water supplier that is not subject to Section 526 shall do both of the following:

(1) Install water meters on all municipal and industrial service connections located within its service area on or before January 1, 2025.

The District meters all service connections and bills customers for water use monthly. Cal Water may install advanced metering infrastructure (AMI) in the future to improve metering accuracy and supply prompt feedback to customers about water use and leaks. Cal Water is currently piloting (AMI) in several districts but does not have plans for full implementation in the Oroville District at this time. AMI may be used by Cal Water in the future to detect and alert households of leaks and other possible problems as well as to provide customers with tailored water use information to help them use water more efficiently.

9.2.3 Conservation Pricing

The CPUC reviews and authorizes District water rates in a General Rate Case every three years. Currently, the District uses a three-tier increasing block rate design for residential water use and a single-tier uniform rate design for non-residential use. The District provides rate assistance to lower income households through its Customer Assistance Program (CAP).

9.2.4 Public Education and Outreach

The District's public outreach program is divided into four components, as follows:

Public Information Program – Cal Water operates an extensive public information program to provide information to customers on ways to use water efficiently and to market its conservation programs through multiple media outlets, including the Cal Water website, direct mail and bills, digital media, social media, and email.

School Education Program - Cal Water's school education program includes the Cal Water H2O Challenge, a project-based learning competition for grades 4-6, individual student competitions for grades K-12 and general information and learning materials for students and teachers. Cal Water deploys its school education program in all its districts. Cal Water H2O Challenge is a project-based competition for classrooms, grades 4-6. The program is offered in partnership with DoGoodery, the California Association of Science Educators (CASE), and the WestEd K-12 Alliance. The program aligns with the Common Core State Standards and the Next Generation Science Standards. The Cal Water H2O Challenge offers a unique opportunity for upper elementary teachers to facilitate their students' learning of standards-based content, while developing the core understanding of environmental principles necessary to becoming science-literate citizens.

Smart Landscape Tune-Up Program – This program provides customers with an irrigation system evaluation and installation of approved efficient irrigation system equipment, such as a smart irrigation controller and high-efficiency sprinkler nozzles. The program also includes irrigation system adjustments and detection and repair of irrigation system leaks. This program is available to all Cal Water customers at no charge.

Residential Customer Portal – Through its residential customer portal, Cal Water provides tailored assistance to each residential customer via customized water-efficiency targets, water savings calculators, and customer-specific recommendations for programs and water-saving tips.

Non-Residential Customer Assistance – Cal Water provides tailored assistance to commercial customers through customized incentives, commercial water surveys, and large landscape water use surveys. The non-residential assistance program helps commercial customers efficiently use water for sanitation/cleaning, heating/cooling, process, and landscape purposes.

9.2.5 Programs to Assess and Manage Distribution System Real Loss

As discussed above, reducing distribution system losses is one of the main focuses of the new Making Water Conservation a California Way of Life regulations. In preparation for these new requirements, Cal Water took part in the California Water Loss Technical Assistance Program (TAP) in both 2016 and 2017. Cal Water annually conducts distribution system audits using the American Water Works Association (AWWA) Free Water Audit Software. It has also developed a Water Loss Control Plan and Water Loss Control Policy to guide future water loss management with respect to:

- Meeting CPUC and state water loss standards and regulations
- Improving audit data and validity scores
- Implementing cost-effective water loss control actions

To coordinate and oversee water loss management actions across its multiple districts, Cal Water has added a Water Loss Program Analyst position to its conservation staff.

9.2.6 Water Conservation Program Coordination and Staffing Support

The CPUC reviews and authorizes Cal Water conservation program and staffing level in a general rate case every three years. Currently, Cal Water has nine full-time conservation positions, as follows:

- Director of Water Resource Sustainability,
- Conservation Program Manager,
- Research, Analytics and Reporting Manager,
- Water Resource Sustainability Analyst,
- Water Loss Program Analyst,
- Three Conservation Program Coordinators, and
- Conservation Assistant.

These staff manage all aspects of Cal Water's conservation programs that are run in 25 districts serving a combined population of 2.5 million people.

9.2.7 Other Demand Management Measures

In addition to the DMM programs described above, Cal Water operates rebate, give-away, and direct installation programs aimed at plumbing fixture replacement and irrigation equipment and landscape efficiency improvements. Following are brief descriptions of each of these DMMs.

High-Efficiency Toilet Replacement – This program replaces old toilets with MaP certified high-efficiency toilets via financial rebates, direct installation, or direct distribution.[41] Current rebate amounts are up to $50/toilet for residential toilet replacement and up to $100/toilet for commercial toilet replacement.

High-Efficiency Urinal Replacement – This program replaces old urinals with high-efficiency urinals meeting the state's 0.125 gallon per flush water use standard via financial rebates and direct installation. While available to all non-residential customers, the program targets sites with higher-than-average bathroom utilization, such as restaurants and office buildings. The current rebate amount is up to $150/urinal.

Clothes Washer Replacement – This program provides a financial rebate to replace an old inefficient clothes washer with a new high-efficiency washer. The program is available to all residential and multi-family customers. The current rebate amount is up to $150/washer.

Residential Conservation Kit Distribution – This program offers residential customers conservation kits featuring a range of water-saving plumbing retrofit devices. The kits are

[41] For information on MaP certified toilets, see: https://www.map-testing.com/

available at no charge and include two high-efficiency showerheads (1.5 gpm), two bathroom faucet aerators (1.0 gpm), one kitchen faucet aerator (1.5 gpd), toilet leak tablets, and an outside multi-function, full-stop hose nozzle.

Smart Irrigation Controller Installation – This program provides a financial rebate for the installation of a smart irrigation controller that automatically adjusts watering schedule in response to changing weather conditions. The current rebate amount is $125/controller for residential customers and $25/station for commercial customers.

High-Efficiency Sprinkler Nozzle Rebate – This program provides a financial rebate for the installation of high-efficiency sprinkler nozzles. This program is available to all Cal Water customers. The current rebate amount is $5/nozzle.

Large Rotary Nozzle Rebate – This program provides a financial rebate for the installation of high-efficiency large rotary nozzles. This program is available to all Cal Water customers. The current rebate amount is up to $30/nozzle toward the nozzle purchase cost and up to $8/spray body toward installation cost, if installed by a C-27 licensed landscape contractor.

Spray Body with Integrated Pressure Regulation and Check Valve Rebate – This program provides a financial rebate for the installation of high-efficiency spray bodies with integrated pressure regulation. This program is available to all Cal Water customers. The current rebate amount is up to $10/body toward the spray body purchase cost and up to $8/spray body toward installation cost, if installed by a C-27 licensed landscape contractor.

Turf Replacement Rebate – This program provides a financial rebate for replacement of turf with approved drought-tolerant landscaping. Cal Water operated this program in 2015/16 as a drought response measure. The program will be re-started as part of Cal Water's irrigation equipment/landscape upgrade program offerings.

Table 9-1 summarizes the DMMs available to Dixon District customers at the time this Plan was prepared.

Table 9-1. Cal Water DMMs Available to District Customers

Programs Offered	Customer Eligibility		
	Single-Family	Multi-Family	Commercial
Plumbing Fixture Replacement			
High-Efficiency Toilet Replacement	✓	✓	✓
High-Efficiency Urinal Replacement			✓
High-Efficiency Clothes Washer Rebate	✓	✓	
Conservation Kits	✓	✓	
Irrigation Equipment/Landscape Upgrades			
Smart Irrigation Controller Rebate	✓	✓	✓
High-Efficiency Sprinkler Nozzle Rebate	✓	✓	✓
Large Rotary Nozzle Rebate		✓	✓
Spray Body Rebate		✓	✓
Turf Replacement Rebate	✓	✓	✓
Customer Assistance			
Smart Landscape Tune-Up Program	✓	✓	✓
Residential Customer Portal	✓		
Non-Residential Customer Assistance		✓	✓

9.3 Implementation over the Past Five Years

Table 9-2 summarizes program implementation for the previous five years. Estimated water savings do not include savings from water waste prevention ordinances, conservation pricing, public information, or distribution system water loss management. Cal Water uses the Alliance for Water Efficiency's Water Conservation Tracking Tool to estimate water savings.

Table 9-2. Implementation of Customer DMMs: 2016-2020

Indoor Programs	2016 – 2020 Total	Average Annual
Toilets & Urinals (number distributed)	32	6
Clothes Washers (number distributed)	20	4
Conservation Kits (number distributed)	24	5
Outdoor Programs		
Smart Controllers (number distributed)	3	1
Nozzles & Spray Bodies (number distributed)	0	0
Turf Buy-Back (sq ft removed)	4,140	828
Residential Assistance Programs		
Surveys/Audits (homes receiving)	1	<1
Non-Residential Assistance Programs		
Surveys/Audits (sites receiving)	0	0
Estimated Water Savings (AF)	8	2
NOTES: Estimated water savings for 2016-2020. DMMs will continue to generate savings after 2020 for their useful life.		

9.4 Implementation to Achieve Water Use Targets

All the DMMs described above contributed to the District's compliance with its SB X7-7 2020 target GPCD.

9.5 Water Use Objectives (Future Requirements)

CWC §10609 requires that urban retail water suppliers develop new water use objectives that are based on specific standards for certain water use sectors. These water use objectives will not be developed until 2023. Suppliers are encouraged in this UWMP cycle to consider how they will align their conservation management actions in order to meet these future obligations.

As noted above, Cal Water's conservation programs are subject to review and approval by the CPUC through a General Rate Case every three years. In making conservation program recommendations to the CPUC, Cal Water carefully considers how they will advance multiple objectives, including compliance with the pending water use objectives. Specific objectives identified in Cal Water's most recent General Rate Case included:

- Maintaining continuity with and furthering implementation of conservation programs authorized by the previous General Rate Case.

- Preserving gains in water conservation achieved during the 2013-2017 drought.
- Ensuring Cal Water districts are well-positioned to comply with state regulations and policies pertaining to water conservation, water loss management, and groundwater management, including Executive Order B-37-16, SB 555, and the Sustainable Groundwater Management Act (SGMA).
- Advancing cost-effective water use efficiency alternatives in districts with high water supply costs.

Cal Water developed a scoring methodology to adjust conservation programs and budgets to further these objectives. The methodology specifically considers five distinct conservation policy drivers:

1. State Conservation Standards and Water Use Objectives
2. SGMA Compliance
3. SB 555 Water Loss Management Requirements
4. Commercial, Institutional, and Industrial (CII) Water Management
5. Avoided Water Cost and Affordability

The methodology assigns greater weight to the State Conservation Standards and Water Use Objectives and SGMA Compliance policy drivers, reflecting their importance in terms of overall water resources management.

Scoring for the SGMA Compliance policy driver is based on groundwater basin priority, district dependence on groundwater supply, and basin adjudication status. The highest scores are assigned to districts in unadjudicated and critically overdrafted or high priority basins where groundwater comprises more than 45 percent of the water supply. The Willows District ranked in the middle of Cal Water's districts for this policy driver.

Scoring for the State Conservation Standards and Water Use Objectives policy driver is based on four metrics that are used to gauge which districts are most likely to require adjustments to their conservation program mix or level of implementation to comply with the new standards. These metrics are:

1. Residential per capita landscape area
2. Residential per capita turf area
3. Size and number of large residential landscapes
4. Difference between a simulated water use budget and average water use for 2011-15

The Willows District ranked in the top third of Cal Water's districts for this policy driver.

Scoring for the SB 555 Water Loss Management Requirements policy driver is based on the district's infrastructure leakage index (ILI) from its most recent validated water loss audit. The ILI

is a performance indicator of real (physical) water loss from the water distribution system. A high ILI indicates possible distribution system inefficiencies and may also indicate significant water system leakage. Proposed adjustments to funding for water loss management are based on the ILI scoring criteria. The Willows District ranked in the top 15 percent of Cal Water's districts for this policy driver.

Scoring for the CII Water Management policy driver is based on the ratio of CII water uses to total water uses in a district. The Willows District ranked in the middle of Cal Water's districts for this policy driver.

Scoring for the Avoided Water Cost and Affordability policy driver is based on the District's avoided cost of water supply, as estimated by the California Urban Water Conservation Council (CUWCC)/Water Research Foundation Avoided Cost Model. The Willows District ranked in the middle of Cal Water's districts for this policy driver.

The combination of scores on each policy driver were used by Cal Water to recommend to the CPUC in its most recent General Rate Case adjustments to the conservation budgets of its districts. The purpose of the adjustments is to increase Cal Water's capacity to deploy conservation programs in districts expected to face the most significant regulatory and water management challenges in coming years. Recommended adjustments ranged from a low of 5 percent to a high of 25 percent. The recommended adjustment for the Willows District was 22.5 percent.

2B-5. GSP Chapter Input Submittal Forms

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Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Donald Bills **Commenter Affiliation (if applicable):** GGA-TAC

This file introduces a table that allows you to easily enter the following key information so we have certainty about your input. The table includes the following categories:

- Chapter Number
- Section Number
- Page Number
- Paragraph Number (starting with the first full paragraph at the top of a given page)
- Figure/Table Number (if applicable)
- Comment

INSTRUCTIONS

1. Please **ONLY** use the MS Word or PDF document titled "Colusa Subbasin GSP Chapter Input" to submit your comments.

2. Review all applicable text and note each Chapter, Section, Page, and Paragraph number associated with a comment you'd like to make. For Paragraph number, please start with the first full paragraph at the top of a given page and count down.

3. Enter your name and if applicable, an organizational affiliation at the top of your table.

4. Once you have completed all your comments, please save the file with your last name at the end in parentheses. For example:
   - *Colusa Subbasin GSP Chapter Input (Jones).docx*

5. If you are located in the Glenn Groundwater Authority, please send your comment file to:
   - Lisa Hunter – Program Manager - Glenn Groundwater Authority: lhunter@countyofglenn.net

6. If you are located in the Colusa Groundwater Authority, please send your comment file to
   - Mary Fahey – Program Manager - Colusa Groundwater Authority: mfahey@countyofcolusa.com

7. If you don't affiliate specifically with either the CGA and/or GGA, please send your comments to both Mary and Lisa.

8. Please make sure that your comments are submitted by midnight May 5, 2021.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
1	1.1	1.1			
1	1.2	1.2	2		1.—Sustainable groundwater resources not only preserve, and enhance the economic viability, social well-being and culture of all beneficial uses and users, but also insure the sustainability of water for natural and environmental needs. Especially those of at risk or critical resource value (i.e. springs, wetlands, riparian habitat, and baseflow reached of perennial and/or intermittent streams). I would suggest adding something like this to the stated goal of the Colusa Subbasin GSP. 2.—there is no such thing as sustainable/safe yield. At best the term means planned depletion. I suggest you replace it with sustainable goal.
1	1.2	1.2	3		1.—Sustainable/safe yield is no longer considered to be a valid term in the context of hydrogeology. The term was originally developed as a legal term to characterize a water budget in balance by relating recharge (from precipitation) with discharge, two terms that are not related. I suggest that you replace it here with sustainable goal.
1	1.3	1.2	3		1.—Suggest that you modify Both GSAs in the last sentence to “Both the Colusa and Glenn GSAs…” for clarity.
1	1.4	1.4	1, bullet 5		1.—Suggest that you add to seawater intrusion, brackish or saline groundwater intrusion. As discussed during TAC meetings, as freshwater is removed from storage in the regional aquifer. The reduced hydraulic head will allow brackish and/or saline water at depth to seep upward into the regional aquifer. Unless

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
					monitoring of water quality at depth in the regional is intended to be the monitoring tool for this.
1	1.4	4 of 7	Article 5 sub-article 2	1-1, GSP regulation section 354.18, bullet 3	Suggest replacing estimate of sustainable yield with estimate of sustainable goals.
1	1.4	4 of 7	Article 5 sub-article 2	1-1 GSP regulation section 354.18, surface water supply	Shouldn't this also include reclaimed water and/or
1	1.4	6 of 7	Article 5 sub-article 4	1-1, GSP regulation section 354.36, representative monitoring.	Remote-sensing data was discussed as an additional proxy in addition to groundwater elevations for other sustainable indicators. Should it be mentioned here?
1	1.4	6 of 7	Article 5 sub-article 4	1-1, GSP regulation section 354.36, Assessment and Improvement	Again remote-sensing methods and data are another tool that seems suited for filling data gaps by improving monitoring frequency, accuracy, and density of data sites. Discussion of DWR INSAR and gravity data as possibilities.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
				of Monitoring Network	

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment

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Commenter Name: Donald Bills **Commenter Affiliation (if applicable):** GGA-TAC

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
2					

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment

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COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
3	3.1	3-1	1, first sentence		First occurrence of abbrev. Should be spelled out in text. I.E. This section describes the hydrologic conceptual model (HCM) of the Colusa Subbasin.
3	3.1.3	3-6		3-3. Note in upper left of plot. Second sentence.	There appears to be missing or jumbled text at the start of sentence 2. “ at r y ars missing more that 30 days…”. Suggest that it be fixed is needed.
	3.1.4	3-8		3-4	Since land surface elevation is color coded on the Topography map, it might help to identify the very light shade of blue as surface water as it can be easily confused with the very light green (greenish-blue?) that is land surface less than 30 ft.
	3.1.5	3-7	Paragraph2, 1st sentence	3-5	“The regional watersheds and natural waterways are shown on Figure 3-5.” Figure 3-5 also shows principal water infrastructure. I suggest it be added to the sentence and the fig. 3-5 title.
	3.1.5	3-10	First paragraph, last sentence		“These streams are intermittent and drain the foothills that border the Coast Ranges to the west.” Perennial streams are connected to the regional groundwater table and get most of their base flow by groundwater discharge. Intermittent streams are only seasonally connected to the regional groundwater table and flow seasonally or in response to runoff. Ephemeral streams are not connected to the regional groundwater table and only flow in response to seasonal runoff. Are Foothill streams of the Coast range truly intermittent?

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
3	3.1.5.1.1	3-10			Is there no range of flow data for Stony Creek pre-Black Butte Dam (and even Stony Gorge Dam)? This would give some context to the releases from Black Butte Dam since 1996.
	3.1.5.1.2	3-13			"Sacramento River stream flows measured at the Ord Ferry-Main Channel stream gauge, in the northern part of the Subbasin, varied between 200 and 160,000 cfs during the 1984 to 2020 time period, with extreme low flows measured in the spring of 1990." Why is the time p3.1.5.1.3eriod limited to 1984 to 2020? If the intent here is to describe natural surface waters, there are documented (USGS) periods of extreme flows greater that this range extending back to the 1920 from stream-flow gaging stations in or adjacent to the Colusa subbasin.
	3.1.5.1.3	3-13			3.1.5.1.4 Glenn Colusa Canal lists acres serviced. Wouldn't it be appropriate to do the same for the Tehama-Colusa Canal? Also the length of the canal and diversions? I watched the Tehama-Colusa Canal being built less that a quarter-mile away from where I grew up on Co. Rd. 21 south of Orland. I even rode my bike in the bottom of the canal once it was cemented in. I noticed at the time there was a line of one-way valves on the bottom of the canal. I later learned they were there to relieve stress on the canal by allow rising groundwater to move into the canal. Is this something you are accounting for in your groundwater models during those wet years when WLS are very close to the surface?
	3.1.5.1.6	3-15	1		"These foothill drainages and their tributaries are classified as part of the Sacramento-Stone Corral Watershed…". I think you mean the Upper Stony Watershed.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	3.1.5.1.6	3-15	2		"Runoff in these ephemeral and intermittent streams generally begins in late fall when the rainy season starts and may continue until late spring." Intermittent streams suggest some seasonal contact with the regional groundwater table. Probably not true for many of these streams in the north part of the subbasin. I do not know about those in the southern part of the subbasin. Springs are overlooked in this discussion (or elsewhere). Many of these smaller streams have springs at or near their headwaters that issue from either the Tehama (exposures of pre-Paleogene, would have a QW signature), Riverbank or Modesto Formations. Discuss here?... High elevation areas to the west of Orland/Willows. GW contours do not extend that far west. 3.1.11.3 does not address springs. Black butte Lake overlies mostly Tehama formation. Is there ant possibility of Reservoir water seeping into Tehama and showing up in springs to the south? QW signature, spring flow related to lake level not climate, etc.
3	3.1.6	3-18		3-9	The color for soil type C and water bodies on fig. 3-9 (light blue) are so similar it is hard to tell them apart. I suggest you consider using more contrasting colors and adding waterbodies to the explanation to make them easier to tell apart.
		3-27		3-16	Top of Cretaceous rocks contours are in meters MSL, and tops of Cretaceous rocks elevation are in feet MSL. Using both metric and SI units makes them a little difficult to compare. Can they both be in the same units? Also, there are places where the contours do not match the elevations (SE of Black Butte, Artois, Princeton, etc.). I assume this is related to structural offsets. I suggest you consider adding the principal structures (faults) to this map to help with the interpretation.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	3.1.7.2.3	3-31	4		During a review of USGS topographic maps that cover the area west of Orland and Willows, I found about 24 marked springs, a few with actual names. Based on their location, these springs appear to be discharging from either the Tehama, Riverbank or Modesto Formations in the northwest part of the Colusa Subbasin, There is little hydrogeologic information shown on the maps of this report for this area owing to a lack or well data. Springs represent a source of hydrogeologic information that can be used in the absence of well data to extend water level contours and improve understanding of groundwater conditions in the area. Any information about these springs from land owners or site inventories by DWR or the USGS will improve the hydrogeologic characterization of this area of the subbasin. Some mention of spring discharge from the Tehama, Riverbank, and Modesto Formations might be appropriate here, with a more complete discussion in groundwater discharge.
	3.1.8.2	3-36	2-3		?... Base of the Tehama and Tuscan Formation and (or, and/or?) Base of freshwater excluding those areas where post-Cretaceous sediments contain brackish water. Freshwater is defined as 3,000, 2,000, and 1,000 mg/L depending on which reference is used (USGS, DWR, of C2VSim). Which is it? I would also suggest that you define brackish water here as its related freshwater and the freshwater boundary. The vertical extent of these boundaries shown on fig. 3-11 to 3-13 while approximate do not appear to consistently align with either of these definitions. Perhaps it would be appropriate to add queries ("?") where the degree of uncertainty is highest.
	3.1.9.2	3-38	1		"These basin faults may act as barriers or conduits to fresh groundwater flows." I think it is also important to mention that, if the faults are deep seated, they can also provide conduits for poorer quality (brackish) water from the marine sediments below to migrate up into the freshwater layer. This is particularly true if the hydraulic head of the freshwater layer is consistently reduced owing to groundwater withdrawal.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
3	3.1.10, Principal aquifers	3-39			Some text edits for clarity.
	3.1.10.3, water Quality	3-42	1		Electrical conductivity (EC) is not a measure of the quality of the water. It is a measure of how electrically conductive the water is. As a result, there is a nearly direct relationship between EC and total dissolved solids (TDS) in the water. TDS is one general measure of water quality. The more dissolved solids in the water, the more electrically conductive it is and, as a result, the quality of the water is generally poorer. For this reason, I suggest you delete reference to EC in the first sentence of the paragraph.
	3.1.10.3	3-42			Fire retardant used to be manufactured in Orland and included boron with other chemicals known for both their fire suppression properties and as chemical fertilizer. Currently, fire retardant is a mix of ammonium polyphosphate, diammonium phosphate, diammonium sulfate, monoammonium phosphate, attapulgus clay, guar gum known as Phos Chek. Over time, after a fire, this material gets watered into a watershed and may be a concern for the water quality of an aquifer. It is also highly concentrated where manufactured and distributed (Airports like Orland, Willows, and USFS and CDF fire bases).
	3.1.10.3	3-42	3		Most drycleaners use both Trichloroethylene (TCE) and Tetrachloroethylene (PCE) (as did the one in Orland). The studies I have seen on this issue for the Orland area refer mostly to TCE.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	3.1.11, Groundwater Inflows and Outflows	3-42 to 48	1		The section heading is groundwater inflows and outflows. The lead sentence begins “Groundwater underflows between the Colusa Subbasin and neighboring groundwater subbasins…”. Groundwater underflow is a specific type of inflow or underflow. I would suggest that a better use of this introductory paragraph would be to list all the relevant GW inflows and outflows to the Colusa Subbasin as discussed in the following subsections. I would also add the Corning Subbasin in the first sentence in relation to groundwater underflow. As water-level contours indicate (fig. 3-19), Stony Creek is not a barrier to groundwater flow.
	3.1.11.2.2, GW banking?	3-43			Groundwater banking. Not in the glossary of terms and it appears to mean something different here (recharge) as opposed to the most common definition (water management mechanism designed to increase water supply reliability through the buying, selling, and storage of surface water and groundwater rights for later use). I would suggest artificial recharge as a alternate term since the main heading (2.1.11.2) is Groundwater Recharge Areas.
	3.1.11.3, Groundwater discharge areas	3-45	2		I suggest that you consider adding a few sentences about springs in the Colusa Basin to this paragraph. Something like: “Most springs in the Colusa Subbasin occur near the western boundary and discharge from the Tehama, Riverbank, or Modesto Formations and stream channel alluvium. About 25 springs can be identified from USGS topographic maps of the subbasin. A number of these springs have been developed for agricultural use by landowners locally (apparent on satellite imagery). The flow, and water quality of these springs may exist in DWR or USGS databases based on past historical inventories.” If properly inventoried these springs would represent significant additional information about the occurrence, movement, and quality of ground water in the regional aquifer of the Colusa Subbasin, especially where this information is poorly defined.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
3	3.1.11.3	3-48	2, 4th sentence		"There are also many unmetered domestic wells located throughout the study area." I suggest adding unmetered small ag wells also: "…unmetered domestic and small agricultural wells…"
			2, 5th sentence		It might be appropriate to add a sentence or two here to briefly explain how the annual rate of withdrawal from domestic wells was determined (estimated). Average pump capacity of all domestic wells, seasonal domestic water use estimates, or other. Adding small unmetered ag. wells to this total would increase significantly I imagine.
	3.1.11.3	3-48	3		I would also add a comment to this paragraph that during years when surface water deliveries are significantly cut back (drought), agricultural lands rely heavily on wells to make up the difference.
3	3.1.12.1	3-51	4		other methods or data sources: I'd like to suggest passive seismic. The method uses seismic signals already available in the environment, either anthropogenic (i.e. freeway traffic), or natural (i.e earthquakes, ocean waves, etc). the seismic signals are processed similar to standard reflection and/or refraction surveys but for much larger areas and depths. Ground-based, non-invasive CSAMT (Controlled Source Audio-frequency Magnetotellurics) and TEM (transient electromagnetic or alternately called time-domain EM (TDEM)) surveys can provide detailed subsurface information on stratigraphy, structure, depth to water and water quality in localized areas of interest. Survey lines that pass over or by existing wells provide ground-truth.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
3	3.1.12.1	3-52	1		Different TDS thresholds to define base of freshwater. Part of the problem may also be that water use type has a lot to do with whether water is considered fresh or not. MCL for safe drinking water is 500 mg/L, Livestock can tolerate about 1,500 mg/l. A lot of commercial ag. plants can tolerate 2,000 to 3,000 mg/L. There is also not broad agreement on what constitutes fresh, saline, or brackish water. It seems to me that the standard for what constitutes freshwater should be the same for all subbasins in the Sacramento Valley, if not the entire Central Valley.
	3.2.2.1	3-53	2, second sentence		"The most notable recovery period occurred around 1983, which was both a wet year and when water users added more surface water to their supply portfolios." The recovery after the 1987 to 1991 drought seems at least as great if not greater.
		3-53		3-22	It is hard to evaluate temporal trends on this plot referring back to the average annual precipitation plot at the beginning of this chapter. To help understand and evaluate this temporal data it would seem appropriate to add a plot of the annual average precipitation to this graph.
	3.2.2.1	3-55	1		Besides showing the general direction of flow to the SE, Figure 2 appendix 3-B appears to show Walker Creek to be a gaining stream (i.e. perennial, groundwater contours point up stream) from the NW part of the subbasin to Artois. Comparing land surface contours (fig 3-4) to the groundwater contours for this area seems to indicate that the depth to water is from -10 to -30 ft below the streambed throughout. Is there a discrepancy here that needs to be resolved?

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
3	3.2.2.1	3-55	4		"Current groundwater levels are similar to those measured in 2017, indicating that regional groundwater levels have been relatively stable since the end of the previous multiple-year drought." I find this statement a little misleading. What it overlooks is the fact that the combined effect of the 2007-09 and 2012-16 droughts was an average depth to water decline of over 30 ft (fig 3-22) from which the principal aquifer has yet to recover. In addition the 2019 and 2020 wls appear to continue trending down, not stable, as cones of depression continue to expand (fig 3-24 and 3-25).
	3.2.2.1	3-55	1,3rd sentence		"Impacts due to pumping are the exception to the typical gradients and disrupt both local and regional gradients." I suggest that you add to this sentence or the first sentence of the paragraph a comment on the effects of changing hydraulic parameters on the lateral groundwater gradient.
	3.2.5	2-64	Second		Delete EC. It is not a water quality parameter.
			third		Who monitors and regulates the water quality of municipal supply systems? Worth mentioning here? Regional water quality control boards? Saline connate water? Connate water is water trapped within the pores of sedimentary rocks. For that to happen it would have to be fully confined laterally and vertically and not be faulted or fractured. In the geologic discussion it states that pre-Cretaceous rocks are faulted and fractured. Groundwater is almost always in motion and always flows in response to gravity and/or the hydraulic gradient. The flow rates can be very slow, ft per hundreds to thousands of years or more. The connate water would be in pre-

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					Cretaceous sediments. Has anyone dated the water to see if it is, in fact, greater than 145 million years old, give or take?
	3.2.5.1.1	3-64	1		End of first sentence add "…and/or EC value (EC is a surrogate [estimate of] for TDS because it is more easily measured on site)." There appears to be a discrepancy in the Secondary MCL for TDS; 500mg/L in sentence 2 and 500 mg/L in sentence 4. Fix?
	3.2.5.1.1	3-66	1		"Wells screened in the unconfined to semi-confined zone of the aquifer (i.e. in wells less than 200 feet deep) had the highest number of wells with elevated TDS concentrations." I suggest adding "in thew central and southern part of the subbasin" to the end of this sentence.
	3.2.5.1.1	3-66	2		First sentence, …In these areas…. What areas? Suggest replacing with …southwest of Colusa…
	3.2.5.1.2	3-67	1		Anthropogenic source for increasing chloride and sulfide concentrations? Septic systems, landfills, other?

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	3.2.5.2.2	3-67	1		Boron. Pre, late 1970's Boron was a component of fire retardant for its fire suppression characteristics. Fire retardant was manufactured in a plant in Orland and stored at firebases (airports) in Glenn and Colusa counties. Is saw wide use in suppressing forest, brush, and grass (at lower elevations) fires in Glenn and Colusa Counties.
	3.2.5.2.3	3-68	1		Known or suspected cause for increases in iron and manganese worth mentioning here? Natural or human caused? Landfill west of Artois? Junk yards? Suggest adding if appropriate.
	3.2.5.2.3	3-68	1		Known or suspected cause for anthropogenic increases in hexavalent chromium worth mentioning here? Landfill west of Artois? Suggest adding if appropriate.
	3.2.7	3-73	2 and 3 paragraphs		The second paragraph is misleading ("While Stony Creek, Sacramento River, and the Colusa Basin Drain all experience gaining and losing conditions throughout the year,…") and appears to contradict the information provided in the 3rd paragraph. I would suggest deleting the second paragraph entirely and moving the table references to the 3rd paragraph.
	3.2.8	3-74	2nd paragraph	3-34	I do not follow the scoring criteria for GDE. A GDE where groundwater is near the surface has a score of 1; least likely to be GDE when it should be more likely to be a GDE. If a GDE is not near surface water OR crop land it scores a 4; most likely to be a GDE when it should be least likely to be a GDE. How the 30 ft DTW line was derived is explained in paragraph 1 on page 3-75. But I could not find or estimate the 30 ft DTW on any or the other figures in the text or appendix. An approximated 30 ft DTW line for 2006

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					data on figure 3-19 would run from between Arbuckle and College City, to near the boundary of the subbasin west of Williams, to just west of Artois, ending at Stony Creek just N/NW of Orland. This is nowhere near the line shown on figure 3-35. Using figure 5 in appx 3B I can approximate a 30 ft contour to the 2017 data. But it also does not compare to the 30 ft DTW contour on figure 3-35. The explanation table on figure 3-35 does not reference a time period (2014 to 2018?) for the 30 ft DTW line or any of the other features shown. Finally, there is no reference to springs and the riparian habitat they support at headwater streams in the NW part of the subbasin between Willows and Orland. These would represent some of the most important and species diverse habitat in the subbasin. I would suggest that the entire GDE section be revised so it more clearly and plainly represents GDE's that occur within the subbasin.
3	3.3 Water budget information	3-77	1		This section describes water budget components in detail but, I did not see a clear statement of what the water budget was for. Water budgets can be used for many things (i.e. GW gains or losses, basin gains or losses, etc). Is there a statement of the purpose of the water budget in the Groundwater Sustainability Plan Emergency Regulations §354.18 that could be added to the introduction here? The name suggests it is to determine groundwater sustainability of the principal aquifer in the subbasin. That implies that all the inflows and outflows are on onside of the equation and +/- change in storage is the result.
3	3.3.3	3-80		3-9	What is the Shasta non-critical and Shasta Critical, mentioned on the table? How does it relate to the Colusa Subbasin? I think it is defined two pages later under Land use. But there is still no explanation of what a Shasta critical and Shasta noncritical year is. Reservoir contents? Outflow? Both? Is there a reference for this missing? It would be worth providing a footnote to table 3-9 to define Shasta critical and Shasta non critical.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	3.3.3.3	3-83	3, Land Use		"…modified based on planned development according to the Colusa County 2030 General Plan." Is there a 2030 Glenn County General plan worth considering here as well?
3	3.3.4	3-84	1, bullet 1		Groundwater pumping and stream accretion are described as inflows here. In paragraph 2 second bullet on page 3-85 they are described as outflows. Which is it? I would suggest they are both outflows from the principal aquifer and the text needs to be fixed accordingly.
	3.3.4	3-85	3rd bullet of first paragraph (3-84)		Change in Storage is defined as changes in soil moisture storage within the upper several feet of soil in the root zone, as well as changes in storage in surface water bodies within the basin. Neither of these are change in storage. They are either inflows or outflows components that when summed with other inflows or outflows result in a change in storage of the principal aquifer. I would suggest that the text be fixed accordingly.
		3- 86 and 3-87		3-10 and 3-11	The tables do a much better job of representing the various SW and GW components of the water budget. Is there some way change the text so it is mere consistent with the tables? Also, In both table 3-10 and 3-11 the column headings for future conditions climate change relate to a specific date (2030 and 2070). It would be useful to the reader if the other columns (historical simulation, current baseline, and future condition no climate change base line) had the time periods they are based on as well. 1990 to 2015, 2015, and 1966 to 2015 respectively.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	3.3.4.1	3-88	4		I would suggest that ET from the riparian corridor of the Sacramento River as well as evaporation from the rivers surface can also be significant and worth discussing here. Especially during the summer months when ET is at a maximum and daytime temperatures can exceed 100 degrees for weeks at a time. This is important to consider under future climate change scenarios where temperatures and the days per year of excessive heat are predicted to increase.
	3.3.4.1	3-89		3-38	I would suggest that you add the change in storage (3taf.yr) to the graph. It is not apparent on the graph even though it is color coded in the legend. The columns look equal. In any case it should not be a color-coded box as inflow or outflow. It is the result of both.
	3.3.4.1	3-90		3-39	The GW change is storage in table 3-12 is shown as a negative number (-27.5 taf/yr, a loss). So, why is it shown as an inflow in this figure? Change in storage is neither an inflow nor a outflow but the result (sum) of both. Showing it this way graphically suggests the inflows and outflows are in balance. They are not. I would suggest that you add the actual change in storage (-27.5 taf/y) to the legend and remove it from the inflow column. I suggest you make similar changes to figures 3-40 to 3-47.
	3.3.4.1.1	3-91	1 and 2	3-12	“The primary sources of surface water in the basin are the Sacramento River and Stony Creek. Surface water supplies are relatively reliable in the basin and represent approximately 74 percent of the total water supplies.” Is this statement accurate? How do Shasta critical and non-critical years affect it? I would think that during Shasta critical years SW deliveries would be much and during Shasta non-critical years would be at or near 100 percent. The second paragraph seems to support this.

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3	3.3.4.2	3-93	2		Average annual inflows to and outflows from the groundwater system were estimated to be 997 taf/yr during the current conditions baseline simulation period on figure 3-41 are shown as 998 taf/yr not 997. Which is right?
	3.3.4.3.1	3-95	4		"There is negligible change in groundwater storage under the future condition, no climate change baseline water budget." I suggest you add the actual change in parentheses: "…negligible change (+0.6 taf/yr)…"
	3.3.4.3.2	3-97	1		"Average annual inflows to and outflows from the groundwater system were estimated to be 1.0 maf/yr." I suggest you add the type and time period to toe sentence so it is consistent with the title of this section and the figure referenced. "Average annual future conditions 2030 climate change baseline groundwater system inflows to and outflows from the groundwater system were estimated to be 1.0 maf/yr."
	3.3.4.3.2	3-98		3-45	Change in storage is not an inflow as shown…. See previous comments.
	3.3.4.3.3	3-100		3-47	Change in storage is not an inflow as shown…. See previous comments

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	3.3.5	3-101	1		"Uncertainty refers to a lack of understanding of the basin setting…" Add Water Budget to uncertainty in the first sentence to be consistent with the section title. I.E. "Water budget uncertainty refers to…"
	3.3.6	3-102	1		"Based on the current conditions and future conditions with no climate change scenarios, which represent long-term average conditions in the subbasin, overdraft conditions are not expected to occur in the Colusa Subbasin." The rest of the paragraph appears to contradict this. I suggest you change not to expected to occur to minor or modest overdraft is expected to occur.
	3.3.7	3-102	1		"As described previously, sustainable yield refers to the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin, and including any temporary surplus that can be withdrawn annually from a groundwater supply without causing an undesirable result." At the beginning of this chapter sustainable yield was also related to a maximum depth below lands surface, 200 ft I believe. I suggest you add that add that condition her also.
	3.5, references				I did not attempt to check or verify references…

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3	3.1.12	3-50			

Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Donald Bills **Commenter Affiliation (if applicable):** GGA-TAC Member

This file introduces a table that allows you to easily enter the following key information so we have certainty about your input. The table includes the following categories:

- Chapter Number
- Section Number
- Page Number
- Paragraph Number (starting with the first full paragraph at the top of a given page)
- Figure/Table Number (if applicable)
- Comment

INSTRUCTIONS

1. Please **ONLY** use the MS Word or PDF document titled "Colusa Subbasin GSP Chapter Input" to submit your comments.

2. Review all applicable text and note each Chapter, Section, Page, and Paragraph number associated with a comment you'd like to make. For Paragraph number, please start with the first full paragraph at the top of a given page and count down.

3. Enter your name and if applicable, an organizational affiliation at the top of your table.

4. Once you have completed all your comments, please save the file with your last name at the end in parentheses. For example:
   - *Colusa Subbasin GSP Chapter Input (Jones).docx*

5. If you are located in the Glenn Groundwater Authority, please send your comment file to:
   - Lisa Hunter – Program Manager - Glenn Groundwater Authority: lhunter@countyofglenn.net

6. If you are located in the Colusa Groundwater Authority, please send your comment file to
   - Mary Fahey – Program Manager - Colusa Groundwater Authority: mfahey@countyofcolusa.com

7. If you don't affiliate specifically with either the CGA and/or GGA, please send your comments to both Mary and Lisa.

8. Please make sure that your comments are submitted by midnight May 5, 2021.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
4	4.2.2.2.1	4-4	1		Groundwater levels should be measured from a pre-established and recorded reference point. — The reference point elevations (RPE) need to have been surveyed to the NAVD 88~~, feet~~ and shall be accurate to within 0.5 feet, at a minimum (23 CCR §352.4(a)(4). The USGS standard is 0.1 ft. The reasoning is related to the accuracy of GW model results. If the accuracy of GWLs input to GW models are not accurately known, any errors in model results propagate over time through the model runs. As a result, GWL changes and associated changes in inflow, outflow and storage become increasing less certain. In the case of the Colusa subbasin knowing the accuracy of the MP to only 0.5 ft could result in WL changes of +/- 0.5 ft and storage changes of +/- 0.5 ft (100,000s af/y potentially). Also, Accurate to within 0.5 ft at a minimum seems a little ambiguous. Do you mean that 0.5 ft is the least accurate value acceptable but greater values (1.0 ft, 5.0 ft, etc.) are also acceptable? I would suggest you change this phrase to : " accurate to within +/- 0.5 ft (+/- 0.1 ft if you are going to use the more broadly accepted standard). If you make the change here, make it throughout the rest of the text.
	4.2.2.2.1	4-4	1, bullet 2		"…Equipment should be operated and maintained in accordance with the manufacturer's instructions." The WL measuring equipment should be calibration checked annually to be sure it is still the same as the original manufacture calibration. In addition, if a well probe is stuck in is a well but can be removed. The calibration of the well probe should be verified before the probe is used again.
	4.2.2.2.1	4-4	1, bullet 3		Monitoring wells developed in partially confined or confined aquifers can have a pressure gage installed in the well cap as a further indication of potential hydraulic head.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	4.2.2.2.1	4-4	1, bullet 4		Near pumping, recently pumping nearby. Nearby stream flowing or not recently following or not, etc.
	4.2.2.2.1	4-4	1, bullet 6		Water levels shall be measured to the nearest 0.1 foot, at a minimum (23 CCR §352.4(a)(3). Measurements to the nearest 0.01 feet are preferred and should be used if the equipment allows. — Groundwater elevations (GWE) are calculated as the RPE minus measured depth to water (DTW). See the problem here? It your RPE is only accurate to +/- 0.5 ft, your GWE is now only accurate to +/- 0.6 ft. USGS standard is to measure RPE's to +/- 0.1 ft and WLS to +/- 0.01 ft (depths less than 500 ft) and round to the nearest 0/1 ft. In addition, all depth to water measurements in wells are repeated until you can get three results within 0.1 ft of each other. The average is used.
4	4.2.2.2.1	4-5	2, bullet 5		"Recorded information should include:…" NOTE: The Height of the RPE can and will change over time. That is why it should be checked at least annually, and the new elevation noted if it has changes.
	4.2.2.3	4-6		Figure 4-1	Significant cones of depression (GW withdrawal for Ag.) occur to the NW of Orland just south of Stony Creek and to the SW of Orland. Yet, there is only one monitoring well (21N04W12A001-004M) available to evaluate these drawdowns as they develop over time. I would suggest additional monitoring wells be places in these areas. The same is true in the area to the west of Artois and Willows.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	4.2.2.3	4-12	2		"Many of the surface waters are near wells included in the current groundwater monitoring network, except for the surface waters within the Colusa National Wildlife Refuge, east of Williams." Suggest you add the following to this: "…east of Williams, N and NW of Orland near Stony Creek, NW of Artois along the middle reaches of Walker Creek, and NW of Willows along the middle reaches of Willow Creek."
	4.2.2.3	4-12	5		Are the caved-in of casing collapsed wells going to be repaired or replaced?
	4.2.2.4	4-12	2, item 2		Consider adding: c. Areas of active drawdowns (storage decline) with minimal monitoring well coverage.
4	4.2.2.5.2	4-14			I would recommend considering adding monitoring wells in the areas mentioned in my comments on page 4-6 and 4.12. Figure 4.2 already shows one well being removed from the network in the areas near Orland mentioned in comments on page 4-6.
	4.2.3	4-14			Irrigated Ag is also known to increase salinity in shallow water-bearing zones as irrigation leaches minerals from the soil. I would also add nitrate as a constituent of concern for the Colusa subbasin. Nitrates resulting from livestock operations and areas with a high density of septic systems are known to also leach in to the subsurface.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	4.2.3.2	4-16	1		Wilde, 2005 has been updated extensively. Newer versions od different chapters of the report were developed in 2008, 2012, 2014, 2018, 2019, 2021 The entire manual is now available online at: https://www.usgs.gov/mission-areas/water-resources/science/national-field-manual-collection-water-quality-data-nfm?qt-science_center_objects=0#qt-science_center_objects 3rd Bullet: Sample integrity, i.e. ppb protocol? Perhaps add a comment about the chain of custody (oops… bullet 14).
	4.2.3.2	4-16	2, bullet 2		And the unique identifier should be verified to already exist in the data base so the data has a home and does not end up in a "unknown site" file.
	4.2.3.2	4-16	2, bullet 6		During purging of the well field parameters should be monitored until stable to insure the well has been correctly purged. Easy to do with a QW multi meter.
	4.2.3.2	4-16	2,bullet 8		Suggest adding dissolved oxygen (DO) to the list of filed parameters. GW typically has low or near zero DO. Water sitting in well casing for a period of time will accumulate concentrations of DO. Represents another good indicator of proper well purge.
	4.2.3.2	4-16	2, bullet 9		Sample labels can be preprinted in the lab with all the appropriate info. Prevents the smearing of hand-written labels using pencil, ink and even waterproof ink (Sharpie). Also be aware that the outside of the sample bottles can "sweat" in coolers or other containers. The result is the label glue will weaken and the labels will come off. Double bag samples is one solution.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	4.2.3.2	4-16	2, bullet 10		Field parameter DO is a good indicator of this. Laminar flow may require the use of a variable speed pump so DD is not excessive during collection of the water sample.
	4.2.3.2	4-16	2, bullet 11		DQOs? Is this a reference to Quality assurance. If so a number of duplicates, blanks and spike samples will need to be processed either in the lab or on site, depending on the type and number of water samples being collected during an individual field run. Maybe briefly explain here?
	4.2.3.2	4-16	2, bullet 12		In this case DQOs appears to be referring to lab detection limits for individual constituents. Correct or no? May need more explanation here.
	4.2.3.5	4-19	1		The lead sentence suggesting the existing QW monitoring programs as sufficient contradicts 4.2.3.4 which says they are not sufficient. If the existing monitoring wells are not spatially located enough to address salinity concerns or, not deep enough to detect upwelling of brackish GW from below, they are indeed not sufficient.
	4,2,3,5	4-19	2		Small diameter monitoring wells pose additional issues for the collection of Value QW samples. Small diameter submersible pumps (less than 2 inches) are few and far in between. Typically, they are limited to lifts of 100 ft or less, and have small pumping rates (~one gpm or less). Bailers (Teflon preferred) are another option and are readily sized to fit in 2-inch monitoring wells. Bailing a well to purge can be difficult depending on the depth. Bailers have to be pre cleaned between each water sample. Bailer sample volumes may be on the order of 1 liter or less meaning several bail volumes to collect a sample.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
					Then there is still the issue if ant of the monitoring wells are deep enough to register upwelling of brackish water from below.
	4.2.4.1 lands subsidence	4-20	2, bullet 8		Land subsidence should be measured at least as accurately as SWLs if not more accurate. Small changes in land subsidence (tenths of a foot, not half a foot or more) can have a significant impact on the surface and on GW storage. If you are measuring the elevation of ground surface to +/- 0.1 ft and the elevation of your RP to +/- 0.5 ft, again the accuracy of your subsidence measurement is no better than +/- 0.6 ft.
	4.2.5.1	4-24	1, bullet 7		Benchmarks at USGS stream-flow gaging stations are surveyed to the nearest 0.01 ft. One-hundredth foot accuracy is critical to development of a good (+/- 5 percent of the actual flow) or better stage-discharge relationship. If not, you risk losing indications of GW supported base flow and any seasonal signature of gaining or losing flow to/from GW. As an aside, the USGS also requires a minimum of 10-years of continuous (every 15-minutes) record for the data to have any statistical significance.
	4.2.5.2	4-24	3		Accuracy of stage data is +/- 0.01 ft (required).
	4.2.5.5	4-24	1		Figure 4-4 is land subsidence. I think you mean figure 4-5. The legend for figure 4-5 does not provide adequate explanation of the different stream types shown on the map (perennial, intermittent, ephemeral, canals, or drains). The line widths and colors vary from thick to very thin and light blue to very light blue respectively. It needs to be revised.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	4.2.5.5	4-25	2		"Additionally, existing stream and drainage reports will be evaluated for additional information on the timing, stage, and magnitude of flows in ephemeral and intermittent streams in the subbasin, if necessary to fill data gaps or support projects and management actions during GSP implementation." There used to be a stream-flow gaging station on Walker Creek at Artois. Still there? Still active? There also use to be a gage on the Glenn-Colusa Canal where it crosses Stony Creek south of Hamilton City. Still there? Still Active? I imagine there are additional discontinued stream-flow gaging stations scattered across the Colusa subbasin. If the structures for these sites are still there, they can be re-established by installing stage recorders and making periodic discharge measurements to verify the old stage discharge relationships. Besides the Colusa Drain, Willow Creek west of Willows is another intermittent/ephemeral stream that would be worth the effort to gage.
	4.3 References	4-27			Add Wilde (2005) or most recent reference(s) available. Reference for California Rice Commission? Reference for California Statewide Groundwater Elevation Monitoring Program (CASGEM)?

Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Emil Cavagnolo **Commenter Affiliation (if applicable):** GGA / OAWD

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COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
2	2.1.2	2-4			Monroeville WD is a Groundwater District
2				2-3	OAWD's Service Area is currently just under 30,000 acres
2	2.2.1.1	2.16	4		OAWD's latest WMP is 2020
2	2.5.1.2	2-29	1		Colusa Sub Basin not Chowchilla
2	2.5.1.3	2-32	5		The public meeting in Orland was at the Glenn County Fairgrounds

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
2	2.5.1.3	2-33	6		I do not remember this type of meeting in Glenn County
3	3.3.3.3	3-83	last		Agricultural Water Demand is a heading and should be Bold Print

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment

Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Mary Fahey **Commenter Affiliation (if applicable):** CGA

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COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
1	Cover Page	Cover Page	N/A	N/A	1. Title: Change to Colusa Subbasin Groundwater Sustainability Plan. 2. Add Logo to page 3. Under "Prepared for", change Colusa GSA and Glenn GSA to: Colusa Groundwater Authority and Glenn Groundwater Authority 4. Make these same changes on the second page
All Chapters	Entire Document – footer				Change footer to read: Colusa Groundwater Authority and Glenn Groundwater Authority Colusa Subbasin Groundwater Sustainability Plan
1	1.3.1	1-3	1		Please specify that there are **two** Private Pumper Representatives from the Colusa County Groundwater Commission, **appointed by the Colusa County Board of Supervisors**
1	1.3.1	1-3	4		Second Sentence, please edit as follows: **Except for the Private Pumper representatives**, Board members are chosen in public meetings by the respective governing boards of the Member Agencies…. **Private Pumper representatives on the CGA Board are recommended by the Colusa County Groundwater Commission and appointed by the Colusa County Board of Supervisors**.
2	2.1.1	2-1	4		Glenn and Yolo County boundary should be **Colusa** and Yolo County boundary

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
2	2.1.2	2-4	1		Fourth line – Change water pumpers to groundwater pumpers: …and two appointed private **groundwater** pumpers…
2	2.1.2	2-4	2		Orland and Willows are in Glenn County. Colusa and Williams are in Colusa County.
2		2-4		Table 2-2	Grimes water district should be: Colusa County waterworks district #1 – Grimes Also in Colusa County: Colusa County waterworks district #2 - Princeton
2				Fig. 2-3	The map is titled Colusa Subbasin GSA Member Agencies but does not show/list Colusa County or Glenn County Under Note 1: There are two private pumpers from the Colusa County Groundwater Commission on the CGA Board There are no private pumpers on the GGA Board
2	2.2.1.1	2-15	6		(NSV IRWM) last sentence, add year that the update was adopted. In March, **2021**….

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
2	2.2.1.1	2-18	2		Second bullet states "The following GSAs have readily available MSRs:" Don't you mean "The following GSA Member agencies…"?
2	2.2.1.2	2-19	1		I believe CCWD has a SCADA system. There may be other districts as well that are not listed.
3	3.1.7.3.1	3-32	5		Faults: Second to last sentence, Zamora Fault should be listed along with the others that were analyzed.
3	3.1.10.2	3-42	1		Primary Users, first sentence – can this be re-worded. It sounds like there are only 20 Stakeholders in the basin.
3	3.1.11.2.3	3-45	2		– The TNC project is better described as an on-farm multi-benefit managed aquifer recharge and shorebird habitat program. Where it says migratory birds, please specify migratory shorebirds.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
3				3-19	Water source layer missing for Colusa County portion
4	4.1	4-1	1+		Should monitoring for GDEs be mentioned in the discussion about the monitoring networks?
4	4.2.2.2	4-4	1		Will this section be expanded to include more details?
4	4.2.3.3	4-17	1		Suggest spelling out Irrigated Lands Regulatory Program (ILRP) in first sentence
4					General chapter 4 comment: This Chapter will need to be updated based on recent activities/discussions/decisions, especially regarding monitoring and filling data gaps for stream interactions and GDEs. Also, information about the coordination efforts taking place along basin boundaries between the neighboring subbasin GSAs should be expanded. Overall, this chapter reads light on describing the Colusa Subbasin monitoring network and heavy on listing excerpts from the regulations.

Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Mary Fahey **Commenter Affiliation (if applicable):** Colusa County/CGA

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COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
5	Intro	5-1	1		Second sentence, instead of "Colusa GSAs", please use either "Colusa Subbasin GSAs" or "Colusa Groundwater Authority and Glenn Groundwater Authority"
5	5.3.1.3	5-6	3		Type-o, line 3, pumping would have **to** increase…
5	5.3.4.1	5-11	1, 2nd bullet		Type-o, increase **in** the number of…
5	5.4.1	5-16	1		Is "Section 0" correct?
5	5.4.7	5-33	5		Type-o, Stony Creek
5	5.4.7	5-32			If you feel it's appropriate, this is a good opportunity to mention here that the CGA, GGA and neighboring GSAs have been coordinating throughout GSP development and will continue to coordinate and share technical data during GSP implementation.
Appx 5A		2	1-3		It should be noted that the SMC were also vetted and approved by both the CGA and GGA Boards at open, publically noticed meetings.
Appx 5A		2	3		Members of the public were welcome to attend all of these meetings and were encouraged to express their opinions and suggestions. There was very good stakeholder attendance and participation at these meetings.

Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Mary Fahey **Commenter Affiliation (if applicable):** County of Colusa/CGA

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COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
6	6-1	6-4	3		2nd bullet: Suggest removing the second sentence regarding demand management. This type of PMA is a last resort and should not be highlighted.
6		6-6		Table 6-2	First project: Colusa Subbasin Multi-Benefit Groundwater Recharge (TNC). This project concludes in the spring of 2021, not 2020.
6	6.3.3.1	6-29	1		Add a program benefit – Groundwater conditions (via groundwater Recharge)
6	6.3.3.1	6-29	3		Pilot program concludes in 2021. The program evaluated flooding that would provide habitat benefits for migrating shorebirds, and groundwater recharge. Both (habitat and recharge) are equal goals of the project.
6	6.3.3.1	6-30	1		While the current project is limited to SDAC communities due to grant funding requirements, ongoing, the project would not be limited to benefitting water levels in DACs.
6	6.3.3.2	6-32	1		Pilot program runs from 2018-2021. Also update dates in Table 6-13.
6	6.3.3.4	6-32	3		Depending on the farm, there may be installation of monitoring equipment required (flow meters, groundwater level monitoring devices)
6	6.3.3.6	6-32	5 (last)		Program completed in 2021
6	6.3.3.6	6-33	2		Last three bullets should be indented further
6	6.3.3.7	6-33	Last		Could the CGA and GGA also serve permitting roles?
6					General comment – excellent work on this chapter. This is a great set of tools that the GSAs can pull from as they implement SGMA in the Colusa Subbasin.

COLUSA SUBBASIN

Colusa Subbasin Groundwater Sustainability Plan Public Review Draft Input

Commenter Name: Lisa Hunter **Commenter Affiliation (if applicable):** GGA

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8. Please make sure that your comments are submitted by 11:59 p.m. October 31, 2021.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
Executive Summary	N/A	ES-1	12-19		This is a general discussion on SGMA- suggest changing "subbasin(s)" to "basin(s)"
Executive Summary	N/A	ES-3		Figure ES-1	In the legend, remove "(Colusa Subbasin)" following "Colusa Groundwater Authority GSA"
Executive Summary	N/A	ES-5		Figure ES-2	The background color makes it difficult to read the cities and see the boundary on the fence diagram- consider changing the color of the background or the boundary & city names
Executive Summary	N/A	ES-14	12		Change "twelve" to "12" to be more consistent with the format in the prior paragraph
Executive Summary	N/A	ES-21		Table ES-5	Consider using thousands rather than millions in the 5th column so there are fewer decimals. It may be easier to ready.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
1	1.1	1-1	11		adopt Groundwater Sustainability Plans (GSPs) for non-critically overdrafted medium- and high-priority groundwater basins
1	1.3	1-2	26		~~Colusa and Glenn GSAs~~ CGA and GGA
1	1.3.1	1-3	18-19		Please add details similar to what is included for the CGA. The GGA was formed 6/20/2017 as a JPA with 9 member agencies (8 Director seats). The JPA was amended 10/14/19 to add a 10th member and one additional Director seat for a total of 9 Director seats. The GGA is the exclusive GSA for the Glenn County portion of the Colusa Subbasin.
1	1.3.1	1-3	19		The GGA has nine Director seats (this change is also suggested in the comment above)
1	1.3.1	1-4	1		Update GGA contact information: Glenn Groundwater Authority: Lisa Hunter, Water Resources Coordinator ~~(530) 934-6501~~ (530) 934-6540 ~~720 North Colusa Street~~ 225 North Tehama Street Willows, CA 95988 lhunter@countyofglenn.net

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
1	1.3.2	1-4	15		with preparing the GSP and coordination activities in
1	1.3.3	1-5	4		under separate rate studies
2	2.1.1	2-1			It might be helpful to note that no basins/subbasins border the western portion of the Colusa Subbasin.
2	2.1.1	2-2		Table 2-1	~~Corning Subbasin GSA~~ ~~Corning Sub-basin GSA~~
2	2.1.2	2-4	8		water/irrigation districts

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
2	2.1.2	2.-4	11		Butte City is in the Butte Subbasin and should not be included here.
2	2.1.2.1	2-4	18-19		"Municipal water users in the Colusa Subbasin depend on groundwater." This sentence seems to be more appropriate in the next paragraph under "Municipal Water Purveyors"
2	2.1.2.1			Figure 2-2	Remove "Colusa Subbasin" after Colusa Groundwater Authority GSA in the legend
2	2.1.2.1				Are small water systems discussed?
2	2.1.2.1			Table 2-3	The page number appears as 2-11 (and should be 2-10)

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
2	2.2.1.1	2-17	16-18		Add “tribes”
2	2.2.1.1	2-17	33		The NSV IRWM Plan was revised March 2020
2	2.2.1.1	2-19	18-30		The Glenn County Groundwater Management Plan was adopted in 2000 (Ordinance 1115), revised in 2012 (Ordinance 1237). Incorporation of the Preliminary Plan and the Export Water Transfer Guidelines in Ordinance 1237 was very important.
2	2.2.1.1	2-20	11		~~A Counties'~~ Local Agency Formation Commissions (LAFCO) in each County conducts reviews of municipal
2	2.2.1.2	2-22	31		When land is in agricultural production it is generally irrigated and fertilized.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
2	2.2.3	2-26	1-4		Exhibit C also contains Export Water Transfer Guidelines
2	2.5	2-31	29		The GSAs in the Colusa Subbasin will seek to work with Colusa and Glenn Counties
2	2.7.1	2-34	28		To guide and facilitate beneficial user engagement in the ~~GSA~~ GSP process,
2	2.7.1	2-35	4-5		"Reflecting its "living document" role as a compilation / repository reflecting various engagement activities implemented or planned to be implemented by the GSAs." This sentence does not appear to be complete. Consider revising.
2	2.7.1.1	2-35	25		Were the mandates adopted by the counties? Is that the appropriate word? Please double-check.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
2	2.7.1.2	2-37		Table 2-8	In the Tribes row, it notes “consult”. Consult has a very specific meaning here. It that the appropriate word. Would it be more accurate to note collaborate? Consult if requested?
2	2.7.1.3	2-38	2		~~SMGA~~ SGMA
2	2.7.1.3	2-38	9-12		Consider revising to be clear that all boards/committees requiring Brown Act compliance were conducted in such a manner and an effort was made to be inclusive. (There are ad hoc committees that did not require Brown Act compliance)
2	2.7.1.3	2-38	25		the GSAs have adopted a comprehensive table-based GSP comment
2	2.7.1.3	2-38	29		~~weekly by GSA staff~~ on a regular basis by facilitation staff and is then included in the agenda packet for each ~~GSP~~ GSA Board meeting beginning in XX (Date)

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
2	2.7.1.3	2-38	32-34		each Board agenda defines said decision as a formal action ~~and further includes an agendized item for~~ which could include discussion by each Board about associated public input recorded in the comments tables that might inform their decision-making.
2	2.7.1.3	2-38	41		• ~~Final public comment period prior to adjournment of each meeting.~~ Final public comment is not agendized on Board or TAC meeting agendas- Member comments are. While frequently, final public comments are taken at that time, I suggest removing the general statement because it may not be accurate.
2	2.7.2.1	2-39	3-4		thereafter ~~to present~~ September 2021, the parties that make up the CGA and GGA have collectively sponsored, publicized and conducted over 236 separate It may be helpful to note in this section, the meetings referenced were the meetings that are open to the public. Additional ad hoc meetings were held (some of which members of the public attended)
2	2.7.2.1	2-39	22-23		Committee and Subcommittee meetings) requiring compliance with the Brown Act, agendas ~~and associated background information~~ are posted no less than 72 hours before a meeting and all materials presented in said meetings Background material is made available once prepared and distributed to the board.
2	2.7.2.1	2-39	29-30		All public outreach meetings were similarly publicized through Facebook and Twitter.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
2	2.7.2.1	4-40	15-17		On a regular ~~and publicly noticed~~ basis, inter-basin meetings of representatives from the Colusa Subbasin met with representatives from the adjacent Corning, Butte, Sutter and Yolo Subbasins (and other non-adjacent subbasin representatives) to discuss interconnected
2	2.7.2.1	4-40	28		As described above, ~~In~~ in the initial stages of GSA
2	2.7.2.1	4-40	35+		There were also 3 meetings in 2015 with general SGMA information co-sponsored by the Glenn County WAC, Glenn County Farm Bureau, and the UC Cooperative Extension.
2	2.7.2.2	2-42		Table 2-9	Include the Preface in the Public Draft Review
2	2.7.3.1	2-42	15-17		~~Confidentiality~~ sensitive information, actual contact information of interested parties is not appropriate to publish as part of this GSP). Any interested member of the public could be added to the lists by signing up via ~~respective~~ online entry options located on the CGA ~~respective GSA's~~ websites and through email sign up options or requesting by phone for each GSA.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
2	2.7.3.1	2-42	18+		Did we connect with Cortina?
2	2.7.3.5	4-43	33		to view all outreach events from late 2020 through (ADD DATE) and including public review and subsequent GSA
2	2.7.3.6	2-44	9		(when available after ~~Match~~ March 2020)
2	2.7.3.6	2-44	22		GSP background documents~~ including Drought Preparedness and Response~~
2	2.7				General comment: It would be helpful to define "public meeting". It is referenced frequently and may confusion between Board and/or committee meetings which are open to the public and public outreach meetings which follow a different process, including the outreach done to advertise public outreach meetings (for instance board meetings are not publicized in the social media and via press release, whereas public outreach meetings were)

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
3	3.1.3	3-4	5-6		with periods ~~of~~ exceeding 100-degree Fahrenheit temperatures.
3	3.1.5.1.1			Figure 3-7	This comment refers to this figure and other similar figures. The small inset graphic is useful to see the trends; however, the x and y axis labels are not legible- can the labels be clearer? Perhaps darker to facilitate reading them?
3	3.1.5.1.3	3-13	21		Missing a "." after Subbasin
3	3.1.7.2.1	3-30	33-34		Is the sentence referencing the average yield in the West Butte Subbasin relevant here? If so, should it reference the Butte Subbasin instead? If not, I suggest removing.
3	3.7.8.1	3-35	39-40		Also reference the CCWD jurisdictional boundary

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
3	3.1.8.2	3-36	6		Is the Corning Subbasin intended to be referenced in the text or was this a carryover from prior work?
3	3.1.11.1	3-43	17-18		, along Stony Creek. ~~Stony Creek is~~ Groundwater underflow may occur…
3				Figure 3-18	Why is there no soils color shading in the vicinity of Orland?
3	3.1.11.3	3-46	11		or through discharge to ponds, springs, wetlands,
3				Figure 3-19	The labels appear to be missing.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
3				Figure 3-21	Figure 3-21 is referenced but appears to be missing. Instead Figure 3-23 is inserted two times (once after page 3-49 and once after page 3-58)
3	3.1.11.3	3-49	25		It may be useful to note that the well extraction information includes more that just the Colusa County portion of the Colusa Subbasin- if I understand, it includes all of Colusa County.
3	3.1.12.4	3-54	31		Glenn County is also mapping and recording reports of dry wells. See regular updates at: https://arcg.is/10nmyT2 Colusa may also be tracking.
3	3.1.12.5	3-55	1		delineation of groundwater dependent ecosystems
3	3.2.2	3-55	29		Add the conditions to 2020 to be consistent with the rest of the sentence.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
3	3.2.2	3-55	32		Consider adding potential environmental impacts
3	3.2.5.1	3-67	38		Is “Eh” a typo? Should it be EC? If so, please correct. If not, please add to the acronym list.
3	3.2.5.2	3-70	35		Is this intended to be Colusa County’s wells of Colusa Subbasin wells?
3	3.2.6	3-73	38		near Zamora in Yolo County (outside of the Colusa Subbasin), at 12N1E34Q1
3				Figure 3-32	It would be helpful to add the cities points layer with labels similar to the other figures.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
3	3.2.7.1	3-78	16		For clarity please note if the net gain is to groundwater or to the stream. (I assume the gain is to groundwater.)
3				Figure 3-34	Suggest adding Stony Creek to the title "Stony Creek Thalweg Analysis"
3				Figure 3-36	In this figure, it is difficult to understand where the final "potential GDEs" or likelihood of GDEs exist. The legend is a bit difficult to follow as well. It may be useful to have a final figure without the extra layers to clearly denote the potential GDEs and likelihood scores.
3	3.3.1	3-86	8		This references a 26-year period. Page 3-98 states a 25-year period. Please reconcile throughout.
3	3.3.1	3-86	30		Capitalize Subbasin

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
3	3.3.3.1	3-89	37-42		Was the Glenn County General Plan used? If not, please specify how the information was interpolated, similar to how it was done under the Urban and Industrial Water Demand section on page 3-93
3	3.3.3.3	3-92	37-39		Was the Glenn County General Plan used? If not, please specify how the information was interpolated, similar to how it was done under the Urban and Industrial Water Demand section on page 3-93
3	3.3.4.1.1	3-101	14-15		Diversion agreements/reductions are specifically called out for Sac River Settlement Contractors. Would it be useful to also note other supply cutbacks such as the TCC Districts?
3	3.3.4.1.2	3-101	36		Change basin to Subbasin.
3	3.3.4.3.1	3-105-3-106	21-22	Figure 3-44	The text indicates +0.6 taf/yr while the figure indicates 1 TAF per year (I assume to figure is rounding). This may be helpful to reconcile.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
3	3.3.4.3.2	3-107-3-108	12-13	Figure 3-46	The text indicates -2.7 taf/yr while the figure indicates -3 TAF per year (I assume to figure is rounding). This may be helpful to reconcile
3	3.3.4.3.3	3-109-3-110	14-15	Figure 3-48	The text indicates -7.3 taf/yr while the figure indicates -7 TAF per year (I assume to figure is rounding). This may be helpful to reconcile
4				Table 4-2	Footnote d- SWL should be SWD
4	4.2.4.5	4-29	29		The ~~Colusa and Glenn~~ Colusa Subbasin GSAs are
4	4.2.4.5	4-29	34		Remove the “s” from Willows. Should be Willow Creek.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
4	4.2.4.5	4-30	7		the ~~Colusa and Glenn~~ Colusa Subbasin GSAs
4	4.2.5.4	4-33	31		monitoring sites for groundwater dependent ecosystems.
5	5.2.1	5-3	28		Might be useful to indicate the PMAs could be implemented by other partners (not just the GSAs).
5	5.3.1.4	5-7			Include stock water impacts (hauling water, selling livestock, etc)
5	5.3.2.5	5-10			Include stock water impacts (hauling water, selling livestock, etc)

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
5	5.3.2.6	5-10	27		Updates should not be capitalized
5	5.3.4.1	5-12	9		Irrigation or stock water supply
5	5.3.6.2	5-15	31		Use GGA and CGA instead of spelling out
5	5.3.6.2	5-15	33		will occur utilizing a subset of wells in the Subbasin's groundwater elevation monitoring network selected for
5	5.4.1.1	5-19	Not present		In the Minimum Thresholds section #1- when discussing domestic wells, it may be appropriate to reference the Human Right to Water. It may also be useful to note in the section (when discussing that very shallow wells likely do not meet current health standards. At the end of #1, add "contained in the DWR database" after protect 80 percent of domestic wells.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
5				Figure 5-1 and similar	It would be useful to add which method was used to determine the MT. Could be added on the right hand side under Minimum Threshold: XX ft
5				Table 5-2	It would be helpful to add a column to denote which method was used to determine the MT. It could be simply 1 or 2 with explanation in the footnote section.
5	5.4.5.1	5-29	3-10		Based on discussion, evaluating infrastructure sensitivity may be a good project for the GSP.
5	5.4.5.1	5-29	17		Glenn County has data from 2004.
5				Figure 5-2 and similar	Minimum Threshold should be ft bgs not ft

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
5	5.4.6.1	5-34	4		better represented local conditions at that time rather than adding an additional 10 feet (in order to be more protective).
5	5.4.7	5-36			Should water quality and subsidence be mentioned in this section?
6					This chapter should discuss the PMA submittal process including the online submittal forms to gather stakeholder ideas and ongoing nature of including PMAs in the GSP.
6				Figure 6-1	The title "Colusa Subbasin PMA" does not seem appropriate for the image and may be unnecessary. The legend indicates blue lines for "Groundwater Basins"- is that correct? It seems to be streams. The legend does not include water districts or what I assume are wells. Those may be helpful to include. Generally, this is quite a busy figure for the purpose. Consider simplifying.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
6	6.1	6-4	6		Planned PMAs ~~that will~~ are expected to be implemented to primarily address current,
6	6.1	6-4	34		Add "The PMAs are not ranked."
6	6.2.1	6-6	24-28		Note that not all projects are the responsibility of the GSAs, but rather a partnership or sometimes the GSAs will have a supporting role.
6	6.2.1	6-6	34		GSAs, ~~and~~ districts, and other partners in the Colusa Subbasin will further develop
6				Table 6-2	DWR is also a partner in the Colusa Subbasin Multi-Benefit Groundwater Recharge moving into the expanded program. In the Sycamore Slough Groundwater Recharge Pilot Project- "from" should not be capitalized. "would be available From settlement contract" The Sites Reservoir Project says "The Sites Project is a new off-stream storage…" It might be helpful to clarify this is in development, not that the project has completed a new storage facility.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
					The well abandonment outreach and funding program should specify this would be accomplished by working with well permitting agencies. Review of County Well Permitting Ordinances should specify the GSAs would work with the counties to review and **suggest** revisions to ordinances (these are outside of the jurisdiction of the GSAs)
6	6.3.1.3	6-19	5		~~County~~ LAFCO
6	6.3.3.1	6-29			See comments on Table 6-2 relating to this project.
6	6.3.3.1	6-30	3		Should this reference waterbirds or shorebirds?
6	6.3.3.4	6-32	11		recharge sites

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
6	6.3.3.4	6-32	13		~~winter~~ specific months
6	6.3.3.5	6-32	24-25		The program is summer/early fall and/or spring (July 15-October 15 and/or March 15-April 15). Please adjust references to timing, here and in other sections relating to this project.
6	6.3.3.6	6-32	29		Add a sentence to provide an update on 2021. Due to dry conditions in 2021, the project implementation was delayed.
6	6.3.3.6	6-33	3		Clarify the availability of **surface** water rights
6	6.3.3.6	6-33	4		Missing bullet point

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
6	6.3.3.6	6-33	21		Indicates the project is not expected to terminate. Please note this is a pilot project that could be continued if deemed appropriate.
6	6.3.4.2	6-37		Table 6-15	Glenn County LAFCO should be changed to Glenn LAFCO
6	6.3.4.3	6-37	13		Glenn County LAFCO should be changed to Glenn LAFCO
6	6.3.4.6	6-38	20		Glenn County LAFCO should be changed to Glenn LAFCO
6	6.4.1	6-46	14		This section ~~described~~ describes ongoing

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
6	6.5.1	6-58	2		If determined to be necessary or desirable under
6				Table 6-34	Reference to migratory waterfowl be changed to migratory birds (could be waterfowl or shorebirds?)
6	6.5.1.7	6-69	11		shorebirds/waterfowl as ~~we pulse flood the field~~ the field is pulse flooded, or
6				Table 6-35	One period after Sycamore Slough in the implementation description. In the benefits and benefit evaluation methodology, it notes waterfowl. Will it also include shorebirds?
6				Table 6-36	In the implementation description, it may be useful to add a sentence indicating that this concept could be applied throughout the Colusa Subbasin.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
6	6.5.2.3	6-84	6		Remove “or MO”
6	6.5.2.3	6-86	1		action ~~will only~~ could be triggered
6	6.5.2.3	6-86	13		Add “for domestic purposed only” when describing de minimis use
6	6.5.2.7	6-91	1		would review and ~~revise~~ suggest revisions to the county
6	6.5.2.7	6-91	11-12		Replace “better” with “appropriate” It might also be useful to note requiring depths to be deeper than MTs.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
6				Table 6-51	In the implementation description, it should not the action would be to review and **suggest revisions** to the county well permitting
6				Table 6-52	In the implementation description, it may be useful to include that this action could be done in coordination with neighboring GSAs, especially along Stony Creek.
7				Table 7-1	There are two Table 7-1 (page 7-3 and 7-4) In the second table, in the well inventory program description: Add that the program would seek to identify wells that are no longer active In the well registration program- remove the reference to voluntary. This could be voluntary or not.
7	7.1.2.8	7-9			Add that the program would seek to identify wells that are no longer active
7	7.1.2.9	7-10	2		Remove reference to voluntary.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
7	7.2	7-16			It might be appropriate to add that some details on the cost allocation between the GSAs remain to be finalized.
7	7.6	7-22	24		GSAs are ~~pursuing~~ considering a combined approach…

Colusa Subbasin Groundwater Sustainability Plan Public Review Draft Input

Commenter Name: Ben King **Commenter Affiliation (if applicable):** Chapter 1 Comments

This file introduces a table that allows you to easily enter the following key information so we have certainty about your input. The table includes the following categories:

- Chapter Number
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INSTRUCTIONS

1. Please use the MS Word or PDF document titled "Colusa Subbasin GSP Input 9.2021" to submit your comments.

2. Review all applicable text and note each Chapter, Section, Page, and Line number associated with a comment you'd like to make.

3. Enter your name and if applicable, an organizational affiliation at the top of your table.

4. Once you have completed all your comments, please save the file with your last name at the end in parentheses. For example:
   - *Colusa Subbasin GSP Input 9.2021 (Jones).docx*

5. If you are located in the Glenn Groundwater Authority, please send your comment file to:
   - Lisa Hunter – Program Manager - Glenn Groundwater Authority: lhunter@countyofglenn.net

6. If you are located in the Colusa Groundwater Authority, please send your comment file to
   - Mary Fahey – Program Manager - Colusa Groundwater Authority: mfahey@countyofcolusa.com

7. If you don't affiliate specifically with either the CGA and/or GGA, please send your comments to both Mary and Lisa.

8. Please make sure that your comments are submitted by 11:59 p.m. October 31, 2021.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
1	1.2				This is a question for the DWR. Since the DWR formally adopted a Human Right to Water ("HRTW) Policy in its Department Administrative Manual during April 2021 – does it want to state that it will be including HRTW considerations in the DWR's decision making, program activities and public engagement in SGMA and the GSP development. Wont this statement promote HRTW engagement?
	1.3.1				Typo for Private Pumpers – appointed by Colusa Groundwater BOS ? Did you mean to say recommended by the Commission and appointed by the BOS? Were there public meetings for the appointment by the Board Members by GSA's? It would be great to know that the GSA's have public meetings. Do they have websites and interested party lists? Please confirm that each GSA has websites and posts notice of meetings at a minimum.
	1.3.3				Are these costs for the Basin as a whole? It would be good to break these costs on a per acre basis and discuss how the costs are allocated to Cities and small water systems. For example – what does the CGA expect the City of Williams to pay going forward? Voters in the Cities need to know. What will the County of Glenn and the County of Colusa be expected to contribute?

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment

COLUSA SUBBASIN

Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Ben King - Chapter 2 Comments **Commenter Affiliation (if applicable):**

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- Page Number
- Paragraph Number (starting with the first full paragraph at the top of a given page)
- Figure/Table Number (if applicable)
- Comment

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3. Enter your name and if applicable, an organizational affiliation at the top of your table.

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7. If you don't affiliate specifically with either the CGA and/or GGA, please send your comments to both Mary and Lisa.

8. Please make sure that your comments are submitted by midnight May 5, 2021.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
2.1.1					How were the vertical boundaries of the annexed area of the previous West Butte Subbasin determined since the HCM did not cover this area during previous data collection?
2.1.1					The lateral extent is not bounded by the Sacramento River to the east but it is bounded by the western boundary of RD 1004.
2.1.2.1					How many wells and what is the volume for Del Oro Arbuckle?
2.3					Why is Colusa Drain Mutual Water Company only on the map in Yolo County? All of Colusa County CDMWC is missing from the Map.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
Table 2-3		2-9			There are no entries for Surface Water Supply or Volume Descriptions for CDMWC or RD479. If there is some valid reason for the omission it should be explained in a footnote rather than just omitted.
Appendix 3-D	2.8	21		Table 2-6	Relating to Table 2-3 above there are no diversions cited for Model Input as Diversions attributable to CDMWC acreage. What is the impact of this omission?
Table 2-6		2-21			The USEPA SDWIS system reports violations and maintains a log of monitoring events. This monitoring data and time line of violations does not seem accessible on the Waterboards site. The EPA link should be included. Why isn't the Drinking Water Open Data Portal referenced as it is in 2.6?
		2-21 2-21			The CV Salt information is not online? How do stakeholders access this data. Where can Stakeholders access GAMA data?
		2-21 2-21			Where is the Sacramento Valley Water Coalition Data? Where is the groundwater quality data relating to wells used for groundwater substitution accessible? It is part of the Appendix of the Environmental Assessment for Tehama-Colusa Canal Authority In-Basin Water Transfers.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
2.3.1.3					According to the City of Colusa Policy PRC – 9.2 - The City will prepare a Water Resources bi-annual report to the City Council. The Public Works Department will analyze the quality of drinking water in the City. The description of the General Plan is incomplete because it does not mention that water quality is addressed and included in this bi-annual report to the City Council for the City of Colusa.
2.4					The Human Right to Fresh Water should be addressed somewhere in 2.3 or 2.4. Ultimately this will affect the priority of beneficial use, management actions and minimum thresholds to comply with the requirements of this Law.
2-8		2-30			Don't understand the reference to Human Right to Water as described. Doesn't this Right apply to all residents in the Colusa Subbasin and all water systems?

Colusa Subbasin Groundwater Sustainability Plan Public Review Draft Input

Commenter Name: Ben King **Commenter Affiliation (if applicable):** Chapter 2 Comments

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8. Please make sure that your comments are submitted by 11:59 p.m. October 31, 2021.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
2	2.1			Table 2-3	Table 2-3 is misleading in that it does not reflect the loss in surface supply due to water transfers. There needs to be a table that reflects the historical amount of water transfers for every water purveyor and how much of the water remains in Basin and out of Basin. Without this stakeholders can not assess the available water supply for the Basin.
	2 generally				The Colusa County GMP does a good job discussing water transfers but the GSP is silent on it. Stakeholders need transparency and understanding how water transfers work and how ground water substitution and fallowing work into the available water supply. The transparency and discussion regarding water transfers, fallowing and groundwater substitution also have potential negative DEI and HRTW outcomes because water transferred out of basin and fallowed acreage means less jobs and ground water pumped for ground water substitution could lead to aquifer degradation if the groundwater pumped is pool quality.
					Again there needs to be discussion about surface water transfers and a Table listing the number of acre feet pumped for groundwater substitution and the acres fallowed by each Settlement Contractor. Stakeholders need to know this for HRTW and DEI concerns and also for the general sustainability of economic health of the Subbasin.
	2.3.2				There needs to be a discussion regarding groundwater trading markets and how this would impact the potential water demands. The California Water Commission are holding hearings regarding groundwater trading and it is very relevant to the effects on water demands and the economic feasibility and sustainability for the subbasin. To not include any discussion is misleading and could lead stakeholders to misallocate resources or make material economic decisions without full

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
					knowledge of a likely outcome. The CWC appears to quite committed to groundwater trading and the PPIC has come out strongly in favor of water markets. It is misleading not to discuss this likelihood especially when there is such a focus on recharge in the PMAs. It would seem that some PMAs may not be economically efficient if water could be traded instead. In June of 2021, Steven Springhorn , Acting Director of SGMA discussed the framework for Water Trading for SGMA Implementation – it seems ingenious to go through this process and not discuss what the Acting Director of SGMA is presenting to the California Water Commission.
					There needs to be reference to the ERA Demand Management Actions if they remain in the GSP. If implemented these Management Actions will have the intended effect which is to limited Demand. These PMAs are DEMAND Management Actions and should be referenced and discussed in this section.
	2.5.1				Discussion about water quality testing, determination of appropriate well depth and what happens if the driller finds poor water quality. I think the answer is that this information is not captured or disclosed and therefore it is a concern for water quality and HRTW issues.
	2.6.1				The following was taken verbatim from the DWR's recent Drought Memo. This is from a footnote: DWR formally adopted the Human Right to Water (HRTW) Policy in its Departmental Administrative Manual which outlines how the HRTW should be included in DWR decision-making, program activities, and public engagement. The Water Board adopted a HRTW Resolution, recognizing HRTW as a core value and directing its implementation across programs and activities. The Water Board is also currently drafting a Racial Equity Resolution.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
					There should be a reference to the emerging HRTW and Racial Equity actions by the DRWR and the SWRCB since it is central to Stakeholder HRTW and Diversity Equity and Inclusion (DEI) concerns regarding the GSP and its future implementation.
					I strongly disagree with the statement that the GSA supported and allowed for effective engagement of all stakeholders regarding HRTW and DEI issues. I would urger the DWR to expressing prohibit GSAs taking any action against a stakeholder unless a mediator is brought in especially regarding situations where there are HRTW and DEI or potentially negative racial outcomes.
					I have asked the related emails and the Memorandum distributed to the GSA Members regarding my public comments to the Colusa City Council, Colusa County Board of Supervisors and Williams City Council be included in Appendix 2A as part of the public record. I also want to note that Mr. Ceppos firm was not brought in as a mediator nor do I think he was asked to before the GCA and Colusa County Administrator made the CGA Memo public record prior to the vote of the Colusa County Board of Supervisors vote on approving the Amended JPA. Although the Memo did probably not change the outcome of the Board of Supervisors vote, it effective took away my creditability to argue for HTRW and DEI concerns and generally challenged my reputation as a truthful and fair minded citizen.
					The concerns I expressed during the 3 to 5 minute public comment periods were the following: (1) I am concerned about the long term water quality for the public supply system in Colusa which is my home town. I pointed out that there was arsenic contamination in the abandoned public supply well for the Del Oro Walnut Ranch system and at Grimes and my concern is that it relates to the water quality surrounding the Sutter Buttes, (2) I am concerned about the long term supply and water quality resilience for the public supply system in Williams since the water quality surrounding Williams has elevated TDS levels and water levels will likely drop further due to climate change and the conversion of surrounding areas to

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
					permanent crops, and (3) like most residents in Colusa County I was against out of basin water transfers because it would hurt the long term sustainability of the County and potentially hurt groundwater quality due to ground water substitution and fallowing measures by GSA Member water sellers. Since I am against out of Basin water transfers I mentioned that I did not believe that it was the best interest of Colusa County residents to have two law firms from Bakersfield represent the CGA because the firms have an extensive list of clients who benefit from out of Basin Water Transfers and that I believed it would not serve the County well to have a CGA counsel who was also the counsel for the Sites JPA and that the former lead CGA counsel was now a Director at the Bureau or Reclamation overseeing water transfer approval, (4) I suggested that the City of Colusa, City of Williams and County of Colusa would best serve the long term interests of its residents by retaining it sovereignty and entering into a cooperation agreement with the irrigation company GSAs and pointed out that this is how the Butte Basin was structured – which is now similar to the neighboring Sutter Basin. I pointed out that Yolo County had a JPA structure but it has strong representation from UC Davis and the municipal GSAs and had other environmental protections. During the period of making these public comments I also made the same public comment and comment to the CGA in which one Member who represents a Settlement Contractor which fallows land and sells water claimed that what I said about the public record was not true which I disputed.
					Without any prior notice I noted that there was an Agenda item discussing a Memo prepared by the CGA and it was going to be distributed. I was traveling with my son in the Midwest and was not able to attend the CGA meeting which approved the Memo and its distribution. Afterwards when I prepared to comment at the Board of Supervisors meeting that had the approval of the amended JPA on the Agenda I found out that this Memo was included in the Agenda Packet. The first time I saw the Memo was when I received it from the CFO for Colusa County after the Board Meeting.

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					The related emails should be included in Appendix 2A as a public record. I would recommend that in light of the DWRs and SWRCB recent pronouncements on HRTW, DEI and Racial Equity that the GCA does not act in a manner hostile to any Stakeholder before a mediator is brought in to resolve an issue. This should especially be the case if it concerns HRTW issues or if the stakeholder is not a native English speaker or is a person of color. I would also recommend to the DWR that all CGA Members be required to be residents of the Subbasin in order to understand the long term environmental and economic sustainability issues facing the Colusa Subbasin. My experience is an example of the abuse of power granted to the CGA by SGMA and in my opinion it is important that there be accountability to the community by all CGA Board Members. Allowing CGA Board Members to be non-residents will allow this type of abuse to continue especially when there are majority owners, consultants and attorneys who also are not residents. Colusa County requires all its elected office holders to be residents and the members of the Colusa Groundwater Commission need to be residents – the residency requirement should be the same for the CGA. This is a necessary protection for HRTW and DEI concerns because it ensures community accountability.
	Public Engagement				The Stakeholder Engagement Process was materially flawed because there was no discussion about the California Water Commissions initiatives around groundwater water trading. It is unreasonable to have no public engagement and submit a GSP without any public discussion of an issue that the DWR Acting Deputy Director of SGMA is presenting at the California Water Commission. As I said, we are spending a lot of time and money considering and debating potential PMAs when we have spent no time regarding the water trading policies being considered by the California Water Commission. Water Trading will have many intended consequences on the allocation of resources and many unintended consequences – some of which could be extremely detrimental to the long term sustainability of

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
	2.7.3.6				the fresh water aquifers of the Sacramento Valley. It seems like the PMA considerations may be a real waste of time – I just found out about the Water Trading discussions of the CWC yesterday which happens to be the last business day for the comment period for this GSP. Where are the GSAs websites. There is a lot of discussion regarding the CGA website but is there any other website. Do they exists for each Member GSA ? If not – why and how can stakeholders gain transparency. Does each Member GSA have an interested person list?

Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Ben King Chapter 3 Comments Part I **Commenter Affiliation (if applicable):**

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8. Please make sure that your comments are submitted by midnight May 5, 2021.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
Table 3-1					What change in Data Sources were used to incorporate the annexed area from the West Butte Basin? What sources were used for Geochemistry and water quality?
3.1.5		3-7			The Hydrology of the Colusa Subbasin is also influenced by the Geochemisty and underlying Faults. Since the Subbasin water quality is influence by the volcanic rock of the Sutter Buttes and influences from the marine and lacustrine geologic history of the Subbasin – can Hydrology be determined without Geochemistry? Faults are known to influence Geochemistry and water quality since there may be anoxic water upwhelling and lateral movement of naturally occurring contaminants via faults like the Willows Fault.
3.1.5		3-11		Figure 3-6	Why is part of the CDMWC delivery area included in ColGGWS? The CDMWC on the west side of Colusa Basin Drain south of Hahn Road receives surface water deliveries as the rest of the CDMWC. There are CDMWC subarea components on multiple sides of this area but for some reason this jurisdictional area of the CDMWC is treated differently. This area is also part of the flood zone and receives significant seepage during seasonal winter flows.
		3-16		Table 3-2	What assumptions are included in Model Diversion ID 113? As mentioned above a portion withing the jurisdictional boundaries of the CDMWC and a CDMWC surface water delivery area is left out of the CDMWC budget subarea.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
3.1.7				3-3	See Springhorn Page 22 – Table 2.1 and Page 93 Table 3.3, Need to incorporate Turlock Lake Lacustrine influence to document Corcoran like clay components to the Lithology and also need to incorporate the formation of the Sutter Buttes Rampart and Geomorphic influence of the Sutter Buttes volcanic structure. Both Springhorn and Harwood and Helly differentiate the lithology of the Pilocene and Pleistocene periods this way. Water quality and subsidence issues are related to this geologic history. Figure 3-10 is probably the most complete Geologic Map I have seen for the region – excellent!
				3.11, 3.14&3.15	See Springhorn Page 113 Figure 4.4. This Geologic Crossection needs to be incorporated in Cross Section C-C on Figure 3-11. Otherwise the Cross section leaves out the influence of the most unique Geomorphic Unit in the Sacramento Valley which is the Sutter Buttes. Also there is a critical need to address the Cross Section next to the City of Colusa because of the interrelationships of the Willows Fault, Sutter Buttes Rampart, Colusa Dome and Sacramento River. As it now stands Cross Section C-C is not consistent with the robust Geology set out in Figure 3-10 which seems to be a recent update since it references Springhorn. Regarding 3.14 how can you have a 3 Dimensional Model that omits the geology of the Sutter Buttes? Regarding 3.15 – it is important to map the area of the Corcoran like clays deposited by the Turlock Formation to know the potential area of impact for future subsidence.
3.1.9.2					See USGS Circular 1358 "Water Quality in Basin-Fill Aquifers of the Southwestern United States: Arizona, California, Colorado, Nevada, New Mexico and Utah, 1993-2009. Thiros,Paul, Bexfield and Anning 2014.(USGS Thiros et al 2014) See Page 56 – it is clear that arsenic contamination occurs and translocates along fault zones like the Willows Fault as is currently is the case in the Middle Rio Grande Basin. The water system for the City of Colusa could have the same fate as the water system for the City of Albuquerque.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
3.1.8.2 3.37		3-35 	2nd and 3rd	 3.17	The base of freshwater should not include brackish water which is defined by the USGS and others at 1000 ug/L. Water quality definitions should be consistent with the California Human Right to Fresh Water. Brackish water is not potable. The reference to brackish water in the Upper Princeton Valley is inconsistent with the outdated Olmstead and Davis referenced in paragraph 2 . See Springhorn Page 149 for additional references. The Base of Freshwater Depths in the annexed area from the old West Butte Basin seem incorrect based on the vertical depths included in Springhorn's Cross Section work. Also the area west of Colusa on Lurline near Roberts Ditch is known to have lower fresh water base levels. Levels are probably in the 300 to 400 ft levels or less in both areas.
3.1.10.2 3.1.10.3		3-39 3-42			The potential for vertical movement via abandoned gas wells and faults needs to be mention since it most likely will lead to aquifer degradidation in areas where the subsurface groundwater have elevated TDS levels and/or anoxic conditions. Arsenic contamination at the abandoned Del Oro Walnut Ranch well and the well at the CIP site which was cited by SWRCB show arsenic contamination has been found in the Colusa City limits. The USEPA reports also show arsenic contamination in the Princeton water supply system.
3.1.12.1		3-50			Additional Areas of Uncertainty: 1. See Springhorn Page 165 Figure 6.1 Areas where subsurface information is needed regarding the area outlined west of the Sutter Buttes, 2. Research regarding the vertical and lateral movement of saline water within and across the Willows Fault as generally described on Page 56 of USGS Thiros et al 2014, 3 The predicted desorption of arsenic from a volcanic structure like the Sutter Buttes in Figure 6-5 of Thiros on Page 58, 3. The breadth and depth of the Corcoran type clays from the Turlock Lake formation highlighting the potential for future

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
					subsidence, 4 – the water quality issues near the Freshwater area west of Williams as described in the Colusa County Groundwater Management Plan.
3.1.12.1 3.1.12.3				3-5 3-51	The C2VSimFG Model has to incorporate the saline and anoxic seawater around and south of the Sutter Buttes. According to the Sutter- Yuba investigations (SWRB Bulletin No. 6, 1952) a TDS level as high as 10,000 was observed near Robbins. Others including the DWR and Curtin have observed TDS levels from 4,000 to 6,000 south of the Sutter Buttes. What are the statutory obligations to address the Human Right to Fresh Water in the HCM?
3.2.5				3-64	The worst reported arsenic contamination for any public water system in the Sacramento Valley water supply system is in Grimes. The USEPA has documented arsenic contamination in the Princeton public supply system. There has been two incidences of arsenic contamination in supply wells within the boundaries of the City of Colusa. The wide scope of arsenic contamination around the extent of the Sutter Buttes Rampart and south of the Sutter Buttes in the Colusa Basin needs to be disclosed as an area of grave concern. See Springhorn Page 164 highlighting the need for more research about the need for more work regarding the relationship of arsenic contamination and the health risks from arsenic.
3.2.5.1.1				Figure 3-30	What is the source for this data? Is there a time series? Stakeholders should have access to time series for water quality data and it should be included in the Appendix like the hydrograph data concerning water levels. Arguably water quality data should have a higher level of access and transparency due to the Human Right to Fresh Water.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
		3-66			According to the 2020 Tehama-Colusa Canal Water Authority Initial Study/Environmental Assessment there were several wells used for Groundwater Substitution with elevated Specific Conductance. As reported in the Appendix for the report GCID, 7 of the 16 reported wells had a consistent annual reported level of Specific Conductance greater than 1000 ug/L. Three of these wells had levels greater than 1500 and the other 4 were between 1000 and 1500. Are these wells included in the data points of Figure 3-30 and the discussion on page 3-66?
3.2.5.2.1		3-67			Where is the location of the well near Grimes with Arsenic at 200 ug/L.? Grimes arsenic levels are reported to be approximately 25 ug/L. The USGS publication by Thiros et al has an extensive discussion of the desorption process of arsenic for volcanic rocks in saline groundwater with PH greater than 8. The USGS predictive model predicts the occurrence of arsenic in basin discharge areas like Robbins and the areas south of Grimes. This USGS publication also highlights how arsenic had moved into the groundwater of Albuquerque via a fault. The Willow fault crosses the Sacramento River at Colusa and runs south towards Grimes and the area where the two arsenic contaminated wells were found at the Del Oro Walnut Ranch site and CIP which is now in the boundary of the City of Colusa. The Sutter GMP includes a Figure showing elevated areas of TDS and Arsenic with levels as high as 370 ug/L. There is discussion of a biotic response that coincides with anoxic groundwater becoming oxidated from soil microbial activity that release arsenic as a bi-product. Arsenic contamination of the Colusa public water supply would be disastrous and a violation of the Human Right to Fresh Water.
3.2.6		3-72		Figure 3.31	Figure 3.31 should overlay the area of the Corcoran like clays from the Turlock Lake geological formation to show a potential relationship of subsidence and the presence of this clay formation The relationship between the Corcoran like clay formation and the presence of inelastic subsidence should be discussed based off the history in the San Joaquin Valley.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment

Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Ben King Chapter 3 Comments Part II **Commenter Affiliation (if applicable):**

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COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
3.3.3	3-80 3-81,2			Table 3-9	Using only 2013 and 2015 water diversion data would lead to a wrong outcome if the diverter did not use surface water available during those years. It is an extremely small and not representative data set. Landowners could have not diverted during those years because they were trying to help other landowners out with their surface water allocations since they had wells or the landowner could have been converting land for orchard development with a new filter system. Using Land Use data only for the years of 2003,2009 and 2014 is not representative if there was a conversion from rice to row crops or row crops to orchards. The impact of this narrow assumption set could lead to incorrect Budget Subareas.
3-4	3-102				Management Areas should not be set until the GSP is approved and implemented for several years. The history and genesis of the Colusa Groundwater Authority JPS was for collective management of the Subbasin and there is no basis to change the jurisdictional management of the Subbasin in contravention of those principals. Stakeholders and property owners who are paying Prop 218 Assessments must know there is a rational basis for any changes in jurisdictional oversight within the Basin to maintain confidence in the GCA's governance. What should not happen are actions which may lead to a perception that a few powerful members have manipulated the process for their own benefit.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment

Colusa Subbasin Groundwater Sustainability Plan Public Review Draft Input

Commenter Name: Ben King **Commenter Affiliation (if applicable):** Chapter 3 Comments

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8. Please make sure that your comments are submitted by 11:59 p.m. October 31, 2021.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
3.	3.1.1				Section 3.1.8.2 can not be satisfied because the DWR has not released it revised BFW contours and any updated research. This work was presented by the DWR in 2013. The lateral depths in the current version of the GSP are clearly wrong and are based on outdated TDS levels which are inconsistent with HRTW concerns. Consequently the Water Budget derived from the assumed BFW levels is also wrong and misleading.
				Table 3.1	The work presented by Springhorn et.al at the US Geological Society and GRA in 2013 needs to referenced and incorporated in the BFW. The water budget and HRTW issues will be materially impacted by this new work.
	3.1.5.1.6				Are these all the Streams - Sand Creek near Arbuckle? Is Salt Creek Arbuckle – Elk Creek? We should have consistent names for PMAs and across the GSP
	3.1.7.3.5				Discussion regarding the Sutter Buttes Rampart as described in Springhorn 2008 is necessary to raise the issue of any stratigraphic induced lateral movement of connate saltwater around the Sutter Buttes volcanic rampart footprint.

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
	3.1.8.2				The Vertical Boundaries can not be determined with enough reliability to determine Groundwater Storage or to address the existence and sustainability of fresh water for HTRW concerns. The reliance on Olmstead is clearly challenged by the outdated TDS threshold and empirical evidence that the BFW assumptions are wrong for substantial parts of the Colusa County portion of the Subbasin. Please refer to CRC Well 16RIM (Figure 5D-22) which has a depth of 25 to 30 feet. The most recent EC reading is over 6000. Please refer to USGS GAMA Site EASC 21 which is a well with a depth of 369 feet with a Arsenic level of 80.5 ug/L and Boron level of 1,010 ug/L. Clearly Olmstead is wrong for a substantial part of the Subbasin and for a substantial part of the Sacramento Valley as a whole.
				3-17	Clearly this Figure is wrong. The EC threshold is outdated and it relies on the 60 year old Olmstead report rather than the work held by the DWR since at least 2013. The Base of Fresh Water for the Colusa Subbasin is materially different and this Figure is clearly misleading.
					Here is the excerpt from the DWR BFW Work as of 2013: A base of fresh groundwater (BFW) contour map was created to identify the approximate lower limit and the thickness of the fresh groundwater aquifer system in the Sacramento Valley. The BFW map is useful for groundwater resource and storage analyses, groundwater modeling, and delineating structural geologic features in the Sacramento Valley. Two BFW maps covering the Sacramento Valley were previously created; Olmsted and Davis (1961) and Berkstresser (1973). The BFW map in this study relies on a substantial amount of new subsurface geophysical and water quality data that has been collected since the earlier BFW maps. Fresh groundwater is defined in this study as water containing less than 1,000 mg/l total dissolved solids (TDS), approximately 1,550 µmhos/cm specific conductance, instead of 2,000 mg/L TDS used in the earlier studies. The BFW was estimated based on a

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
					comparative analysis of geophysical logs and lithologic data from approximately 2,800 geophysical logs from water resource wells and CA Division of Oil and Gas well records. The BFW selection criteria were calibrated using water chemistry data and constrained by comparing multiple well-logs and lithologic information in the same geographic area. The BFW boundary occurs primarily in late Tertiary to Quaternary unconsolidated sediments at depths near land surface to more than 3,500 feet below ground surface. The BFW is an uneven boundary that in some places reflects the major geologic structures underlying the Sacramento Valley, and in other areas, transgresses underlying geologic structures. In some areas, the BFW boundary is well above the base of post-Eocene marine strata. **This is most likely caused by high artesian pressures and upward vertical gradients in deep aquifers in the Sacramento Valley, which have been documented in DWR monitoring wells.** This suggests that migration of poor quality water into continental sediments that previously contained freshwater has occurred over geologic time**. This finding has implications for brackish and saline water upconing beneath areas of prolonged groundwater pumping in the Sacramento Valley.** ***Figure 3-17 should be based off the most recent DWR work as described above for the calculation of the Water Budget , Groundwater Storage, Sustainable Yield and HTRW Concerns***
	3.19				Sutter Buttes Rampart description from Springhorn 2008 is needed.

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
	3.1.10.3	3-42			The discussion about water quality should reference the DWR 2013 work and the recent work by Susan Thiros and Laura Bexfield from the USGS regarding Redox and degradation due to overpumping. CRC Well 16R1M in Figure 5D-22 should be highlighted since EC has 4000 to 6000 over the last 17 years. This illustrates that the BFW assumptions are wrong and the upconing identified by the DWR is having a material impact on the fresh water aquifer. Where is this salt water going? Does upconing and Redox degrade our future resiliency for drinking water and other HTRW issues?
		3.1.11.2			How is recharge effected by the upconing and redox discussed by the DWR and USGS? Can you recharge in high water table areas like Maxwell are where there is degraded water and drainage tiles?
		3.1.12			The fact that the DWR has not supplied the most recent BFW studies is fatal to the reliability for the GSP. It can be used as an approximation but raises significant HRTW risks and can not be relied on to develop a reliable Water Budget.
		3.1.12.1			We don't know what is certain or uncertain. The only thing we can be certain about is that we do not have the best and most recent information regarding the BFW and the BFW water quality standards are outdated elevated levels which are not consistent with the DWR's HRTW Departmental Policy.
		3.1.12.3			The requirements of 354.14 can not be met without the DWR BFW research that has been withheld. All that can be achieved is an approximation but substantial HRTW risk exist regarding the potential for the degradation of the fresh water aquifer. CRC Well 16R1M seems to indicate it has been occurring during the last 17 years.

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
	3.2.3 3.2.5 3.68	3-64			Groundwater storage can not be adequately calculated without the correct BFW model and correct water quality standards. The area where the TDS standards are above maximum levels for TDS should not be included in the aggregate storage for the Subbasin. Need to discuss the redox process and how overpumping can degrade water quality Discuss elevated Cloride levels and its relationship to redox. Also discuss CRC 16R1M and its location as indicative of the legacy TDS issues east of Maxwell. This well has a known depth of less than 30 feet and is draining into the Subbasin.
	3.2.6 3.28	3-73 3.82 -4			There needs to be a discussion about what we do not know about the cause of sbsidence near Arbuckle. The CGA needs to engage Cal Trans to find out what they think the cause of this is. We cant have I-5 collapse – there already has been issues south of Arbuckle immediately east of Pierce High School. It would be a disaster for the State and County if I-5 had to be diverted at Arbuckle. There should be a discussion regarding the elevated TDS and other naturally occurring contaminants under the GDE around the Sutter Buttes. EASC 21 is a well centrally located in a GDE on the east side of the Subbasin with Boron levels of 1,010 ug/L. Adjacent overpumping could harm the GDE and there have been reports of dead fish in this area caused by the release of contaminated well water from 500 feet in depth.

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
	3.3 3.11 3.3.4.3.1	3.85			The Water Budget can not be relied on until the correct BFW study is included in the GSP. Table 3.11 - Where is the accounting for water transfers. Where is the historical data for water transfers – what are the future assumption for water transfers?

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment

Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Ben King Chapter 4 Comments **Commenter Affiliation (if applicable):**

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COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
4.2.3.3		4-17		Table 4-4	The Monitoring Network is woefully inadequate to protect against groundwater quality degradation and to protect the Human Right to Fresh Water. All wells used for Groundwater Substitution should be used to collect water quality samples and to preserve public accountability against over pumping. There is an incentive for quantity rather than quality and Stakeholders should be entitled to publicly available water quality data from groundwater substitution wells. In order to protect Colusa County Resident's Human Right to Fresh Water Monitoring Wells should be placed in the study area suggested by Springhorn as referenced in the Comments on Section 3. Springhorn raised concerns about high Saline TDS levels and arsenic levels in a large area west and southwest of the Sutter Buttes. Several monitoring wells should be placed in this area. Monitoring wells may also need to be placed around the City of Williams to provide a historical time series to monitor TDS levels over time. If water banking activities start with the development of Sites, this enhanced Monitoring Network and time series will become critical to protect the water supply for the City of Williams.
4.2.3.4		4-19			Springhorn highlighted a wide area where there are water quality monitoring data gaps. Monitoring wells should be placed in this area in consultation with the DWR and Springhorn's personal input since he highlighted this concern in the first place. Additional monitoring wells may be needed around the City of Williams and any potential water banking sites that could cause degradation of drinking water supplies for on the west side of the Subbasin.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
4.2.4.4		4-20			One or two Extensometers need to be installed near Arbuckle and Dunnigan. One site should be near the intersection of Bailey Road and Hwy 99 since it is the site of greatest subsidence and because the infrastructure of I-5 is there in addition to the Arbuckle Cemetery and old railroad tracks. The other Extensometer should be installed near Dunnigan working with the Yolo County GSA to choose a site. There are approximately 500 residences in the area and an evergrowing commercial infrastructure.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment

Colusa Subbasin Groundwater Sustainability Plan Public Review Draft Input

Commenter Name: Ben King **Commenter Affiliation (if applicable):** Chapter 4 and Appendix 5

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COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
4	4.2.5.2				The Groundwater quality network does not adequate monitor the TDS contamination around Maxwell and Williams. CRC 16R1M is very concerning and represents an area where there is known water quality problems but there are no multi-completion wells to monitor upconing or provide a way to monitor upconing. The lack of multi-completion wells in this area and next to the public supply systems for Williams and Maxwell raise concerns about having enough information to protect the HRTW. Additionally, if the proposed Sites reservoir is completed there will be an urgent need to add monitoring sites to monitor possible contamination caused by the hydraulic head differential from Sites.
				4-7	It is unfortunate that the SVWQC observation wells were placed in areas where there are not any known water quality problems. It was clear from the Colusa County GMP that the problem areas are near Williams and Maxwell. The extreme variance between CRC Well 16 R IM and the nearby SVWQC wells highlight this disparity.
	Appendix 5				Since the public supply systems for Grimes and Princeton are know to have elevated arsenic levels, there should be a Figure monitoring arsenic over time at these sites and included in the GSP. The Appendix should include water level and water quality observations for each observation zone for all the multi-completion wells. Since there is abundant empirical evidence of upconing in the Colusa Subbasin this phenomenon needs to be continuously monitored by zone of depth for both gradient and water quality constituients. Where there is a concern for arsenic the monitoring should be for both EC and Arsenic. Additionally there should be more mulit-completion wells installed on the West side of the Sacramento Valley down hill from Sites since the

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
					head gradient could be as much as 800 feet in differential. After an earthquake or in a fault structure this trend should be especially important to monitor.

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment

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Commenter Name: Ben King **Commenter Affiliation (if applicable):**

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COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
5.3.1.3		5-6			Last paragraph should include impact of SWRCB water curtailments to TC Contractors. The example just refers to Federal curtailments. Comment should also highlight the fact that TC Member groundwater pumpers will have no alternative but to pump groundwater during curtailments because they need to irrigate their permanent plantings.
	3.1.4				Comment should address the dewatering of small water systems and domestic wells and the impact on DAC and SDAC households in the affected areas. This is not a hypothetical issue – domestic wells in College City and Arbuckle have run dry. This should be highlighted in the GSP.
	3.1.5				Discussion should include the impact on small water systems and domestic wells. The number of reported domestic wells should be recorded and highlighted. It is my understanding that over 19 domestic wells have already ran dry. The impact on households in SDAC and DAC areas should be highlighted.
5.3.4.1		5-10			Discussion of the role of the USEPA should be included. The USEPA has cited the small water systems of Grimes and Princeton for arsenic contamination. It is very important that that the discussion includes the degradation of fresh water aquifers caused by upwhelling of poor quality water. There is a possibility that over pumping could cause or exasperate this undesired outcome.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	3.4.2	5-11			Impact on SDAC and DAC areas should be identified and discussed by the GSA. Water quality of monitoring wells with multi-completion stages should be documented for each depth stage to identify degraded fresh water aquifers caused by upwhelling. We should avoid water quality monitoring cherry picking and record the data for all depth stages and monitor trends over time to identify possible upwhelling.
	3.4.3	5-11			If Sites is contructed, water quality may be adversely impacted by the elevation gradient between the elevation of sites and the bowels of wells on the valley flow. This gradient could be 600 to 900 feet of elevation head and may take decades to document. Especially around the Sutter Buttes Rampart we need to monitor for potential effects of a redox reaction when connate water upwhells and starts an oxidation process. Arsenic desorption is a predicted outcome when the pH of the connate water is greater than 8. There are also potential biotic outcomes again arsenic related when connate salt water starts the oxidation process. Certain anoxic microbes may add to the arsenic contamination similar to the cause of arsenic contamination in Chesapeake Bay. Earthquake activity could also affect the movement of upwelled contaminants. The west side of the valley has a history of geothermal conditions which could be impacted by earthquakes and earthquakes could also be a catalyst for upwhelling via active faults.
	3.4.4.	5-12			How about birth defects, mother health and other arsenic contamination related outcomes Rather than adverse effect to property values – loss homeowner values and loss of housing if a domestic well becomes contaminated.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	3.4.5	5.12			USEPA and SWRCB Citations should be evaluated.
	4.1	5-16			The stakeholder input regarding the 80 pct level should be documented and recorded for future public comment. As you may know there has been over 20 domestic wells reported dry with several in the College City area. The domestic well threshold should be an area of future discussion and stakeholder input as the drought progresses. The advocates of the 80 pct threshold should be documented and disclosed and the issue of domestic wells should have a future public discourse. Was there a GSA vote on the 80 percent level?
	5.4.1.1.1				The adverse degradation from the redox process for connate salt water will most likely be permanent. Significant lowering of groundwater near Grimes and the East Side of the Sacramento River could be the most vulnerable are for redox and potential adverse biotic outcomes. On the west side where there is natural geothermal pressures the lowering of groundwater levels could affect the hydrologic balance of groundwater and result in more upwhelling. Again another reason to measure all water quality at all observable depths.
	5.4.4.1				There should be a Minimum Threshold for Arsenic Contamination. There are two small water supply systems in Colusa County with USEPA Citations, two abandoned wells at the southern part of the City of Colusa and a reported observation of 200 ug/L near Grimes. Trends in arsenic contamination should be monitored over time due to the potential for continued redox of connate salt water and potential movement via faults which could be adversely aggravated by future techtonic activity.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
	5.4.4.2				The Measurable Objective for arsenic should be the USEPA MCL of 10 ug/L
	5.4.4.4				The Interim Milestone discussion should include the GSA's role in working with the State of California to guarantee the Human Right to Fresh Water to the residents of the Colusa Subbasin. The State has the responsibility to uphold this Human Right and the GSA will likely have to work with the State on targeted solutions or mitigation efforts.

Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Ben King **Commenter Affiliation (if applicable):**

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COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
5A		2	Outreach		Since the majority of the Outreach and Public Involvement Process was done before the severity of the current drought was known the outreach process does not reflect the impact on domestic well users nor does have domestic well users had the opportunity to give their input. The reported number of domestic well problems should be documented and there should be a concerted outreach program to get their input on the Minimum Threshholds and mitigation measures. The GSA has an opportunity to truly understand the impact on domestic wells from lowered groundwater levels and act in a proactive manner to help manage and mitigate adverse outcomes for the future. The current Memorandum does not reflect input from domestic well users.
			Hydrographs		The hydrograph for 14N02W22A002 does not have any data on the two pages it is presented.
5B		1			The statement " This appendix describes an economic analysis of MT's that was developed and presented to the TAC at the May 13,2021 Meeting" is false. While it is clear that the economic analysis was included in the presentation there is no indication that the economic analysis was presented or discussed at the meeting. The Minutes of the May 13, 2021 TAC Meeting do not reflect any discussion of the ERA proposal and states on Page 8 of the Minutes in Agenda Item 4.b Projects and Management Actions (PMAs) - **" This Agenda item was not discussed during the TAC meeting due to time constraints"**

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
5B		2			What are the assumed capital cost for refurbishing potentially dewatered domestic wells? What are the assumptions for energy costs caused by additional pumping? What rate schedule? As you probably are aware there are many critical assumptions depending on season and time of use.
		4		Figure 2	What does the Table Crop and Acres mean? There is not explanation for the inclusion of this table of the documentation for and reference source.
		2			Why does the economic analysis assume that demand management would be adopted by the GSA? The economic analysis in Chapter 6 appears to be highly speculative and is difficult to assess since the assumptions for the analysis have not been disclosed.
		All	General Comment		Regarding the costs of replacing the domestic well it is hard to assess whether or not the analysis is based on representative costs because the assumptions were not disclosed. The analysis seems to make rudimentary assumptions and not real life assumptions. In the crisis of a drought, local drilling capacity and well repair services are very limited and usually focused on serving the biggest and best customers. Domestic well owners are likely to have to wait until the growing season is over and pay for the costs to maintain their personal health and livelihood during the loss of the well. Some domestic well owners may not have access to the capital they need to make the repairs and most would not be able to secure 20 year financing unless they had equity in their houses and could refinance. Having a well run dry and being ablet to get an appraisal for refinancing is probably near impossible and ultimately the loss of a well may mean substantial loss of market value of their house.

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
					To make this a meaningful analysis, there is a timely opportunity to contact the County administrators and survey the domestic well users that have lost their wells during the current drought and ask them about direct and consequential economic costs and costs due to loss of income due to their well depletions. There are more than 20 such dry domestic wells in Colusa County alone.
5C	General				Arsenic levels should be included for Grimes and Princeton since the USEPA has continuously reported that observed levels are above the USEPA MCL. Arsenic should also be reported for all the wells for the Colusa Supply system since there has been the Del Oro Walnut Ranch well abandonment and the CIP enforcement action. Also the well near Grimes with the 200 ug/L observation should be included and reported for each observable depth if it is a multi-completion well.
					All of the reported locations should have EC observations for each observable stage if any of the reported locations are multi-completion wells. The new well drilled by the County of Darrin Williams property should be included in the appendix and water quality observations should be tracked for each observable depth. Mr. Williams reported upwhelling near the 1000 foot depth and the water quality from the upwhelling aquifer should be observed and tracked.
					Overall the Appendix needs to incorporate the wells discussed in Section 3.2.5.11. There is a multicompletion well near Maxwell with 4 stages and TDS levels as high as 1640 mg/L. There is a shallow well west of Grimes with a measurement of 2,040 mg/L. Wells near College City with TDS concentrations greater than 1000 should be of immediate concern since domestic wells are running dry and bowls are being lowered. Where are the measurements for the shallow wells west of Colusa with TDS levels greater than 2000 mg/L.
					Generally we should have up to date observations for all reported wells. The data for the Maxwell public supply system ends before 2013. The data for the Princeton public supply system ends before 2014 Arbuckle only has 3 observations ending in 2016. Since the Williams supply system has elevated EC levels, all the supply wells for Williams should be reported so as to avoid cherry picking and also to monitor any adverse trends.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment

Colusa Subbasin Groundwater Sustainability Plan Public Review Draft Input

Commenter Name: Ben King **Commenter Affiliation (if applicable):** Chapter 5 Comments

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
5	5.3.4	5-11	33		Why isn't upconing being addressed since it is a known common occurrence? How does this reconcile with the HRTW goals of the DWR? The public supply systems of Williams and Maxwell seem particularly vulnerable to heightened TDS levels like at least one of its wells has experienced lately. This would be a primary concern from the head gradient from Sites and this trend needs to be monitored more closely than the current monitoring network would do.
	5.3.4.2	5-12			What are the minimum thressholds for each site? These levels should be in a Table because it is confusing to understand what they may be? What are the historical numbers that will be used? Shouldn't there be a Table like Table 5-2 for quality thresholds?
	5.3.4.3	5-12/13			There is no discussion about redox causing degradation? The potential from upwhelling caused by the gradient differential from Sites and possibly in combination with earthquake and fault activity?
	5.3.5	5-13			This SMC seems to be very dangerous because the current problem area for subsidence is so close to I-5. If the subsidence monitoring site next to I-5 dropped by 5 feet would the SMC be triggered? It would seem that there should be zero tolerance for more additional subsidence next to I-5 and that Cal Trans should be engaged now to figure out the cause and what can be done. Perhaps funding could come from Cal Trans – especially given all the infrastructure money being allocated right now.

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
	5-4				How does the HTRW fit into the monitoring of these Sustainability Thresholds?

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment

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Colusa Subbasin Groundwater Sustainability Plan Public Review Draft Input

Commenter Name: Ben King **Commenter Affiliation (if applicable):** Chapter 6 and 7 Comments

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COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
6				6-2, 6-4 ect	The boundary for the CDMWC needs to be corrected to reflect the acreage south of Hahn Road west of the Colusa Basin Drain.
	6.3.1				Since there was not a project submittal for this project how can Stakeholders obtain the proposal submitted? It was mentioned that there was a planned annexation in the public meetings – how can stakeholders know what acreage is intended to be annexed? Who is paying for this PMA development? How can Stakeholders know that proprietary consulting activities are not also being done with public funded 218 assessments since many of the PMAs are being considered by legacy clients of the Consultants? What control procedures are in place to prevent abuse of the PMA financing process by consultants and legacy clients?
	6.5.1.2			Westside Diversions	The Salt Creek potential diversion should be closely analyzed for potential harm to Williams public supply system from both a quantity and quality perspective. There are substantial HRTW and DEI considerations to be considered with any diversion of Salt Creek or any other west side stream above a public supply system or in an area where subsidence is a problem or an emerging problem
	6.5.1.3			Sites	The top of Sites Reservoir is expected to be 500 feet above sea level which is likely 800 feet above the intake levels for the public supply systems of Maxwell and Grimes and all wells generally on the Valley floor. This head gradient could materially degrade water quality generally and/or the public supply systems for Williams and Maxwell. Additionally lateral movement via localized faults and/or future earthquake

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
					activity could materially negatively impact groundwater quality at any point in the future. This again has HRTW and DEI potential negative material impacts.
	6.5.2	6-81			Why hasn't the GSP covered the proposed groundwater trading program being considered by the California Water Commission? It appears that this is being seriously considered but it was not discussed our considered in the public engagement process for the GSP.
					The Short Term and Long Term Demand Management Actions need to be reviewed by the Economic Development departments of the Counties and Cities in the Colusa Subbasin. How does the costs of these Demand Actions compare to the cost of groundwater trading as discuss? Who is going to pay to administer these type of Demand Actions and what are the estimated costs for the administration?
	7.1.1				What is the status of the GSA establishment cost reimbursement requests that are part of the JPA? Is this reimbursement possible ? How much is the amount and how much will be paid to each entity? Is this amount included in the estimates? If the GCA is sued for a settlement contractor issue such as the Aqua Alliance suit – who pays for the legal fees for the suit?
	7.1.2				How do Stakeholders have confidence that 218 fees are not being used to pay costs that are not appropriate to charge the GCA bit should be charged to the Member GSA.? What type of audit and control procedures are in place to protect against abuse

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Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment

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Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Evan Markey/Michael Bolzowski **Commenter Affiliation (if applicable):** GGA/Cal Water

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
2	2.1.2.1	8	4	-	The plan states Willows used 1.6 MGD. Our records show and average of 1.2 MGD for the same time.
Appendix	2.7.3	121	-	2-4	Table shows Willows average per capita as 231 Gallons per Capita Per Day from 1990 to 2015. Our current average 2015 to 2020 is much lower, 143 Gallons per Capita Per Day. The model maybe overestimating our demands for the basin.

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Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: **Lester Messina** **Commenter Affiliation:** **Colusa Glenn Subwatershed Program (SVWQC)**

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Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
2	**2.2.1.2**	**2-20**	**2**		Recommended Change: Irrigated Lands Regulatory Program The Central Valley Regional Water Quality Control Board (CVRWQB) has adopted waste discharge requirements (WDRs) for discharges from irrigated commercial croplands to protect both surface water and groundwater supplies. When land is in agricultural production it is irrigated and fertilized. It is assumed that portions of the soil amendments, particularly fertilizer, is converted to ***nitrate which has the potential to percolate into groundwater*** The ILRP regulates such discharges, growers can ***minimize the percolation of nitrate to groundwater through the implementation of effective management practices***. Commercial irrigated lands, including managed wetlands are required to obtain regulatory coverage.

COLUSA SUBBASIN

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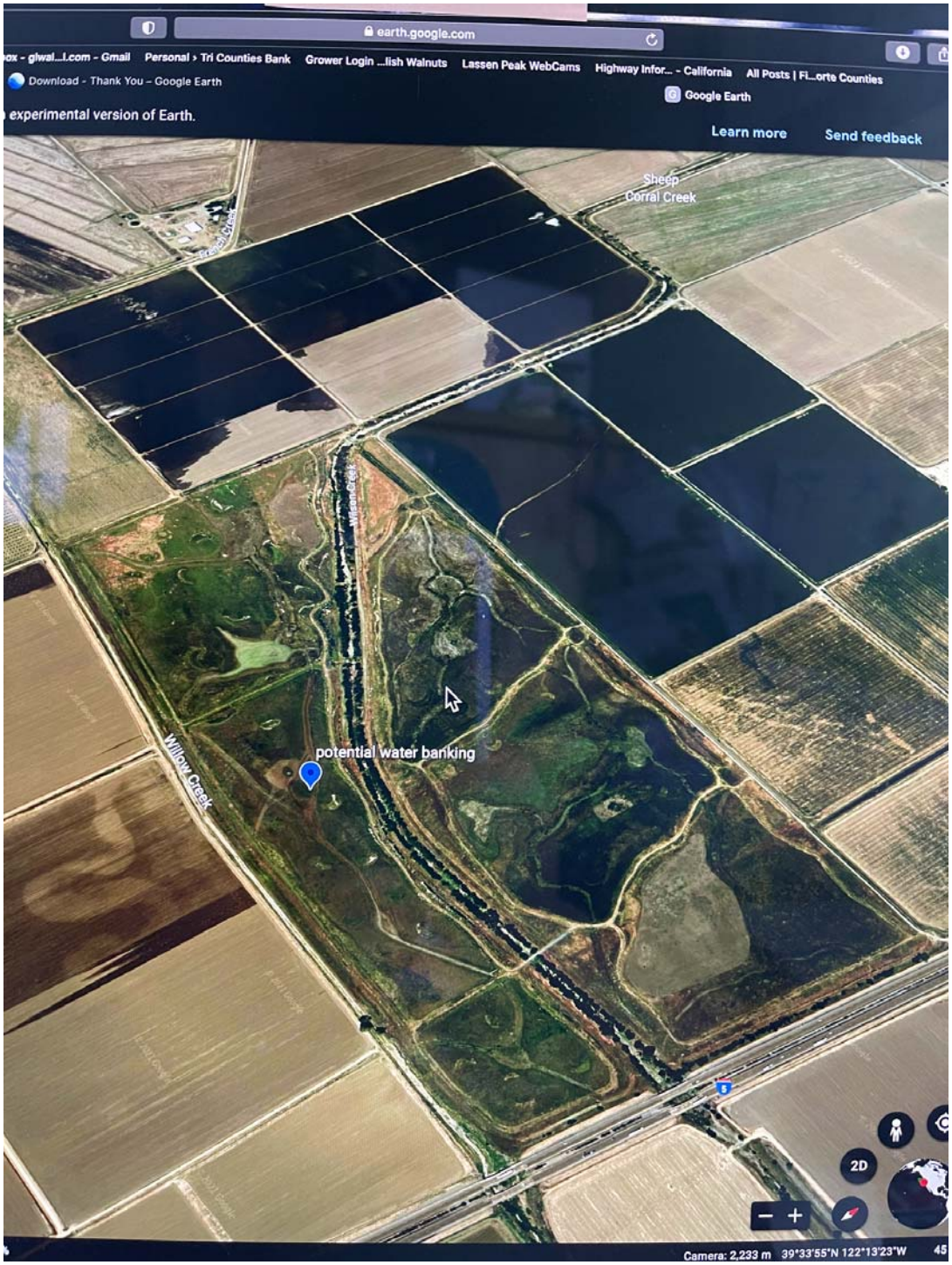
Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment

From: Leslie Nerli < >
Sent: Monday, April 26, 2021 10:12 AM
To: Grant Davids <grant@davidsengineering.com>; Lisa Hunter <LHunter@countyofglenn.net>
Subject: Fwd: attached map and ideas for potential recharge

HI Grant and Lisa
Sorry the previous emails were hand written and hopefully legible for you to review. I have been very busy spraying long hours for potential blight from the past rain prediction that panned out to be a waste of time and money in spray as very little precipitation.
I could not get a hold of the people I wanted to over the weekend to give you more information to use for this potential project.
First off, the land owner of the property has changed hands from Pete Galaya to:
RD 45 , LLC
1380 East Ave, Ste 124
Chico, CA
Parcel number 020-240-0140
There is 41.5 acres of Glide water district in the block of Habitat, not waterfowl wetlands like I thought. Not sure what plain ole Habitat is but definitely good percolation in this area. Of course this is a statement made only by experience and not as a geologist/hydrologist which would have to be confirmed by science. A rice farmer to the west of the proposed property for recharge used almost 10 acre feet one year for his crop. Again, the cost of water and other crop costs combined with returns have forced this farmer to sell part of his land using the sale of his land from many generations in his family to develop orchards so that he can keep some of the remaining 4rth or 5th generation family farm. Sad but true for many farmers.
From what I was told by Mike Alves regarding there are 41.5 acres of glide district land within the 300+/- acres of Habitat. When available from the Bureau, water can be surface water that can be purchased at each year's allocation rate for the **only the 41.5**, but not more than the allocation for each year. In addition to the glide surface water yearly allocation, any Bureau excess flow water could be captured in the 41.5 acres **and** remaining property acres as well. So using the Glide means of transportation from the TC canal, possible surface water available year to year could increase throughout the year time to time as the Bureau sees fit to call in "excess flows available" Of course, they still charge a fee and Glide a fee as well, but usually at a more reasonable price.
Because this property lies between the 2 creeks, it does flood during wet years. So, maybe some improvements could be made to capture more of the flood water that flows so quickly away and allow for more time to capture excess flood water to our groundwater storage. Maybe it will be so simple and cost effective as placing Check damns? and/or doesn't need them just some drainage management.
I do not know who the RD 45 LLc people are or if they would even consider working with the ground water recharge project. Even to the north of Wilson Creek is land in the habitat. It is a very large piece of property. 300 +/- acres.

Hope all this helps and let me know if you have any questions.
Thank you
Leslie Nerli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Google Earth
experimental version of Earth.
Learn more
Send feedback
Sheep
Corral Creek
potential water banking
Willow Creek
2D
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From: Leslie Nevis GGA Board

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
2	2.1.2		1	Plan Area	Paragraph 2 The obvious and probably already corrected is... Primary urban . . . . Colusa & Williams in Glenn Co. . . . wrongly printed for both counties
2	2.4	23		Conjunctive use Programs	Paragraph 3 – Purveyors (water) along TC Canal — Re: 0% – 100% depending on available water – truely dependant on what Bureau feels to allow each year and is announced very early in year. Thus Paragraph 4 – also wrote well but I would like to add that Ag users try to utilize these transfers which are always at a very high price per A/F instead of pumping ground water. Or some Ag user combine the very costly cost of transfers with ground water pumping to survive and turn a profit. These costs are what have driven the Agriculture users to change crop planting from row crops to tree crops due to costs. (or rice)

cont 2.2.4 Conjunctive Use programs

Some Ag users have no groundwater availible and dare not plant trees, therefore fallow when either cost of water is prohibited and/or Not availible to buy — Fallow ground means less money for county in many ways — labor / Tractor equip purchases for improvements / taxes etc. . . . Not sure how or if this needs to be addressed but just saying . . . . Ag $ cost of transfers should be reognized — Nothing high is reasonable and is driving land use to demand more ground water and less land use to replenish what is taken.

From: Leslie Nerki GGA Board

Joint TAC
April 23 Mtng

COLUSA SUBBASIN

Potential Recharge Project

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
		32		Areas of Sustainability Concerns	- Glide Water District - Please see attached MAP
					of what I believe to be an excellent area of land to recharge. The land owner is Pete Galaya from Colusa
					Not sure how to approach the whole thing but maybe Grant David can - It is wetlands for waterfowl
					hunting and between the 2 creeks where as you could divert water from creek when flow allows. I know it floods when wet years flood. Maybe build
					up catch ment areas to hold flood water longer. Surface water from Glide could be used

Cont'

when excess Bureau water is availible. This past February we were offered excess flow water, of course always for a fee from both the Bureau and Glide wheeling fees — Maybe we can lease the ground from Pete and somehow determine what we put into ground water system could be credit for when we have to pump — Could approach Districts or a group of local ag. users to develop land to better utilize rain/s.w. for recharge and somehow get credit to pump g.w. when s.w. is not available. ? ? Maybe the land just needs some check dams? Might be already to capture (recharge) water.

Colusa Subbasin Groundwater Sustainability Plan Public Review Draft Input

Commenter Name: Pamela Plemmons **Commenter Affiliation (if applicable):**

This file introduces a table that allows you to easily enter the following key information so we have certainty about your input. The table includes the following categories:

- Chapter Number
- Section Number
- Page Number
- Paragraph Number (starting with the first full paragraph at the top of a given page)
- Figure/Table Number (if applicable)
- Comment

INSTRUCTIONS

1. Please use the MS Word or PDF document titled "Colusa Subbasin GSP Input 9.2021" to submit your comments.

2. Review all applicable text and note each Chapter, Section, Page, and Line number associated with a comment you'd like to make.

3. Enter your name and if applicable, an organizational affiliation at the top of your table.

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   - Lisa Hunter – Program Manager - Glenn Groundwater Authority: lhunter@countyofglenn.net

6. If you are located in the Colusa Groundwater Authority, please send your comment file to
   - Mary Fahey – Program Manager - Colusa Groundwater Authority: mfahey@countyofcolusa.com

7. If you don't affiliate specifically with either the CGA and/or GGA, please send your comments to both Mary and Lisa.

8. Please make sure that your comments are submitted by 11:59 p.m. October 31, 2021.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment
Executive Summary			22-27		(Executive summary-Line 22-27 and corresponding sections in the text) I believe that the foundational assumptions with the water budgets do not reflect the reality of future climate change and the assumptions of data used as the baseline were not indicative of drought years. In addition, the idea that using a central tendency for climate change is short sighted at best. It seems to me that a "critical' tendency for climate change should also be included in the analysis—one that looks at a serious increase in overall earth temperature above 2.5*C. Otherwise, we are just putting our heads in the sand with regard to future water/crop issues. What mitigation factors could be planned for? How is water distributed equitably in times like that? What future cropping patterns might be considered? (maybe more annual crops when water is available..)
Executive Summary			17-21		(Executive summary-Line 17-21 and corresponding sections in the text)) I also would like to add that the assumptions of surface water use and a reduction in irrigated acreage from Shasta in critical years would be less is actually inaccurate. Since much of the irrigated agriculture in the Glenn and Colusa area are permanent crops (almonds and walnuts), they need to be irrigated no matter what…what it does trigger is a significant increase in ground water use.
Additional Comment					Finally, what I find distinctly disturbing is that in the entire plan there is no individual accountability for ground water use by individual growers, no monitoring of private wells or individuals who are excessive consumers of our precious and shared resource. For example, I am aghast at the practice of almond farmers extensively irrigating to "fatten up" the nuts just prior to harvest. Seriously!!! What a waste of water!!! The extra moisture has to be dried out using more energy in the drying process. Why is there no individual accountability for each well and that each grower pay the price for water just like most consumers have to do? I believe this is something that truly needs to be included in the plan.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Line Number	Figure/ Table Number (if applicable)	Comment

Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Holly Reimers **Commenter Affiliation (if applicable):** _____

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6. If you are located in the Colusa Groundwater Authority, please send your comment file to
   - Mary Fahey – Program Manager - Colusa Groundwater Authority: mfahey@countyofcolusa.com

7. If you don't affiliate specifically with either the CGA and/or GGA, please send your comments to both Mary and Lisa.

8. Please make sure that your comments are submitted by midnight May 5, 2021.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
1	1.1	1-1	2		The priority being to halt overdraft and bring basins into balance? This is not even close to being complied with. The overdraft is far greater than the recharge with the ground water tables lowering each year.
1	1.1	1-1		1, 2 & 6	Sounds good but is NOT will not work and is not doable.
1	1.1	1-1	4		Achieving the groundwater management within 20 years WILL BE TOO LATE.
1	1.2	1-2	1		SEE ABOVE!
1	354-10	3 OF 7		1-1	The whole process has been trotally lacking in "public engagement". Nor has the GGA encuraged any "active involvement". As the times we have given input we have been overridden by councel.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
2	2.1.2	2-4	2.1.2.1		With the Colusa Subbasin depending on ground water for their potable water the ground water for these wells should be closely watched as the number of wells are going dry or having to be lowered at an alarming rate.
2				2-6	The table shows the density of Ag. wells around Orland. Is anyone reporting the number of domestic wells that are being affected by this?
2	2.2	2-16	2.2.1.1		"Manage and reduce invasive plant populations" This has been one of my main talking points for many years. The Salt Ceder and the Bamboo are non native and are using more water than any other source. Especally in this dry year these plants need to be eradicated!
2	2.2	2-17	2.2.1.1		"Ensure long-term Gropundwater Sustainability" At the rate this is going and where it is headed the train has left the station and we in Glenn County will have little or no ground water in the very near future. Domestic and livestock wells MUST be protceted.
same as above					The defination of sustainable: "related to, or being a method of harvesting or using a resource so that the resource is NOT depleted or PERMANENTLY damaged". To date all that I have seen and hear coming from the GGA has been a JOKE!!!

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
2		2-23	2.2.4		With 2021 being one of if not the dryest years on record to transfer serfice water OUT of the subbasin should be at the very least suspended. To transfer serfice water then pump ground water as a substitute should not be allowed.
2		2-29	2.5.1.2		Chowchilla?????
3		ALL OF IT!			Anyone reading this needs a Masters degree in Geology. Anyone looking for something to put them to sleep at night can try this chapter. Most of what is contained is FAR above most people and especally those here in Nrthern California. Maybe this chapter is necessary but it is way over the top on so much detail that it loses the normal person. It certently lost me.
4		ALL OF IT.			There is no mention of using those locals that are drillers and or anyone that repairs pumpa and wells. It should be noted that those working in the "field" just might have a better idea as to what is happening to our groundwater than someone sitting at a computer someplace other then in the field in Glenn County.
	FINAL THOUGHTS				After reading through this whole draft. Witch I will have to admit was in many places very boring, I see no offers of solutions. Lots of "we will Keep lookionmg at it" but nothing to address what some are saying is a major overdraft of our gropund water. Domestic and stock wells are having to be lowered or are running out of water. The word on the street is that the ground water is dropping by over 1' per year and that was BEFORE the current very dry year. To me this is nothing more than a "make someone feel good" and a waste of time and energy of some that are well meaning but this is NOT getting the job done.

Comments on the Glenn Subbasin GSA
Comments by Holly E. Reimers, Landowner

Page	Line	Table	Figure	Comments
ES-14	14-15			What happened to the wells between 200' and 2,000'?
ES-16		ES-3		Wells falling below their MT should be monitored more often than every 24 months. Every two years allows for a severe lowering of the ground water level that might not be recoverable. Any well falling below it's MT should be checked at least twice a year. Any land subsidence should not be acceptable. This is not something that is recoverable.
ES-17	12-15			"..not currently occurring..." WHAT?? Has anyone noted the number of dry and going dry wells in Glenn County? Granting that this is an usually dry year and that Stony Creek has not run all year it is almost amazing that there have not been more dry wells. Yet there are those around the County that continue to pump great amounts of ground water from their deep wells. Sort of like putting a straw on a glass and sucking. The top part of the glass will go dry first as the water is pulling from the bottom.
2-1				The basin boundaries should be redrawn to exclude those lands that do not have access to groundwater primarily those lands in the western portion of the basin. Not only is there little to no groundwater these lands are receiving no benifit from being in the basin, only an expense.
3-15	3.1.5.16			Why is Hambright creek not mentioned? When running it is a major source of groundwater recharge.
6.5.1		6-27		The OUWUA is acknowledged as direct Groundwater Recharge. The land owners in the OUWUA should also be acknowledged as having the ability to assist in the ground water recharge. Those that apply only surface water should be given credit and not charges as they are helping the recharge when ever they apply surface water.
7.6	8-23			Charging the landowners on the west side of the basin, with no groundwater, the same amounts as those that have the water under their ground and are pumping for their perennial crops is unfair. Paying a "tax" or "fee" when

there is no benefit to the landowner, there should be some benefit but so far we on the west side are seeing none. To place this additional burden on these land owners may force them to look at other uses of their ground to be able to "pay" for your additional fees.

Appendix 7A
Page 3 Table 1

All "fees" should be passed only by a majority approval vote. Any "vote" should be conducted on a per/acre basis and should take into consideration what benefit there is to the landowner(s). You can call it is "fee" BUT if it looks like a duck, quacks like a duck IT IS A DUCK! A "fee" by any other name is still a tax on our property.

General Comments

It has been said that there are outside groups purchasing ground in the basin with the only purpose of mining the ground water. This is not a supportable option for the basin to be able to sustain its self. **NO GROUND WATER SHOULD BE EXPORTED FROM THE BASIN - EVER!**

Chapters 3, 4 & 5 one needs to have a Doctorate Degree in Hydrology, Geology and Engineering to even start to understand any of this. This should be written so that the general public and landowners would have some kind of understanding as to what some of these proposals are and how they as landowners will be effected. Or at least put in a summary that the landowner can understand, it may be included I might have missed it in all the other "stuff".

Colusa Subbasin Groundwater Sustainability Plan Chapter Input

Commenter Name: Emily Reinhart **Commenter Affiliation (if applicable):** Davis Ranches/Sycamore Mutual Water Company

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8. Please make sure that your comments are submitted by midnight May 5, 2021.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
6	5.1.7	6-70	1 (above Table 6-35)		**Question**: What do you mean by "newly formed water storage district"? We are already within an existing water district (Sycamore Mutual Water Company). Davis Ranches is the participating Landowner within the district that will be hosting the recharge site.
6	5.1.7	6-70	1 (above Table 6-35)		Water would be sources from Sacramento River during high flows in the system. Currently, Sycamore Mutual Water Company (a Sacramento River Settlement Contractor). We will be looking to rely on our Riparian water rights in order to do winter flooding (beneficial use). We will not have 215 water from the Colusa Drain. Should project start before Nov. 1, we would use some of our settlement contract water to recharge.
6	5.1.7	6-70	1 (above Table 6-35)		Habitat benefits also include winter floodplain habitat for migrating shorebirds/waterfowl as we pulse flood the field
6	5.1.7	6-71	Table 6-35	Water Source & Reliability	Source is Sacramento River. Reliability is good, but still unknown at this time.
6	3.5.1	6-42	1		30 – 45 days during fall/winter. We aren't tied to a specific start date. There is flexibility built into the project to allow for water availability, etc. The target is Fall/Winter for the habitat benefits as well as availability of water in the system. Settlement contract waters would be used if the project starts before Nov. 1.

COLUSA SUBBASIN

Chapter Number	Section Number	Page Number	Paragraph Number	Figure/ Table Number (if applicable)	Comment
6	3.5.1	6-42	2		We do not have contract for 215 water. We do have riparian rights that we would be exercising for this project for beneficial use (habitat).
6	3.5.1	6-42	2		5,000 acre feet over 10-years is our goal.
6	3.5.5	6-44	1		No 215 water.
6	3.5.7	6-45	2		No 215 water.
		6-8		Table 6-2	Diversion of winter flows from Sacramento River (riparian) or settlement contract flows (should project start before Nov.1).

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Appendix 2C

Distribution Lists

2C-1: GSA-Specific Coordination Meetings

2C-2: Media and Outreach Contacts

Note: Some information has been redacted for confidentiality purposes and GSA commitments.

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2C-1. GSA-Specific Coordination Meetings

Note: Some information has been redacted for confidentiality purposes and GSA commitments.

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Appendix 2C-1
Colusa Subbasin
GSA-Specific Beneficial Users

Category of Interest	Examples of Beneficial User Groups	Engagement Purpose
General Public	• Citizens groups • Community leaders • Interested individuals • Universities/Academia	Inform to improve public awareness of sustainable groundwater management
Land Use	• Municipalities • Local land use agencies • Regional land use agencies • Community Service Districts	Consult and involve to ensure land use policies are supporting GSPs and there are no conflicting policies between the GSAs / GSP and said local government agencies
Private Users	• Private pumpers (domestic and agricultural) • Schools and colleges • Hospitals	Inform and involve in assessing impacts to groundwater users
Urban/ Agricultural Users	• Water agencies • Irrigation districts • Municipal water companies • Mutual water companies • Resource conservation districts • Farmers/Farm Bureaus • Water Districts • Water users associations • Irrigated Lands Regulatory Program Coalition	Collaborate to ensure sustainable management of groundwater
Industrial Users	• Commercial and industrial self-suppliers • Local trade associations or groups	Inform and involve in assessing impacts to users
Environmental and Ecosystem Uses	• Federal and State agencies • Wetland managers • Environmental groups	Inform and involve to consider/incorporate potential ecosystem impacts to GSP process
Surface Water Users	• Irrigation Districts • Water Districts • Water users associations • Agricultural users	Inform and involve to collaborate to ensure sustainable water supplies
Economic Development	• Chambers of commerce • Business groups/associations • Elected officials • State Assembly members • State Senators • Economic Development Team	Inform and involve to support a stable economy
Human Right	• Disadvantaged communities	Inform and involve to provide safe and

Category of Interest	Examples of Beneficial User Groups	Engagement Purpose
to Water	• Small water systems • Environmental justice groups/community-based organizations • De minimis well owners	secure groundwater supplies to all communities reliant on groundwater
Tribes	• Federally Recognized Tribes • Non-Federally Recognized Tribes	Inform, involve and consult with tribal government
Federal Lands	• U.S. Fish and Wildlife Service • U.S. Bureau of Reclamation • U.S. Army Corps of Engineers	Inform, involve and collaborate to ensure basin sustainability
Integrated Water Management	• Regional water management groups (IRWM regions) • Flood agencies	Inform, involve and collaborate to improve regional sustainability

2C-2. Media and Outreach Contacts

Note: Some information has been redacted for confidentiality purposes and GSA commitments.

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Appendix 2C-2
Colusa Subbasin
Media and Outreach Contacts

The following media outlets and outreach partner organizations are contacted to publicize every Colusa Subbasin outreach event and to publish associated press releases and associated narrative materials (e.g. Op-Ed, newsletter publications, etc.).

Media Contacts

The Sacramento Valley Mirror
Glenn County Transcript
Colusa County Sun Herald
Colusa Appeal Democrat
Chico Enterprise Record
Williams Pioneer Review
Action News Now
KRCR
NSPR
CPAY Radio

Outreach Partners

California Department of Water Resources
Colusa County Farm Bureau
Colusa County Resource Conservation District
Colusa Glenn Subwatershed Program
Colusa County Farm Service Agency
Colusa County Cooperative Extension
Colusa County Department of Agriculture
Colusa Basin Drainage District
Glenn County Farm Bureau
Glenn County Resource Conversation District
Glenn County Rangeland Association
Northern California Water Association
Orland Unit Water Users Association
Ord Bend Community Services District
UC Cooperative Extension – Colusa County
UC Cooperative Extension – Glenn County

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Appendix 2D

Public and Engagement Materials

2D-1: Interbasin SGMA Coordination Meetings

2D-2: Initial SGMA Information Workshops

2D-3: GSA Financing – Proposition 218 Public Information Meetings and Hearings

2D-4: SGMA General Information, Basin Setting and Sustainable Management Criteria Workshops

2D-5: SGMA-Series Public Events

2D-6: Subbasin Branding

2D-7: Media Materials

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2D-1. Interbasin SGMA Coordination Meetings

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Northern Sacramento Valley Inter-basin Coordination Report

Antelope | Bowman | Butte | Colusa | Corning | Los Molinos | Red Bluff | Sutter | Vina | Wyandotte Creek | Yolo

Table of Contents

Glossary of Acronyms ***1***

1. Introduction & Background ***2***

2. Intent & Purpose ***3***

3. Evolution of Inter-basin Coordination Efforts ***4***

4. Inter-basin Coordination Framework ***6***

4.1. Inter-basin Coordination Groups **7**

5. Conclusion and Next Steps ***8***

Appendices ***9***

Glossary of Acronyms

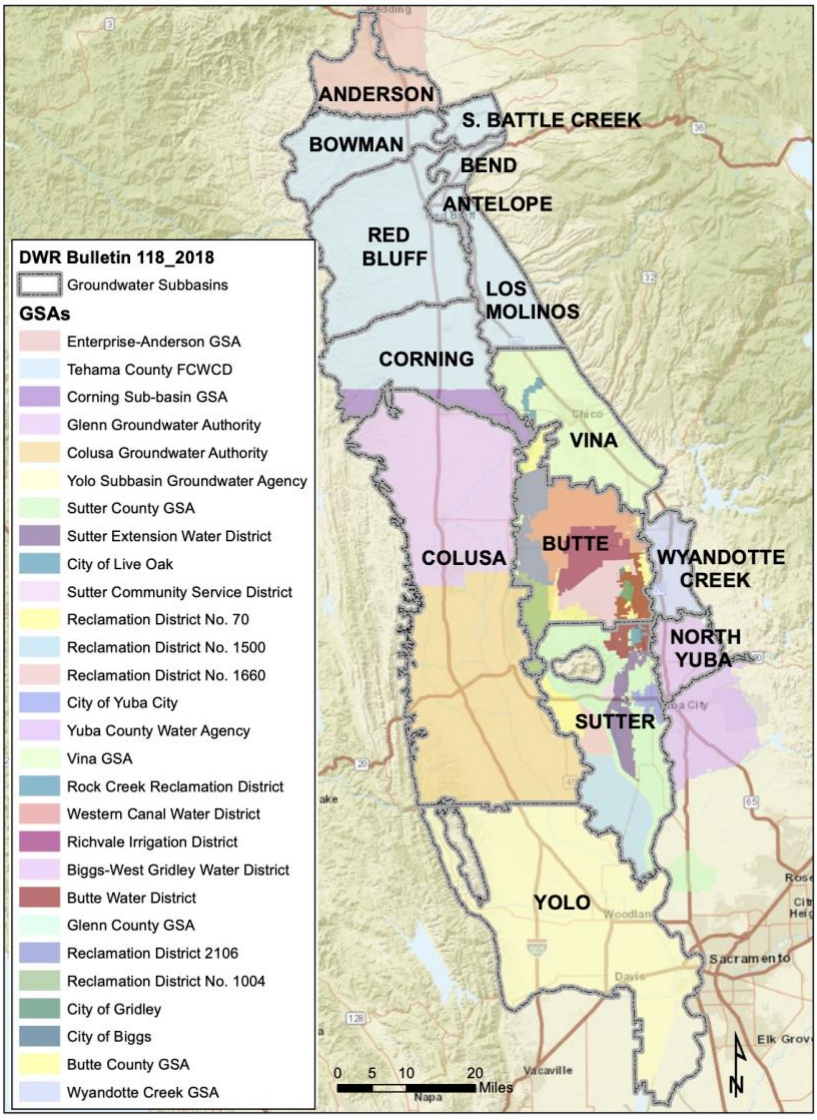
- ***CBI*** – *Consensus Building Institute [link]*
- ***DWR*** – *California Department of Water Resources*
- ***GSA*** – *Groundwater Sustainability Agency*
- ***GSP*** – *Groundwater Sustainability Plan*
- ***MOU*** – *Memorandum of Understanding*
- ***NCWA*** – *Northern California Water Association*
- ***NSV IRWM***– *Northern Sacramento Valley Integrated Regional Water Management*
- ***PMAs*** – *Projects and Management Actions*
- ***SGMA*** – *Sustainable Groundwater Management Act*
- ***SMC*** – *Sustainable Management Criteria*

1. Introduction & Background

The content of the report is the result of staff recommendations resulting from regional inter-basin coordination staff meetings in the Northern Sacramento Valley (2020-2021). The content will be presented to inform discussions among Groundwater Sustainability Agencies (GSAs) and gather public input through existing public venues, such as advisory committees, groundwater commissions, and GSA Board meetings.

Inter-basin coordination is critical in the Northern Sacramento Valley as GSAs develop and implement Groundwater Sustainability Plans (GSPs). Since groundwater subbasins in the Northern Sacramento Valley are hydrologically interconnected, water management decisions and actions in subbasins (i.e., groundwater pumping and processes affecting recharge, water demand, and supply including climate change) could change aquifer conditions. Understanding and accounting for these processes is important towards achieving sustainability in all subbasins.

Figure 1. Map of the Northern Sacramento Valley



Inter-basin coordination is described in the GSP Regulations in Article 8. Under the regulations, GSAs must describe how they coordinate with adjoining subbasins to demonstrate implementation will not adversely affect adjoining subbasins. The Department of Water Resources (DWR) is required to evaluate whether a GSP adversely affects the ability of an adjacent basin to implement their GSP or impedes achievement of sustainability goals in an adjacent basin (Water Code 17033(c)). Coordination among GSAs can be formalized in different ways and inter-basin agreements are voluntary. Appendix A describes components of Sec 357.2.

Inter-basin coordination discussions among staff representatives from 11 subbasins (Antelope, Bowman, Butte, Colusa, Corning, Los Molinos, Red Bluff, Sutter, Vina, Wyandotte Creek, and Yolo), with facilitation support from the Consensus Building Institute (CBI) began during the summer of 2020. While efforts have focused on these subbasins, coordination will occur, as warranted, with other neighboring subbasins (Anderson and North Yuba).

Initial stages of inter-basin coordination efforts (May-December 2020) were closely aligned with the GSP Regulations in Article 8 components and delineated in Section 3 *Evolution of Inter-basin Coordination Efforts*. After an initial attempt to compile technical information to better understand basin conditions at respective boundaries, staff realized differing timelines for the completion of Basin Setting content in each subbasin meant there would not be sufficient time during initial GSP development to fully characterize or address major inconsistencies. Therefore, the goal for regional inter-basin coordination shifted towards establishing a framework for long-term inter-basin coordination and dialogue (post GSP submittal in 2022). Informal coordination discussions among staff and consultants between neighboring subbasins continued during the GSP development process.

This report outlines the intent and purpose of inter-basin coordination in the Northern Sacramento Valley. It describes the process followed and materials developed throughout the process. It also outlines foundational elements, referred to as "key pillars," of a framework for sustained coordination through GSP implementation.

2. Intent & Purpose

Inter-basin coordination efforts in the Northern Sacramento Valley are focused on establishing a foundation and guidelines for sustained inter-basin coordination through GSP implementation, following the initial submittal of GSPs by January 31, 2022. GSAs intend to:

1. *Establish a framework allowing for continued dialogue and a venue to address issues and discrepancies during the implementation of the GSPs;*
2. *Coordinate on consistent messaging and communicate shared expectations at a regional level;*
3. *Demonstrate regional coordination efforts and outcomes; and*
4. *Leverage existing agreements and arrangements in the region (e.g., Northern Sacramento Valley Integrated Regional Water Management (NSV IRWM), the Six County Memorandum of Understanding among Butte, Colusa, Glenn, Tehama, Shasta, and Sutter).*

The proposed deliverable from this effort is the development of a common approach and draft language for incorporation into each subbasin's GSP. This narrative describes the facilitated effort as well as the framework and scope for long-term coordination during plan implementation. The public will have opportunities to weigh in and provide input on the proposed framework through each subbasin's existing public venues, such as advisory committees, groundwater commissions, and GSA board meetings.

3. Evolution of Inter-basin Coordination Efforts

Inter-basin coordination efforts, facilitated by the Consensus Building Institute (CBI) began in summer 2020 among Subbasin staff from Antelope, Bowman, Butte, Colusa, Corning, Los Molinos, Red Bluff, Vina, and Wyandotte Creek subbasins to identify priorities and resources available for inter-basin coordination. Soon after, staff representatives from the Sutter and Yolo subbasins joined the meetings. To date, CBI has facilitated nine inter-basin coordination meetings with staff and periodically with technical consultants from the subbasins. Subbasin staff and/or CBI communicated regular updates to GSA Boards and advisory committees in each of the subbasins regarding the status of inter-basin coordination activities [Access Webpage Here].

Initial stages of inter-basin coordination efforts were closely aligned with the GSP Regulations in Article 8:

1. ***General information*** *of subbasins, plans and agencies participating in the coordination agreement,*
2. ***Technical information*** *including consistent and coordinated data or methodology for inter-basin boundary flows and stream-groundwater interactions at basin boundaries, and information on sustainable management criteria and monitoring that would confirm that no adverse impacts of implementing the GSPs would result to any party to the agreement,*
3. *A description of the* ***process for identifying and resolving conflicts*** *between Agencies that are parties to an inter-basin coordination agreement.*
   Reference: *Sections 10727.2, 10733, and 10733.2, Water Code.*

The goal at the initial stage was to compile general and technical information identified by DWR in a consistent manner to establish an accurate basis of comparison and to identify any significant inconsistencies that may need to be addressed or resolved. This included developing a series of information-sharing documents and outreach materials, summarized below.

1. ***Inter-basin Coordination Directory–*** *This document provides an updated and centralized directory with contact information for GSA managers, technical consultants, and facilitators in the various subbasins. This document seeks to facilitate communication among the various representatives leading GSP development [Access Here].*
2. ***Technical Information-Sharing Template–*** *This template was developed among the managers and technical consulting teams to compile and compare information on modeling tools and water budget results for inter-basin flows, stream-aquifer interactions, and hydro-geologic conditions in the subbasins. Potentially, this document could be used to compile information about Sustainable Management Criteria and Monitoring Networks [Access Draft Template Here]. The first output from the technical information-sharing template summarizes the highlights of compiled model information across the subbasins [Access Here].*
3. ***Outreach Presentation****–This PowerPoint presentation provides updates on inter-basin coordination activities to the various SGMA public venues (GSA boards, advisory committees, etc.) and an overview of the scope and timeline of inter-basin coordination efforts. This presentation is continuously updated*

after each inter-basin coordination staff meeting for use in consistently communicating with GSA Boards/advisory committees and the public throughout the region [Access Here].

4. ***Outreach Factsheet–*** *The inter-basin coordination factsheet aims to support public outreach and information sharing in the various subbasins. This two-page flier or factsheet summarizes why regional coordination is important under SGMA, who is involved in ongoing efforts, what the coordination priorities are, and includes a table with links to each subbasin's website for additional subbasins' specific information [Access Here].*
5. ***Inter-basin Coordination Webpage****– Butte County hosts a webpage to provide the most up-to-date information on inter-basin coordination efforts in the Northern Sacramento Valley. The webpage provides an overview of the scope and makes available documentation and results of the inter-basin coordination work, including meeting agendas, summaries, and outputs [Access Here].*
6. ***Meeting Summaries****–CBI develops meeting summaries after each regional inter-basin coordination staff meeting to summarize key discussion themes, action items, and next steps. These summaries are publicly available on the inter-basin coordination webpage [Access Here].*

After an initial attempt to compile technical information, staff realized the broad aspirations were not feasible during the initial stages of GSP development. The process of compiling and comparing modeling outputs from the diverse regional hydrological models required a significant amount of time, resources, and varying levels of data. Further, subbasins were at different stages of GSP development and GSAs were facing tight timelines, competing priorities, and capacity limitations to meet the regulatory deadline. While communication on a neighbor-to-neighbor basis on technical components was encouraged through GSP development, subbasin staff representatives realized more robust technical analysis and coordination between and among subbasins was not possible until initial plans (including water budgets) were more fully developed or after adoption of the initial GSPs.

Following reflection from the separate inter-basin efforts and priorities moving forward, subbasin staff recommended shifting the focus of regional coordination meetings to establishing a framework for long-term inter-basin coordination and dialogue following GSP submission in January 2022. To do so, subbasin staff identified desired outcomes in the short-term (during initial GSP development), mid-term (first 5-year update), and long-term (GSP Implementation through 2042) [Access Here]. This approach recognizes adoption of the 2022 GSPs as an initial step in sustainable groundwater management, not the final step. Subbasin staff acknowledged while model outputs may not match perfectly, the main objective is to identify and acknowledge significant discrepancies, understand why those differences exist, and evaluate to the extent they need to be reconciled. Inter-basin coordination has been characterized as "a marathon not a sprint," and current efforts will serve to pave the path for long-term collaboration. Further, GSAs can take advantage of annual reporting and five-year GSP updates to identify and address discrepancies. Lastly, subbasin staff representatives acknowledge public participants are interested in inter-basin coordination efforts and concerns from some subbasins can easily affect others. Subbasin staff understand the need to share and educate the public on what is in the various GSPs, and the SGMA requirements for inter-basin coordination. Staff will continue to provide updates and gather GSA Board and public input related to the direction of current efforts and desired priorities, shared concerns, and possible ideas for inter-basin coordination during GSP implementation.

4. Inter-basin Coordination Framework

This section outlines the foundational pillars that comprise the framework for inter-basin coordination under SGMA between and among subbasins in the Northern Sacramento Valley. These pillars build upon a long-standing history of regional collaboration and embody a commitment for continued coordination, collaboration, and communication for successful groundwater management in the region. Honoring the individual authorities of the GSAs, these pillars represent a menu of options neighboring subbasins can draw upon, based on individual or neighboring subbasins' needs and challenges. GSA Boards can decide which of these options they would like to support and implement, acknowledging circumstances may change over time.

Pillars	Scale(s)	Timing
1. Information-sharing a. Inform each other on changing conditions (i.e., surface water cutbacks, land use changes, policy changes that inform groundwater management) b. Share annual reports and interim progress reports c. Share data and technical information and work towards building shared data across and/or along basin boundaries (e.g., monitoring data, water budgets, modeling inputs and outputs, and Groundwater Dependent Ecosystems)	• Neighbor-to-neighbor • Coordination groups [Refer to section 4.1 below]	• *Ongoing (GSP Development)* • *Near-term (5-year update)* • *Long-term (GSP implementation)*
2. Joint analysis & evaluation a. Evaluate and compare contents of GSPs with a focus on establishing a common understanding of basin conditions at boundaries b. Identify significant differences, uncertainties, and potential issues of concern related to groundwater interaction at the boundaries c. Engage in analysis and evaluation of SMCs between GSPs to assess impacts and identify significant differences and possible impacts between subbasins that could potentially lead to undesirable results	• Neighbor-to-neighbor • Coordination groups [Refer to section 4.1 below]	• *Near-term (5-year update)* • *Long-term (GSP implementation)*
3. Coordination on mutually beneficial activities a. Communicate, coordinate, and collaborate on mutually beneficial activities, which could include joint monitoring, joint reporting, regional modeling, and other efforts to address data gaps at subbasin boundaries b. Collectively pursue funding and collaborate on mutually agreed upon projects and management actions that provide benefits across boundaries c. Leverage existing collaboratives (NSV IRWM, NCWA etc.)	• Neighbor-to-neighbor • Coordination groups • Regional: NSV IRWM, NCWA Groundwater Task Force	• *Ongoing (GSP Development)* • *Near-term (5-year update)* • *Long-term (GSP implementation).*
4. Coordinated communication and outreach a. Coordinate and collaborate on regional-scale public engagement and communication strategies that promote awareness on groundwater sustainability, enhance public trust, and maintain institutional knowledge b. Maintain list of GSP/subbasin staff contacts and websites	• Regional: NSV IRWM and NCWA Groundwater Task Force	• *Ongoing (GSP Development)* • *Near-term (5-year update)* • *Long-term (GSP implementation)*
5. Issue-resolution process a. Establish and follow an agreed-upon process for identifying and resolving conflicts between GSAs by the first five-year update [Refer to Appendix D for more details and discussion prompts on issue resolution processes]	• Neighbor-to-neighbor • Coordination groups	• *Near-term (5-year update)* • *Long-term (GSP implementation).*

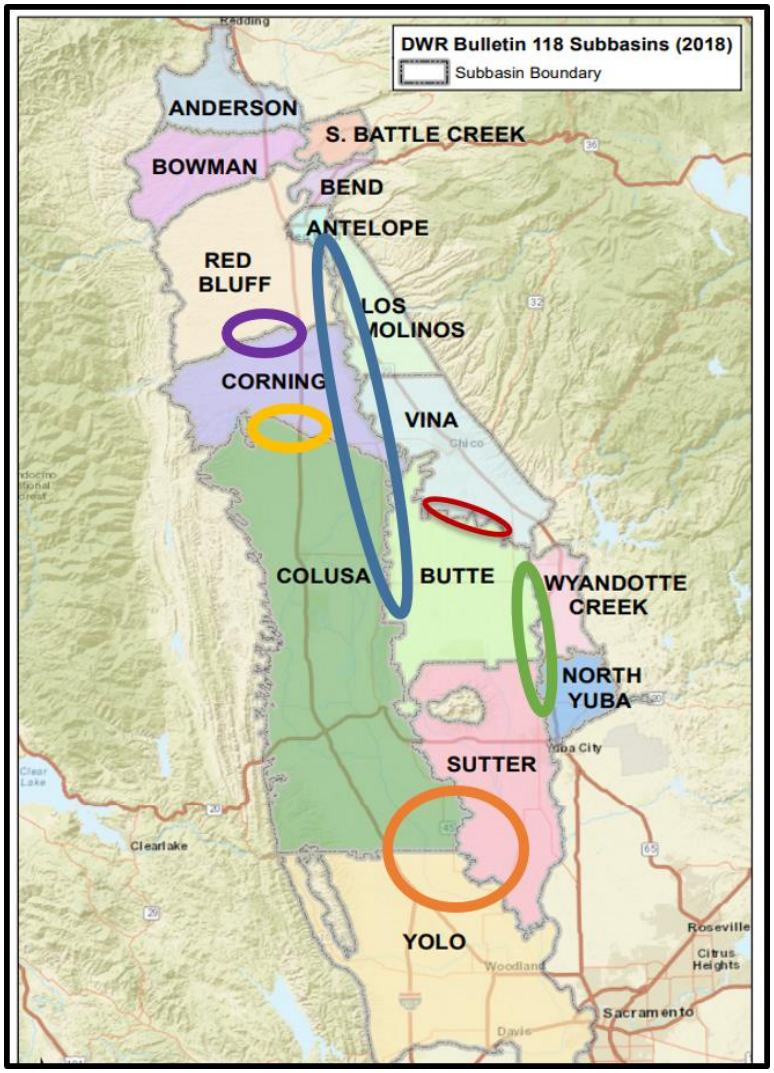
4.1. Inter-basin Coordination Groups

Inter-basin coordination efforts, as outlined in the pillars above, would require resources and technical support. Subbasin staff recommend organizing inter-basin coordination priorities by specific subbasin boundaries. One suggested approach identifies specific "Coordination Groups" (see Figure 3 and list below). Some of these groups are pairs and others include multiple subbasins around a river boundary.

1. ***Feather River Corridor***- *Butte, Wyandotte Creek, North Yuba, Sutter*
2. ***North Sacramento River Corridor***- *Antelope, Los Molinos, Red Bluff, Corning, Vina, Butte, Colusa*
3. ***South Sacramento Corridor***- *Colusa, Sutter, Yolo*

Neighbor to Neighbor, examples:

4. ***Stony Creek***- *Corning, Colusa*
5. ***Thomes Creek***- *Red Bluff, Corning*
6. ***Butte/Vina***- *Vina, Butte*



5. Conclusion and Next Steps

In sum, this report outlines a framework for inter-basin coordination for sustainable groundwater management in the Northern Sacramento Valley. The inter-basin coordination framework describes a menu of options for ongoing communication and collaboration around substantive issues over the twenty-year implementation of SGMA.

The pillars and other content from this report could be used by GSAs to support GSP development and implementation in a number of ways. This inter-basin coordination report could be included as an Appendix to the GSP and could be updated on a yearly basis. Individual subbasins can incorporate sections of the report into the body of the GSP, depending upon specific boundary conditions at adjoining subbasins. Finally, subbasins could draw on the inter-basin coordination framework if they would like to consider entering into one or more voluntary inter-basin agreements during GSP implementation.

The content of the report is the result of staff recommendations resulting from regional inter-basin coordination staff meetings. Staff will present the framework as a supporting document to guide and inform discussions with the GSA Boards and other existing public venues, such as advisory committees or groundwater commissions. GSAs in turn will discuss the menu of options for inter-basin coordination outlined in this report to determine their priorities and desired approach to draw on the inter-basin coordination framework in their individual GSPs. Lastly, Subbasin staff will come together to share input received and determinations from their respective GSAs.

Subbasin staff acknowledge that while this report builds upon a long-standing history of regional collaboration, this is just the beginning of inter-basin coordination efforts under SGMA. Therefore, this framework and inter-basin coordination activities will be continually refined throughout GSP implementation.

Appendices

Appendix A: GSP Emergency Regulations, Article 8: Interagency Agreements §357.2

§ 357.2. Inter-basin Agreements (access here)

Two or more Agencies may enter into an agreement to establish compatible sustainability goals and understanding regarding fundamental elements of the Plans of each Agency as they relate to sustainable groundwater management. Inter-basin agreements may be included in the Plan to support a finding that implementation of the Plan will not adversely affect an adjacent basin's ability to implement its Plan or impede the ability to achieve its sustainability goal. Inter-basin agreements should facilitate the exchange of technical information between Agencies and include a process to resolve disputes concerning the interpretation of that information. Inter-basin agreements may include any information the participating Agencies deem appropriate, such as the following:

(a) General information:
  (1) Identity of each basin participating in and covered by the terms of the agreement.
  (2) A list of the Agencies or other public agencies or other entities with groundwater management responsibilities in each basin.
  (3) A list of the Plans, Alternatives, or adjudicated areas in each basin.

(b) Technical information:
  (1) An estimate of **groundwater flow across basin boundaries**, including consistent and coordinated data, methods, and assumptions.
  (2) An estimate of **stream-aquifer interactions** at boundaries.
  (3) A **common understanding of the geology and hydrology** of the basins **and the hydraulic connectivity** as it applies to the Agency's determination of groundwater flow across basin boundaries and description of the different assumptions utilized by different Plans and how the Agencies reconciled those differences.
  (4) **Sustainable management criteria and a monitoring network** that would confirm that no adverse impacts result from the implementation of the Plans of any party to the agreement. If minimum thresholds or measurable objectives differ substantially between basins, the agreement should specify how the Agencies will reconcile those differences and manage the basins to avoid undesirable results. The Agreement should identify the differences that the parties consider significant and include a plan and schedule to reduce uncertainties to collectively resolve those uncertainties and differences.

(c) A description of the **process for identifying and resolving conflicts** between Agencies that are parties to the agreement.

(d) Inter-basin agreements submitted to the Department shall be posted on the Department's website.

Note: Authority cited: Section 10733.2, Water Code.
Reference: Sections 10727.2, 10733, and 10733.2, Water Code.

Appendix B: Inter-basin Coordination Fact Sheet

Northern Sacramento Valley | Sustainable Groundwater Management Act

Regional Coordination Between Subbasins

Antelope | Bowman | Butte | Colusa | Corning | Los Molinos | Red Bluff | Sutter | Vina | Wyandotte Creek | Yolo

Sustainable Groundwater Management Act

What is SGMA? California enacted the Sustainable Groundwater Management Act (SGMA) in 2014 to better manage groundwater over the long term. Sustainability is achieved by avoiding significant and unreasonable conditions for the six "sustainability indicators."

- Lowering of Groundwater Levels
- Reduction of Groundwater Storage
- Land Subsidence
- Surface Water Depletion
- Water Quality Degradation
- Sea Water Intrusion

Why is regional coordination important? In the Sacramento Valley, inter-basin coordination is critical as Groundwater Sustainability Agencies (GSA) develop their Groundwater Sustainability Plans (GSP). Since groundwater subbasins in the Northern Sacramento Valley (NSV) are hydrologically interconnected, water management decisions and actions in one subbasin (e.g. groundwater pumping) and processes like climate change could change aquifer conditions and affect flows to other subbasins. Understanding and accounting for these processes is key to achieve sustainability in all subbasins.

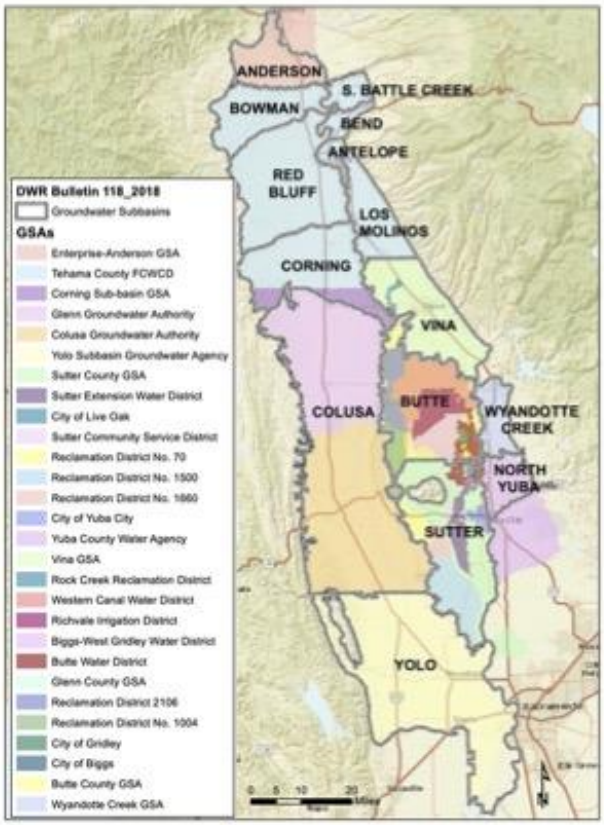
Who is involved in ongoing efforts?

Collaborative efforts have begun among representatives from 11 subbasins (Antelope, Bowman, Butte, Colusa, Corning, Los Molinos, Red Bluff, Sutter, Vina, Wyandotte Creek, Yolo), with facilitation support from the Consensus Building Institute. While efforts have focused on the subbasins mentioned, coordination will occur, as warranted, with other neighboring subbasins (Anderson and North Yuba).

What are the coordination priorities?

Groundwater Sustainability Agencies are working together to establish a foundation for open and transparent inter-basin coordination and communication by developing tools to:

- SHARE & COMPILE INFORMATION IN A CONSISTENT WAY
- OUTLINE A PROCESS TO IDENTIFY & RESOLVE ISSUES
- DOCUMENT COORDINATION EFFORTS



CBI
CATALYZING COLLABORATION

Learn More & Get Involved



Receive Updates
Sign up for your GSA's interested parties list.



Contact Your GSA
Talk to your GSA representative



Attend Meetings
Attend public workshops, Advisory Board, and GSA Board meetings

Subbasin	GSA(s)	Website
Antelope	Tehama County Flood Control and Water Conservation District (FCWCD)	Website
Bowman	Tehama County FCWCD	Website
Butte	Biggs West Gridley WD, Butte County, Butte WD, City of Biggs, City of Gridley, Colusa Groundwater Authority, Glenn County, RD 1004, RD 2106, Richvale ID, Western Canal WD	Website
Los Molinos	Tehama County FCWCD	Website
Red Bluff	Tehama County FCWCD	Website
Corning	Corning Sub-basin GSA, Tehama County FCWCD	Website
Colusa	Glenn Groundwater Authority; Colusa Groundwater Authority	Websites (Glenn) | (Colusa)
Sutter	Butte WD, City of Live Oak, Sutter Community Service District, Sutter County, Sutter Extension Water District, RD 70, RD 1660, RD 1500, City of Yuba City	Website
Vina	Rock Creek Reclamation District, Vina GSA	Websites (Vina) | (RCDC)
Wyandotte Creek	Wyandotte Creek GSA	Website
Yolo	Yolo Subbasin Groundwater Agency	Website



Find more information about regional inter-basin coordination at:
ButteCounty.net/waterresourceconservation/Sustainable-Groundwater-Management-Act/Inter-basin-Coordination

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APPENDIX C

Memorandum of Understanding
Four County (Butte, Colusa, Glenn, and Tehama Counties)
Regional Water Resource Coordination, Collaboration, and Communication

Memorandum of Understanding
Four County (Butte, Colusa, Glenn, and Tehama Counties) Regional Water Resource Coordination, Collaboration, and Communication

1. BACKGROUND
The counties of Butte, Colusa, Glenn, and Tehama share common surface water and groundwater resources. Based on these common resources, local water resource managers understand that regular coordination, collaboration, and communication can result in an improved water resource understanding at both the county and regional level.

2. PURPOSE
The purpose of this document is to establish the mutual understandings of the four counties with respect to their voluntary joint efforts toward regional coordination, collaboration, and communication.

3. GOALS
The goals of the Four County Memorandum of Understanding (MOU) are:

2.1. To foster coordination, collaboration and communication between the four counties on water-related issues, to achieve greater efficiencies, and enhance public services.

2.2. To provide a framework for the management and disbursement of funding associated with activities pursued jointly under this MOU.

2.3. To improve competitiveness for State and Federal grant funding.

4. DEFINITIONS
4.1. Four County. Participants including the counties of Butte, Colusa, Glenn, and Tehama, with representation by the following:

- Butte County: Department of Water and Resource Conservation
- Colusa County: Department of Planning and Building
- Glenn County: Department of Agriculture
- Tehama County: Flood Control and Water Conservation District

4.2. Project Manager. A project manager will be determined by the Counties signatory to this MOU for any given project regardless of funding source to meet the goals set forth in this MOU.

5. MUTUAL UNDERSTANDINGS
5.1. Participation. Signatories to this MOU constitute the current participants. Participation is strictly on a voluntary basis and may be

terminated at any time without recourse. Neighboring counties who share water resources common to the participating counties and who are engaged in similar activities will be invited to be signatory to this MOU. Signatories aspire to work collaboratively with other regional programs and technical outreach efforts.

5.2. Activities. Efforts pursued under this agreement will remain consistent with and will not exceed the current authority for any individual participating county. Efforts will include the study and investigation of water resources common to participants, monitoring and reporting, information dissemination and sharing between counties and with other county departments, public outreach and education, and other activities at the agreement and direction of individual county governing bodies.

5.3. County Funding. Counties are not required to commit funding associated with activities completed under this MOU. It is understood that activities under this MOU may result in the more efficient use of existing and future department funding resulting from improved collaboration and coordination.

5.4. External Funding. Signatories will work collaboratively in pursuit of external funding associated with common interest activities based on voluntary participation and agreement. When required, a mutually agreed upon County representative will serve as the Project Manager for activities completed under a contract with an external funding source. Existing county contracting mechanisms will be utilized where available for contractual and invoicing purposes between participating counties. Nothing in this MOU precludes individual counties from the individual pursuit, contracting and completion of work from an externally funded source regardless of a real or perceived regional interest.

5.5. Decision-making. Consensus will be sought when the need for a decision arises.

5.6. Non-binding nature. This document and participation under this MOU are nonbinding, and in no way suggest that a county may not continue its own activities as each county is expected to continue its own policies and procedures and undertake efforts to secure project funding from any source. A county may withdraw from participation at any time.

5.7. Termination. Because the MOU will require periodic review and updating for use into the future, it is envisioned that the joint efforts of those involved will be ongoing in maintaining a living document. Thus this document will remain as a reflection of the understandings of the participants. Individual signatories of this MOU may terminate their involvement at any time with no recourse.

6. SIGNATORIES TO THE MEMORANDUM OF UNDERSTANDING

We, the undersigned representatives of our respective counties, acknowledge the above as our understanding of how the Four County Coordination, Collaboration, and Communication MOU will be implemented.

MAR 14 2006 APPROVED JAN 24 2006

Date

Curt Josiassen, Chairman
Butte County Board of Supervisors

2/28/06

Approved As To Form:
Bruce Alpert, Butte County Counsel

6. SIGNATORIES TO THE MEMORANDUM OF UNDERSTANDING
We, the undersigned representatives of our respective counties, acknowledge the above as our understanding of how the Four County Coordination, Collaboration, and Communicative MOU will be implemented.

Date April 4, 2006

By Christy Scofield

Christy Scofield, Chairperson
Colusa County Board of Supervisors

Approved As To Form:
Henry Rodegerdts, Colusa County Counsel

EXHIBIT B
PAGE 3 OF 3

6. SIGNATORIES TO THE MEMORANDUM OF UNDERSTANDING

We, the undersigned representatives of our respective counties, acknowledge the above as our understanding of how the Four County Coordination, Collaboration, and Communication MOU will be implemented.

12-13-05
Date

Vice Chairman, Tehama County Flood Control
And Water Conservation District

Approved As To Form:

by
County Counsel, Tehama County

Date

By Board Chair

County
Approved As To Form:

County Counsel

Date

By Board Chair

County
Approved As To Form:

County Counsel

Date

By Board Chair

County
Approved As To Form:

TEHAMA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT
MINUTE ORDER

December 13, 2005

8. Approval of Four-County Regional Water Resource Coordination- MOU: Ernie Ohlin reviewed that in August 2004, the Board authorized staff to participate in the four county water effort. The MOU attached is allowing all counties to participate together in water resource collaboration and communication. This non-binding voluntary MOU recognizes coordination among Butte, Colusa, Glenn and Tehama County.

Roger Sherrill encouraged the four-county groups to participate and noted in Item 5.1 "Participation" is strictly voluntary. Shasta County provides a major part of the recharge for the northern part of the Sacramento Valley and to move forward could only make for a stronger overall group.

Mark Black, Ag Commissioner for Glenn County, added this will be presented to Glenn County next Tuesday for support. Discussions with Sutter and Yuba County brings interest and they are awaiting the outcome of the four counties. This is a good collaborative effort, giving us strength of possible capturing of funding.

Motion by Director Warner to approve the MOU for signature.

Director Willard questioned if this has been reviewed by County Counsel. Upon his approval, signature will be completed.

Motion revised by Director Warner to approve the MOU for signature by the Chair upon review of County Counsel. Second by Director Avilla and carried by those present 3-0 with 2 absent.

Ayes: Directors':, Charles Willard; Ron Warner; Gregg Avilla
Noes: None
Absent or Not Voting: Director's: Ross Turner, George Russell

STATE OF CALIFORNIA)
) ss
COUNTY OF TEHAMA)

I, Gary Antone, Director of the Tehama County Flood Control and Water Conservation District of the County of Tehama, State of California, hereby certify the above and foregoing to be full, true and correct copy of an order adopted by said Tehama County Flood Control and Water Conservation District on this **13th day of December, 2005**

Dated: This 13th day of **December, 2005**.

Gary Antone
Director of the Tehama County Flood Control and Water Conservation District of the County of Tehama, State of California

By Linda Madea
Linda Madea, Deputy

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FOUR COUNTY MEMORANDUM OF UNDERSTANDING
ADDENDUM ONE:
Statement of Principles Regarding Water Related Programs and Projects

In recognition that certain activities related to water resources do not recognize jurisdictional boundaries and require regional solutions, the parties identified in the Four County Memorandum of Understanding hereby agree to adhere to the following Statement of Principles Regarding Water Related Programs and Projects:

1. Programs and projects related to groundwater level and water quality monitoring shall be conducted in a cooperative manner and related data shall be shared between the participants to prevent negative impacts to our constituents.
2. Environmental documents associated with water projects and programs will automatically be circulated to all four counties for review and comment.
3. Incidents of abnormal water level or water quality readings will be immediately communicated to all participating counties resulting in a collaborative review and dissemination of related information.
4. Project and program related information will be disseminated on a regional basis through the independent county websites, augmented by regional public outreach meetings.
5. The parties will work cooperatively to acquire grant funding to conduct aquifer studies that further identify the linkages of the common groundwater resources.
6. Efforts pursued under this agreement will remain consistent with and will not exceed the current authority of any participating county.

We, the undersigned representatives of our respective counties, agree to adhere to the conditions of **Addendum One to the Four County MOU: Statement of Principles Regarding Water Related Programs and Projects.** The original MOU was signed by the Counties of Butte, Glenn, Colusa and Tehama in 2006.

Chair, Butte County Board of Supervisors	3-8-07 Date	County Counsel Approved As to Form	2/23/07 Date
Chair, Glenn County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Tehama County Board of Supervisors	Date	County Counsel Approved As to Form	Date

Vice-Chair, Colusa County
Board of Supervisors

4-17-07
Date

County Counsel
Approved As to Form

Date

EXHIBIT A
PAGE 2 OF 2

COUNTY CONTRACT
1788

FOUR COUNTY MEMORANDUM OF UNDERSTANDING
ADDENDUM ONE:
Statement of Principles Regarding Water Related Programs and Projects

In recognition that certain activities related to water resources do not recognize jurisdictional boundaries and require regional solutions, the parties identified in the Four County Memorandum of Understanding hereby agree to adhere to the following Statement of Principles Regarding Water Related Programs and Projects:

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6. Efforts pursued under this agreement will remain consistent with and will not exceed the current authority of any participating county.

We, the undersigned representatives of our respective counties, agree to adhere to the conditions of **Addendum One to the Four County MOU: Statement of Principles Regarding Water Related Programs and Projects.** The original MOU was signed by the Counties of Butte, Glenn, Colusa and Tehama in 2006.

Chair, Butte County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Glenn County Board of Supervisors	4/3/2007 Date	County Counsel Approved As to Form	3/26/07 Date
Chair, Tehama County Board of Supervisors	Date	County Counsel Approved As to Form	Date

FOUR COUNTY MEMORANDUM OF UNDERSTANDING
ADDENDUM TWO:
Adding Sutter County to the Four County MOU

In recognition that certain activities related to water resources do not recognize jurisdictional boundaries and therefore require regional solutions, the parties identified in the original Four County Memorandum of Understanding: Counties of Butte, Colusa, Glenn and Tehama are hereby joined by Sutter County in the regional efforts discussed in the Four County MOU and the Statement of Principles Regarding Water Related Programs and Projects as discussed in Addendum One to the Four County MOU.

We, the undersigned as representative of our respective counties, agree to adhere to the conditions of the **Four County Memorandum of Understanding; Addendum One to the Four County MOU: Statement of Principles Regarding Water Related Programs and Projects. And Addendum Two: Adding Sutter County to the Four County MOU.**

The original MOU was signed by the Counties of Butte, Glenn, Colusa and Tehama in 2006. Through approval of this addendum, Sutter County makes the same commitment to regional cooperation and coordination that is outlined in the original MOU.

Bill Connelly Chair, Butte County Board of Supervisors	05 MAY 2009 Date	Bruce L. Alpert County Counsel Approved As to Form	Date
Chair, Glenn County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Tehama County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Colusa County Board of Supervisors	Date	County Counsel Approved As to Form	Date

C09-082

FOUR COUNTY MEMORANDUM OF UNDERSTANDING
ADDENDUM TWO:
Adding Sutter County to the Four County MOU

In recognition that certain activities related to water resources do not recognize jurisdictional boundaries and therefore require regional solutions, the parties identified in the original Four County Memorandum of Understanding: Counties of Butte, Colusa, Glenn and Tehama are hereby joined by Sutter County in the regional efforts discussed in the Four County MOU and the Statement of Principles Regarding Water Related Programs and Projects as discussed in Addendum One to the Four County MOU.

We, the undersigned as representative of our respective counties, agree to adhere to the conditions of the **Four County Memorandum of Understanding; Addendum One to the Four County MOU: Statement of Principles Regarding Water Related Programs and Projects. And Addendum Two: Adding Sutter County to the Four County MOU.**

The original MOU was signed by the Counties of Butte, Glenn, Colusa and Tehama in 2006. Through approval of this addendum, Sutter County makes the same commitment to regional cooperation and coordination that is outlined in the original MOU.

Chair, Butte County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Glenn County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Tehama County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Colusa County Board of Supervisors	5/5/09 Date	County Counsel Approved As to Form	Date 5/5/09

C09-082

FOUR COUNTY MEMORANDUM OF UNDERSTANDING
ADDENDUM TWO:
Adding Sutter County to the Four County MOU

In recognition that certain activities related to water resources do not recognize jurisdictional boundaries and therefore require regional solutions, the parties identified in the original Four County Memorandum of Understanding: Counties of Butte, Colusa, Glenn and Tehama are hereby joined by Sutter County in the regional efforts discussed in the Four County MOU and the Statement of Principles Regarding Water Related Programs and Projects as discussed in Addendum One to the Four County MOU.

We, the undersigned as representative of our respective counties, agree to adhere to the conditions of the **Four County Memorandum of Understanding; Addendum One to the Four County MOU: Statement of Principles Regarding Water Related Programs and Projects. And Addendum Two: Adding Sutter County to the Four County MOU.**

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Chair, Butte County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Glenn County Board of Supervisors	5/21/09 Date	County Counsel Approved As to Form	Date
Chair, Tehama County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Colusa County Board of Supervisors	5/5/09 Date	County Counsel Approved As to Form	5/5/09 Date

Chair, Sutter County
Board of Supervisors

Date

William J. Vanasek

County Counsel
Approved as to Form

4/14/09
Date

FOUR COUNTY MEMORANDUM OF UNDERSTANDING
ADDENDUM TWO:
Adding Sutter County to the Four County MOU

In recognition that certain activities related to water resources do not recognize jurisdictional boundaries and therefore require regional solutions, the parties identified in the original Four County Memorandum of Understanding: Counties of Butte, Colusa, Glenn and Tehama are hereby joined by Sutter County in the regional efforts discussed in the Four County MOU and the Statement of Principles Regarding Water Related Programs and Projects as discussed in Addendum One to the Four County MOU.

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Chair, Butte County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Glenn County Board of Supervisors	Date	County Counsel Approved As to Form	Date
George Runner Chair, Tehama County Flood Control & Water Conservation District	6-23-09 Date	County Counsel Approved As to Form	Date
Chair, Colusa County Board of Supervisors	Date	County Counsel Approved As to Form	Date

FOUR COUNTY MEMORANDUM OF UNDERSTANDING:
ADDENDUM THREE
Expression of a Commitment to Begin An
Integrated Regional Water Management Planning Process
Within the Counties of Butte, Colusa, Glenn, Tehama and Sutter

Through adoption of this addendum, the signatories agree to begin a regional water management planning process pursuant to the Four County MOU, geographically covering the area of Butte, Colusa, Glenn, Tehama and Sutter Counties. The planning process shall utilize and incorporate existing plans and processes. The California legislature has recently adopted new criteria associated with the Integrated Regional Water Management Planning process. This new legislative criteria requires that acceptance and approval of the composition of all Integrated Regional Water Management Planning Areas be completed prior to accepting public funding associated with IRWMP grant funds. All IRWMP planning Regions and Plans must comply with the requirements as set forth in the Final Regional Acceptance Process Program Guidelines.

We, the undersigned as representative of our respective counties, agree to adhere to the conditions of **The Four County Memorandum of Understanding; Addendum One to the Four County MOU: Statement of Principles Regarding Water Related Programs and Projects; Addendum Two: Adding Sutter County to the Four County MOU; Addendum Three: Expression of a Commitment to Begin An Integrated Regional Water Management Planning Process Within the Counties of Butte, Colusa, Glenn, Tehama and Sutter.**

Bill Connelly	05 MAY 2009	Bruce L. Alpert	
Chair, Butte County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Glenn County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Tehama County Board of Supervisors	Date	County Counsel Approved As to Form	Date

Chair, Colusa County Board of Supervisors	5/5/09 Date	County Counsel Approved As to Form	5/6/09 Date
Chair, Sutter County Board of Supervisors	Date	County Counsel Approved as to Form	Date

C09-095
5-5-09

FOUR COUNTY MEMORANDUM OF UNDERSTANDING:
ADDENDUM THREE
Expression of a Commitment to Begin An
Integrated Regional Water Management Planning Process
Within the Counties of Butte, Colusa, Glenn, Tehama and Sutter

Through adoption of this addendum, the signatories agree to begin a regional water management planning process pursuant to the Four County MOU and geographically covering the area of Butte, Colusa, Glenn Tehama and Sutter Counties. The planning process shall utilize and incorporate existing plans and processes. The California legislature has recently adopted new criteria associated with the Integrated Regional Water Management Planning process. This new legislative criteria requires that acceptance and approval of the composition of all Integrated Regional Water Management Planning Areas be completed prior to accepting public funding associated with IRWMP grant funds. All IRWMP planning Regions and Plans must comply with the requirements as set forth in the Final Regional Acceptance Process Program Guidelines.

We, the undersigned as representative of our respective counties, agree to adhere to the conditions of **The Four County Memorandum of Understanding; Addendum One to the Four County MOU: Statement of Principles Regarding Water Related Programs and Projects; Addendum Two: Adding Sutter County to the Four County MOU; Addendum Three: Expression of a Commitment to Begin An Integrated Regional Water Management Planning Process Within the Counties of Butte, Colusa, Glenn, Tehama and Sutter.**

Chair, Butte County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Glenn County Board of Supervisors	5/21/09 Date	County Counsel Approved As to Form	Date
Chair, Tehama County Board of Supervisors	Date	County Counsel Approved As to Form	Date

Chair, Colusa County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Sutter County Board of Supervisors	Date	County Counsel Approved as to Form	4/14/09 Date

FOUR COUNTY MEMORANDUM OF UNDERSTANDING:
ADDENDUM THREE
Expression of a Commitment to Begin An
Integrated Regional Water Management Planning Process
Within the Counties of Butte, Colusa, Glenn, Tehama and Sutter

Through adoption of this addendum, the signatories agree to begin a regional water management planning process pursuant to the Four County MOU and geographically covering the area of Butte, Colusa, Glenn, Tehama and Sutter Counties. The planning process shall utilize and incorporate existing plans and processes. The California legislature has recently adopted new criteria associated with the Integrated Regional Water Management Planning process. This new legislative criteria requires that acceptance and approval of the composition of all Integrated Regional Water Management Planning Areas be completed prior to accepting public funding associated with IRWMP grant funds. All IRWMP planning Regions and Plans must comply with the requirements as set forth in the Final Regional Acceptance Process Program Guidelines.

We, the undersigned as representative of our respective counties, agree to adhere to the conditions of **The Four County Memorandum of Understanding; Addendum One to the Four County MOU: Statement of Principles Regarding Water Related Programs and Projects; Addendum Two: Adding Sutter County to the Four County MOU; Addendum Three: Expression of a Commitment to Begin An Integrated Regional Water Management Planning Process Within the Counties of Butte, Colusa, Glenn, Tehama and Sutter.**

Chair, Butte County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Glenn County Board of Supervisors	Date	County Counsel Approved As to Form	Date
George Lowell Chair, Tehama County Flood Control & Water Conservation District	6-23-09 Date	County Counsel Approved As to Form	Date

FOUR COUNTY MEMORANDUM OF UNDERSTANDING:
ADDENDUM FOUR
Expression of a Commitment to Begin An
Integrated Regional Water Management Planning Process
Within the Counties of Butte, Colusa, Glenn, Tehama, Sutter and Shasta

Through adoption of this addendum, the signatories agree:

1. Shasta County shall join the parties involved in the original Four County Memorandum of Understanding (MOU) and Addendum Two;

2. Signatories to the MOU and its addenda shall be called the Northern Sacramento Valley Integrated Regional Water Management Planning Group; and,

3. Begin a regional water management planning process pursuant to the Four County MOU, geographically covering the area of Butte, Colusa, Glenn, Tehama, Sutter and Shasta Counties. The planning process shall utilize and incorporate existing plans and processes. The California legislature has recently adopted new criteria associated with the Integrated Regional Water Management Planning process. This new legislative criteria requires that acceptance and approval of the composition of all Integrated Regional Water Management Planning Areas be completed prior to accepting public funding associated with IRWMP grant funds. All IRWMP planning Regions and Plans must comply with the requirements as set forth in the Final Regional Acceptance Process Program Guidelines.

4. The signatories to the MOU and its addenda reaffirm the provisions of section 5.6 of the MOU that the MOU and its addenda and participation under the MOU and its addenda are nonbinding.

We, the undersigned as representative of our respective counties, agree to adhere to the conditions of **The Four County Memorandum of Understanding; Addendum One to the Four County MOU: Statement of Principles Regarding Water Related Programs and Projects; Addendum Two: Adding Sutter County to the Four County MOU; Addendum Three: Expression of a Commitment to Begin An Integrated Regional Water Management Planning Process Within the Counties of Butte, Colusa, Glenn, Tehama and Sutter; Addendum Four: Expression of a Commitment to Begin An Integrated Regional Water Management Planning Process Within the Counties of Butte, Colusa, Glenn, Tehama, Sutter and Shasta.**

Bill Connelly — Chair, Butte County Board of Supervisors

APR 13 2010 — Date

County Counsel Approved As to Form

4.9.10 — Date

Chair, Glenn County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Tehama County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Colusa County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Sutter County Board of Supervisors	Date	County Counsel Approved as to Form	Date
Chair, Shasta County Board of Supervisors	4/27/10 Date	County Counsel Approved as to Form	5/6/10 Date

Chair, Glenn County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Tehama County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Colusa County Board of Supervisors	Date	County Counsel Approved As to Form	Date
Chair, Sutter County Board of Supervisors	4/20/10 Date	County Counsel Approved as to Form	4/13/10 Date
Chair, Shasta County Board of Supervisors	Date	County Counsel Approved as to Form	Date

Appendix D: Issue Resolution Process for Discussion Purposes

This document aims to guide discussions and provide pertinent information as subbasins consider inclusion of an issue resolution process in the Northern Sacramento Valley inter-basin coordination framework. These discussions will take place in the period leading up to the first five-year GSP update.

Discussion Prompts

1. *What are potential benefits/challenges or concerns of including an issue/dispute resolution process in the inter-basin coordination framework?*
2. *What are shared expectations between and among subbasins?*
3. *What are the GSAs preferences for addressing conflicts if/when they arise?*

Background

The Groundwater Sustainability Plan Regulations in Article 8 recommend including a "description of a process for identifying and resolving conflicts between Agencies" as a part of inter-basin coordination (Sections 10727.2, 10733, and 10733.2, Water Code). A recent study by Tara Moran, Janet Martinez, and William Blomquist, part of Stanford University's Water in the West found that the ability of interagency coordination "to solve complex challenges will be contingent on the ability of these organizations to effectively prevent and manage conflicts before they arise and to resolve these conflicts equitably and efficiently when they do." (Moran, Martinez, and Blomquist, 2021). Further, given how likely it is for disagreements at a local level to occur during SGMA implementation, the study suggests investing in establishing issue resolution processes before disagreements arise. Meanwhile, deferring their development could complicate the resolution process in times of conflict. Given these recommendations, consider the following questions for reflection and discussion.

Purposes of issue resolution processes

There are many options to identify and resolve issues that involve different parties, goals/objectives, and resources. Ideally, issue resolution processes are thoughtfully designed and tailored to specific contexts. **The broader goal for such a process can be to meet the agencies' long-term needs, considering local dynamics, desired outcomes, and expected uses**. Goals can include keeping things simple and efficient, maintaining relationships, ensuring quality of the process, fostering participation and community engagement, etc.

The figure below shows different types of dispute resolution processes. In some cases, agencies draft clauses that outline a tiered approach. They often begin with negotiation, which gives the parties control over the process and outcomes. Then, mediation, which brings in a neutral third-party (mediator) to facilitate the discussion and help parties work towards resolving issues. Often, negotiation and mediation lead to "non-binding" outcomes, non-enforceable by courts. Parties could opt to move towards arbitration or litigation, which are controlled by a third party (arbitrator or judge/jury) and can lead to binding and non-binding outcomes (Moran, Martinez, and Blomquist, 2019).

Figure 2. The spectrum of dispute resolution process. Modified from Amsler et al. (2020a).



Negotiation	Mediation	Arbitration	Trial
• No third party	• Third part (mediator)	• Third party (arbitrators)	• Third party (judge/jury)
• Non-binding	• Non-binding	• Non-binding or binding	• Binding

From Moran, Martinez, and Blomquist, 2019

Examples

1. Example from Moran, Martinez, and Blomquist, 2019

Box 2. A Draft Dispute Resolution Clause.

The blue text notes indicate how each of the preceding five questions are incorporated into the dispute resolution language.

In the event that any dispute [Q1: Provides instruction on what disputes can be addressed. Additional process goals, while not explicit should be subject to discussion.] arises among the Members relating to (i) this Agreement, (ii) the rights and obligations arising from this Agreement, (iii) a Member proposing to withdraw from membership in the Agency, or (iv) a Member proposing to initiate litigation within the Basin or the management of the Basin, the aggrieved Member or Members proposing to withdraw from membership shall provide written notice to the other Members of the controversy or proposal to withdraw from membership [Q2: Provides instruction on who can initiate and participate in the process.]. Within forty-five (45) days after such written notice, the Members shall attempt in good faith to resolve the controversy through informal negotiation [Q3: Describes a series of processes for dispute resolution, beginning with negotiation. Also includes a timeline for process stages.]. If the Members cannot agree upon a resolution of the controversy within forty-five (45) days from the providing of written notice specified above, the dispute shall be submitted to mediation prior to commencement of any legal action or prior to withdrawal of a Member proposing to withdraw from membership. The mediation shall be no less than a full day (unless agreed otherwise among the Members) and the cost of mediation shall be paid in equal proportion among the Members [Q4: Provides instruction on who will pay for dispute resolution processes.]. The mediator shall be either voluntarily agreed to or appointed by the Superior Court upon a suit and motion for appointment of an impartial mediator [Q3a: Provides a clear process for choosing an impartial mediator.]. Upon completion of mediation, if the controversy has not been resolved, any Member may exercise all rights to bring a legal action relating to the controversy or withdraw from membership as otherwise authorized pursuant to this Agreement. The Agency may, at its discretion, participate in mediation upon request by a stakeholder [to be defined by the parties to the Agreement] concerning a dispute alleged by the stakeholder concerning the management of the Basin or rights to extract groundwater from the Basin, with the terms of such mediation to be determined in the sole discretion of the Member Directors [Q2: Allows third-party participation in the dispute resolution process].

Note: This above dispute resolution clause is not intended to serve as an endorsement or illustration of effective practice.

2. Example from Butte Subbasin Cooperation Agreement

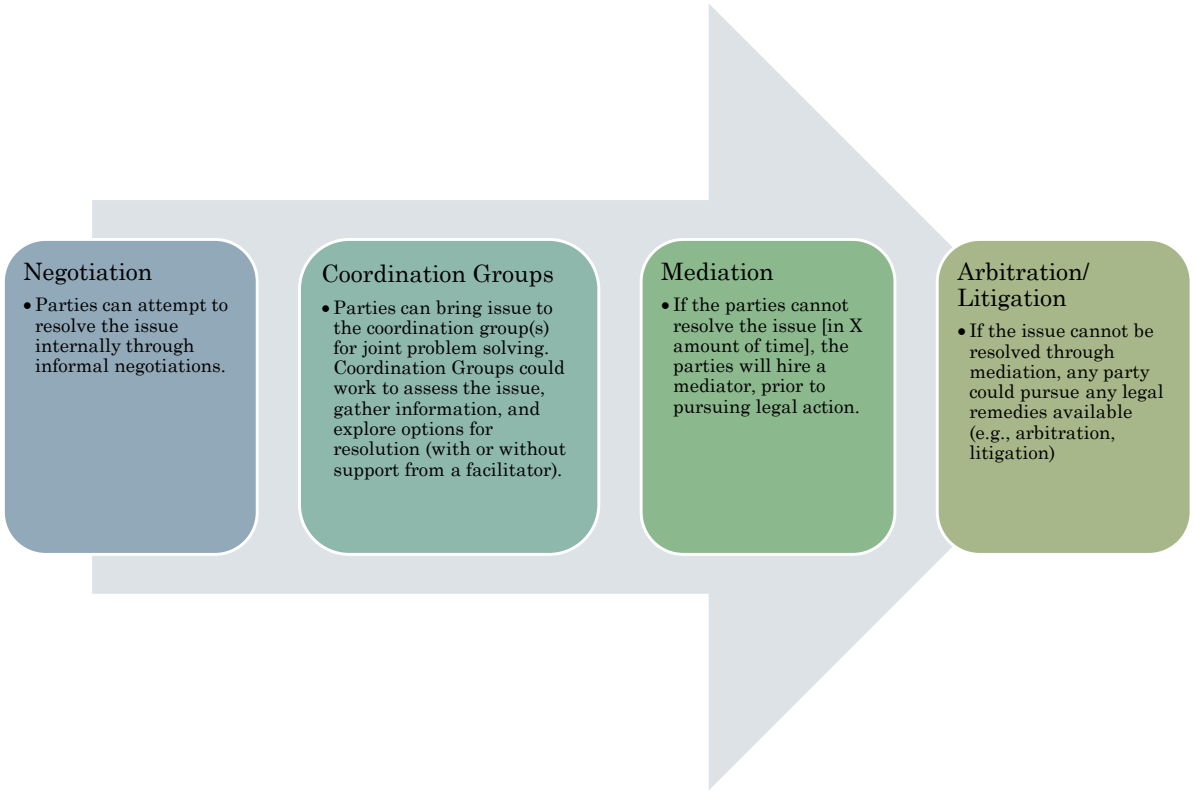
Note: This example doesn't provide much specificity. However, acknowledges shared intent to resolve disputes.

ARTICLE 9. DECISION-MAKING AND DISPUTE RESOLUTION

9.1. Decision-making Authority. Topics where the Members desire coordinated decision-making will be considered by the Advisory Board, and the Member Directors will strive for unanimous recommendations that will be presented to each Member's governing body for consideration. Such topics include, but are not limited to, development and implementation of the GSP, and associated financial arrangements. When unable to reach unanimous recommendations, the Advisory Board will outline the areas in which it does not agree, providing some explanation to inform the respective GSAs' governing bodies. Despite the recommendations of the Advisory Board, ultimate decision-making authority for topics considered by the Advisory Board resides with each Member's governing body.

9.2. Dispute Resolution. It is the desire of Members to informally resolve all disputes and controversies related to this Agreement, whenever possible, at the least possible level of formality and cost. If a dispute occurs, the disputing Members shall meet and confer in an attempt to resolve the matter. If informal resolution cannot be achieved, the matter will be referred to the Advisory Board for resolution. The Advisory Board may engage the services of a trained mediator or resort to all available legal and equitable remedies to resolve disputes.

Possible Process in the Northern Sacramento Valley



Worksheet: Key Questions and Considerations for Issue Resolution Process

The questions below could be used to guide the development of a specific issue resolution process in the context of inter-basin coordination in the Northern Sacramento Valley by the first 5-year GSP update. These questions could help to clarify the level of specificity that subbasins would find beneficial and mutually agreeable when/if conflict occurs.

Adapted from Moran, Martinez, and Blomquist, 2019

1) What are the process goals? a) Consider what disputes the process aims to address – all disputes arising at basin boundaries or only a subset? b) Consider inclusivity and transparency of the process, cost efficiency for parties and the GSA(s), timeframes, and other factors important to your agency(ies). c) Other potential objectives include dispute prevention, enhanced relationships, procedural and substantive fairness, legal compliance, durability of resolution and organizational improvement.	
2) Who can initiate and participate in the dispute resolution process? a) Consider what parties can initiate the dispute resolution process – is it only parties to the agreement or can external parties invoke it? There are pros and cons to both choices, so discussing this in advance will ensure thoughtful consideration.	
3) What processes are used to make decisions related to dispute resolution and what information is necessary? a) What is the process for selecting a mediator, facilitator, lawyer or other impartial party? b) Consider including a range of processes beginning with internal negotiations and escalating based on clear timelines.	
4) Who pays for the dispute resolution process? a) Consider who will pay for the mediator, facilitator, lawyer or other impartial party. Will it be paid for by the disputing parties, the GSA(s) or through a state-funded program? b) How could you assess whether the outcome of the dispute resolution process was successful?	

Other Resources

- Dutton, A. SGMA Updates, Coordination Considerations, and Potential Next Steps, Cosumnes Subbasin Working Group. February 21, 2018. http://cosumnes.waterforum.org/wp-content/uploads/2018/02/EKI_Cosumnes_TAC_meeting_2018-02-21.pdf
- Moran T., Martinez, J., and Blomquist W. Dispute Resolution Processes: Thinking through SGMA Implementation. Water in the West. Fall, 2019. https://waterinthewest.stanford.edu/publications/dispute-resolution-processes-thinking-through-sgma-implementation
- Moran T. Basin-scale Coordination is Key to SGMA's Success: Thoughts on DWR's Draft GSP Regulations. March 1, 2016. Stanford University. Water in the West. https://waterinthewest.stanford.edu/news-events/news-press-releases/basin-scale-coordination-key-sgma%E2%80%99s-success-thoughts-dwr%E2%80%99s-draft-gsp
- Moran et al. Dispute Resolution Clauses in Interorganizational Coordination Agreements: A Comparative Analysis. 2021. pending publication.
- Butte County. 2017. Technical Collaboration on Interconnected Subbasins to Advance Sustainable Groundwater Management: Assessment of Interconnected Subbasins. Available at: https://www.buttecounty.net/wrcdocs/Reports/SpecialProjects/InterbasinGWFlow/InterbasinSBAssessment-FINAL.pdf
- Butte County. 2017. Inter-basin Groundwater Flows Fact Sheet. Available at: https://www.buttecounty.net/wrcdocs/Reports/SpecialProjects/InterbasinGWFlow/FactSheet.pdf
- Buck, Christina. 2017. Butte County Inter-Basin Groundwater Flows Presentation, https://www.buttecounty.net/wrcdocs/Reports/SpecialProjects/InterbasinGWFlow/NSVBoardAssessment20170615.pdf

2D-2. Initial SGMA Information Workshops

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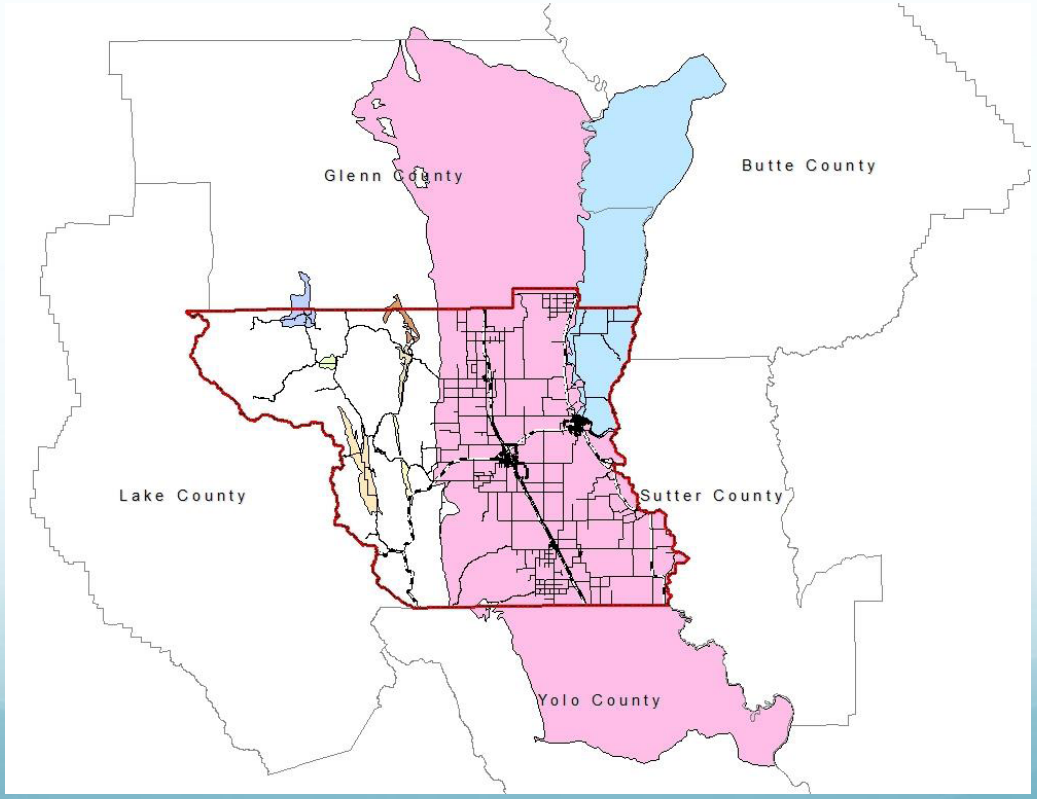
The Sustainable Groundwater Management Act

Key elements of the law, early implementation steps and expected benefits for Colusa County



Presentation Outline

I. SGMA Background

II. Preparing to Advance SGMA Locally

III. Recent SGMA Activities

IV. Early Implementation in Colusa County

V. Next Steps

SGMA Background

Comprehensive statewide legislation that creates a framework for sustainable groundwater management

- Became law on January 1, 2015
- All medium and high priority basins managed sustainably
- Emphasis on local control with State oversight
- Groundwater Sustainability Agencies
- Groundwater Sustainability Plans

SGMA Background

SGMA affects all citizens of Colusa County

- Offers beneficial opportunities to achieve sustainable groundwater conditions
- Supports agriculture, industry and domestic/public uses
- Requires residents to work together and address our common interest in groundwater resources
- The County supports a collaborative approach to implement SGMA

SGMA Background

How does SGMA define sustainability?

Sustainability: Manage groundwater to prevent undesirable results (significant and unreasonable):

- Chronic lowering of groundwater levels
- Reduction of groundwater storage
- Seawater intrusion
- Degraded water quality
- Land subsidence
- Depletions of interconnected surface waters

SGMA Background

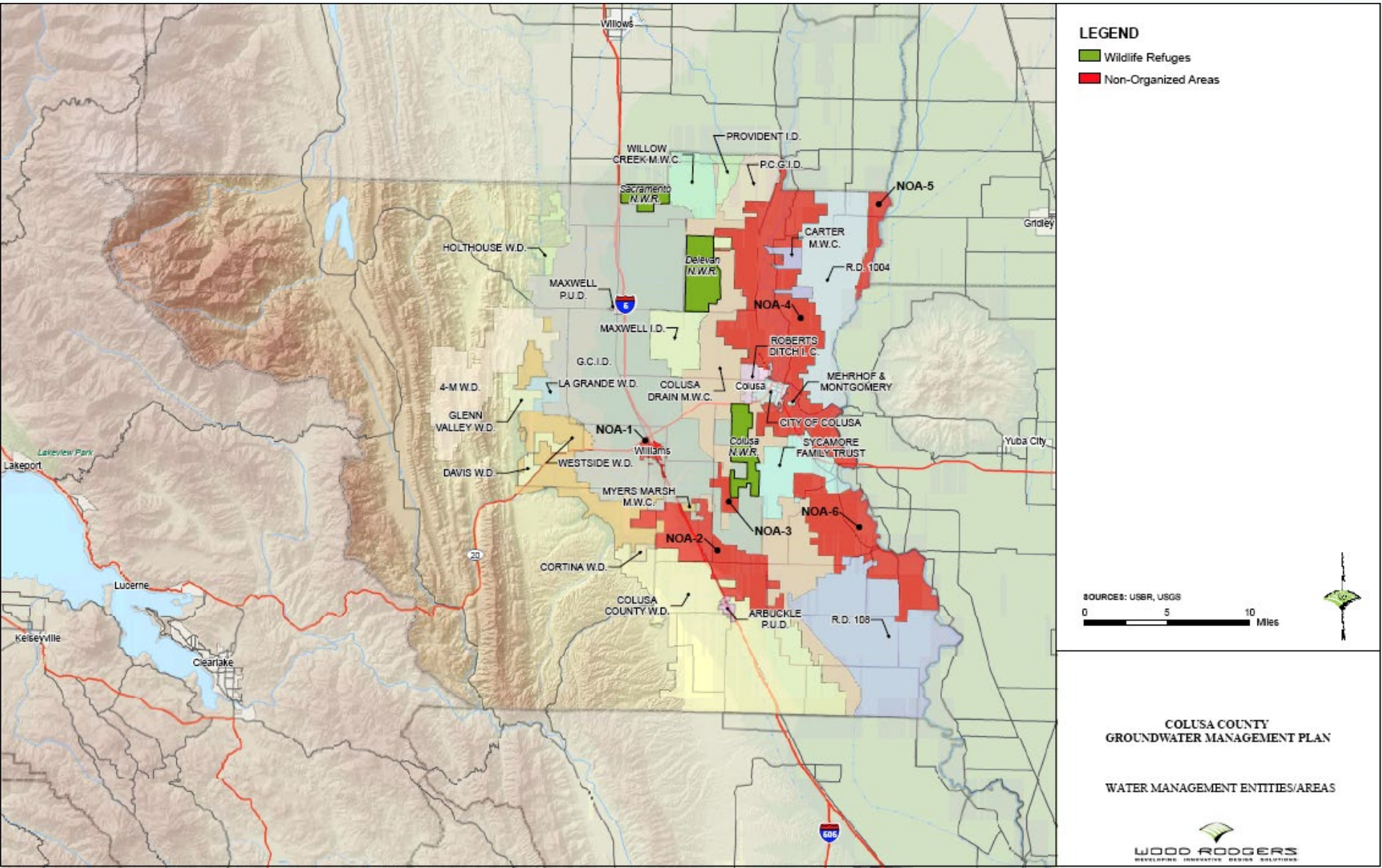
Formation of Groundwater Sustainability Agencies (GSAs)

- SGMA requires formation of GSAs to implement SGMA at the local level

- Public agencies with land or water use authority are eligible to become GSAs
  - Counties, cities, water agencies, irrigation districts, PUDs
  - GSA may include one or more local public agencies

- May include a single GSA or multiple GSAs per basin
  - Multiple GSAs must coordinate planning efforts

Colusa Water Management Entities/Areas



SGMA Background

GSA Roles and Responsibilities – *At their discretion, GSAs may…*

- Adopt rules, regulations and ordinances
- Conduct groundwater studies / investigations
- Register and monitor wells
- Require reports of groundwater extraction
- Implement capital projects to meet goals
- Assess fees to cover management costs

SGMA Background

GSA Roles and Responsibilities – *Interested parties must be included in SGMA planning:*

- All Groundwater Users
- Holders of Overlying Rights (agriculture and domestic)
- Municipal Well Operators and Public Water Systems
- Tribes
- County
- Planning Departments / Land Use
- Local Landowners
- Disadvantaged Communities
- Business
- Federal Government
- Environmental Uses
- Surface Water Users (*if connection between surface and ground water*)

SGMA Background

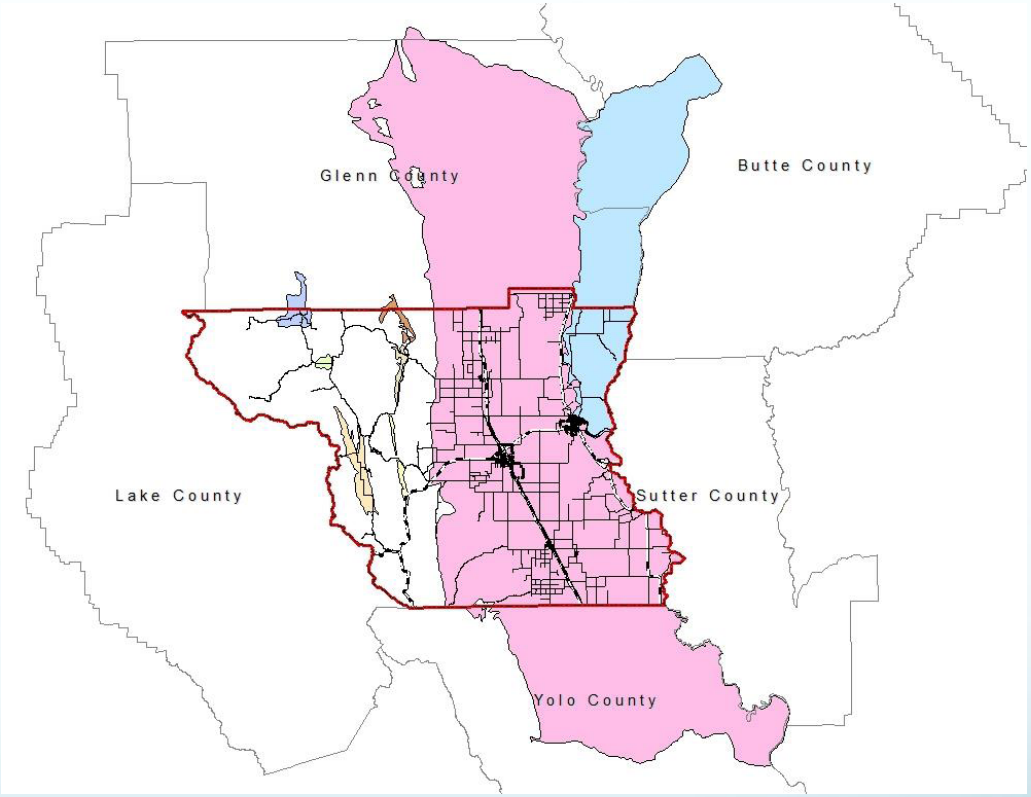
How are domestic well owners affected by SGMA?

- Referred to in SGMA as “de minimis” users IF…
  - Use 2 acre-feet per year or less for domestic purposes
- De minimis users are subject to SGMA, depending on local needs
  - GSAs will decide how de minimis users are addressed
  - GSAs can decide to exclude or include
  - GSAs can decide on fees but *cannot* require metering
  - May be subject to reporting / fees to State if intervention occurs
- Domestic wells can also be regulated by authorities (counties, water districts, etc.) outside scope of SGMA

SGMA Background

"White Areas"

- County is presumed to be the GSA over areas that are not covered by another GSA-eligible agency
- If the County opts out, the State will manage those areas



SGMA Background

Development of Groundwater Sustainability Plans (GSPs)

- GSAs are responsible to develop GSPs
- Every high and medium priority groundwater basin must be covered by a GSP or GSPs
- Option of a single GSP covering the entire basin, or a combination of GSPs, developed by multiple GSAs, covering the entire basin
- Multiple GSPs must coordinate, utilize the same data / methodologies, and have a coordination agreement

SGMA Background

Key Implementation Milestones

- June 1, 2016 – GSP regulations
- **June 30, 2017 – GSAs formed**
- July 1, 2017 – Counties affirm GSA status
- January 31, 2020 – GSPs complete for critically over-drafted basins
- **January 31, 2022 – All other GSPs complete**

SGMA Background

DWR and State Water Board Roles

- DWR:
  - Develop Basin Boundary and GSP regulations
  - Review GSPs, decide on adequacy, implementation

- State Water Board:
  - Implement State intervention
  - Reporting
  - Assess fees
  - Designate Probationary Basins
  - Develop Interim Plans, implement those Plans

SGMA Background

State Water Board Intervention – In all triggering events, intervention is the result of failure by locals to create a GSA(s) and/or adopt and implement a GSP.

- Data
  - Same data needed by a GSA, but now managed by State
  - Higher frequency (monthly minimum reporting)
- Fees
  - Fees associated with reporting
  - Board recovers cost for all intervention-related activities (monitoring plans, well construction, facilitation, technical studies, models)
- Interim plans
  - Pumping restrictions are most straight-forward
  - State developed physical solutions are unlikely

Initial comments and/or questions

Preparing to Advance SGMA Locally

What has the County done to advance SGMA locally?

- Dedicated staff resources
- Fostered early communication with GSA filers, many of whom are here tonight to join the conversation
- Maintained communication with surrounding counties
- Received grant for impartial facilitation services from the Center for Collaborative Policy
- Initiated a local groundwater assessment
- Pursued DWR grant to support local planning efforts
- Committed to sharing resources with local partners

Recent SGMA Activities

GSA Notifications in Colusa County

- Provident Irrigation District and Princeton-Codora-Glenn Irrigation District
- Glenn-Colusa Irrigation District
- Colusa County Water District
- Reclamation District 1004
- Reclamation District 108
- County of Colusa



Recent SGMA Activities

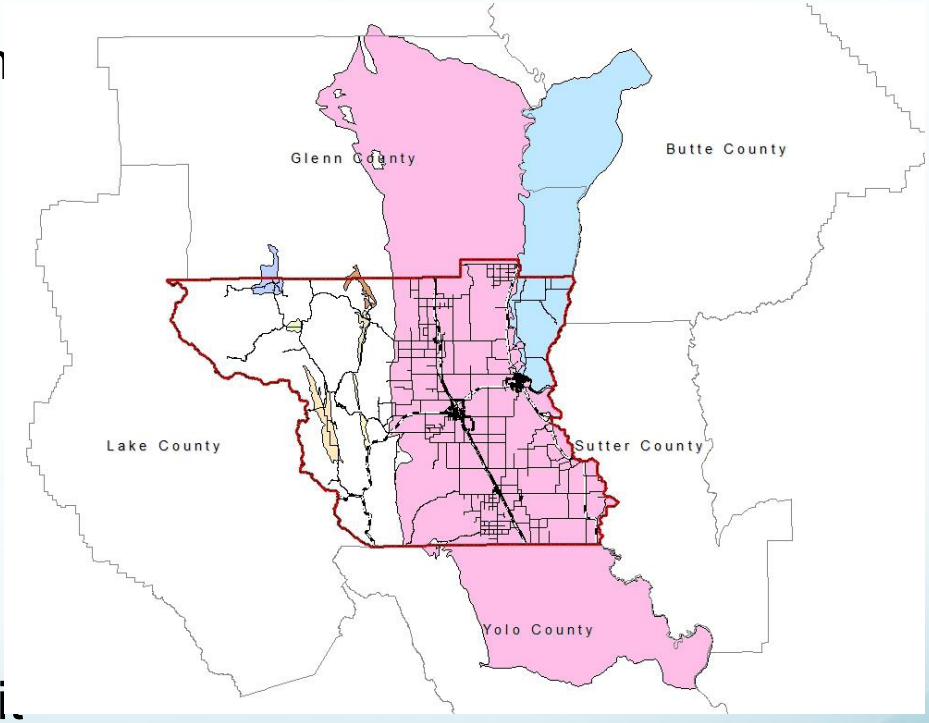
SB 13 Amendment – Interpreted by DWR as retroactive

- Removed the Notice of Intent to be a GSA
- Allows a mutual water company to be part of a GSA through a legal agreement
- **Prohibits overlap of service area boundaries**
- **Prohibits local agencies from imposing fees or reg. requirements on entities outside their boundaries**
- Requires DWR to post all “complete” notices within 15 days of receipt

Recent SGMA Activities

Basin Boundary Modifications

- Existing groundwater basins or subasins defined in DWR's Bulletin 118
- Local agencies may request boundary modifications
- May include scientific or jurisdictional modifications
- Starting January 1, 2016: 90 day window for local agencies to submi requests for DWR consideration



Recent SGMA Activities

Groundwater Sustainability Plan Regulations

- By June 1, 2016 DWR shall adopt regulations for:
  - Evaluating GSPs
  - Implementing GSPs
  - Coordination agreements

- The regulations shall identify:
  - Required GSP components and additional elements
  - Coordination of multiple GSPs in a basin
  - Additional information that assists GSAs

Proposed Process in Colusa County

Background Preparation

- Review background materials
- Conduct initial interviews with eligible GSA agencies
- Prepare 90-Day Plan
- Prepare initial facilitation strategy



Proposed Process in Colusa County

Outreach and Education

- Prepare education and outreach materials
- Coordinate and facilitate local outreach and education meetings for agencies and private well owners
- Facilitate collaboration so all interested parties can participate and work together towards sustainability

Proposed Process in Colusa County

GSA Governance

- Coordinate and facilitate public meetings about governance
- Coordinate and facilitate meetings of several GSA eligible agencies
- Conduct meetings with individual GSA eligible agencies
- Support representation of domestic well owner interests

Panel Discussion with Eligible GSAs

Summary of Steps Towards Sustainability

Step 1

- Local agencies form GSAs by June, 2017

Step 2

- Local agencies in medium and high priority basins adopt GSPs by January, 2022 (faster if in critical overdraft)

Step 3

- Local agencies have 20 years to demonstrate they are meeting measurable goals and achieving sustainability

Key Considerations as We Move Forward

The County believes a partnered approach is best

- We all have a vested interest in our groundwater
- GSA formation, GSP preparation, and and long-term implementation will create costs for many users
- Pooling resources will improve efficiencies and capitalize skills and strengths of various partners

Panel Questions / Topics

- Implications of SGMA to your District members and all groundwater users in the County?
- Steps you've taken so far to form a GSA?
- What you want to be sure your District achieves and avoids as you, the other organizations, and the County form GSAs?
- Thoughts you have about impacts to private well owners?

Next Steps

So where do we go from here?

- Convene Governance Workgroup
- Hold additional public meetings
- Continued coordination with adjacent subbasins

Discussion

Your comments, questions and input

Colusa Subbasin
Sustainable Groundwater Management Act |Public Meeting
Local Planning Effort

Monday, January 11, 2016
6:00 p.m. – 8:00 p.m.
Location: Colusa County Fairgrounds, Atwood Hall

Meeting purpose

- Provide an overview of the Sustainable Groundwater Management Act (SGMA)
- Review expected SGMA benefits and early implementation steps in Colusa County
- Create an opportunity for public input: questions, comments and considerations

Time	Topic
6:00	**Introduction** • Welcome and opening remarks • Agenda review and meeting purpose
6:15	**SGMA Background, Overview and Requirements** • Need and rationale for sustainable groundwater management • Implementation across the State • Core SGMA elements, associated requirements and timeline • Expected benefits for Colusa County and its residents • Q&A session
6:35	**Early SGMA Outreach and Implementation Steps in Colusa County** • County support role to-date • Process to form Groundwater Sustainability Agencies • Partnerships between County and other Water Managers • Role and involvement of private well owners • Q&A session
7:15	**Open Discussion / Public Comment** • Comments, questions, suggested considerations
7:45	**Next Steps** • Groundwater Sustainability Agency formation and function • Ongoing outreach / role of the public and groundwater users
8:00	**Meeting Adjourns**

Sustainable Groundwater Management Act (SGMA)
Public Meeting on Local Planning Efforts

For immediate release

Contact: Mary Fahey, Colusa County Water Resources Coordinator
mfahey@countyofcolusa.org
530-458-7709

Colusa County officials and other local groundwater managers will host a public meeting on the Sustainable Groundwater Management Act (SGMA). SGMA is a new law that offers beneficial opportunities to achieve sustainable groundwater conditions and support Colusa County's vital agricultural economy, industry, and domestic and public water uses.

The meeting will provide an overview of SGMA, expected responsibilities and benefits for groundwater users, and describe early steps taken to implement the new law. The public is encouraged to attend to learn more about SGMA, ask questions of local water managers and submit comments.

"SGMA implementation has begun throughout California," says Supervisor Denise Carter. "We hope groundwater users throughout Colusa County will attend to learn more. SGMA is an important change in how groundwater is managed and everyone needs to be aware and involved to manage and sustain our precious water resources."

To support local planning efforts, the County has secured facilitation support from the Department of Water Resources (DWR), initiated a county-wide groundwater assessment and applied for a groundwater planning grant through the Water Bond. The County is committed to sharing these resources with local SGMA partners.

"County officials have worked closely for decades with managers of local water agencies and knows them to be exceptional water leaders and partners," says Water Resources Coordinator Mary Fahey. "We expect these water leaders to fill a similar role as partners implementing SGMA, and thereby working together to keep our citizens ahead of the curve on groundwater management policies."

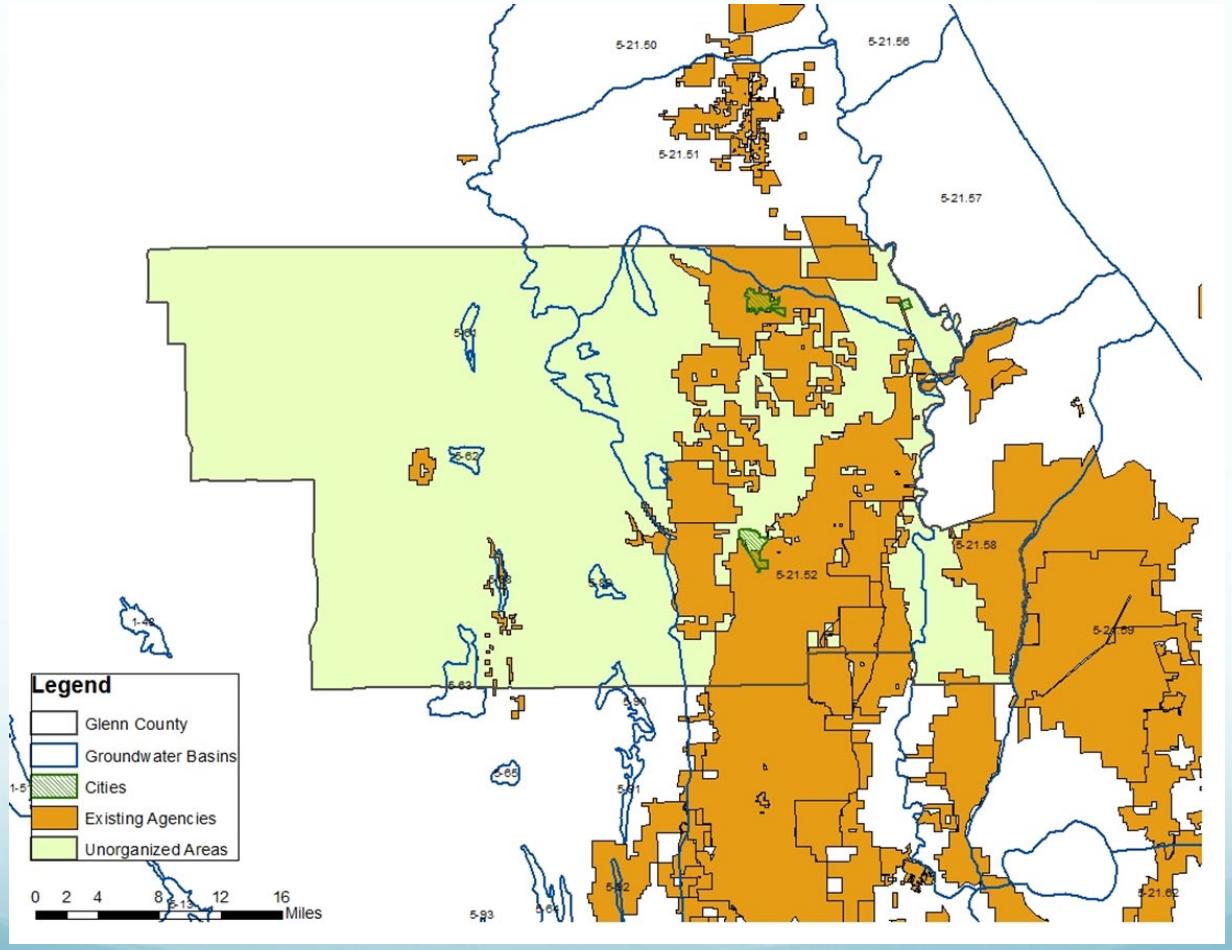
Meeting date, time and location:

January 11, 2016
6:00 p.m. – 8:00 p.m.
Colusa County Fairgrounds
1303 10th Street (Highway 20)
Colusa, CA 95932
Atwood Hall

For more information please visit DWR's SGMA webpage: http://groundwater.ca.gov/

The Sustainable Groundwater Management Act

Implementation in Glenn County



Presentation Outline

I. SGMA Background

II. Preparing to Advance SGMA Locally

III. Recent SGMA Activities

IV. Early Implementation

V. Next Steps

SGMA Background

Comprehensive statewide legislation that creates a framework for sustainable groundwater management

- Became law on January 1, 2015
- All medium and high priority basins managed sustainably
- Emphasis on local control with State oversight
- Groundwater Sustainability Agencies
- Groundwater Sustainability Plans

SGMA Background

SGMA affects <u>all citizens</u> of Glenn County

- Offers beneficial opportunities to achieve sustainable groundwater conditions
- Supports agriculture, industry and domestic/public uses
- Requires residents to work together and address our common interest in groundwater resources
- Glenn County supports a collaborative approach to implement SGMA

SGMA Background

How does SGMA define sustainability?

Sustainability: Manage groundwater to prevent undesirable results (significant and unreasonable):

- Chronic lowering of groundwater levels
- Reduction of groundwater storage
- Seawater intrusion
- Degraded water quality
- Land subsidence
- Depletions of interconnected surface waters

SGMA Background

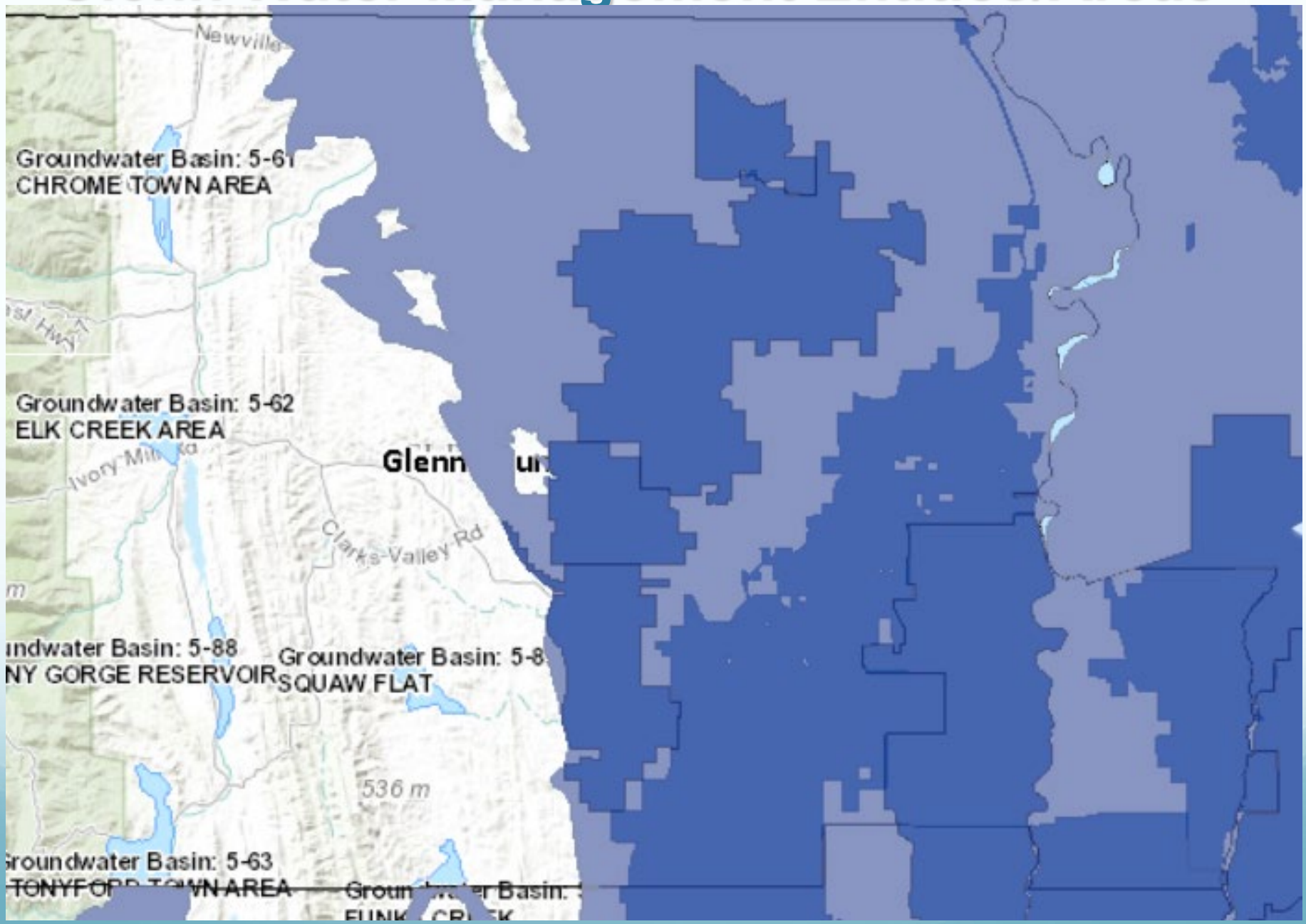
Formation of Groundwater Sustainability Agencies (GSAs)

- SGMA requires formation of GSAs to implement SGMA at the local level

- Public agencies with land or water use authority are eligible to become GSAs
  - Counties, cities, water agencies, irrigation districts, PUDs
  - GSA may include one or more local public agencies

- May include a single GSA or multiple GSAs per basin
  - Multiple GSAs must coordinate planning efforts

Glenn Water Management Entities/Areas



SGMA Background

GSA Roles and Responsibilities
At their discretion, GSAs may…

- Adopt rules, regulations and ordinances
- Conduct groundwater studies / investigations
- Register and monitor wells
- Require reports of groundwater extraction
- Implement capital projects to meet goals
- Assess fees to cover management costs

SGMA Background

GSA Roles and Responsibilities

Interested parties must be included in SGMA planning:

- All Groundwater Users
- Holders of Overlying Rights (agriculture and domestic)
- Municipal Well Operators and Public Water Systems
- Tribes
- County
- Planning Departments / Land Use Agencies
- Local Landowners
- Disadvantaged Communities
- Business
- Federal Government
- Environmental Uses
- Surface Water Users (*if connection between surface and groundwater*)

SGMA Background

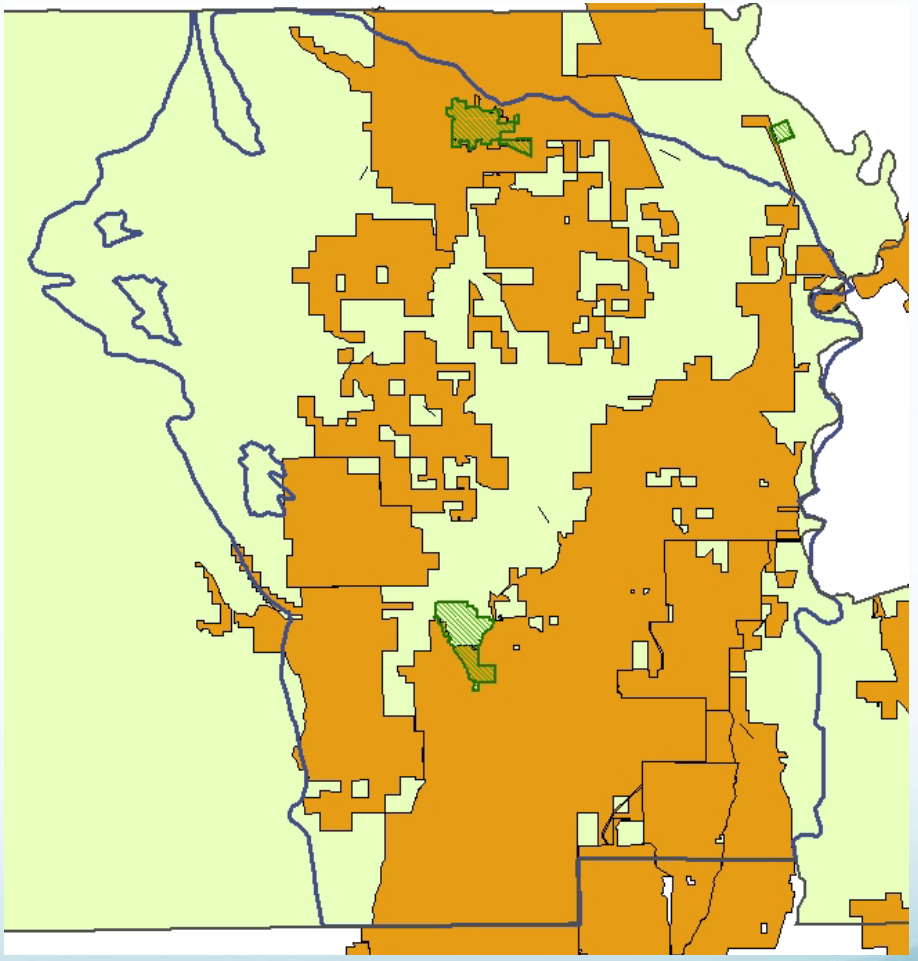
How are domestic well owners affected by SGMA?

- Referred to in SGMA as "de minimis" users IF…
  - Use 2 acre-feet per year or less for domestic purposes
- De minimis users are subject to SGMA, depending on local needs
  - GSAs will decide how de minimis users are addressed
  - GSAs can decide to exclude or include
  - GSAs can decide on fees but *cannot* require metering
  - May be subject to reporting / fees to State if intervention occurs
- Domestic wells can also be regulated by authorities (counties, water districts, etc.) outside scope of SGMA

SGMA Background

"White Areas"

- County is presumed to be the GSA over areas that are not covered by another GSA-eligible agency
- If the County opts out, the State will manage those areas



SGMA Background

Development of Groundwater Sustainability Plans (GSPs)

- GSAs are responsible to develop GSPs
- Every high and medium priority groundwater basin must be covered by a GSP or GSPs
- Option of a single GSP covering the entire basin, or a combination of GSPs, developed by multiple GSAs, covering the entire basin
- Multiple GSPs must coordinate, utilize the same data / methodologies, and have a coordination agreement

SGMA Background

Key Implementation Milestones

- February 18, 2016 - Draft GSP regulations released
- June 1, 2016 – Final GSP regulations approved by CWC
- June 30, 2017 – GSAs must be formed
- July 1, 2017 – Counties affirm GSA status
- January 31, 2020 – GSPs complete for critically over-drafted basins
- January 31, 2022 – All other GSPs complete

SGMA Background

Department of Water Resources (DWR) and State Water Board Roles and Oversight

- DWR:
  - Develop Basin Boundary and GSP regulations
  - Review GSPs, decide on adequacy, implementation

- State Water Board:
  - Implement State intervention
  - Reporting
  - Assess fees
  - Designate Probationary Basins
  - Develop Interim Plans, implement those Plans

SGMA Background

State Water Board Intervention

In all triggering events, intervention is the result of failure by locals to create a GSA(s) and/or adopt and implement a GSP.

- Data
  - Same data needed by a GSA, but now managed by State
  - Higher frequency (monthly minimum reporting)
- Fees
  - Fees associated with reporting
  - Board recovers cost for all intervention-related activities (monitoring plans, well construction, facilitation, technical studies, models)
- Interim plans
  - Pumping restrictions are most straight-forward
  - State developed physical solutions are unlikely

Initial comments and/or questions

Preparing to Advance SGMA Locally

What has the County done to advance SGMA locally?

- Dedicated staff resources
- Fostered early communication with GSA filers
- Maintained communication with surrounding counties
- Received grant for impartial facilitation services from the Center for Collaborative Policy
- Committed to sharing resources with local partners

Recent SGMA Activities

GSA Notifications in Glenn County

- Glenn-Colusa Irrigation District
- Reclamation District No. 1004
- County of Glenn
- Orland-Artois Water District
- City of Orland
- Glide Water District
- Kanawha Water District
- Provident Irrigation District and Princeton-Cordora-Glenn Irrigation District
- Western Canal Water District



Recent SGMA Activities

SB 13 Amendment – Interpreted by DWR as retroactive

- Removed the Notice of Intent to be a GSA
- Allows a mutual water company to be part of a GSA through a legal agreement
- Prohibits overlap of service area boundaries
- Prohibits local agencies from imposing fees or reg. requirements on entities outside their boundaries
- Requires DWR to post all “complete” notices within 15 days of receipt

Recent SGMA Activities

Basin Boundary Modifications

- Existing groundwater basins or subasins defined in DWR's Bulletin 118
- Local agencies may request boundary modifications
- May include scientific or jurisdictional modifications
- Starting January 1, 2016: 90 day window for local agencies to submit requests for DWR consideration

Recent SGMA Activities

Groundwater Sustainability Plan Regulations

- By June 1, 2016 DWR shall adopt regulations for:
  - Evaluating GSPs
  - Implementing GSPs
  - Coordination agreements

- The regulations identify:
  - Required GSP components and additional elements
  - Coordination of multiple GSPs in a basin
  - Additional information that assists GSAs

Draft GSP Regulations

- Require a course to achieve sustainable groundwater management within 20 years of plan implementation
- Fundamental Principle - Local control and management
  - Preserve role of local agencies to manage basins and achieve sustainability,
  - Local flexibility to define problems in basins,
  - Establish minimum thresholds,
  - Set measurable objectives,
  - Determine projects and management actions that will be required to achieve sustainability.
  - Recognize adaptive management as an important tool to address plan uncertainties and improve

Draft GSP Regulations - Timeline

- 57 Pages
- Available for public review at www.water.ca.gov/groundwater/sgm/gsp.cfm
- Public comments in writing through March 25, 2016.
- 3 public meetings and a statewide webinar in March
- Final GSP Regulations Completed – June 1, 2016

Draft GSP Regulations - Timeline

Public Meetings and Webinar

- Monday, March 21, 2016 - Visalia
  - 4:00 P.M. to 6:00 P.M.
- Tuesday, March 22, 2016 – Santa Ana
  - 1:00 P.M. to 3:00 P.M.
- Thursday, March 24, 2016 - Webinar
  - 1:00 P.M. to 3:00 P.M.
- Friday, March 25, 2016 - Sacramento
  - 9:00 A.M. to 11:00 A.M.

Proposed Process In Glenn County

The County received Department of Water Resources grant funding for facilitation services from the Center For Collaborative Policy.

- Background preparation
- Outreach and education
- GSA Governance development

Proposed Process in Glenn County

Background Preparation

- Review background materials
- Conduct initial interviews with eligible GSA agencies
- Prepare 90-Day Plan
- Prepare initial facilitation strategy



Proposed Process in Glenn County

Outreach and Education

- Prepare education and outreach materials
- Coordinate and facilitate local outreach and education meetings for agencies and private well owners
- Facilitate collaboration so all interested parties can participate and work together towards sustainability

Proposed Process in Glenn County

GSA Governance

- Coordinate and facilitate public meetings about governance
- Coordinate and facilitate meetings of several GSA eligible agencies
- Conduct meetings with individual GSA eligible agencies
- Support representation of domestic well owner interests

Key Considerations as We Move Forward

The County believes a collaborative approach is best

- We all have a vested interest in our groundwater
- GSA formation, GSP preparation, and and long-term implementation will create costs for many users
- Pooling resources will improve efficiencies and capitalize skills and strengths of various partners

Next Steps

So where do we go from here?

- Convene Governance Workgroup
- Hold additional public meetings
- Continued coordination with adjacent subbasins

Discussion

Your comments, questions and input

Sustainable Groundwater Management Act (SGMA)
Public Meeting on Local Planning Efforts

For immediate release
Contact: Lisa Hunter, Glenn County Water Resources Coordinator
LHunter@countyofglenn.net
(530) 934-6501

Willows, California- Glenn County officials and other local groundwater managers will host a public meeting on the Sustainable Groundwater Management Act (SGMA). SGMA is a new law that offers beneficial opportunities to achieve sustainable groundwater conditions and support Colusa County's vital agricultural economy, industry, and domestic and public water uses.

The meeting will provide an overview of SGMA, expected responsibilities and benefits for groundwater users, and describe early steps taken to implement the new law. The public is encouraged to attend to learn more about SGMA, ask questions of local water managers and submit comments.

"Water supply issues in Glenn County are challenging, but SGMA provides the tools to develop local solutions for local problems" said Willow-area farmer Larry Domenighini. "In the next couple of years we will need to craft a plan to address the sustainability issues we all face here. Water supply sustainability issues affect everyone in the County whether they recognize it or not. This is not going to be a quick or easy solution, so it is important that everyone keeps up with our local water issues and be engaged so that we can develop our solutions."

To support local planning efforts, the County has secured facilitation support from the Department of Water Resources (DWR), initiated a county-wide groundwater assessment and applied for a groundwater planning grant through the Water Bond.

"Glenn County is committed to working through local challenges to ensure that our groundwater resources are protected" said Lisa Hunter, the County's Water Resources Coordinator". "Groundwater resources are especially important for our household water uses and our agricultural economy, as well as other water uses in our area. Glenn County is committed to work collaboratively with local water managers to ensure sustainable water supplies into the future for all County citizens."

Meeting date, time and location:

March 8, 2016
6:00 p.m. – 8:00 p.m.
Orland Memorial Hall
320 Third Street
Orland, CA 95963

For more information please visit DWR's SGMA webpage: http://groundwater.ca.gov/

Save the Date! Save the Date!

Glenn County

is Hosting a Public Meeting

About California's

Sustainable Groundwater Management Act (SGMA)

Tuesday, March 8, 2016
6:00-8:00 PM
Orland Memorial Hall
320 Third Street, Orland

The meeting will include:

- An overview of the Sustainable Groundwater Management Act (SGMA)
- A presentation of SGMA early implementation in Glenn County
- Discussion of anticipated SGMA benefits and impacts
- Public input: questions, comments and considerations

For more information on this meeting and SGMA implementation in Glenn County visit our website at:

www.glenncountywater.org

Glenn County Water Resources: 530-934-6501



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2D-3. GSA Financing – Proposition 218 Public Information Meetings and Hearings

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Affidavit of Publication

State of California, County of Colusa

COLUSA COUNTY GROUNDWATER AUTHORITY

NOTICE OF PUBLIC HEARING

I am a citizen of the United States and a resident of Colusa County; I am over the age of eighteen years, and not a part to or interested in the above entitled matter. I am the principal clerk, and publisher of the **Williams Pioneer Review**, a newspaper of general circulation, published in the County of Colusa, and which newspaper has been adjudged to be a newspaper of general circulation by the Superior Court of the County of Colusa, State of California, under the date of September 19, 2017, Case No. CV24253, that the notice of which the annexed is a true printed copy, has been published in each regular and entire issue of said newspaper and not in any supplement thereof on the following dates, to wit:

- **05/08/2019**
- **05/15/2019**

I certify (or declare) under the penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed at Colusa, Colusa County, California, on:

DATE: MAY 15, 2019

Lloyd M. Green Jr., Publisher

DOCUMENT No.: 2019-0683

WILLIAMS PIONEER REVIEW
310 5th St., Colusa, CA
(530) 458-4141

PIONEER REVIEW
COLUSA COUNTY NEWS

LEGAL NOTICE

COLUSA GROUNDWATER AUTHORITY

NOTICE OF PUBLIC HEARING

NOTICE IS HEREBY GIVEN THAT the COLUSA GROUNDWATER AUTHORITY (hereinafter "Authority"), in accordance with (i) Authority Resolution 2019-01, adopted on March 26, 2019, (ii) Article XIIID, Section 6, of the California Constitution, and (iii) Section 10730(b)(2) of the California Water Code, will hold a public hearing on a proposed Operations Fee on June 5, 2019 at 5:00 p.m. at the Colusa Industrial Properties, 100 Sunrise Blvd., Colusa, CA 95932 to consider a proposal by the Authority to adopt a new fee in the amount of $1.21 per acre annually, indexed to Consumer Price Index, Western Region, for the 2019 Fiscal Year and the subsequent four fiscal years for everyday operations of the CGA.

Further information regarding this matter is available online at https://colusagroundwater.org, by calling the Authority's consultant at (916) 918-2002, or visiting the Authority's office at Colusa Industrial Properties, 100 Sunrise Blvd., Suite A, Colusa, CA 95932.

Date: March 26, 2019

/s/ Mary Fahey
Secretary of the Colusa Groundwater Authority

WPR - 05/08, 05/15/2019 · #2019-0683

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Notice of Workshop Regarding Implementation of SGMA by the Colusa Groundwater Authority, and Proposed Funding

The Colusa Groundwater Authority (CGA or Agency) is a 12-Member, multi-agency Joint Powers Authority that was formed on June 29, 2017 to meet the Groundwater Sustainability Agency formation deadline under the Sustainable Groundwater Management Act (SGMA). The CGA is responsible for implementation of SGMA in the County of Colusa (County) portion of the Colusa Subbasin (8-21.52) and the County portions of the West Butte Subbasin (5.21-58) outside of Reclamation District 1004. The Board of the CGA is composed of representatives of the following Agencies (1 seat per agency): County, City of Colusa, City of Williams, Colusa County Water District, Glenn-Colusa Irrigation District, Princeton-Codora-Glenn/Provident Irrigation District, Westside Water District/Maxwell Irrigation District, Reclamation District 108, Reclamation District 479, and Colusa Drain Mutual Water Company. In addition, there are two Private Pumper representatives appointed by the Colusa County Board of Supervisors, as recommended to the Board by the County Groundwater Commission. The CGA was formed to comply with and implement SGMA.

As a groundwater regulating agency, the CGA (in partnership with other adjacent GSAs such as the Glenn Groundwater Authority [GGA]) is tasked with achieving and maintaining sustainable groundwater conditions in the above mentioned subbasins over a 20-year window starting on January 31, 2022 and extending to 2042. Compliance with SGMA during this time period is done through the preparation and implementation of a Groundwater Sustainability Plan (GSP or Plan). GSP development is just getting underway in the Colusa and West Butte Subbasins and the Plans must be adopted by the aforementioned January 31, 2022 date. If any of the SGMA deadlines are not met, or if the CGA cannot fund the necessary activities committed to in the GSPs, the State Water Resources Control Board will take over groundwater management responsibilities. In order to ensure initial SGMA compliance and as an effective start to this long-range effort, the Member Agencies on the CGA Board agreed to fund CGA activities for the first two years of operation (July 2017 – June 2019), after which a long-term funding plan would need to be in place including contributions from landowners. The CGA has retained Provost & Pritchard Consulting Group to prepare a fee study to review the best options to fund CGA operations over the next five years. An operations cost and fee analysis is to be included in the study.

A public workshop will be held January 31, 2019, at 6:00 pm at the Colusa Indian Community Event Center, 3720 Highway 45, Colusa, CA 95932 to provide information about the cost and fee analysis and what this may mean for landowners. The public workshop will also provide an opportunity for you to provide input for the study, will inform you of SGMA requirements and current implementation status in the CGA jurisdictional area, and the consequences of not managing the groundwater subbasins (e.g. State intervention). One of the foundational Guiding Principles committed to by all CGA Members during the Agency's inception is to ensure that the areas under CGA jurisdiction **avoid extremely expensive and intrusive State groundwater intervention actions** to all beneficial users of groundwater.

Additional Background:

CGA operations include a variety of administrative activities, development of the GSP, monitoring groundwater conditions, annual reporting to the California Department of Water Resources, five-year updates to the GSP, and potentially conducting special studies. As stated above, the CGA is just beginning development of the GSP for the CGA jurisdictional areas, in coordination with other GSAs in the basins, including the Glenn Groundwater Authority, among others. State Proposition 1 grant funding has been awarded to cover a large portion of GSP development, however this grant does not and cannot support long-range operations and implementation of SGMA. The member agencies of the CGA will continue to pursue any grant funding opportunities that become available to support SGMA activities.

More information about the CGA and additional SGMA outreach meetings can be found at https://colusagroundwater.org/

Protest Process Required for any CGA Operations Fee or Charge:

If after the cost and fee analysis study is completed, the CGA Board opts to propose a fee or charge for its operations to avoid State intervention fees, landowners will have the option to protest under California's Proposition 218 requirements. More information about CGA, SGMA, and alternatives for funding SGMA compliance activities and Proposition 218 requirements will be provided at the January 31st public workshop.

Opportunity to Provide Input:

SGMA is a complex and important new law requiring statewide management of groundwater. The upcoming workshop is an opportunity for you to be informed about SGMA implementation, the funding process, and to ask questions. Please come to the public workshop. If you are unable to attend and want to be notified of other opportunities to provide input, please contact Mallory Serrao (mserrao@ppeng.com; 916-918-2002).

Colusa Groundwater Authority
Attn: Mary Fahey
100 Sunrise Blvd., Suite A
Colusa, CA 95932

Customer APN#
Customer Name
Customer Address
City, CA Zip

Colusa Groundwater Authority Information Meeting

Sustainable Groundwater Management Act Implementation and Funding

January 31, 2019

Program



1. Sustainable Groundwater Management Act (SGMA) Overview
2. Colusa Groundwater Authority (CGA) Background
3. Financing SGMA Implementation
   - CGA Activities and the Need for Funding
   - Proposition 218 Majority Protest
4. SGMA Local Compliance and Potential State Intervention
5. CGA Panel Questions and Answers

SGMA: Who is Affected



Agriculture



Municipal



Industrial



Environmental

SGMA Foundations



- Sustainable Groundwater Management Act of 2014
- **Groundwater Sustainability Agency(ies) (GSA)** by **June 30, 2017**
- **Groundwater Sustainability Plan(s) (GSP)** by **January 31, 2022**
- Yearly reporting and GSP Update every 5 years, demonstrating progress towards sustainability
- 20 years to achieve Sustainability – 2042
- **SGMA is a completely different program than the Irrigated Lands Regulatory Program!**

SGMA Foundations



- 517 Groundwater Basins / Subbasins Statewide
- 127 Basins / Subbasins required to comply with SGMA
- Compliance based on basin prioritization as mandated by State Legislature in 2009.
- Prioritization variables include (but not limited to):
  - Population
  - Socioeconomics
  - Number of wells
  - Groundwater elevation
- Approx. 18 Basins / Subbasins in Sacramento Valley are High or Medium priority

SGMA Foundations



- One or more GSAs must be formed per Basin / Subbasin
- A GSA may be formed by a single eligible agency or by legal agreement between two or more eligible agencies.
- Two or more GSAs must prepare a Coordination Agreement (a legal agreement) between them if preparing more than one GSP. (Water Code§10721, 10727)(b)(3), etc.)
- Counties represent / manage all groundwater conditions outside another managed area (Water Code§10724)

SGMA Foundations



Six "**Undesirable Results**"

1. Chronic lowering of groundwater levels
2. Land subsidence
3. Reduction of groundwater storage
4. Depletions of interconnected groundwater and surface water
5. Degraded water quality
6. Seawater intrusion (*not applicable in the Colusa Subbasin*)

SGMA: Who is Affected



Agriculture



Municipal



Industrial



Environmental

<u>De minimis</u> (less than 2 acre/feet pumped per year for domestic purposes)

SGMA: Who is Affected



De Minimis Well Owners

- **Pump less than 2 acre/feet per year for domestic purposes**
- **GSAs can include De Minimis in GSP**
- **CGA will seek to avoid impacts**

SGMA Foundations



Beneficial Users (Water Code§10723.2)

- All Groundwater Users
- Holders of Overlying Rights (agriculture and domestic)
- Municipal Well Operators
- Public Water Systems
- Tribes
- Local Land Use Planning Agencies
- Counties
- Local Landowners
- Disadvantaged Communities
- Business
- Federal Government
- Environmental Users
- Surface Water Users (*if connection between surface and ground water*)

GSA Roles and Responsibilities



- **Governance** – Colusa Groundwater Authority
- **Outreach/Engagement (Transparency)** with all beneficial users
- **Compliance** with local ordinances, state and federal laws and regulations, and similar
- **Funding** which may include one or more of the following: regulatory fees, property-related fees or assessments, local taxes, local general obligation bonds, contributions from member agencies, grants from other state or federal agencies

GSA Roles and Responsibilities



- **Authorities**

  General:

  - Do anything "necessary and proper" to carry out SGMA's purposes
  - Adopt rules, regulations, ordinances and resolutions
  - Use any other authority allowed to the GSA to apply and enforce SGMA requirements

  Information Gathering

  Groundwater Extraction Oversight

  Property Acquisition and Management

  Enforcement:

  - Sue to collect delinquent fees, interest, or penalties or order extraction stopped until delinquent fees are paid
  - Pursue civil penalties for extraction exceedances
  - Pursue civil penalties for violations of SGMA-related rules, regulations, ordinances, or resolutions

GSA Roles and Responsibilities



- **Coordination** with adjacent Subbasins and Counties (if applicable), and between Management Areas (if applicable)
- **Technical** – access technical expertise; conduct/oversee monitoring, data collection and reporting; develop water budget and identify sustainable yield; assess basin history and potential paths to sustainable management; remediate or oversee remediation of polluted groundwater.

GSA Roles and Responsibilities



- **Summary**
  - SGMA is the law.
    - Foundational change to groundwater management in California
  - SGMA allows for significant Local Control
  - SGMA has "Few Shalls…Many Mays…"
    - Shall…Create GSA
    - Shall…Prepare GSP
    - Shall…Do Public Engagement
  - GSAs are new, local government, **Regulating Agencies**

Colusa Groundwater Authority



- CGA Formation; 2 years, Guiding Principles
- CGA formed June 29, 2017 as mandated by SGMA
- CGA is the GSA-covering the Colusa County portions of the Subbasins within the county, outside of RD 1004
- CGA is a 12-member Joint Powers Authority Board
- Board includes two Private Pumper representatives

Colusa Groundwater Authority



Board of Directors

County of Colusa
Denise Carter (Chair) / Alternate: Gary Evans

City of Colusa
Tom Reische / Alternate: Dave Markss

City of Williams
Alfred Sellers, Jr. / Alternate: TBD

Colusa County Water District
Knute Myers / Alternate: Shelly Murphy

Glenn-Colusa Irrigation District
Blake Vann / Alternate: Thad Bettner

Maxwell I.D. and Westside I.D.
Zachary Dennis / Alternate: Dan Ruiz

Princeton-Codora-Glenn I.D. and Provident I.D.
David Alves / Alternate: Lance Boyd

RD 108
Hilary Reinhard, PE (Vice Chair)
Alternate: Bill Vanderwaal

RD 479
Charles Marsh / Alternate: Derick Strain

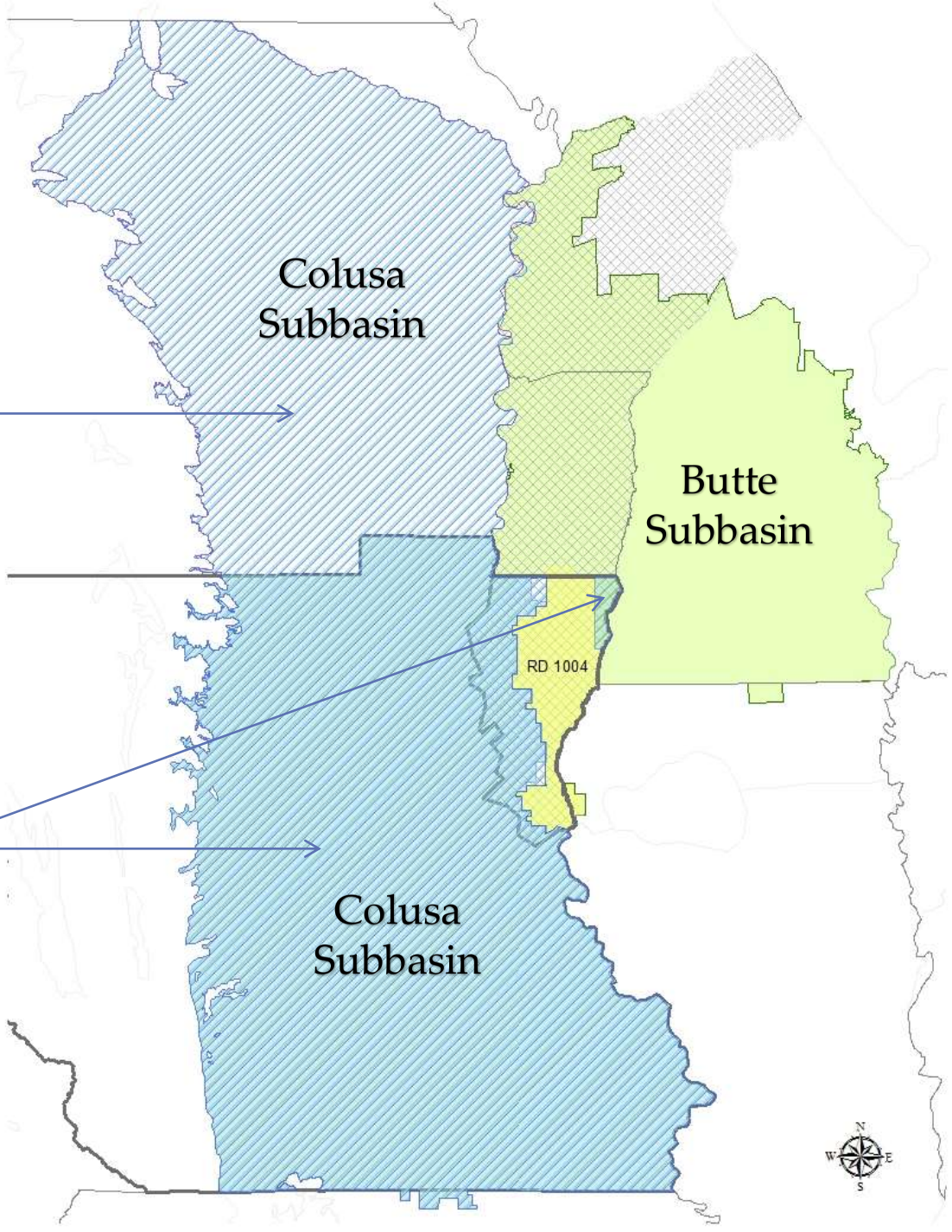
Colusa Drain Mutual Water Company
Jim Wallace / Alternate: Lynell Pollock

2 Private Pumper Representatives from the Colusa County Groundwater Commission:
Darrin Williams and Jeff Moresco

Subbasin Locations

Glenn Groundwater Authority (GGA) GSA

Colusa Groundwater Authority (CGA) GSA



CGA Activities



- Groundwater Sustainability Plan (GSP) for the Colusa Subbasin (CGA & GGA)
  - Awarded $1 million Proposition 1 grant funding for GSP development
  - Consultant team is developing Basin Setting for GSP
- Installing a new monitoring well in the Arbuckle area (DWR funded)
- Coordinating with GGA on GSP development and other activities in the Colusa Subbasin
- Coordinating with GSAs in other surrounding basins/counties
- Organizing ongoing public meetings and public outreach activities
- Developing long-term funding strategy for the CGA to maintain local control of Groundwater Management under SGMA

Financing SGMA



- CGA members working together, pooling resources to keep costs to a minimum
- Leveraging grant funding, Facilitation Support and Technical Support services
- **Need for Long-term funding for day to day operations of the CGA:**
  - **Technical:** GSP development ($1.5 million), technical studies, monitoring and data management, coordination and outreach efforts, implementation of the GSP, yearly reporting to DWR, Plan updates every five years
  - **O&M:** Staff, insurance, legal services, bookkeeping, office needs, etc.
- CGA Member Agencies agreed to fund the JPA for the first two years (July, 2017 – June, 2019) = $616,181.00 + over $150,000 in donated staffing and special studies prior to GSA formation
- Fees are needed to comply with SGMA and fund the GSP and basin monitoring activities

Financing SGMA



Proposition 218 Option

- Approved by voters in 1996, Prop 218 imposes certain requirements relative to the imposition of certain assessments, fees and charges by local agencies.
- Procedures act to fully inform the Agency's landowners while simultaneously giving them a direct say in the matter.
- Two processes for approval of revenue generation under Proposition 218
  - Land-based assessments (per acre charge)
  - Fees or charges on a unit basis.

Financing SGMA



Proposition 218 Majority Protest Requirements

- CGA contracted with Provost and Pritchard Engineering to initiate a Proposition 218 Majority Protest
- Consultants will complete a rate study to determine a fee structure based on CGA budget and acreages in the CGA's jurisdiction
- Amount of fee cannot exceed the reasonable cost of the activity to be funded
- Public information meetings being planned, January – March
- A similar process is beginning in the GGA portion of the Colusa Subbasin

Financing SGMA



Proposition 218 Majority Protest Requirements

- Fees must be based on the reasonable cost of providing service
  - CGA's annual operating budget
- Fees must proportionally recover costs from ratepayers (i.e. no subsidies)
  - $/acre fee
- Fees in the Prop 218 notice are the max fees that may be adopted
  - Board may lower fees without conducting another Prop 218 notice and hearing process

Financing SGMA



Proposition 218 Majority Protest Requirements

- Hold public informational meeting (NOT required)
- Mail a protest notice to property owners
- Hold a public hearing minimum of 45 days later – anticipated in May, 2019
- Absent majority protest, CGA may adopt fees
- If the Proposition 218 effort passes, a fee will appear on December 2019 property tax roll

Financing SGMA



Initial Estimate: Proposition 218 Majority Protest Fee Calculation

	Estimates
Budget	$540,000
Acres	413,256
Fee ($/acre)	$1.31

- Pending outcome of fee study
- Pending CGA Board approval and budget review
- SGMA is a new program, many unknowns
  - Budget is the best estimate at this time
  - The fee cannot exceed the reasonable costs of the CGA activities
- This fee is for day to day operations of the CGA. Additional project-specific fees may also apply in the future

Financing SGMA



Statewide GSA Fee Examples

1. GSA 1 – in Fresno County - $19.00/acre – entirely dependent on groundwater

2. GSA 2 – in Kings County - $5.00/acre initially, reduced to $3.00/acre in second year

3. GSA 3 – Salinas Valley - $2.27/non-ag acre to $4.81 irrigated ag acre

Financing SGMA



Who is Subject to Fees?

- All property owners have an overlying right and benefit from a healthy groundwater system
- Small Community Water Systems: homeowners in the Cities of Colusa and Williams and the small communities of Arbuckle, Grimes, Maxwell and Princeton may be charged through their water suppliers.
  - This will save money processing multiple property tax bills on these small parcels

Financing SGMA



What if the Prop 218 Effort Fails?

- If the CGA cannot be funded, it will dissolve.
- If a basin is not covered entirely by a GSA(s) and/or approved GSP, the State Water Resources Control Board assumes SGMA responsibilities.
- Lose local control of the groundwater resource.

State Intervention



- **State Board intervention actions can include:**
  - Well Head fees
  - Volumetric fees (fee per acre-foot of water pumped)
  - Late fees (subject to backdating to 2017)
  - Mandatory extraction reporting including monthly pumping data
  - May require installation of meters on wells at owner's expense
  - Technical reporting and special studies at landowners' expense
  - Any corrective actions will likely result in pumping restrictions

State Intervention



SWRCB Fees, 2018

BASE FEE (per well)	**$300**
Volumetric Fee (per AF)	
Unmanaged, metered	**$10/AF**
Unmanaged, unmetered	**$25/AF**
An unmanaged area is a part of a basin not within the management area of a GSA before July 1, 2017	
Probation	**$40/AF**
If locals fail to form a GSA, fail to develop an adequate sustainability plan, or fail to implement the plan successfully, the Board may designate the entire basin probationary. The Board may require the use of a meter to measure extractions and reporting of additional information.	
Interim Plan	**$55/AF**
If local agencies are unable to fix the deficiencies, the Board will develop an interim plan to directly manage groundwater extractions.	
De minimis (less than 2 AF/year)	**$100/well**
Late Fee	**25% per month**

https://www.waterboards.ca.gov/water_issues/programs/gmp/sgma.html

State Intervention



Sample Fee Comparison

100 acre irrigated parcel with one well, probationary basin

- **SWRCB Fees: $14,300**
  - 1 well = $300
  - 3.5 AF/ac = 350 AF X $40 = $14,000

- **Estimated CGA Fee: $131**
  - 100 Acres X $1.31 = $131

CGA Panel Questions & Answers



Panel Members:

- Denise Carter, County Supervisor, CGA Board Chair
- Hilary Reinhard, RD 108, CGA Vice Chair
- Darrin Williams, Private Pumper
- Jesse Cain, City Manager, City of Colusa

Thank You

Landowner input is essential to GSP development and SGMA planning and implementation.

Please visit the website or contact Staff to get on the contact list:

Mary Fahey
Program Manager, Colusa Groundwater Authority
530-458-0719
mfahey@countyofcolusa.com

CGA Website: www.colusagroundwater.org

Colusa County Groundwater Commission Informational Forum
February 13
10:00 a.m. – noon
Colusa Industrial Properties Conference Room

COLUSA GROUNDWATER AUTHORITY
NOTICE OF PROPOSED FEE

In compliance with California State Law, a **public hearing will be held:**

June 5, 2019 at 5:00 p.m. at the Colusa Industrial Properties, 100 Sunrise Blvd., Colusa, CA 95932 to consider a proposal by the Colusa Groundwater Authority (CGA) to adopt a **new fee in the amount of $1.21 per acre annually**, indexed to Consumer Price Index, Western Region, for the 2019 Fiscal Year and the subsequent four fiscal years, for everyday operations of the CGA.

Background:

The Colusa Groundwater Authority is a 12-Member, multi-agency Joint Powers Authority that was formed on June 29, 2017 to meet the Groundwater Sustainability Agency (GSA) formation deadline under the Sustainable Groundwater Management Act (SGMA). The CGA is responsible for implementation of SGMA in the County of Colusa (County) and Yolo County portions of the Colusa Subbasin (5-021.52) and the County portions of the Butte Subbasin (5.021-70) outside of Reclamation District 1004 (Basins). The Board of the CGA is composed of representatives of the following Agencies (1 seat per agency): County of Colusa, City of Colusa, City of Williams, Colusa County Water District, Glenn-Colusa Irrigation District, Princeton-Codora-Glenn Irrigation District / Provident Irrigation District, Westside Water District / Maxwell Irrigation District, Reclamation District 108, Reclamation District 479, and Colusa Drain Mutual Water Company. In addition, the Board includes two Private Pumper representatives appointed by the Colusa County Board of Supervisors, as recommended to the Board by the County Groundwater Commission. The CGA was formed to comply with and implement SGMA.

As a groundwater regulating agency, the CGA (in partnership with other adjacent GSAs such as the Glenn Groundwater Authority [GGA]) is tasked with achieving and maintaining sustainable groundwater conditions in the Basins. Compliance with SGMA is done through the preparation and implementation of a Groundwater Sustainability Plan (GSP or Plan). GSP development is underway in the Basins and the Plans must be adopted by January 31, 2022. If any of the SGMA deadlines are not met, or if the CGA cannot fund preparation of the GSP(s) or the necessary activities committed to in the GSPs, the State Water Resources Control Board may take over groundwater management responsibilities.

Long-Term Funding:

In order to ensure initial SGMA compliance and as an effective start to this long-range effort, the CGA Member agencies agreed to fund the CGA for the first two years of operation (July 2017 – June 2019), after which a long-term funding plan (proposed CGA Operations Fee) would be initiated to cover everyday operations of the CGA related to SGMA implementation and compliance. CGA operations include administration, legal services, consultant services, insurance, office and outreach materials, accounting, monitoring and reporting to DWR, and potentially some special studies. The CGA has received Proposition 1 grant funding to cover a majority of the work to develop a GSP however, costs for GSP preparation and initial implementation that can't be covered by grants will also need to be covered by the CGA Operations Fee. It is anticipated that any necessary management actions resulting from GSP implementation that cause a funding shortfall will be funded by other localized fees or assessments.

CGA has developed a budget for annual operations expenses and GSP preparation costs not covered by grant funding for a five-year period spanning fiscal years 2019/20 to 2023/24. Based on the Agency's needs, the CGA Board of Directors is seeking to collect the Operations Fees to generate sufficient revenue to fund CGA operations. GSP development is scheduled to occur over the next several years and GSA operations expenses are anticipated to be on-going during that period and beyond.

The proposed CGA Operations Fee is a property-related fee governed by Proposition 218. Each parcel of land within the CGA's boundary that will be subject to the CGA Operations Fee shall pay the CGA Operations Fee in proportion to the cost of providing services to each acre of land comprising each parcel. SGMA provides authority for CGA to charge fees to support its operations. The CGA has retained Provost & Pritchard Consulting Group to prepare a fee study to review the best options to fund CGA operations over the next five years. An operations cost and fee analysis is included in the study.

One of the foundational Guiding Principles committed to by all CGA Members is to ensure that the areas under CGA jurisdiction **avoid extremely expensive and intrusive State groundwater intervention actions**.

If the State Water Resources Control Board intervenes in the Basins, it may impose annual fees ranging from $100 per de minimis well, to $300 per well plus up to $55 per acre-foot pumped per well, with no guarantee of assistance in bearing costs to address the groundwater issues that prompt its intervention. See https://www.waterboards.ca.gov/water_issues/programs/gmp/docs/intervention/intervention_fs.pdf. for more complete information. By collecting the Operations Fees, CGA will provide landowners with a more affordable and locally managed option for managing the Basins.

As stated above, the CGA is just beginning development of the GSP for the CGA jurisdictional areas, in coordination with other GSAs in the Basins. State Proposition 1 grant funding has been awarded to cover a large portion of GSP development, however this grant does not and cannot support long-range operations and implementation of SGMA. The CGA will continue to pursue any grant funding opportunities that become available to support SGMA activities.

Proposed Charges:

This notice is for the CGA's proposal to implement a per-acre charge to fund the CGA operations, supplement GSP preparation, and begin initial GSP implementation. The CGA is requesting a maximum charge of:

- **$1.21 per acre** (in 2019 dollars, indexed for Consumer Price Index, Western Region, for the subsequent four years).
- The proposed charges, if approved, will become effective for the 2019/20 Colusa County fiscal year, with the first payment due by December 10, 2019.

The actual amount of the CGA Operations Fee may vary from time to time however, absent a subsequent Proposition 218 proceeding, it will not exceed the fee set forth above, plus the indexed inflation factor.

For more information, including the fee study summarizing the findings, please visit the CGA website at **https://colusagroundwater.org/long-term-funding/**

Public Hearing:

Under the California State Constitution, owners of land subject to the proposed CGA Operations Fee have the right to protest its adoption. If you have received this notice, parcel(s) under your ownership will be subject to the CGA Operations Fee if adopted. In the event of a majority protest, the fee will not be instituted.

Landowners desiring to protest the proposed CGA Operations Fee should send their written protest to:

Colusa Groundwater Authority
c/o Provost & Pritchard Consulting Group
P.O. Box 8929
Chico, California 95927

Protests may also be submitted to the Board Secretary at the Public Hearing, located at 100 Sunrise Blvd., Colusa, California. **All protests must be received by 5:00 p.m. June 5, 2019 or in person by the close of the Public Hearing on June 5, 2019**.

There are multiple ways to obtain additional information about this topic:

- Call CGA's Consultant at **(916) 918-2002.**
- View more information online at **https://colusagroundwater.org**
- To read this notice in Spanish, please visit the CGA website: https://colusagroundwater.org/long-term-funding/
- For more information about SGMA, see the California Department of Water Resources website: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management

If you do not wish to protest the proposed CGA Operations Fee, you need not take any action.

To Protest:

All protests must include:

- Landowners printed name(s),
- Parcel number for each property affected by the CGA Operations Fee,
- Reason for the protest, and
- Valid signature(s)

Each parcel is entitled to one protest. If a parcel has more than one owner, all must sign the protest; otherwise the protest will be counted in accordance with the percentage of ownership of the person or persons signing the protest.

For your convenience, you may utilize the Protest Form below:



PROTEST FORM FOR THE ADOPTION OF PROPOSED CGA OPERATIONS FEE

Landowner(s) printed name: _____

_____

_____

_____

_____

Parcel Number(s): _____

_____

Reason for Protest:

Landowner(s) signature: _____

_____

_____

_____

_____

COLUSA GROUNDWATER AUTHORITY
AVISO DE PROPUESTA DE TARIFA

En cumplimiento de la Ley del Estado de California, se **llevará a cabo una audiencia pública:**

El día 5 de Junio del 2019 a las 5:00 p.m. en las Propiedades Industriales de Colusa, 100 Sunrise Blvd. Colusa, CA 95932 para considerar una propuesta de la Colusa Groundwater Authority (CGA) para adoptar **una nueva tarifa anual de $1.21 por acre**, indexada de acuerdo al Índice de Precios al Consumidor, Región Occidental, para el Año Fiscal del 2019 y los cuatro años fiscales subsiguientes, para la operación regular de la CGA.

Antecedentes:

La Colusa Groundwater Authority es una Autoridad de Poderes Conjuntos y una multi-agencia de 12 miembros que se formó el 29 de Junio del 2017 para cumplir con la fecha límite de formación de la Agencia de Sostenibilidad de Aguas Subterráneas (GSA) bajo la Ley de Administración Sostenible del Agua Subterránea (SGMA). La CGA es responsable de la implementación de SGMA en las porciones del Condado de Colusa (Condado) y el Condado de Yolo de la Subcuenca de Colusa (5-021.52) y las porciones del Condado de la Subcuenca Butte (5.021-70) fuera del Reclamation District 1004 (Cuencas). La Junta de la CGA está compuesta por representantes de las siguientes Agencias (1 asiento por agencia): Condado de Colusa, Ciudad de Colusa, Ciudad de Williams, Colusa County Water District, Glenn-Colusa Irrigation District, Princeton-Codora-Glenn Irrigation District / Provident Irrigation District, Westside Water District / Maxwell Irrigation District, Reclamation District 108, Reclamation District 479, y la Colusa Drain Mutual Water Company. Además, la Junta incluye dos representantes privados nombrados por la Junta de Supervisores del Condado de Colusa, según lo recomendado por la Comisión del Agua Subterránea del Condado. La CGA se formó para cumplir e implementar SGMA.

Como una agencia reguladora del agua subterránea, la CGA (en asociación con otras GSA adyacentes como la Glenn Groundwater Authority [GGA]) tiene la tarea de lograr y mantener condiciones sostenibles del agua subterránea en las Cuencas. El cumplimiento con SGMA se realiza a través de la preparación e implementación de un Plan de Sostenibilidad del Agua Subterránea (GSP o Plan). El desarrollo del GSP está en marcha en las Cuencas y los Planes deben adoptarse antes del 31 de enero del 2022. Si no se cumple alguno de los plazos de SGMA, o si la CGA no puede financiar la preparación del (los) SGP o las actividades necesarias a las que se han comprometido en los GSPs, la State Water Resources Control Board pueden asumir las responsabilidades de la administración del agua subterránea.

Financiamiento a Largo Plazo:

Con el fin de garantizar el cumplimiento inicial de la SGMA y como un inicio efectivo de este esfuerzo de largo alcance, las agencias de Miembros de la CGA acordaron financiar la CGA durante los primeros dos años de operación (Julio de 2017 - Junio de 2019), después del cual se iniciaría un plan de financiamiento de largo plazo (Tarifa Propuesta para las Operaciones del CGA) se iniciaría para cubrir las operaciones diarias de la CGA relacionadas con la implementación y el cumplimiento de SGMA. Las operaciones de CGA incluyen administración, servicios legales, servicios de consultoría, seguros, materiales de oficina y educación, contabilidad, monitoreo e informes a DWR, y potencialmente algunos estudios especiales. La CGA ha recibido fondos de la Proposición 1 para cubrir la mayor parte del trabajo para desarrollar un GSP. Sin embargo, los costos para la preparación del GSP y la implementación inicial que no pueden ser cubiertos por los fondos recibidos también deberán cubrirse con la Tarifa Propuesta para las Operaciones del CGA. Se anticipa que cualquier acción de administración necesaria que resulte de la implementación del GSP que cause un déficit de financiamiento será financiada por otras tarifas o evaluaciones puntuales que sean necesarias.

CGA ha desarrollado un presupuesto para los gastos de operación anuales y los costos de preparación del SGP no cubiertos por los fondos recibidos para un período de cinco años que abarca los años fiscales 2019/20 al 2023/24. Basado en las necesidades de la agencia, la Junta de Directores de CGA está buscando cobrar la Tarifa de Operaciones para generar ingresos suficientes para financiar las operaciones de CGA. El desarrollo del SGP está programado para ocurrir en los próximos años y se anticipa que los gastos de operaciones de GSA continúen durante ese período y más allá.

La Tarifa de Operaciones del CGA propuesta es una tarifa relacionada con la propiedad y gobernada por la Proposición 218. Cada parcela de tierra dentro del límite de la CGA estará sujeta a la Tarifa de Operaciones de la CGA y pagará la Tarifa de Operaciones de la CGA en proporción al costo de proporcionar servicios a cada acre de terreno que incluye cada parcela. SGMA otorga autoridad a CGA para cobrar tarifas para respaldar sus operaciones. La CGA ha contratado a Provost & Pritchard Consulting Group para preparar un estudio de tarifas para revisar las mejores opciones para financiar las operaciones de CGA en los próximos cinco años. Se incluye un análisis de costos y tarifas de operaciones en el estudio.

Uno de los Principios Rectores fundamentales a los que se comprometen todos los Miembros de la CGA es el de garantizar que las áreas bajo jurisdicción de la CGA **eviten acciones de intervención del agua subterránea extremadamente costosas e intrusivas por parte del Estado**.

Si la State Water Resources Control Board interviene en las cuencas, puede imponer tarifas anuales con un mínimo de $100 por pozo, y hasta de $300 por pozo, y adicionalmente hasta $55 por acre-pie bombeado por pozo, sin garantía de asistencia en los costos de soporte para resolver los problemas de agua subterránea que causan su intervención. Consulte https://www.waterboards.ca.gov/water_issues/programs/gmp/docs/intervention/intervention_fs.pdf. para información más completa. Al cobrar la Tarifa de Operaciones, CGA les brindará a los propietarios una opción más accesible y localmente administrada en relación con la administración de las Cuencas.

Como se indicó anteriormente, la CGA está recién comenzando el desarrollo del GSP para las áreas jurisdiccionales de la CGA, en coordinación con otras GSA en las Cuencas. La financiación que ofrece la Proposición Estatal 1 se ha otorgado para cubrir una gran parte del desarrollo del GSP, sin embargo, este fondo no apoya y no puede respaldar las operaciones de largo plazo y la implementación de SGMA. La CGA continuará buscando cualquier oportunidad de financiamiento que esté disponible para apoyar las actividades de SGMA.

Cobros Propuestos:

Este aviso es para la propuesta de la CGA de implementar un cobro por acre para financiar las operaciones de la CGA, complementar la preparación del GSP, y empezar la implementación inicial del GSP. La CGA está solicitando un cargo máximo de:

- **$1.21 por acre** (en dólares corrientes del año 2019, indexados por el Índice de Precios al Consumidor, Región Occidental, para los siguientes cuatro años).
- Los cargos propuestos, si se aprueban, entrarán en vigor para el año fiscal 2019/20 del Condado de Colusa, con el primer pago que debe realizarse antes del 10 de Diciembre del 2019.

El monto real de la Tarifa de Operaciones de la CGA puede variar de vez en cuando, sin embargo, en ausencia de un procedimiento posterior de la Propuesta 218, no excederá la tarifa establecida anteriormente, más el factor de inflación indexado.

Para más información, incluido el estudio de tarifas que resume las recomendaciones, visite el sitio web de CGA en **https://colusagroundwater.org/long-term-funding/**

Audiencia Pública:

Según la Constitución del Estado de California, los propietarios de tierras sujetas a la Tarifa de Operaciones propuesta del CGA tienen derecho a protestar por su adopción. Si ha recibido este aviso, las parcelas de su propiedad estarán sujetas a la Tarifa de Operaciones de CGA si se adoptan. En el caso de una protesta mayoritaria, la tarifa no será instituida.

Propietarios que deseen protestar por la Tarifa de Operaciones propuesta del CGA deben enviar su protesta por escrito a:

Colusa Groundwater Authority
c/o Provost & Pritchard Consulting Group
P.O. Box 8929
Chico, California 95927

Las Protestas también pueden presentarse al Secretario de la Junta en la Audiencia Pública, ubicada en el 100 Sunrise Blvd., Colusa, California. **Todas las protestas deben ser recibidas antes de las 5:00 p.m. día 5 de Junio del 2019 o en persona al cierre de la Audiencia Pública el 5 de Junio del 2019.**

Hay varias maneras de obtener información adicional sobre este tema:

- Llame al Consultor del CGA al **(916) 918-2002.**
- Vea más información en línea en la página **https://colusagroundwater.org**
- Para leer este aviso en Español, visite el sitio web de CGA: https://colusagroundwater.org/long-term-funding/
- Para más información sobre SGMA, consulte el sitio web del Departamento de Recursos Hídricos de California: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management

Si no desea protestar por la Tarifa de Operaciones propuesta del CGA, no necesita realizar ninguna diligencia.

Para Protestar:

Todas las protestas deben incluir:

- Nombre escrito del dueño(s),
- Número de parcela para cada propiedad afectada por la Tarifa de Operaciones del CGA.
- Razón para la protesta, y
- Firma(s) válida(s)

Cada parcela tiene derecho a una protesta. Si una parcela tiene más de un propietario, todos deben firmar la protesta; de lo contrario, la protesta se computará de acuerdo con el porcentaje de propiedad de la persona o personas que firman la protesta.

Para su conveniencia puede utilizar el Formulario de Protesta que está a continuación:



FORMULARIO DE PROTESTA PARA LA ADOPCIÓN DE LA TARIFA DE OPERACIONES PROPUESTA DEL CGA

Nombre escrito del Dueño(s): _____

_____

_____

_____

_____

Número de Parcela(s): _____

_____

Razón para la Protesta:

Firma del propietario(s): _____

_____

_____

_____

_____

COLUSA GROUNDWATER AUTHORITY

AFFIDAVIT OF MAILING OF NOTICE OF HEARING AND MAJORITY PROTEST FORM TO CERTAIN LANDOWNERS WITHIN THE BOUNDARIES OF THE COLUSA GROUNDWATER AUTHORITY

STATE OF CALIFORNIA)
) ss.
COUNTY OF COLUSA)

The undersigned says:

That I, Linda G. Sloan, am Vice President of Provost & Pritchard Consulting, an agent of the Colusa Groundwater Authority, and was responsible for managing the mailing the Notice of Public Hearing to landowners from a list prepared from the County's tax roll on the Authority's proposed property-related fee.

I declare that at or before 5:00 p.m. on April 17, 2019, I supervised the mailing of copies of the "**NOTICE OF PROPOSED FEE**", and protest form, both in the form attached hereto marked Exhibit "A", to all landowners that would be affected by the Authority's proposed fee within the boundaries of the Authority as shown on the roll attached as Exhibit "B". Each Notice contained the specific applicable information taken from the roll.

That said mailing was accomplished by depositing in the United States Mail at Chico, California, with proper and necessary postage prepaid, envelopes addressed as aforesaid.

I CERTIFY under penalty of perjury that the foregoing is true and correct.

Executed at ~~Colusa~~ Siskiyou County, California, this 30th day of May, 2019.

Linda G. Sloan

Please see attached sheet
for CA Acknowledgment/Jurat
As per CA Civil Codes 1189/8202

Exhibit A: Notice and Protest Form
Exhibit B: County's Tax Roll

CALIFORNIA ALL-PURPOSE ACKNOWLEDGMENT

A notary public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity

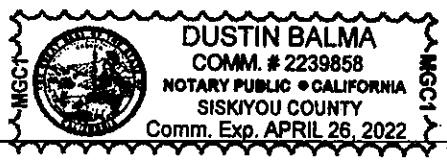
State of California)
)
County of Siskiyou)

On 05-30-2019 before me, Dustin Balma, Notary Public, personally appeared

Linda G Sloan, who proved to me on the basis of satisfactory evidence to be the person(s) whose name is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.



SIGNATURE OF NOTARY

Colusa Groundwater Authority

Groundwater Sustainability Agency

100 Sunrise Blvd., Suite A | Colusa, CA 95932 | 530.458.7709

AGENDA

Informational Meeting
Sustainable Groundwater Management Act (SGMA)
Implementation and Funding

January 31, 2019
6:00 - 8:00 p.m.
Colusa Indian Community Events Center,
3740 Highway 45, Colusa, CA 95932 (Just south of Casino)

6:00 **Meeting Kickoff and Agenda Review*** (Facilitator – Dave Ceppos, Sacramento State)

6:05 **Welcome and Introductions** (Denise Carter, Chair – Colusa Groundwater Authority [CGA] and Colusa County Supervisor)

6:15 **Presentation**

- **Sustainable Groundwater Management Act Overview** (Dave Ceppos)
- **Colusa Groundwater Authority Background** (Denise Carter)
- **Financing SGMA** (Dave Ceppos, Linda Sloan, Provost & Pritchard Consulting Group)
- **SGMA Local Compliance and Potential State Actions** (Dave Ceppos)

7:10 **CGA Board Member Panel – Questions and Answers** (Denise Carter, Hilary Reinhard - RD 108, CGA Vice Chair; Darrin Williams – Private Pumper, Jessie Cain - City Manager, City of Colusa)

8:00 **Adjourn**

*Every agenda item will include an opportunity for public questions and answers.
*Breaks will be taken as time permits and at the discretion of the facilitator

Public Workshop

Sustainable Groundwater Management Act and Proposed Funding

Hosted by the Glenn Groundwater Authority

YOUR Local Groundwater Management Agency

March 21, 2019 at 6:00 pm, Glenn Success Square Conference Center, 131 E. Walker St., Orland, CA 95963

Workshop topics include:

Sustainable Groundwater Management Act (SGMA)

- ✓ SGMA Requirements
- ✓ Deadlines and Milestones
- ✓ Local control vs. State Intervention
- ✓ Groundwater Basins/Subbasins
- ✓ Groundwater Sustainability Agencies
- ✓ Groundwater Sustainability Plan development and implementation

The Glenn Groundwater Authority (GGA)

- ✓ Agency responsible for SGMA planning and implementation in Glenn County portion of the Colusa subbasin
- ✓ Board of Directors with membership from local cities, irrigation districts and the County
- ✓ Coordinates with the Colusa Groundwater Authority and neighboring agencies
- ✓ Long-term funding

Glenn Groundwater Authority
PO Box 351
Willows, CA 95988

Process Required for GGA Operations Fee or Charge:



Your Input is Needed:

SGMA is a complex new state law requiring management of groundwater. This workshop is an opportunity to learn about SGMA, the funding process and proposed assessment. **Questions and input are encouraged**. If you are unable to attend and want to be notified of other opportunities to provide input, please contact Mallory Serrao (mserrao@ppeng.com; 916-918-2002).

For more information regarding GGA: www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority

Additional SGMA information available at:

- ✓ Department of Water Resources: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management
- ✓ State Water Resources Control Board: https://www.waterboards.ca.gov/water_issues/programs/gmp/sgma.html

GLENN GROUNDWATER AUTHORITY
NOTICE OF HEARING ON PROPOSED FEE

In compliance with California State Law, notice is hereby given that the Glenn Groundwater Authority (GGA) will conduct a **public hearing on:**

July 8, 2019 at 5:30 p.m. at the City of Willows Council Chamber, 201 N. Lassen St., Willows, CA to consider the adoption of a **new property related fee in the amount of $1.93 per acre annually** for the 2019 Fiscal Year and the subsequent four fiscal years, to fund operations of the GGA.

Notificación en Español:

Para leer este aviso en Español, visite el sitio web de GGA https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority o llame (916) 918-2020 para solicitar que se le envíe un aviso por correo o correo electrónico.

Background:

The GGA is a nine-member, multi-agency Joint Powers Authority that was formed on June 20, 2017. The GGA is the Groundwater Sustainability Agency (GSA) responsible for implementation and compliance of the Sustainable Groundwater Management Act (SGMA) in the Glenn County portion of the Colusa Subbasin (5-21.52). The Board of the GGA is composed of representatives of the following:

> County of Glenn, City of Orland, City of Willows, Glenn-Colusa Irrigation District, Glide Water District, Princeton-Codora-Glenn/Provident Irrigation District (1 seat), Orland-Artois Water District, and Kanawha Water District.

As a groundwater regulating agency, the GGA (in partnership with other adjacent GSAs such as the Colusa Groundwater Authority [CGA]) is tasked with achieving and maintaining sustainable groundwater conditions in the Colusa Subbasin (Basin). Compliance with SGMA is achieved through the preparation and implementation of one or more Groundwater Sustainability Plans (GSP or Plan). Plan development is underway in the Basin and the Plan(s) must be adopted by January 31, 2022. If the local GSAs do not comply with SGMA including the development of the Plan(s) and the necessary activities required to implement the Plans, the State Water Resources Control Board may take over groundwater management responsibilities.

Long-Term Funding:

In order to ensure initial SGMA compliance and to provide a mechanism to begin this long-range effort, the GGA Member agencies agreed to fund the agency operations for the first two years. GGA operations include administration, legal services, consultant services, insurance, office and outreach materials, accounting, monitoring and reporting to DWR, and special studies, if needed. The GGA has received Proposition 1 grant funding to cover a majority of the work to develop a Plan; however, costs for Plan preparation and initial implementation that are in excess of grant funding will also need to be covered by the GGA Operations Fee.

To fund its activities and the development of an adequate Plan, the GGA developed a budget for annual operations expenses for a five-year period spanning fiscal years 2019/20 to 2023/24. This budget includes projected costs for Plan preparation and initial implementation, administration, legal services, insurance, printing/copying, accounting, facilitation, monitoring and reporting to the Department of Water Resources (DWR), and special studies, if needed.

SGMA provides authority for GGA to charge fees to support its operations. The GGA has retained Provost & Pritchard Consulting Group to prepare a fee study to review the best options to fund GGA operations over the next five years. An operations cost and fee analysis is included in the study. Each parcel of land within the GGA's

boundary is receiving SGMA management services from the GGA and the fee was developed by allocating the GGA budget in proportion to the cost of providing services to each acre of land in its service area. By law, the GGA may not collect more revenue from property related fees than is necessary to provide the cost of the water related service.

One of the GGA's foundational Guiding Principles is to protect its service area from **extremely expensive and intrusive State groundwater intervention actions**.

If the State Water Resources Control Board intervenes in the Basin, it may impose annual fees ranging from $100 per de minimis well, to $300 per well plus up to $55 per acre-foot pumped per well, with no guarantee of assistance in bearing costs to address any groundwater issues that prompt its intervention. See https://www.waterboards.ca.gov/water_issues/programs/gmp/docs/intervention/intervention_fs.pdf. for more complete information. By collecting the Operations Fees, GGA will provide landowners with local groundwater management with a tailored, more affordable approach for managing the Basin.

Notice:

In addition to this notice, the GGA has also posted the notice on the GGA website at https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority and has been published in accordance with Government Code 6066 and Water Code section 10730.

Proposed Property Related Fee:

This notice is for the GGA's proposal to implement a per-acre charge to fund the GGA operations, supplement Plan preparation, and begin initial GSP implementation. The GGA is considering the adoption of a property related fee in the amount of:

- **$1.93 per acre** (in 2019 dollars)
- The proposed charges, if approved, will become effective for the 2019/20 Glenn County fiscal year, with the first payment due by December 10, 2019.

For more information, including the fee study summarizing the findings, please visit the GGA website at https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority or call Provost & Pritchard (GGA's Consultant) at (916) 918-2002. The fee study is also available for review during normal business hours at 720 N Colusa St., Willows, CA 95988.

Public Hearing and Majority Protest:

The proposed GGA Operations Fee is a property related fee governed by Proposition 218. Under the California State Constitution, owners of land subject to the proposed GGA Operations Fee have the right to protest its adoption. If you have received this notice, parcel(s) under your ownership will be subject to the GGA Operations Fee if adopted. If written protests are submitted accounting for a majority of the total assessed parcels, GGA will not adopt the Operations Fee. Absent a majority protest, GGA is authorized to adopt the proposed Operations Fee at the public adoption hearing.

Landowners desiring to protest the proposed GGA Operations Fee should send their written protest to:

Glenn Groundwater Authority
c/o Provost & Pritchard Consulting Group
P.O. Box 8929
Chico, California 95927

Protests may also be submitted to the Board Secretary at the Public Hearing, located at the City of Willows Council Chamber, 201 N. Lassen St., Willows, California. **All protests must be received by the close of the Public Hearing on July 8, 2019 to be counted**.

Information Availability:

- Call Provost & Pritchard (GGA's Consultant) at **(916) 918-2002**
- View more information online at https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority
- Para leer este aviso en Español, visite el sitio web de GGA https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority o llame (916) 918-2020 para solicitar que se le envíe un aviso por correo o correo electrónico.

- The Fee Study is available for review during normal business hours at 720 N Colusa St., Willows, CA 95988
- For more information about SGMA, see the California Department of Water Resources website: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management

If you do not wish to protest the proposed GGA Operations Fee, you need not take any action.

To Protest:

All protests must include:

- Landowners printed name(s),
- Parcel number(s) or street address for each property affected by the GGA Operations Fee,
- Statement of opposition or protest, and
- Valid signature(s)

Each parcel is entitled to one protest. The protest may be mailed in or hand delivered at the hearing but must be received by the GGA by the close of the hearing to count toward the protest vote.

For your convenience, you may utilize the Protest Form below:



PROTEST FORM FOR THE ADOPTION OF PROPOSED GGA OPERATIONS FEE

Landowner(s) printed name: _____

_____

_____

Parcel Number(s): _____

_____

Reason for Protest:

Landowner(s) signature: _____

_____

_____

GLENN GROUNDWATER AUTHORITY
AVISO DE AUDIENCIA SOBRE LA TARIFA PROPUESTA

En cumplimiento de la Ley del Estado de California, se notifica que la Glenn Groundwater Authority (GGA) realizará una **audiencia pública el día:**

8 de Julio del 2019 a las 5:30 p.m. en la Cámara del Consejo de la Ciudad de Willows ubicada en 201 N. Lassen St., Willows, CA para considerar la adopción de una **nueva tarifa relacionada con la propiedad en la cantidad de $ 1.93 por acre por año** para el Año Fiscal 2019 y los cuatro años fiscales subsiguientes, para financiar las operaciones de la GGA.

Antecedentes:

La GGA es una multi-agencia de Autoridad de Poderes Conjuntos constituida por nueve miembros que se formó el 20 de Junio del 2017. La GGA es la Agencia de Sostenibilidad del Agua Subterránea (GSA) responsable de la implementación y el cumplimiento de la Ley de Administración Sostenible del Agua Subterránea (SGMA) en el Condado de Glenn en la porción correspondiente de la Subcuenca de Colusa (5-21.52). El Consejo de la GGA está compuesta por representantes de las siguientes agencias:

> Condado de Glenn, Ciudad de Orland, Ciudad de Willows, Glenn-Colusa Irrigation District, Glide Water District, Princeton-Codora-Glenn Irrigation District / Provident Irrigation District (1 asiento), Orland-Artois Water District, y Kanawha Water District.

Como agencia reguladora del agua subterránea, la GGA (en asociación con otras GSA adyacentes, como la Colusa Groundwater Authority [CGA]) tiene la tarea de lograr y mantener condiciones sostenibles de las aguas subterráneas en la Subcuenca de Colusa (Cuenca). El cumplimiento con SGMA se logra a través de la preparación e implementación de uno o más Planes de Sostenibilidad de Agua Subterránea (GSP o Plan). El desarrollo del plan está en marcha en la Cuenca y el (los) Plan (es) debe (n) ser adoptado (s) antes del 31 de Enero del 2022. Si las GSA locales no cumplen con SGMA, incluido el desarrollo del (los) Plan (es) y las actividades necesarias para implementar los Planes, la Junta de Control de los Recursos Hídricos del Estado puede asumir las responsabilidades de administración del agua subterránea.

Financiamiento a Largo Plazo:

Con el fin de garantizar el cumplimiento inicial de SGMA y proporcionar un mecanismo para comenzar este esfuerzo de largo plazo, las agencias de Miembro de GGA acordaron financiar las operaciones de la agencia durante los primeros dos años. Las operaciones de GGA incluyen administración, servicios legales, servicios de consultoría, seguros, materiales de oficina y educación, contabilidad, monitoreo e informes al DWR, y estudios especiales, si son necesarios. El GGA ha recibido fondos de la Proposición 1 para cubrir la mayoría del trabajo para desarrollar un Plan; sin embargo, los costos para la preparación del Plan y la implementación inicial que excedan los fondos iniciales disponibles deberán también cubrirse con la Tarifa de Operaciones de GGA.

Para financiar sus actividades y el desarrollo de un Plan adecuado, el GGA desarrolló un presupuesto para los gastos de operaciones anuales para un período de cinco años que incluye los años fiscales 2019/20 a 2023/24. Este presupuesto incluye los costos proyectados para la preparación e implementación inicial del Plan, la administración, los servicios legales, los seguros, la impresión / copia, la contabilidad, la facilitación, el monitoreo y la presentación de informes al Departamento de Recursos Hídricos (DWR), y estudios especiales, si son necesarios.

SGMA otorga autoridad a GGA para cobrar tarifas para apoyar sus operaciones. GGA ha contratado a Provost & Pritchard Consulting Group para preparar un estudio de tarifas para revisar las mejores opciones para financiar las operaciones de GGA en los próximos cinco años. El estudio incluye un análisis de costos y tarifas de operaciones. Cada parcela de terreno dentro del límite de GGA recibe servicios de administración de SGMA de GGA y la tarifa se desarrolló asignando el presupuesto de GGA en proporción al costo de proporcionar servicios a cada acre de terreno en su área de servicio. Por ley, la GGA no puede recaudar más ingresos de las tarifas relacionadas con la propiedad de lo que es necesario para proporcionar el costo del servicio relacionado con el agua.

Uno de los Principios Rectores fundamentales es el de proteger su área de servicio de **acciones de intervención estatales del agua subterránea extremadamente costosas e intrusivas**.

Si la Junta de Control de los Recursos Hídricos del Estado interviene en la cuenca, podría imponer tarifas anuales con un mínimo de $100 por pozo, y hasta de $300 por pozo, y adicionalmente hasta $55 por acre-pie bombeado por pozo, sin garantía de asistencia en los costos de soporte para resolver los problemas de agua subterránea que causan su intervención. Para mayor información consulte el vínculo https://www.waterboards.ca.gov/water_issues/programs/gmp/docs/intervention/intervention_fs.pdf.
Al cobrar la Tarifa de Operaciones, la GGA les brindará a los propietarios una administración local del agua subterránea con un enfoque personalizado y más accesible para la administración de la Cuenca.

Notificación en Español:

Para leer este aviso en Español, visite el sitio web de la GGA https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority o llame al (916) 918-2020 para solicitar que se le envíe un aviso por correo o correo electrónico.

Aviso:

Además de este aviso, la GGA también publicó el aviso en el sitio web de la GGA en https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority y se publicó de conformidad con el Código de Gobierno 6066 y la sección 10730 del Código de Aguas.

Tarifa de Propriedad Propuesta:

Este aviso es para la propuesta de la GGA para implementar un cobro por acre para financiar las operaciones de la GGA, suplementar la preparación del Plan, y empezar la implementación inicial del GSP. La GGA está solicitando un cargo de:

- **$1.93 por acre** (en dólares del 2019)
- Los cargos propuestos, si se aprueban, entrarán en vigencia para el año fiscal 2019/20 del Condado de Glenn, con el primer pago que debe realizarse antes del 10 de Diciembre del 2019.

Para obtener más información, incluido el estudio de tarifas que resume los resultados, visite el sitio web de la GGA en https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority o llame a Provost & Pritchard (Consultor de GGA) al (916) 918-2002. El estudio de tarifas también está disponible para revisión durante las horas normales de trabajo en 720 N Colusa St., Willows, CA 95988.

Audiencia Pública y Protesta Mayoritaria:

La Tarifa de Operaciones del GGA propuesta es una tarifa relacionada con la propiedad que se rige por la Proposición 218. Según la Constitución del Estado de California, los propietarios de tierras sujetas a la Tarifa de Operaciones de la GGA propuesta tienen el derecho de protestar por su adopción. Si ha recibido este aviso, las parcelas bajo su propiedad estarán sujetas a la adopción de la Tarifa de Operaciones de la GGA. Si se presentan protestas por escrito que representan la mayoría del total de parcelas evaluadas, la GGA no adoptará la Tarifa de Operaciones. A falta de una protesta mayoritaria, la GGA está autorizada para adoptar la Tarifa de Operaciones propuesta en la audiencia pública de adopción.

Los propietarios que deseen protestar la Tarifa de Operaciones de la GGA propuesta deben enviar su protesta por escrito a:

Glenn Groundwater Authority
c/o Provost & Pritchard Consulting Group
P.O. Box 8929
Chico, California 95927

Las protestas también pueden presentarse al Secretario de la Junta en la Audiencia Pública, ubicada en la Cámara del Consejo de la Ciudad de Willows, 201 N. Lassen St., Willows, California. **Todas las protestas deben recibirse antes del cierre de la audiencia pública del 8 de Julio del 2019 para ser contadas.**

Disponibilidad de Información:

- Llame a Provost & Pritchard (Consultor de GGA) al **(916) 918-2002**
- Vea más información en línea en https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority
- Para leer este aviso en Español, visite el sitio web de la GGA https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority o llame al (916) 918-2020 para solicitar que se le envíe un aviso por correo o correo electrónico.
- El Estudio de Tarifas está disponible para revisión durante las horas normales de trabajo en 720 N Colusa St., Willows, CA 95988
- Para obtener más información sobre SGMA, consulte el sitio web del Departamento de Recursos Hídricos de California: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management

Si no desea protestar por la Tarifa de Operaciones de la GGA propuesta, no necesita realizar ninguna acción.

Para Protestar:

Todas las protestas deben incluir:

- Nombre escrito del(los) dueño(s),
- Número de la(s) parcela(s) o dirección para cada propiedad afectada por la Tarifa de Operaciones de la GGA.
- Declaración de oposición o protesta, y
- Firma(s) válida(s)

Cada parcela tiene derecho a una protesta. La protesta puede ser enviada por correo o entregada personalmente en la audiencia, pero debe ser recibida por la GGA antes del cierre de la audiencia para el conteo de los votos de protesta.

Para su conveniencia puede utilizar el Formulario de Protesta que está a continuación:



FORMULARIO DE PROTESTA PARA LA ADOPCIÓN DE LA TARIFA DE OPERACIONES

Nombre escrito del(los) Dueño(s): _____

_____

_____

Número(s) de Parcela(s): _____

_____

Razón para la Protesta:

Firma del(los) propietario(s): _____

_____

_____

GLENN GROUNDWATER AUTHORITY

AFFIDAVIT OF MAILING OF NOTICE OF HEARING AND MAJORITY PROTEST FORM TO CERTAIN LANDOWNERS WITHIN THE BOUNDARIES OF THE GLENN GROUNDWATER AUTHORITY

STATE OF CALIFORNIA)
) ss.
COUNTY OF GLENN)

The undersigned says:

That I, Linda G. Sloan, am Vice President of Provost & Pritchard, an agent of the Glenn Groundwater Authority, and was responsible for managing the mailing the Notice of Public Hearing to landowners from a list prepared from the County's tax roll on the Authority's proposed property-related fee.

I declare that at or before 5:00 p.m. on May 23, 2019, I supervised the mailing of copies of the "**NOTICE OF PROPOSED FEE**", and protest form, both in the form attached hereto marked Exhibit "A", to all landowners that would be affected by the Authority's proposed fee within the boundaries of the Authority as shown on the roll attached as Exhibit "B". Each Notice contained the specific applicable information taken from the roll.

That said mailing was accomplished by depositing in the United States Mail at Chico, California, with proper and necessary postage prepaid, envelopes addressed as aforesaid.

I CERTIFY under penalty of perjury that the foregoing is true and correct.

Executed at Siskiyou County, California, this 8 day of July, 2019.

Linda G. Sloan

Please see attached sheet for CA
Acknowledgment/Jurat
As per CA Civil Codes 1189/8202

Exhibit A: Notice and Protest Form
Exhibit B: County's Tax Roll

CALIFORNIA ALL-PURPOSE ACKNOWLEDGEMENT

A Notary Public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity of that document.

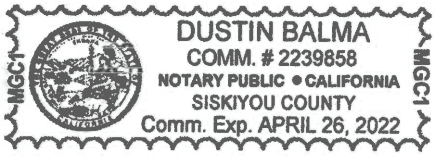
State of California
County of Siskiyou }

On 8th July 2019, before me, Dustin Balma, Notary Public,

personally appeared Linda G Sloan

who proved to me on the basis of satisfactory evidence to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of State of California that the foregoing paragraph is true and correct.



PLACE NOTARY SEAL ABOVE

WITNESS my hand and official seal.

SIGNATURE

PROOF OF PUBLICATION

No. 3778

In the Matter of

Glenn Groundwater Authority- Notice of Public Hearing on July 8, 2019 at 5:30 pm Pursuant to Water Code section 10730(b)(2) and Government Code section 6066...

State of California)
County of Glenn) ss

The undersigned resident of the County of Glenn, State of California, says:

That I am, and at all time herein mentioned was a citizen of the United States and not a party to nor interested in the above entitled matter; that I am the principal clerk of the publisher of:

The Sacramento Valley Mirror

That said newspaper is one of general circulation as defined by Section 6000 Government Code of the State of California, Case No. 27,207 by the Superior Court of the State of California, in and for the County of Glenn,Case #02CV00614; that said newspaper at all times herein mentioned was published twice a week (on Wednesdays and Saturdays) in the town of Willows and County of Glenn; that the notice of which the annexed is a true printed copy, was published in said newspaper on the following days:

June 22, 29, 2019

I certify (or declare), under penalty of perjury, that the foregoing is true and correct, at the County of Glenn,Willows, California.

Date July 1, 2019
at Willows, California.

Tim Crews, Publisher

NOTICE OF PUBLIC HEARING

Pursuant to Water Code section 10730(b)(2) and Government Code section 6066, notice is hereby given that the Glenn Groundwater Authority will hold a public hearing on **July 8, 2019** at 5:30 pm, or as soon thereafter as may be heard, at the Willows City Council Chambers, 201 North Lassen Street, Willows, CA 95988, to consider the adoption of a new property related fee in the amount of $1.93 per acre annually for the 2019 Fiscal Year and the subsequent four fiscal years to fund the operations of the Glenn Groundwater Authority to comply with the Sustainable Groundwater Management Act of 2014.

Information regarding the proposed fee is available online at https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority/gga-information, by calling the Glenn Groundwater Authority Consultant at (916) 918-2002, or by visiting the Glenn Groundwater Authority office at 720 North Colusa Street, Willows, CA 95988.

RECEIVED
JUL 03 2019
GLENN COUNTY
DEPARTMENT OF AGRICULTURE

Glenn Groundwater Authority

Groundwater Sustainability Agency

PO Box 351, Willows, CA 95988 | 530.934.6501

AGENDA

Public Information Workshop
Sustainable Groundwater Management Act (SGMA)
Implementation and Funding

March 21, 2019
6:00 - 8:00 p.m.
Glenn Success Square Conference Center
131 E. Walker Street, Orland, CA

6:00 **Welcome and Introductions** (John Viegas – Glenn Groundwater Authority [GGA])

6:10 **Meeting Kickoff and Agenda Review*** (Facilitator – Dave Ceppos - Sacramento State)

6:15 **Presentation** (Dave Ceppos)

- **Sustainable Groundwater Management Act Overview**
- **Glenn Groundwater Authority Background**
- **Financing SGMA Implementation**
- **SGMA Local Compliance and Potential State Intervention**

7:15 **Questions and Answer Session**

8:00 **Adjourn**

*Attendees will be given cards to write questions they would like answered during the Question and Answer Session. Board members and staff will be available to help formulate questions, bring new comment cards, and collect comment cards.
*Breaks will be provided as time permits and at the discretion of the facilitator

Glenn Groundwater Authority

Groundwater Sustainability Agency

PO Box 351, Willows, CA 95988 | 530.934.6501

AGENDA

Public Information Workshop
Sustainable Groundwater Management Act (SGMA)
Implementation and Funding

March 28, 2019
6:00 - 8:00 p.m.
Willows City Council Chambers
201 N Lassen St, Willows, CA

6:00 **Welcome and Introductions** (John Amaro – Glenn Groundwater Authority [GGA])

6:10 **Meeting Kickoff and Agenda Review*** (Facilitator – Dave Ceppos - Sacramento State)

6:15 **Presentation** (Dave Ceppos)

- **Sustainable Groundwater Management Act Overview**
- **Glenn Groundwater Authority Background**
- **Financing SGMA Implementation**
- **SGMA Local Compliance and Potential State Intervention**

7:15 **Questions and Answer Session**

8:00 **Adjourn**

*Attendees will be given cards to write questions they would like answered during the Question and Answer Session. Board members and staff will be available to help formulate questions, bring new comment cards, and collect comment cards.
*Breaks will be provided as time permits and at the discretion of the facilitator

Glenn Groundwater Authority Contact Information

Lisa Hunter
Program Manager
PO Box 351
720 N Colusa St
Willows, CA 95988
(530) 934-6501
Lhunter@countyofglenn.net

Stay Involved

- Sign up for email updates and notifications
  - Fill out the email sign-up form
  - Email glennsgma@countyofglenn.net
  - Call (530) 934-6501 and request to be added to the email list
- Attend meetings- check website (see below) for location, updates, meeting announcements, or cancellations
  - Regular Board Meetings: 2nd Monday of each month at 1:30 pm
  - Executive Committee Meetings: 4th Wednesday of each month at 9:30 am

Public Workshops

March 21
6-8pm
Glenn Success Square Conference Center
131 E Walker St
Orland, CA 95963

March 28
6-8pm
Willows City Council Chambers
201 N Lassen St
Willows, CA 95988

April 2
6-8pm
Ord Bend Community Hall
3241 Highway 45
Glenn, CA 95943



Links to additional information:

- Glenn Groundwater Authority: https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority
- Glenn County SGMA Activities: https://www.countyofglenn.net/dept/agriculture/water-resources/sustainable-groundwater-management-act-sgma-0
- Department of Water Resources: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management
- State Water Resources Control Board: https://www.waterboards.ca.gov/water_issues/programs/groundwater/

Glenn Groundwater Authority

Groundwater Sustainability Agency

PO Box 351, Willows, CA 95988 | 530.934.6501

AGENDA

Public Information Workshop
Sustainable Groundwater Management Act (SGMA)
Implementation and Funding

April 2, 2019
6:00 - 8:00 p.m.
Ord Bend Community Hall
3241 Highway 45, Glenn, CA

6:00 **Welcome and Introductions** (John Viegas – Glenn Groundwater Authority [GGA])

6:10 **Meeting Kickoff and Agenda Review*** (Facilitator – Dave Ceppos - Sacramento State)

6:15 **Presentation** (Dave Ceppos)

- **Sustainable Groundwater Management Act Overview**
- **Glenn Groundwater Authority Background**
- **Financing SGMA Implementation**
- **SGMA Local Compliance and Potential State Intervention**

7:15 **Questions and Answer Session**

8:00 **Adjourn**

*Attendees will be given cards to write questions they would like answered during the Question and Answer Session. Board members and staff will be available to help formulate questions, bring new comment cards, and collect comment cards.
*Breaks will be provided as time permits and at the discretion of the facilitator

Glenn Groundwater Authority Contact Information

Lisa Hunter
Program Manager
PO Box 351
720 N Colusa St
Willows, CA 95988
(530) 934-6501
Lhunter@countyofglenn.net

Stay Involved

- Sign up for email updates and notifications
  - Fill out the email sign-up form
  - Email glennsgma@countyofglenn.net
  - Call (530) 934-6501 and request to be added to the email list
- Attend meetings- check website (see below) for location, updates, meeting announcements, or cancellations
  - Regular Board Meetings: 2nd Monday of each month at 1:30 pm
  - Executive Committee Meetings: 4th Wednesday of each month at 9:30 am

Public Workshops

March 21
6-8pm
Glenn Success Square Conference Center
131 E Walker St
Orland, CA 95963

March 28
6-8pm
Willows City Council Chambers
201 N Lassen St
Willows, CA 95988

April 2
6-8pm
Ord Bend Community Hall
3241 Highway 45
Glenn, CA 95943



Links to additional information:

- Glenn Groundwater Authority: https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority
- Glenn County SGMA Activities: https://www.countyofglenn.net/dept/agriculture/water-resources/sustainable-groundwater-management-act-sgma-0
- Department of Water Resources: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management
- State Water Resources Control Board: https://www.waterboards.ca.gov/water_issues/programs/groundwater/

Glenn Groundwater Authority

Public Hearing on Proposed Property Related Fee

July 8, 2019

Dave Ceppos
Consensus and Collaboration Program
College of Continuing Education, Sacramento State

Program

- Sustainable Groundwater Management Act (SGMA) Overview
- Glenn Groundwater Authority
- Financing SGMA Implementation



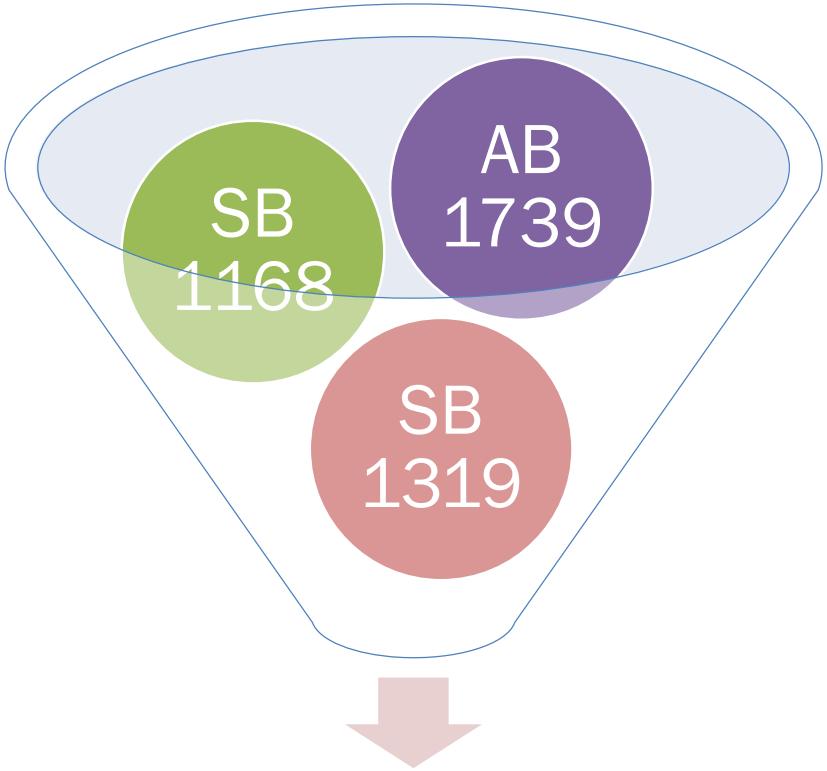


SGMA Overview

SGMA: Sustainable Groundwater Management Act of 2014

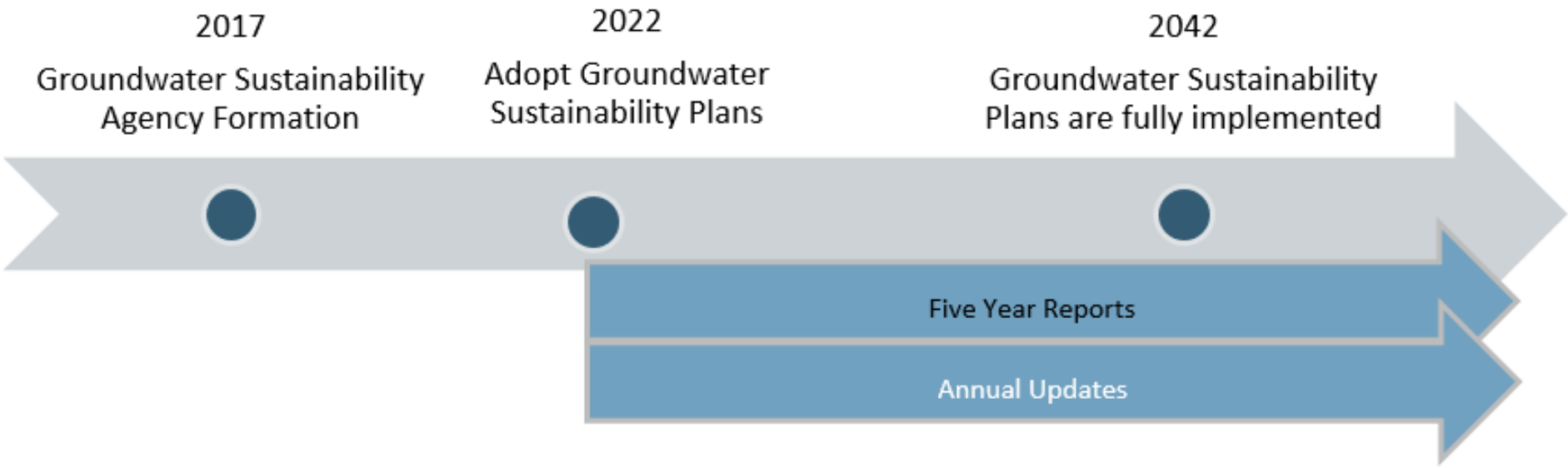
SGMA is Law

- Collection of Three Bills signed into law in 2014
- Established new structure for managing groundwater resources in California
- SGMA is NOT the Irrigated Lands Regulatory Program (Colusa-Glenn Subwatershed)



Sustainable Groundwater Management Act of 2014

SGMA Timeline-
Basins not in Critical Overdraft



Note: Critically overdrafted subbasins have a compressed timeline

SGMA: Who is Affected



Agriculture



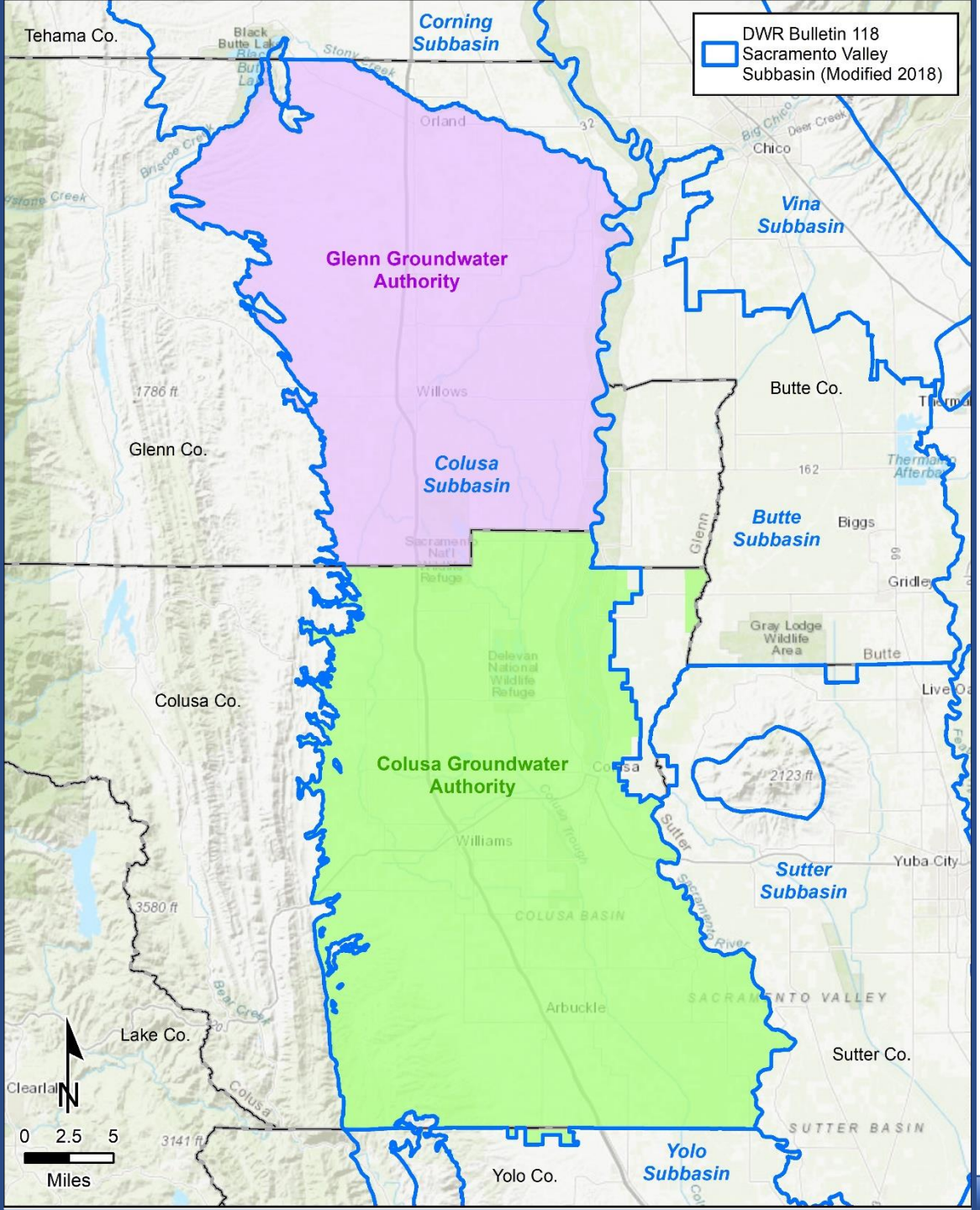
Municipal



Industrial



Environmental



Groundwater Basins & Subbasins

- Department of Water Resources defines:
  - Basin/Subbasin Boundaries (Bulletin 118)
  - Basin Priority
  - Designation of Critical Overdraft (or not)

Map of the Colusa Subbasin

Who Can Manage the Basin?

- Groundwater Sustainability Agency
  - Local Public Agency
  - Land Use
  - Water Supply
  - Water Management

(Glenn Groundwater Authority)

- State Water Resources Control Board

(State Intervention)

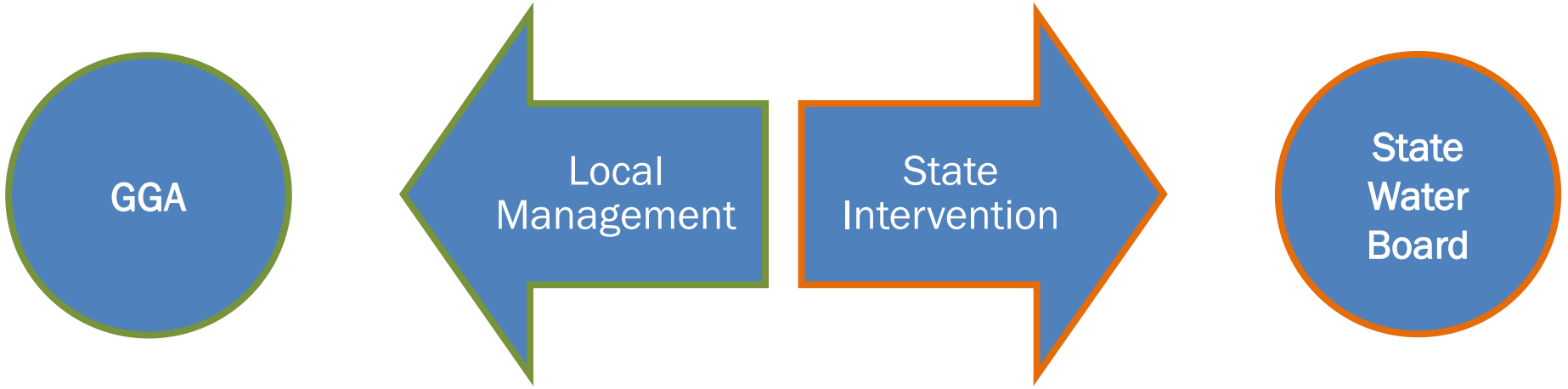


Managing Agency Roles & Responsibilities

- Groundwater Sustainability Plan
  - Development
  - Implementation
  - Reporting
- Consider Interests of Beneficial Uses and Users (Water Code §10723.2)
- Enforcement



Sample Fee Comparison



Scenario:

- 100 acre irrigated parcel
- 1 well
- GGA Local Control

Maximum Local GGA Fees: $193

- 100 acre X $1.93= $193

Scenario:

- 100 acre irrigated parcel
- 1 well
- Probationary basin status

State Water Board Fees: $14,300

- 1 well = $300
- 3.5 AF/ac = 350 AF X $40 = $14,000

Sustainability

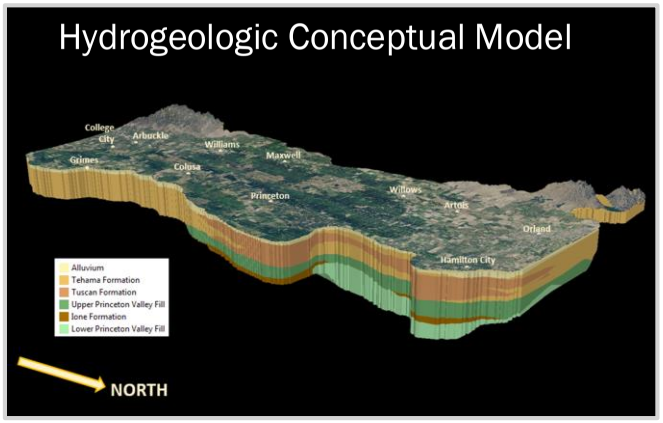
What is Sustainability?

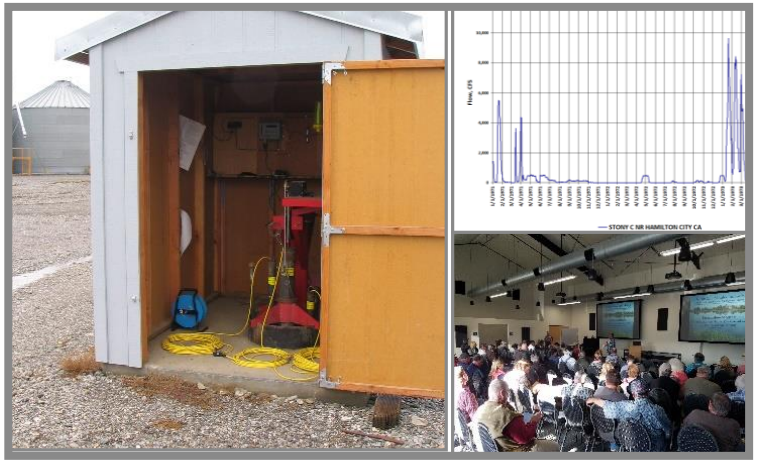
Manage groundwater to prevent significant and unreasonable undesirable results

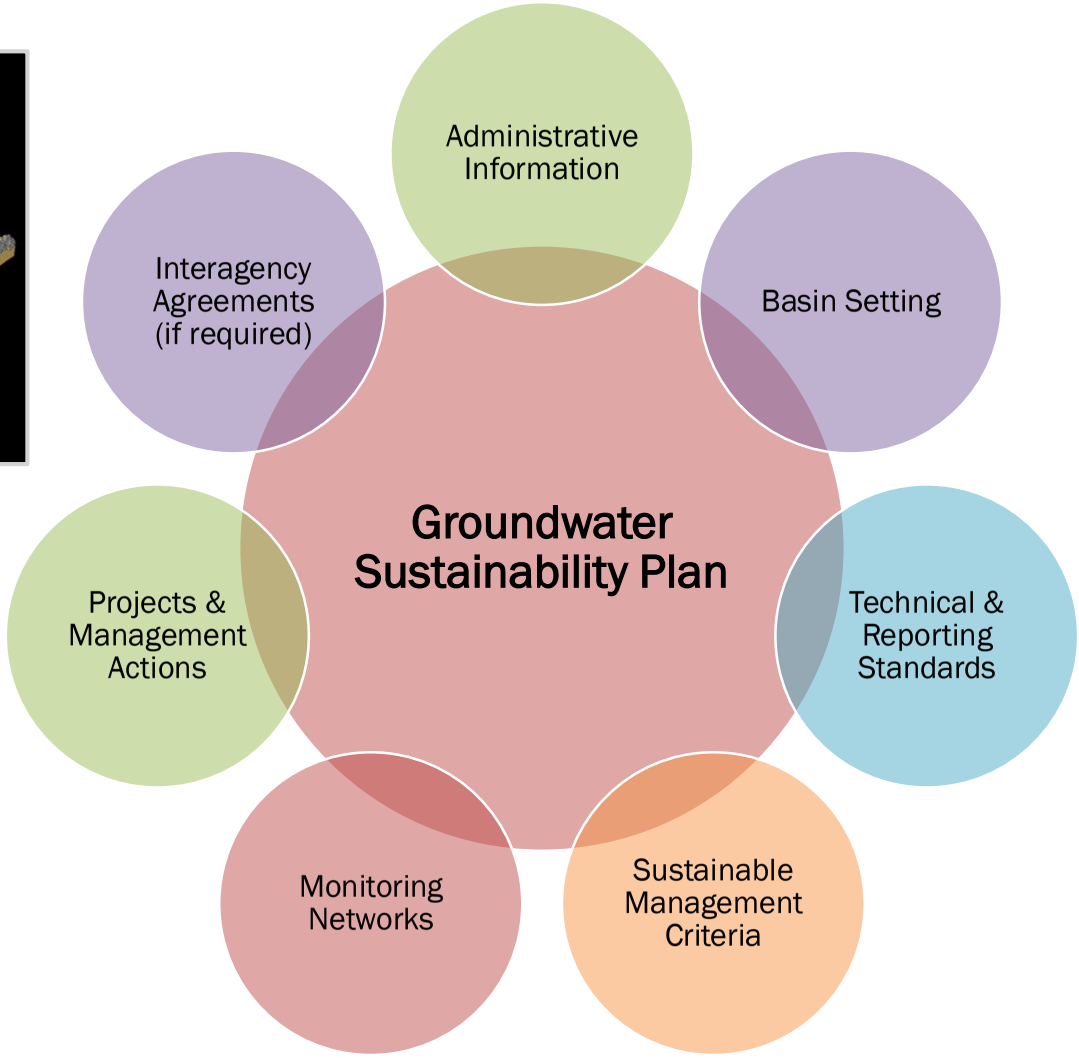


Groundwater Sustainability Plan

What is in a Plan?



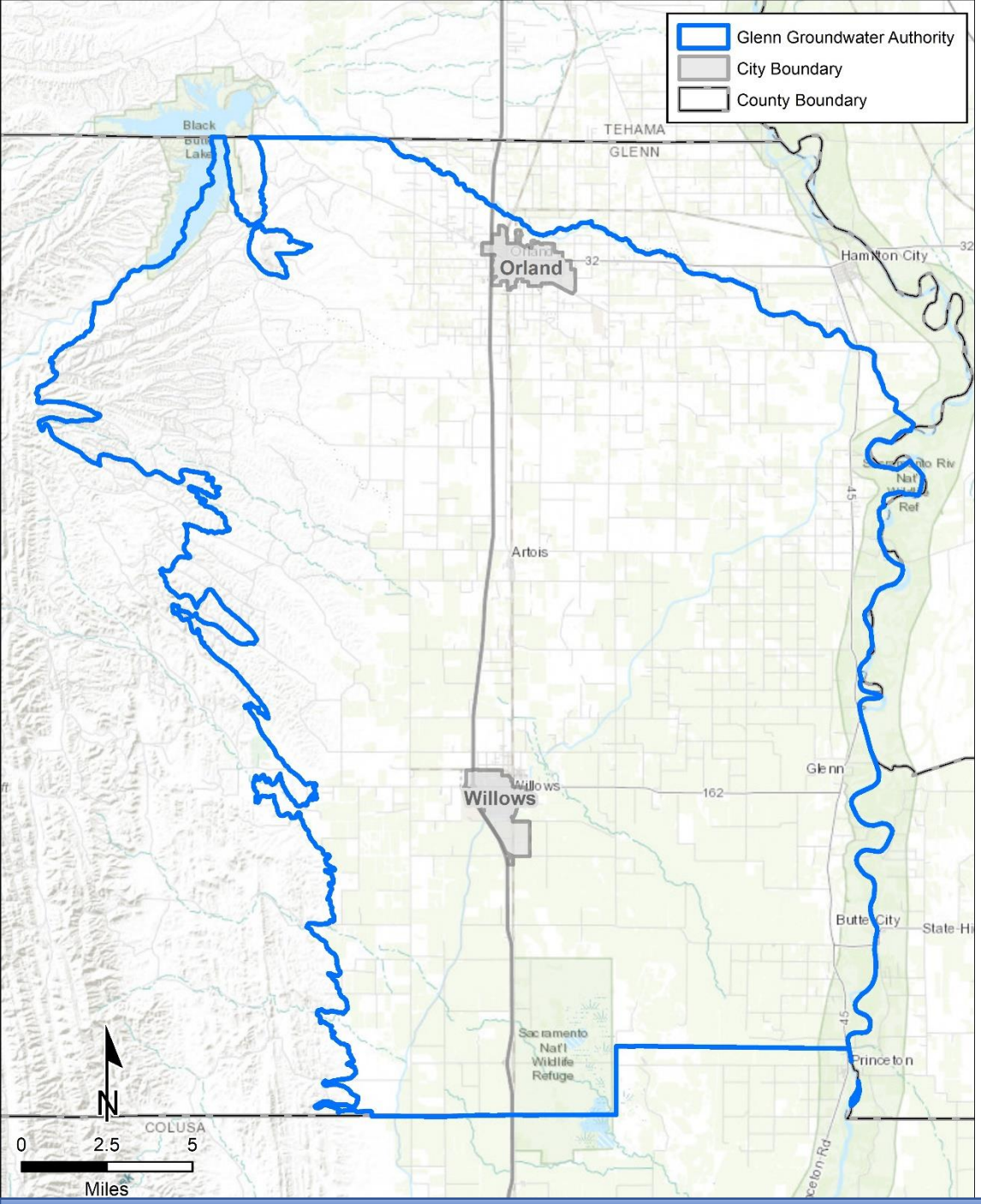






Glenn Groundwater Authority

Your Groundwater Sustainability Agency: Local Management

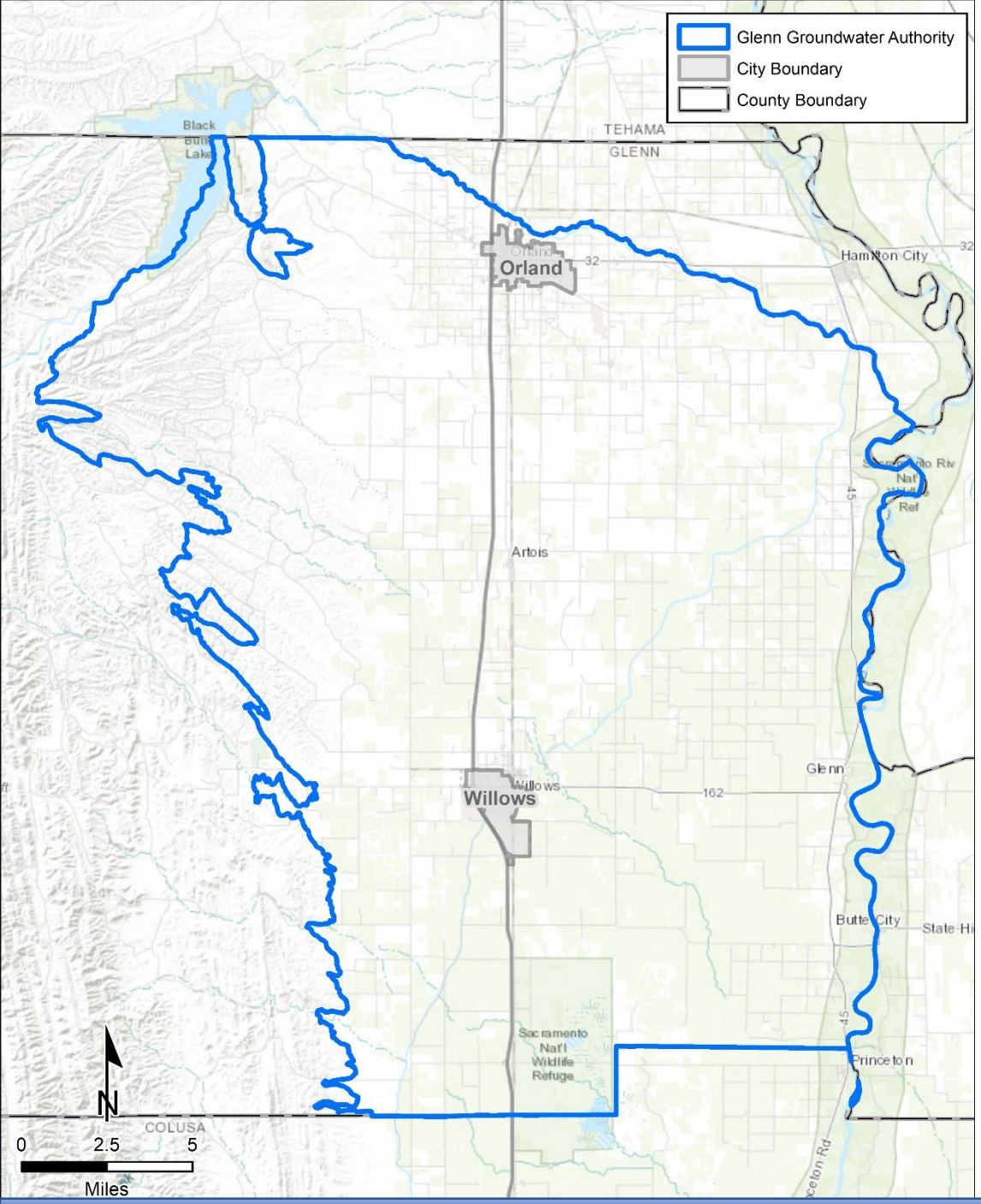


Glenn Groundwater Authority members:

- City of Orland
- City of Willows
- County of Glenn
- Glenn-Colusa Irrigation District
- Glide Water District
- Kanawha Water District
- Orland-Artois Water District
- Princeton-Codora-Glenn Irrigation District
- Provident Irrigation District

One new member pending:

- Glenn Ground Water District



Activities:

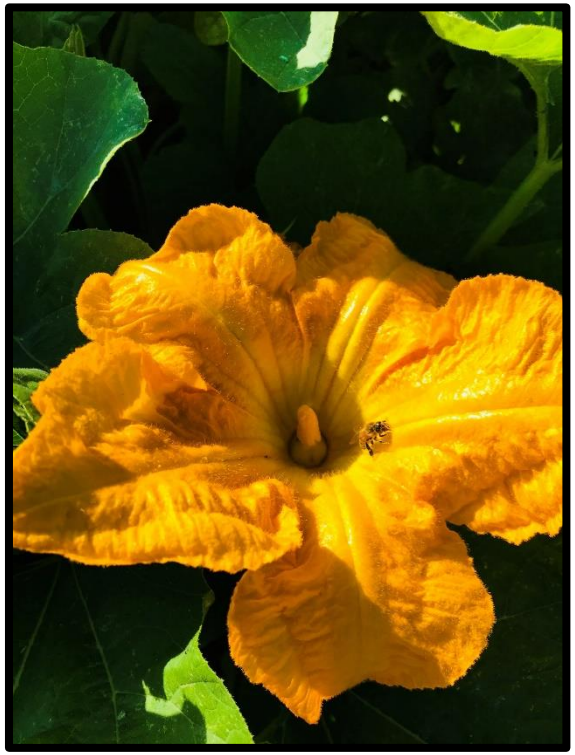
- **Proposition 1 GSP Grant**
- MOU with Colusa Groundwater Authority
- Basin Setting work
  - Hydrogeologic Conceptual Model
  - Water Budget
- **Facilitation Support Services**
  - Stakeholder Communication & Engagement Plan
- **Technical Support Services**
  - Monitoring Well installation
- Request for Proposals for GSP development
- Long-Term Funding Process



Financing SGMA

Financing SGMA

- Activities funded by member agencies for 2 years- beginning in 2017
- Pursued basin-wide funding opportunities with Colusa Groundwater Authority
  - Proposition 1 GSP Development Grant
  - Technical Support Services
  - Facilitation Support Services



Financing SGMA

- **Need long-term funding for day to day operations of the GGA:**

  •Technical: GSP development ($1.5 million), technical studies, monitoring and data management, coordination and outreach efforts, implementation of the GSP, yearly reporting to DWR, Plan updates every five years

  •O&M: Staff, insurance, legal services, bookkeeping, office needs, etc.



Financing SGMA

Proposition 218 Requirements

- GGA contracted with Provost and Pritchard Engineering (P&P) to conduct a Proposition 218 Majority Protest
- P&P completed a fee study to determine a fee structure based on GGA budget and acreages in the GGA's jurisdiction
- Amount of fee cannot exceed the reasonable cost of the activity to be funded
- Three Public Information Workshops were held March-April 2019
- A similar process was completed for the Colusa Groundwater Authority

Financing SGMA

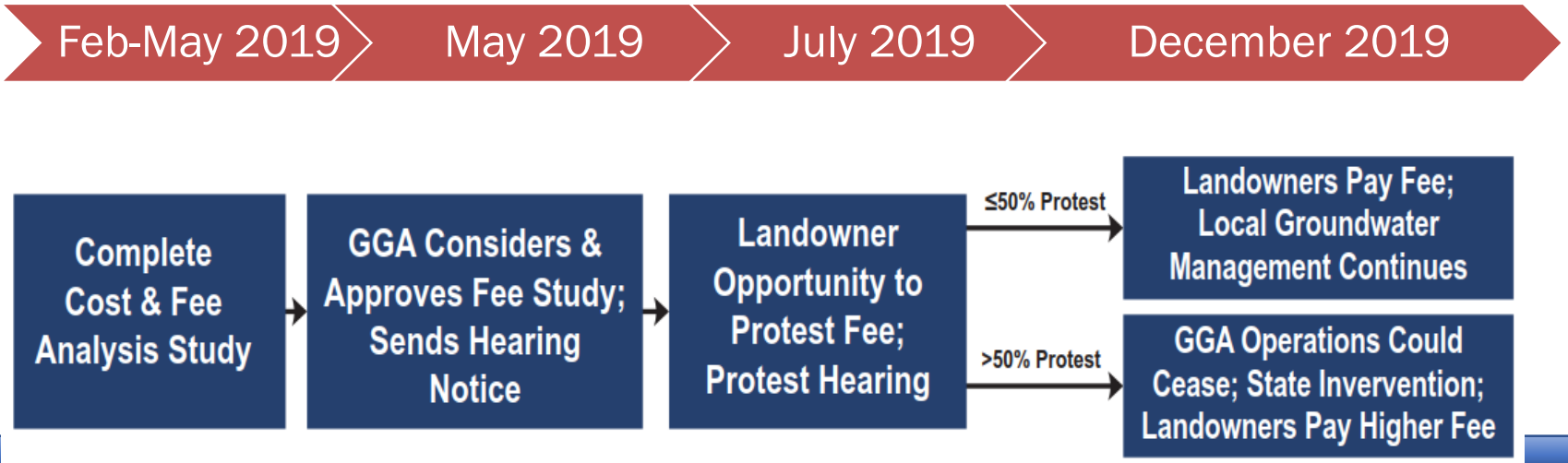
Proposition 218 Requirements

- Fees must be based on the reasonable cost of providing service
  - GGA's annual operating budget
- Fees must proportionally recover costs from ratepayers (i.e. no subsidies)
  - $/acre fee
- Fees in the Prop 218 notice are the max fees that may be adopted
  - Board may lower fees without conducting another Prop 218 notice and hearing process

Financing SGMA

Proposition 218 Requirements

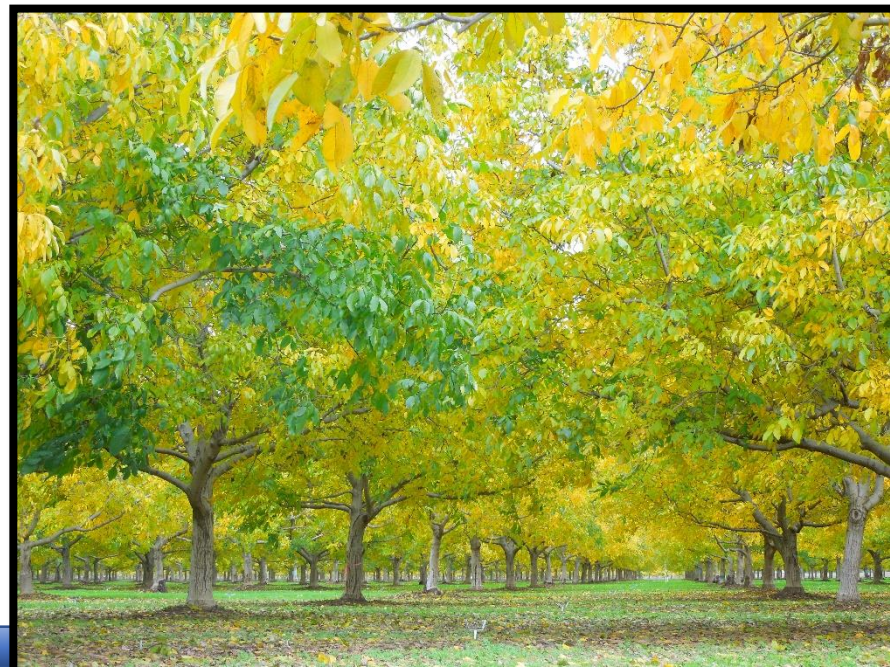
- Hold public informational meeting (NOT required)
- Mail a protest notice to property owners
- Hold a public hearing minimum of 45 days later
- If there is NOT a majority protest, GGA may adopt fees
- If the Proposition 218 effort passes, a fee will appear on December 2019 property tax roll



Financing SGMA

Who is Subject to the Fees?

- All property owners have an overlying right and benefit from a healthy groundwater system
- If the fee is adopted, the City of Orland and the City of Willows agreed to pay the GGA directly on behalf of the landowners for all acreage within the cities' boundaries



Financing SGMA

What Benefits Do I Receive?

- All property owners have an overlying right whether exercised or not
- All property owners benefit from a healthy groundwater system
- Local Representation (GGA Represents You)
  - Seeks funding opportunities for GSP development and studies
  - Venue for local input & stakeholder engagement
  - Local Control & Planning
  - Coordinate with other local plans & build on previous efforts
- Avoid State Intervention (Control & Fees)



Financing SGMA

GGA Fee Calculation

Category	Calculation
Budget	$550,900
Acres	285,190.63
Max Fee ($/acre)	$1.93

State Intervention

State Board intervention actions can include:

- Well Head fees
- Volumetric fees (fee per acre-foot of water pumped)
- Late fees (subject to backdating to 2017)
- Mandatory extraction reporting including monthly pumping data
- May require installation of meters on wells at owner's expense
- Technical reporting and special studies at landowners' expense
- Any corrective actions will likely result in pumping restrictions

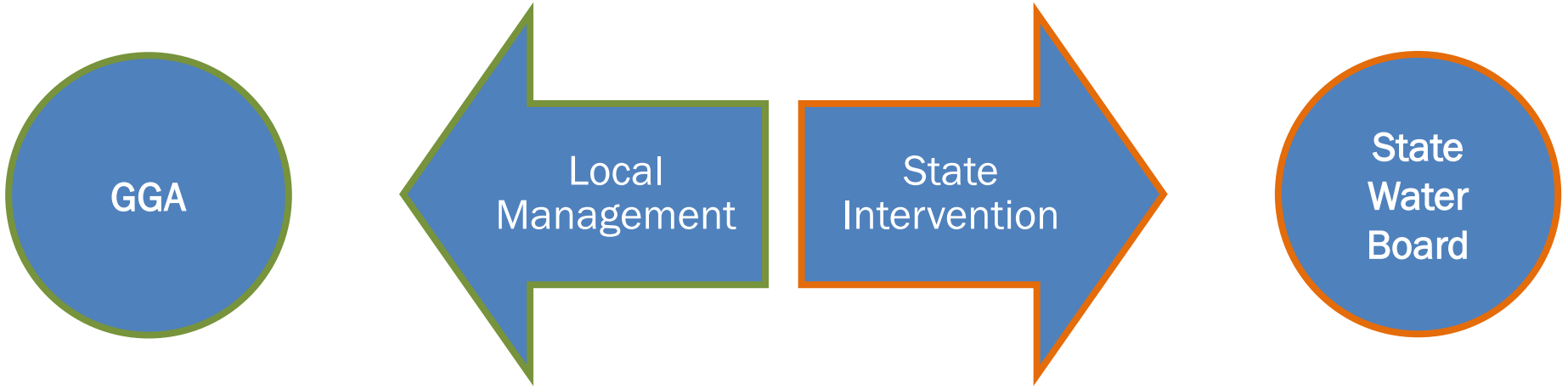
State Intervention

SWRCB Fees, 2018

BASE FEE (per well)	**$300**
Volumetric Fee (per AF)	
Unmanaged, metered	**$10/AF**
Unmanaged, unmetered	**$25/AF**
An unmanaged area is a part of a basin not within the management area of a GSA before July 1, 2017	
Probation	**$40/AF**
If locals fail to form a GSA, fail to develop an adequate sustainability plan, or fail to implement the plan successfully, the Board may designate the entire basin probationary. The Board may require the use of a meter to measure extractions and reporting of additional information.	
Interim Plan	**$55/AF**
If local agencies are unable to fix the deficiencies, the Board will develop an interim plan to directly manage groundwater extractions.	
De minimis (less than 2 AF/year)	**$100/well**
Late Fee	**25% per month**

https://www.waterboards.ca.gov/water_issues/programs/gmp/sgma.html

Sample Fee Comparison



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Thank You

Please contact staff to be added to the interested parties list:

Lisa Hunter
Program Manager, Glenn Groundwater Authority
530-934-6501
Lhunter@countyofglenn.net

GGA Website:
https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority

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2D-4. SGMA General Information, Basin Setting and Sustainable Management Criteria Workshops

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Colusa Groundwater Authority
Groundwater Sustainability Agency

100 Sunrise Blvd., Suite A | Colusa, CA 95932 | 530.458.7709

CGA Town Hall Public Meeting
Arbuckle/Williams/College City
Co-hosted by the Colusa Groundwater Authority and Colusa County Groundwater Commission

March 6, 2019
6:00 p.m.
Arbuckle I.O.O.F. Building, 5th and King Streets, Downtown Arbuckle

AGENDA

1. Overview: SGMA, the Colusa Groundwater Authority (CGA), Financing SGMA;
    - *Mary Fahey, CGA Program Manager*

2. CGA Board Member Statements
    - *Denise Carter, CGA Board Chair*
    - *Darrin Williams, CGA Board Member, Private Pumper representative*
    - *Jim Wallace, CGA Board Member, Colusa Drain Mutual Water Company*

3. Audience Q & A
    - Time for audience questions and dialogue with CGA Board Members and Staff

Colusa Groundwater Authority
Colusa County Groundwater Commission

Town Hall Public Information Meeting

Arbuckle/Williams/College City

March 6, 2019
Arbuckle I.O.O.F. Hall
6:00 p.m.

Program

1. **Overview:**
   Sustainable Groundwater Management Act (SGMA), Colusa Groundwater Authority, Financing SGMA

2. **Board Member Comments**

3. **Q&A**

SGMA: Sustainable Groundwater Management Act of 2014

SGMA: Sustainable Groundwater Management Act of 2014

* Historic Law, signed by Gov. Brown Dec., 2014
* First time Groundwater is regulated in California

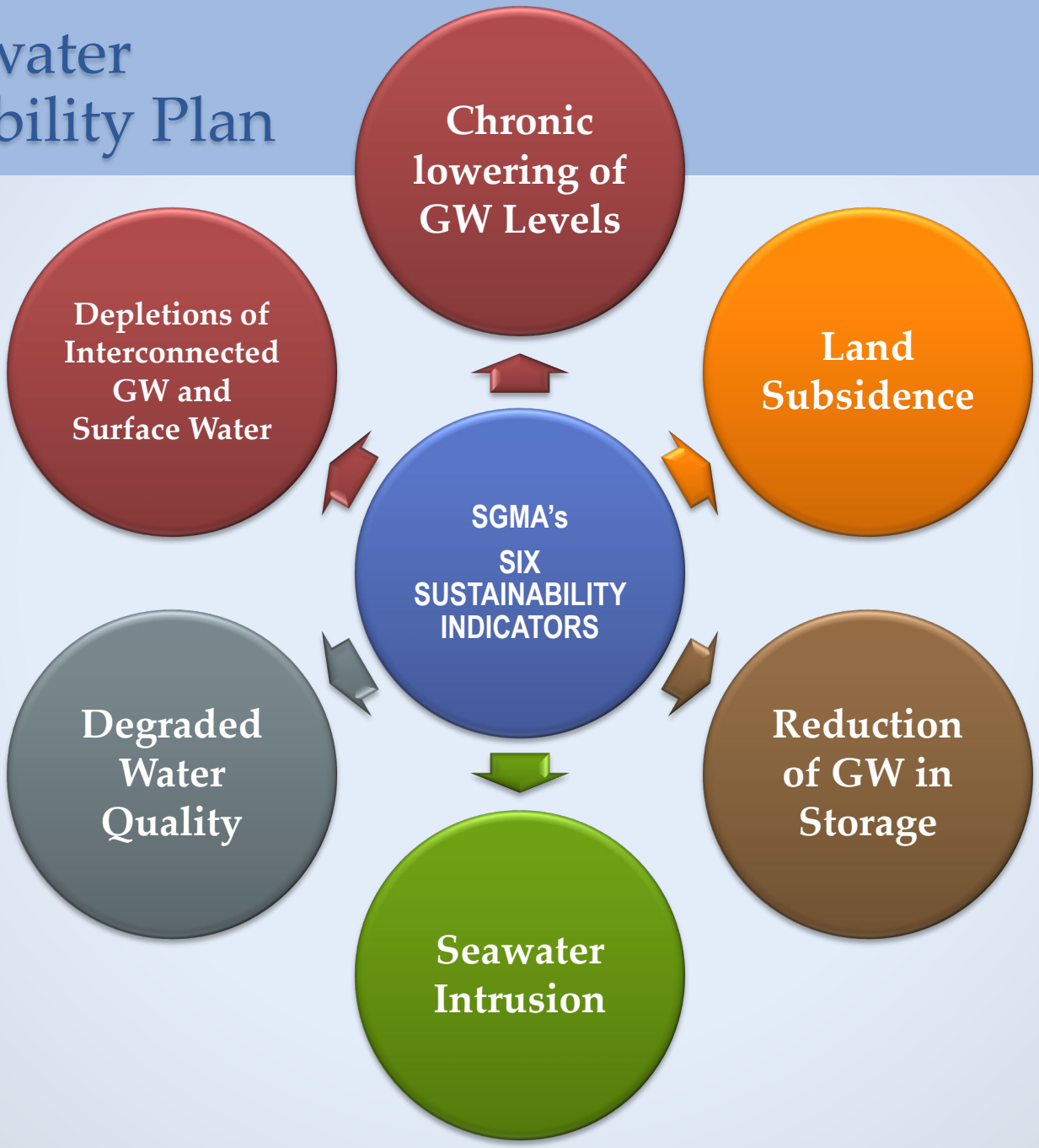
CFBF: "SGMA is the most significant change to water law in a century and will significantly impact farmers and ranchers throughout California."

SGMA is a completely different program than the Irrigated Lands Regulatory Program.

SGMA: Sustainable Groundwater Management Act of 2014



Groundwater Sustainability Plan



Colusa Groundwater Authority, GSA

CGA formed June 29, 2017 as mandated by SGMA, after 2 years of meetings

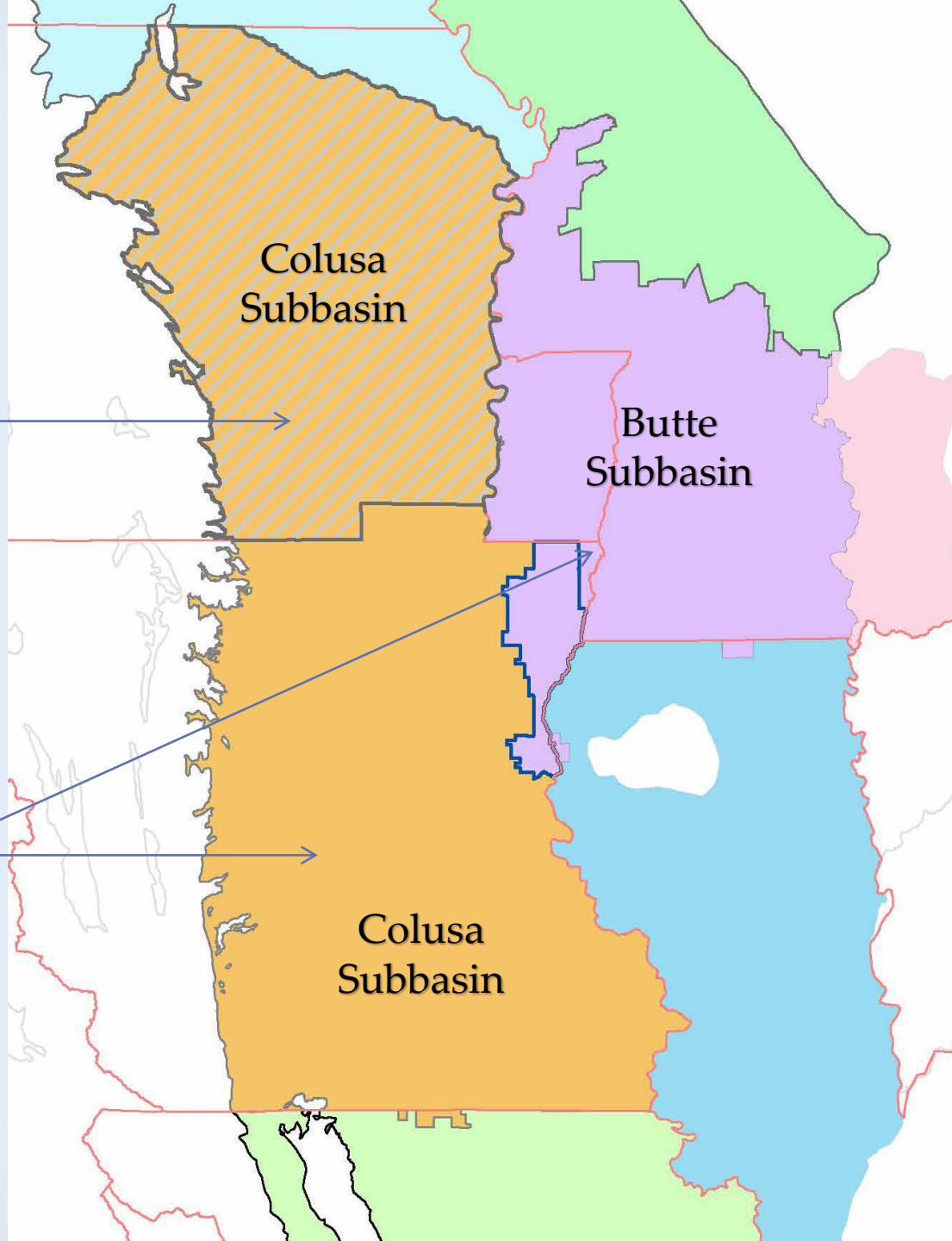
CGA is a 12-member Joint Powers Authority Board

Efficiencies gained by forming one multi-agency GSA

- Public Meetings were held over the period of January, 2016 – June, 2017 to determine the best governance structure for the Colusa County portions of the groundwater basins
- JPA structure provides many efficiencies:
  - Allows the agencies to pool resources and work together closely, keeping expenses to a minimum
  - SGMA requires coordinated basin-wide planning and implementation – multiple GSAs/GSPs creates added expense and duplication of efforts
  - It is much easier for the public to have one agency and one set of meetings to go to for information

Glenn Groundwater Authority (GGA)
Groundwater Sustainability Agency

Colusa Groundwater Authority (CGA)
Groundwater Sustainability Agency



Colusa Groundwater Authority

Board of Directors

County of Colusa
Denise Carter (Chair) / Alternate: Gary Evans

City of Colusa
Tom Reische / Alternate: Dave Markss

City of Williams
Alfred Sellers, Jr. / Alternate: Sajit Singh

Colusa County Water District
Knute Myers / Alternate: Shelly Murphy

Glenn-Colusa Irrigation District
Blake Vann / Alternate: Thad Bettner

Maxwell I.D. and Westside W.D.
Zachary Dennis / Alternate: Dan Ruiz

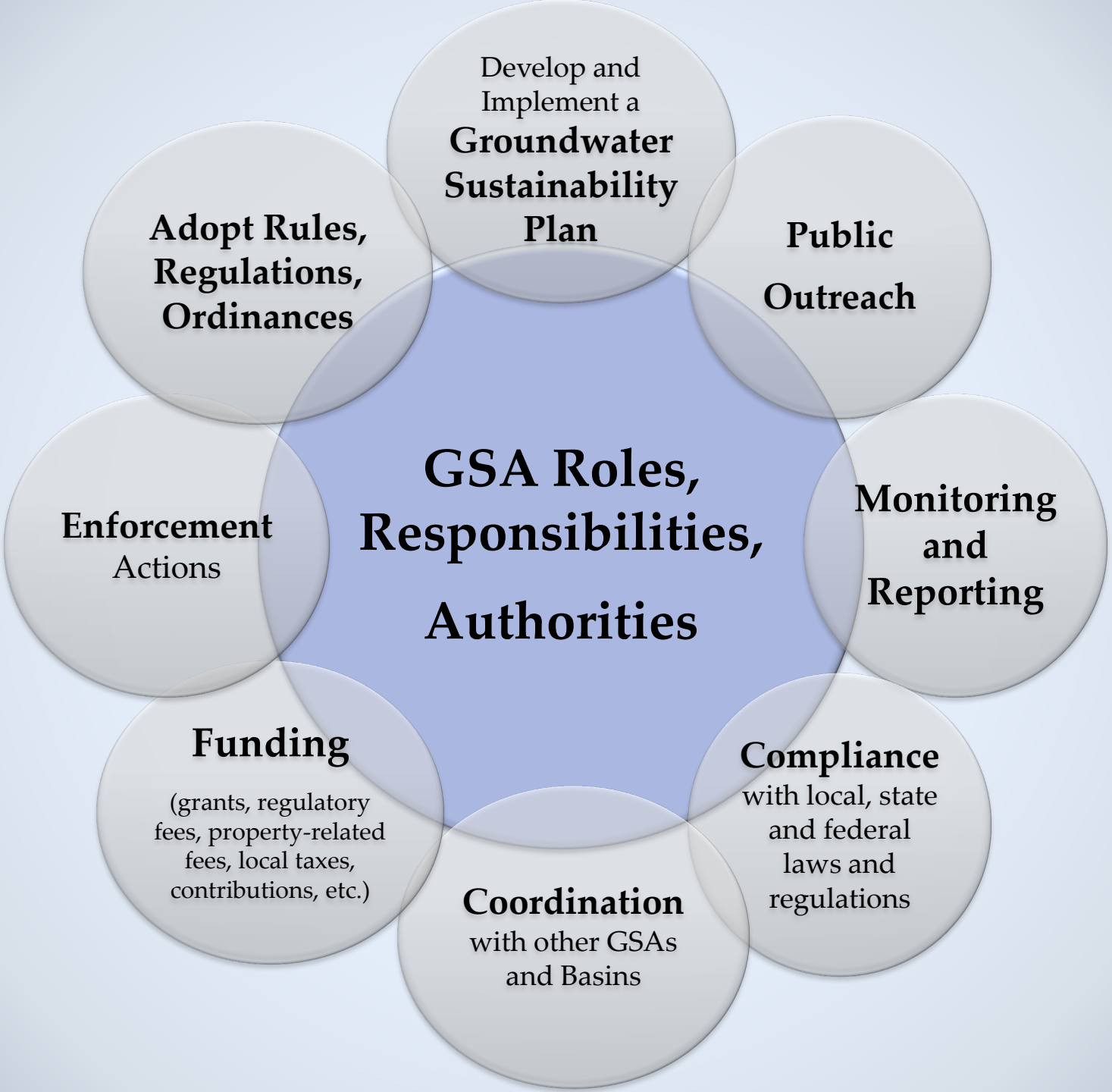
Princeton-Codora-Glenn I.D. and Provident I.D.
David Alves / Alternate: Lance Boyd

RD 108
Hilary Reinhard, PE (Vice Chair)
Alternate: Bill Vanderwaal

RD 479
Charles Marsh / Alternate: Derick Strain

Colusa Drain Mutual Water Company
Jim Wallace / Alternate: Lynell Pollock

2 Private Pumper Representatives from the Colusa County Groundwater Commission:
Darrin Williams
Jeff Moresco


Develop and Implement a Groundwater Sustainability Plan
Public Outreach
Monitoring and Reporting
Compliance with local, state and federal laws and regulations
Coordination with other GSAs and Basins
Funding (grants, regulatory fees, property-related fees, local taxes, contributions, etc.)
Enforcement Actions
Adopt Rules, Regulations, Ordinances
GSA Roles, Responsibilities, Authorities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(grants, regulatory fees, property-related fees, local taxes, contributions, etc.)
Enforcement Actions
Adopt Rules, Regulations, Ordinances
GSA Roles, Responsibilities, Authorities

Financing SGMA – Why?

- SGMA is the law – "unfunded mandate"
- GSAs are new, local government, **Regulating Agencies**
- GSAs must be funded to operate

If the CGA is unable to comply with SGMA due to a lack of sufficient funding , the State will intervene

- The agencies on the Board of the CGA funded the agency for the first two years (July 2017-June 2019)
- By June, 2019, CGA Member Agencies will have contributed a total of **$616,181, plus staff time, and other resources**
- Leveraging Grant Funding and other programs to keep costs down:
  - $1 million in Proposition 1 grant funding for GSP development in the Colusa Subbasin (shared with Glenn GW Authority)
  - DWR Facilitation Support Services, Technical Support Services

Financing SGMA – How?

- A Proposition 218 Majority Protest
- Similar process starting in the Glenn County portion of the Colusa Subbasin
- A fee study is being developed by a consultant team at Provost and Pritchard
- Per Acre Fee

Financing SGMA – Who?

Who is Subject to Fees?

- **All property owners in the CGA's jurisdiction:**
  - All property owners have an overlying right to groundwater and benefit from compliance with SGMA
- **Community Water Systems**:
  - The **Cities of Colusa and Williams** have a seat on the CGA Board and will continue to pay a fee to the CGA as before to cover the landowners in their jurisdiction. ***Homeowners within the cities' boundaries will not participate in the Proposition 218 process***
  - Homeowners in the communities of Arbuckle, Grimes, Maxwell and Princeton will be covered through their water suppliers, similar to the cities, ***and will not participate in the Proposition 218 process.***
  - This approach will keep costs down – it is not economically feasible to assess these small parcels

Financing SGMA - CGA Budget Forecast

	FY 2017/18	FY 2018/19	FY 2019/20	FY 2020/21	FY 2021/22	FY 2022/23	FY 2023/24
EXPENSES							
Administration	87,456	100,000	150,000	150,000	150,000	150,000	150,000
Legal Services	22,588	100,000	150,000	150,000	150,000	150,000	150,000
Office/Outreach Materials	516	1,000	8,500	8,500	8,500	8,500	8,500
Annual/Biennial Audits	-	9,500	9,750	10,000	-	20,000	-
Bookeeping		10,000	14,000	8,000	2,000	2,000	2,000
JPA Insurance	1,577	1,800	1,800	1,800	1,800	1,800	1,800
Consultant Prop 1 Grant GSP Proposal	6,343	-	-	-	-	-	-
GSP Development			102,175	67,175	79,350	-	-
Prop 218 Engineering Study	-	65,000	-	-	-	-	-
County Tax Collector	-	-	10,000	10,000	10,000	10,000	10,000
GSP Implementation, Monitoring/Reporting					50,000	50,000	50,000
Contingency	-	-	50,000	50,000	50,000	50,000	50,000
Total Expenses	118,480	287,300	496,225	455,475	501,650	442,300	422,300

Financing SGMA – Projected Costs

Initial Fee Estimate: $1.21/Acre

With yearly inflation factor (Consumer Price Index currently 3%):

2020/21 - **$1.25**	2021/22 - **$1.28**	2022/23 - **$1.32**	2023/24 - **$1.36**

Estimated at 3% - could vary

Cannot go above 2023/24 rate without another Prop. 218 effort

- Rate is pending outcome of final fee study
- SGMA is a new program, many unknowns
  - Budget is the most reasonable estimate at this time
  - The fee cannot exceed the reasonable costs of the CGA activities
- Fee is for day to day operations of the CGA
- Additional project-specific fees may also apply in the future

Financing SGMA - Statewide

GSA 1 – in Fresno County
$19.00/acre
entirely dependent on groundwater

GSA 2 – in Kings County
$5.00/acre initially
$3.00/acre in second year

GSA 3 – Salinas Valley
$2.27/non-ag acre to
$4.81 irrigated ag acre

State Intervention – Alternative to Prop. 218 Fee

State Board Intervention actions may include:

- Well Head fees
- Volumetric fees (fee per acre-foot of water pumped)
- Late fees (subject to backdating to 2017)
- Mandatory extraction reporting including monthly pumping data
- May require installation of meters on wells at owner's expense
- Technical reporting and special studies at landowners' expense
- Any corrective actions will likely result in pumping restrictions

Any **fees collected by the State will not benefit local groundwater management, or local projects**. Fees will go to SWRCB staffing.

State intervention will come at a **much greater cost** than SGMA implementation by the CGA.

State intervention will impose **restrictions without any local benefits.**

State Intervention – Alternative to Prop. 218 Fee

SWRCB Fees, 2018

BASE FEE (per well)	**$300**
Volumetric Fee (per AF)	
Unmanaged, metered	**$10/AF**
Unmanaged, unmetered	**$25/AF**
An unmanaged area is a part of a basin not within the management area of a GSA before July 1, 2017	
Probation	**$40/AF**
If locals fail to form a GSA, fail to develop an adequate sustainability plan, or fail to implement the plan successfully, the Board may designate the entire basin probationary. The Board may require the use of a meter to measure extractions and reporting of additional information.	
Interim Plan	**$55/AF**
If local agencies are unable to fix the deficiencies, the Board will develop an interim plan to directly manage groundwater extractions.	
De minimis (less than 2 AF/year)	**$100/well**
Late Fee	**25% per month**

https://www.waterboards.ca.gov/water_issues/programs/gmp/sgma.html

State Intervention – Alternative to Prop. 218 Fee

Sample Fee Comparison

100 acre irrigated parcel with one well, probationary basin

Estimated Max. CGA Fee: $136

100 Acres X $1.36 = $136

→ **Local Control, Local Management Local Benefit**

SWRCB Fees: $12,300

1 well = $300

3 AF/ac = 300 AF X $40 = $12,000

→ **Fees will not benefit local groundwater management, or local projects.**

Corrective actions will equal reduced pumping.

Financing SGMA – Next Steps

1. Continued Public Outreach Meetings
2. Fee Study Completed (within next two weeks)
3. Protest Notice and instructions mailed to property owners **April 19 (tentative)**- election is a written protest.
4. Public Hearing minimum of 45 days after mailing – anticipated **June 5, 2019 (tentative)** also deadline to submit a written protest
5. Absent majority protest, CGA may adopt fees
6. If passed, fee will appear on December 2019 property tax roll, and yearly there after

Stay Informed

Visit the website:
colusagroundwater.org

Get on the CGA Email List

Upcoming Town Hall Meetings

COLUSA/PRINCETON/GRIMES
March 14, 2019 at 6:00 p.m.
Colusa Veteran's Hall
108 East Main Street, Colusa, CA 95932

MAXWELL/WILLIAMS
March 20, 2019 at 6:00 p.m.
Sites Project Authority Office
122 Old Highway 99 W., Maxwell, CA 95955

The Colusa Groundwater Authority (CGA)

And

The Colusa County Groundwater Commission

Present:

The Sustainable Groundwater Management Act Town Hall Public Information Meetings

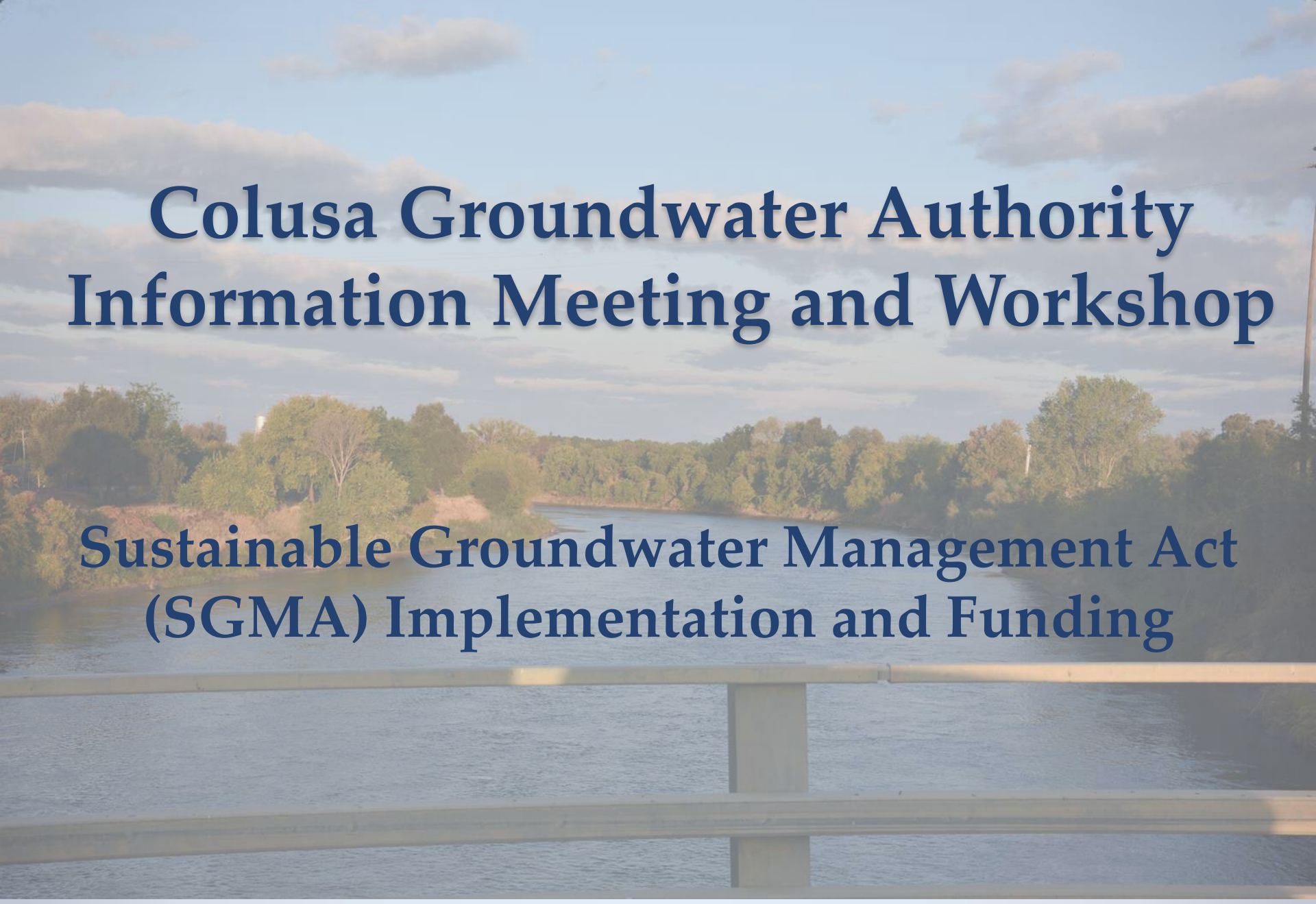
This is an opportunity to learn about the Sustainable Groundwater Management Act (SGMA) and local groundwater management efforts, and have a dialogue with CGA Board Members and Colusa County Groundwater Commissioners. We hope you can join us at one of these meetings:

ARBUCKLE/WILLIAMS/COLLEGE CITY
March 6, 2019 at 6:00 p.m.
Arbuckle I.O.O.F. Building
5th and King Streets, Downtown Arbuckle

COLUSA/PRINCETON/GRIMES
March 14, 2019 at 6:00 p.m.
Colusa Veteran's Hall
108 East Main Street, Colusa, CA 95932

MAXWELL/WILLIAMS
March 20, 2019 at 6:00 p.m.
Sites Project Authority Office
122 Old Highway 99 W., Maxwell, CA 95955

For more information, contact
Mary Fahey | 530.458.0719
Colusa Groundwater Authority Website



Colusa Groundwater Authority Information Meeting and Workshop

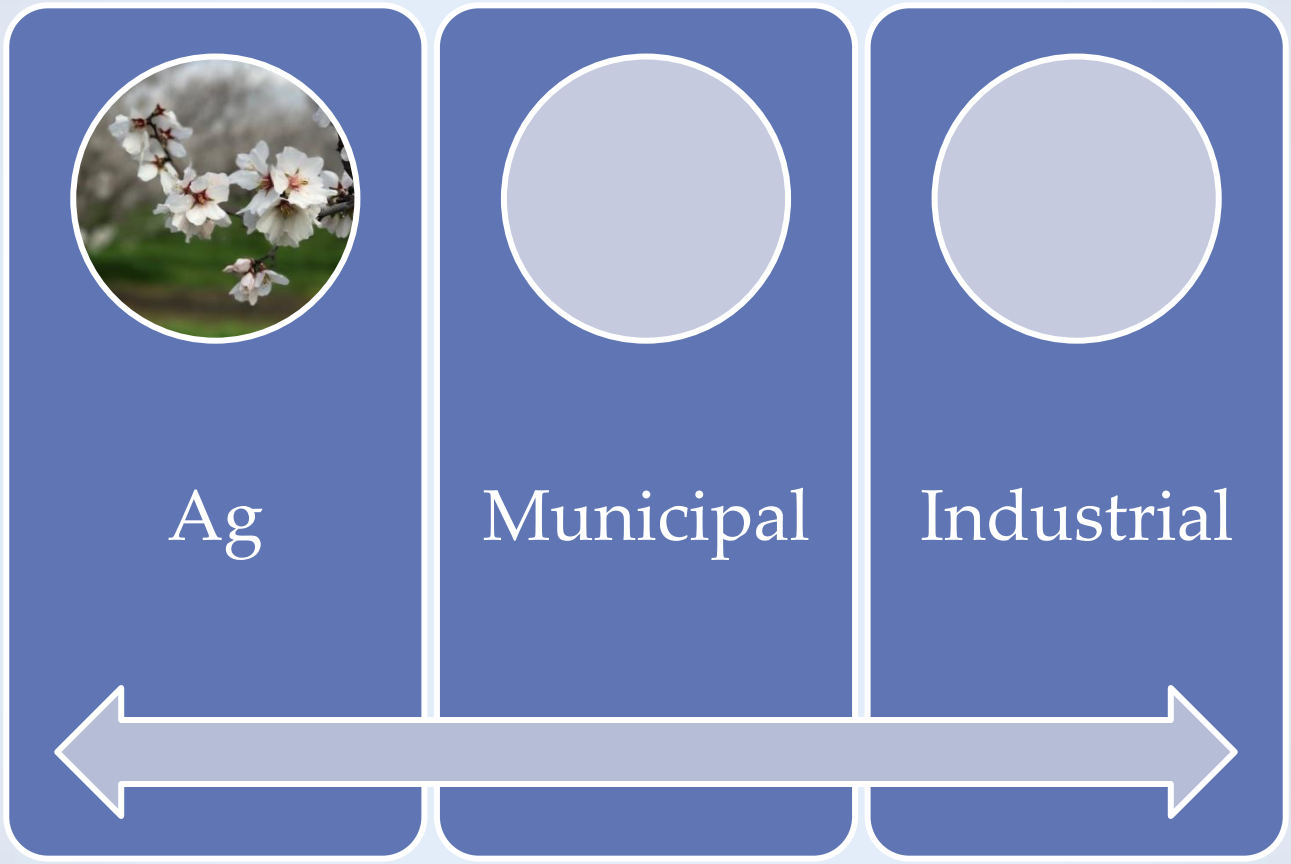
Sustainable Groundwater Management Act (SGMA) Implementation and Funding

January 31, 2019

Program

* 1. Sustainable Groundwater Management Act (SGMA) Overview
* 2. Colusa Groundwater Authority
* 3. Financing SGMA Implementation
  * CGA Activities and the Need for Funding
  * Proposition 218 Majority Protest
* 4. State Intervention
* 5. CGA Panel Questions and Answers

SGMA: Who is Affected



Diminimus (less than 2 A/F pumped per year) are not the focus.

SGMA Foundations

- Sustainable Groundwater Management Act of 2014
- **Groundwater Sustainability Agency(ies) (GSA)** by **June 30, 2017**
- **Groundwater Sustainability Plan(s) (GSP)** by **January 31, 2022**
- Yearly reporting and GSP Update every 5 years, demonstrating progress towards sustainability
- 20 years to achieve Sustainability – 2042
- **SGMA is a completely different program than the Irrigated Lands Regulatory Program!**

SGMA Foundations

Six "**Undesirable Results**"

1. Chronic lowering of groundwater levels
2. Reduction of groundwater storage
3. Degraded water quality
4. Land subsidence
5. Depletions of interconnected groundwater and surface water
6. Seawater intrusion (*not applicable in the Colusa Subbasin*)

GSA Roles and Responsibilities

- **Governance** – Colusa Groundwater Authority
- **Outreach/Engagement (Transparency)** with all beneficial users
- **Compliance** with local ordinances, state and federal laws and regulations, and similar
- **Funding** which may include one or more of the following: regulatory fees, property-related fees or assessments, local taxes, local general obligation bonds, contributions from member agencies, grants from other state or federal agencies

GSA Roles and Responsibilities

- **Authorities**

  General:

  - Do anything 'necessary and proper" to carry out SGMA's purposes
  - Adopt rules, regulations, ordinances and resolutions
  - Use any other authority allowed to the GSA to apply and enforce SGMA requirements

  Information Gathering

  Groundwater Extraction Oversight

  Property Acquisition and Management

  Enforcement:

  - Sue to collect delinquent fees, interest, or penalties or order extraction stopped until delinquent fees are paid
  - Pursue civil penalties for extraction exceedances
  - Pursue civil penalties for violations of SGMA-related rules, regulations, ordinances, or resolutions*

GSA Roles and Responsibilities

- **Coordination** with adjacent subbasins and Counties (if applicable), and between Management Areas (if applicable)
- **Technical** – access technical expertise; conduct/oversee monitoring, data collection and reporting; develop water budget and identify sustainable yield; assess basin history and potential paths to sustainable management; remediate oversee remediation of polluted groundwater.

Colusa Groundwater Authority

- CGA Formation; 2 years, common principles
- CGA formed June 29, 2017 as mandated by SGMA
- CGA is the Groundwater Sustainability Agency (GSA) covering the Colusa County portions of the Subbasins within the county, outside of RD 1004
- CGA is a 12-member Joint Powers Authority Board
- Board includes two Private Pumper representatives

Colusa Groundwater Authority

Board of Directors

County of Colusa
Denise Carter (Chair) / Alternate: Gary Evans

City of Colusa
Tom Reische / Alternate: Dave Markss

City of Williams
Alfred Sellers, Jr. / Alternate: TBD

Colusa County Water District
Knute Myers / Alternate: Shelly Murphy

Glenn-Colusa Irrigation District
Blake Vann / Alternate: Thad Bettner

Maxwell I.D. and Westside I.D.
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David Alves / Alternate: Lance Boyd

RD 108
Hilary Reinhard (Vice Chair)
Alternate: Bill Vanderwaal

RD 479
Charles Marsh / Alternate: Derick Strain

Colusa Drain Mutual Water Company
Jim Wallace / Alternate: Lynell Pollock

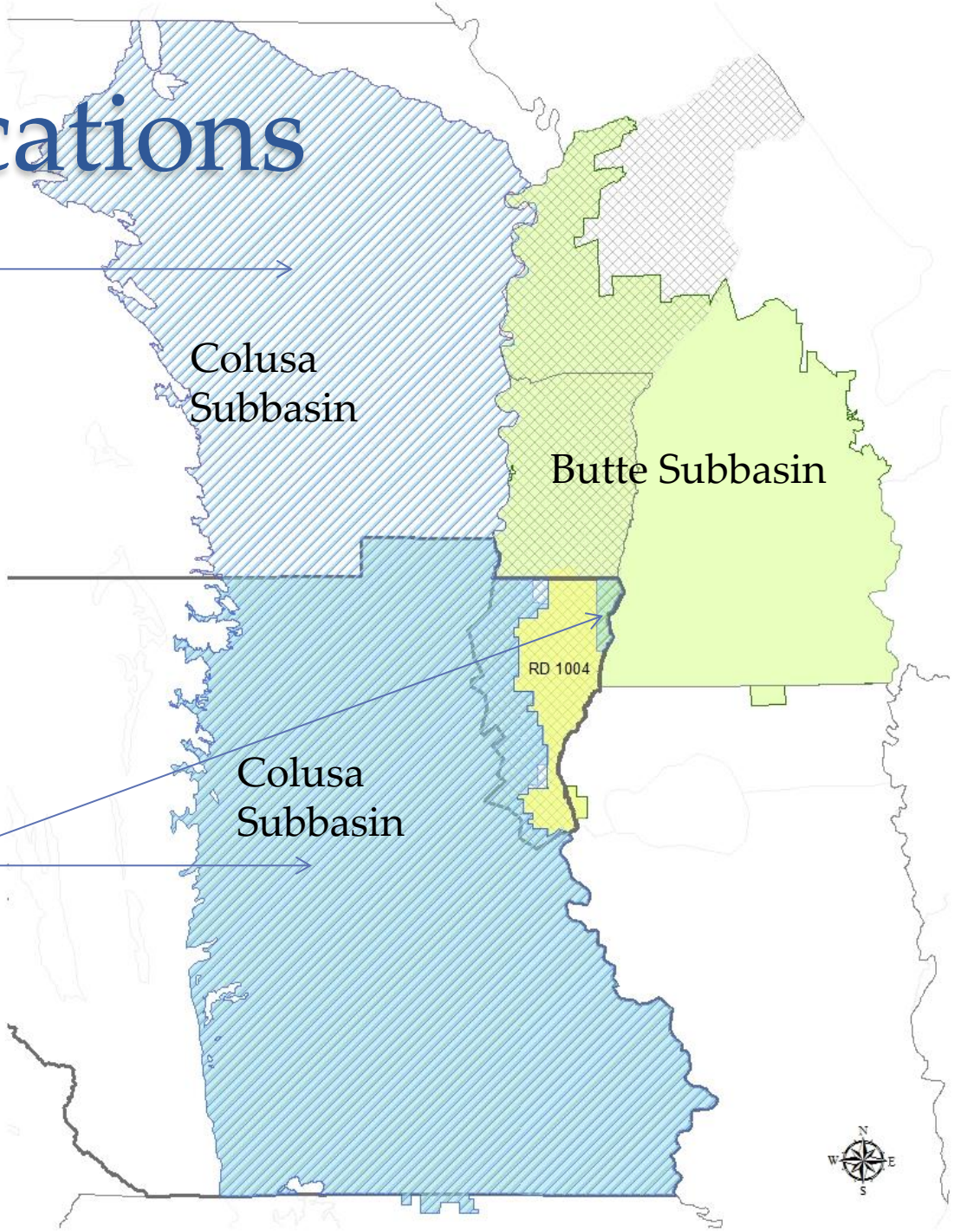
2 Private Pumper Representatives from the Colusa County Groundwater Commission:
Darrin Williams and Jeff Moresco

Subbasin Locations

Glenn Groundwater Authority (GGA) GSA

Mallory fix map

Colusa Groundwater Authority (CGA) GSA



CGA Activities

- Groundwater Sustainability Plan (GSP) for the Colusa Subbasin (CGA & GGA)
  - Awarded $1 million Proposition 1 grant funding for GSP development
  - Consultant team to developing Basin Setting for GSP
- Installing a new monitoring well in the Arbuckle area (DWR funded)
- Coordinating with Glenn Groundwater Authority (GGA) on GSP development and other activities in the Colusa Subbasin
- Coordinating with GSAs in other surrounding basins/counties
- Organizing ongoing public meetings and public outreach activities
- Developing Long-term Funding strategy for the CGA to maintain local control of Groundwater Management under SGMA

Financing SGMA

- CGA members working together, pooling resources to keep costs to a minimum
- Leveraging grant funding, Facilitation Support and Technical Support services

Need for Long-term funding for day to day operations of the CGA:

- **Technical:** GSP development ($1.5 million), technical studies, monitoring and data management, coordination and outreach efforts, implementation of the GSP, yearly reporting to DWR, Plan updates every five years
- **O&M:** Staff, insurance, legal services, bookkeeping, office needs, etc.

- CGA Member Agencies agreed to fund the JPA for the first two years (July, 2017 – June, 2019) (dollar amount)
- Fees are needed to comply with SGMA and fund the GSP and basin monitoring activities

Financing SGMA

Proposition 218 Option

- Approved by voters in 1996, Prop 218 imposes certain requirements relative to the imposition of certain assessments, fees and charges by local agencies.
- Procedures act to fully inform the Agency's landowners while simultaneously giving them a direct say in the matter.
- Two processes for approval of revenue generation under Proposition 218
  - Land-based assessments (per acre charge)
  - Fees or charges on a unit basis.

Financing SGMA

Proposition 218 Majority Protest Requirements

- Fees must be based on the reasonable cost of providing service
  - CGA's annual operating budget
- Fees must proportionally recover costs from ratepayers (i.e. no subsidies)
  - $/acre fee
- Fees in the Prop 218 notice are the max fees that may be adopted
  - Board may lower fees without conducting another Prop 218 notice and hearing process

Financing SGMA

Proposition 218 Majority Protest: Next Steps

* CGA contracted with Provost and Pritchard Engineering to initiate a Proposition 218 Majority Protest
* Consultants will complete a rate study to determine a fee structure based on CGA budget and acreages in the CGA's jurisdiction
* Amount of fee cannot exceed the reasonable cost of the activity to be funded
* Public information meetings being planned, January – March
* A similar process is beginning in the GGA portion of the Colusa Subbasin

Financing SGMA

Prop 218 procedural requirements

- Mail a protest notice to property owners
- Hold a public hearing minimum of 45 days later – anticipated in March, 2019
- Absent majority protest, CGA may adopt fees
- If the Proposition 218 effort passes, a fee will appear on December 2019 property tax roll

Financing SGMA
Who is Affected?

- All property owners have an overlying right and benefit from a healthy groundwater system
- Small Community Water Systems: homeowners in the Cities of Colusa and Williams and the small communities of Arbuckle, Grimes, Maxwell and Princeton may be charged through their water suppliers.
  - This will save money processing multiple property tax bills on these small parcels

Financing SGMA

Initial Estimate: Proposition 218 Majority Protest Fee Calculation

	Estimates
Budget	$540,000
Acres	402, 541
Fee ($/acre)	$1.34

- Pending outcome of fee study
- Pending CGA Board approval and budget review
- SGMA is a new program, many unknowns
  - Budget is the best estimate at this time
  - The fee cannot exceed the reasonable costs of the CGA activities

Financing SGMA

What if the Prop 218 Effort Fails?

* If the CGA cannot be funded, it will dissolve.
* If a basin is not covered entirely by a GSA(s) and/or approved GSP, the State Water Resources Control Board assumes SGMA responsibilities.
* Lose local control of the groundwater resource.

Financing SGMA

What if the Prop 218 Effort Fails?

- State Board intervention actions can include:
  - Well Head fees
  - Volumetric fees (fee per acre-foot of water pumped)
  - Late fees (back dated to 2017)
  - Mandatory extraction reporting including monthly pumping data
  - May require installation of meters on wells at owner's expense
  - Technical reporting and special studies at landowners' expense
  - Any corrective actions will likely result in pumping restrictions

State Intervention

SWRCB Fees, 2018

BASE FEE (per well)	**$300**	
Volumetric Fee (per AF)		
Unmanaged, metered	**$10/AF**	
Unmanaged, unmetered	**$25/AF**	
An unmanaged area is a part of a basin not within the management area of a GSA before July 1, 2017		
Probation	**$40/AF**	
If locals fail to form a GSA, fail to develop an adequate sustainability plan, or fail to implement the plan successfully, the Board may designate the entire basin probationary. The Board may require the use of a meter to measure extractions and reporting of additional information.		
Interim Plan	**$55/AF**	
If local agencies are unable to fix the deficiencies, the Board will develop an interim plan to directly manage groundwater extractions.		
Deminimus (less than 2 AF/year)	**$100/well**	
Late Fee	**25% per month**	

https://www.waterboards.ca.gov/water_issues/programs/gmp/sgma.html

State Intervention

Sample Fee Comparison

100 acre irrigated parcel with one well, probationary basin

* **SWRCB Fees**:
  * 1 well = $300
  * 3.5 AF/ac = 350 AF X $40 = $14,000
  * **TOTAL: $14,300**

* **Estimated CGA Fee:**
  * 100 Acres X $1.34 = $134
  * **TOTAL: $134**

CGA will not know the proposed fee until the Rate Study is completed.

CGA Panel Questions & Answers

Panel Members:

- Denise Carter, CGA Board Chair
- Hilary Reinhard, RD 108
- Darrin Williams, Private Pumper
- City Rep

Thank You

Landowner input is essential to GSP development and SGMA planning and implementation.

Please visit the website or contact Staff to get on the contact list:

Mary Fahey
Program Manager, Colusa Groundwater Authority
530-458-0719
mfahey@countyofcolusa.com

CGA Website:
www.colusagroundwater.org

Sustainable Groundwater Management Act
Public Workshop

Question / Comment Card

Please write your question / comment on this card and turn it in when requested.

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Group Worksheet

Colusa Subbasin
Groundwater Workshop
Small Group Discussions

There are 5 "Sustainability Indicators" that the Groundwater Sustainability Agency potentially must address to comply with the Sustainable Groundwater Management Act. These are:

1. Lowering Groundwater Levels
2. Reduction of Groundwater Storage
3. Subsidence
4. Water Quality
5. Surface Water Depletion

For each of these Sustainability Indicators, Please answer the following questions:

Are any of following, groundwater problems in the Colusa Subbasin right now? If so, where and why?
1 - Lowering Groundwater Levels
2 - Reduction of Groundwater Storage
3- Subsidence
4 - Water Quality
5 - Surface Water Depletion

Do you think any of these could be groundwater problems in the future? If so, where and why?
1 – Lowering Groundwater Levels
2 - Reduction of Groundwater Storage
3- Subsidence
4 - Water Quality
5 - Surface Water Depletion

If you identified current and/or potential problems, can you describe if and how these will affect you?
1 - Lowering Groundwater Levels
2 - Reduction of Groundwater Storage
3- Subsidence
4 - Water Quality
5 - Surface Water Depletion



COLUSA GROUNDWATER AUTHORITY AND GLENN GROUNDWATER AUTHORITY

Colusa Subbasin Groundwater Workshop

September 19 & 23, 2019

Program



- Welcome and Introductions
- Sustainable Groundwater Management Act (SGMA) Overview
- SGMA Basin Setting - Colusa Subbasin
  - Basin Setting Presentation
  - Small Group Discussion – Subbasin Challenges
  - Water Budget Update
  - Modelling Update
- Groundwater Sustainability Planning - Next Steps
- GSA Question and Answer Session (Comment Cards Available)
- Adjourn

Sustainable Groundwater Management Act (SGMA) Overview

Dave Ceppos – Facilitator, Sacramento State University

SGMA: Who is Affected



Agricultural



Municipal



Industrial



Environmental

Sustainable Groundwater Management Act SGMA

- Sustainable Groundwater Management Act of 2014
- **Groundwater Sustainability Agency(ies) (GSA)** by **June 30, 2017**
- **Groundwater Sustainability Plan(s) (GSP)** by **January 31, 2022**
- Annual reporting and GSP Update every 5 years, demonstrating progress towards sustainability
- 20 years to achieve Sustainability – 2042
- **SGMA is a completely different program than the Irrigated Lands Regulatory Program (Colusa Glenn Subwatershed Program)**

Groundwater Sustainability Agency Eligibility Requirements

- Local Public Agencies Responsible for:
  - Water Management
  - Water Supply
  - Land Use Authority
    - *For Example: Cities, Counties, Irrigation Districts*

- One or more GSAs must be formed per Basin / Subbasin
- Formed by a single eligible agency or by legal agreement between two or more
- Counties represent / manage all groundwater conditions outside another managed area (Water Code §10724)

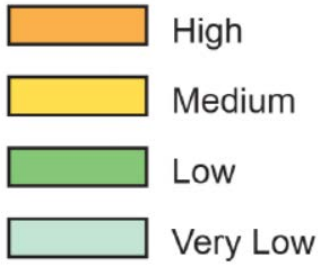
GSA Roles and Responsibilities

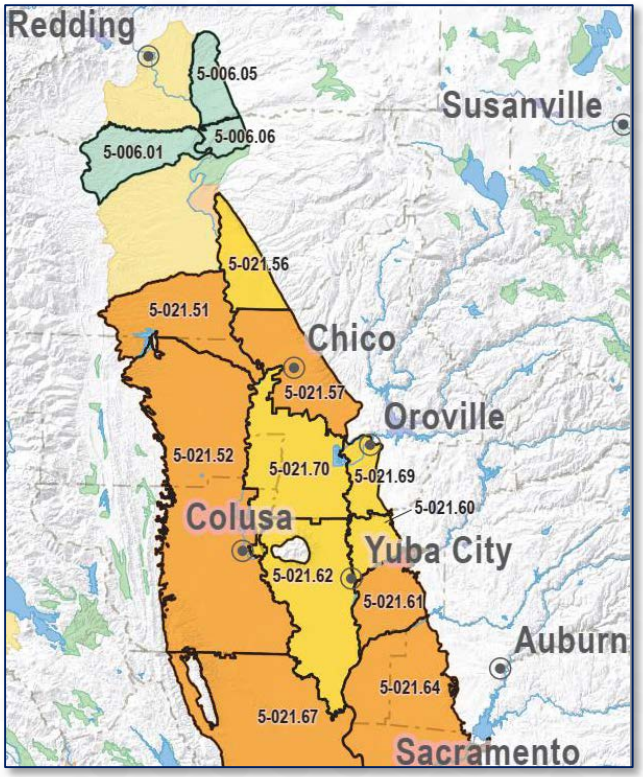


- Governance
- Outreach and Engagement
- Funding
- Information Gathering
- Plan Development and Reporting
- Projects (e.g. Groundwater Recharge)
- Groundwater Regulation and Enforcement
- Groundwater Extraction Oversight
- Property Acquisition and Management

SGMA Foundations

- 515 Groundwater Basins / Subbasins Statewide
- 98 Basins / Subbasins required to comply with SGMA*
- Compliance based on basin prioritization as mandated by State Legislature in 2009.
- Prioritization variables include (but not limited to):
  - Population
  - Socioeconomics
  - Number of wells
  - Groundwater elevations
  - Irrigated acres







*Draft Prioritization Results as of September 2019

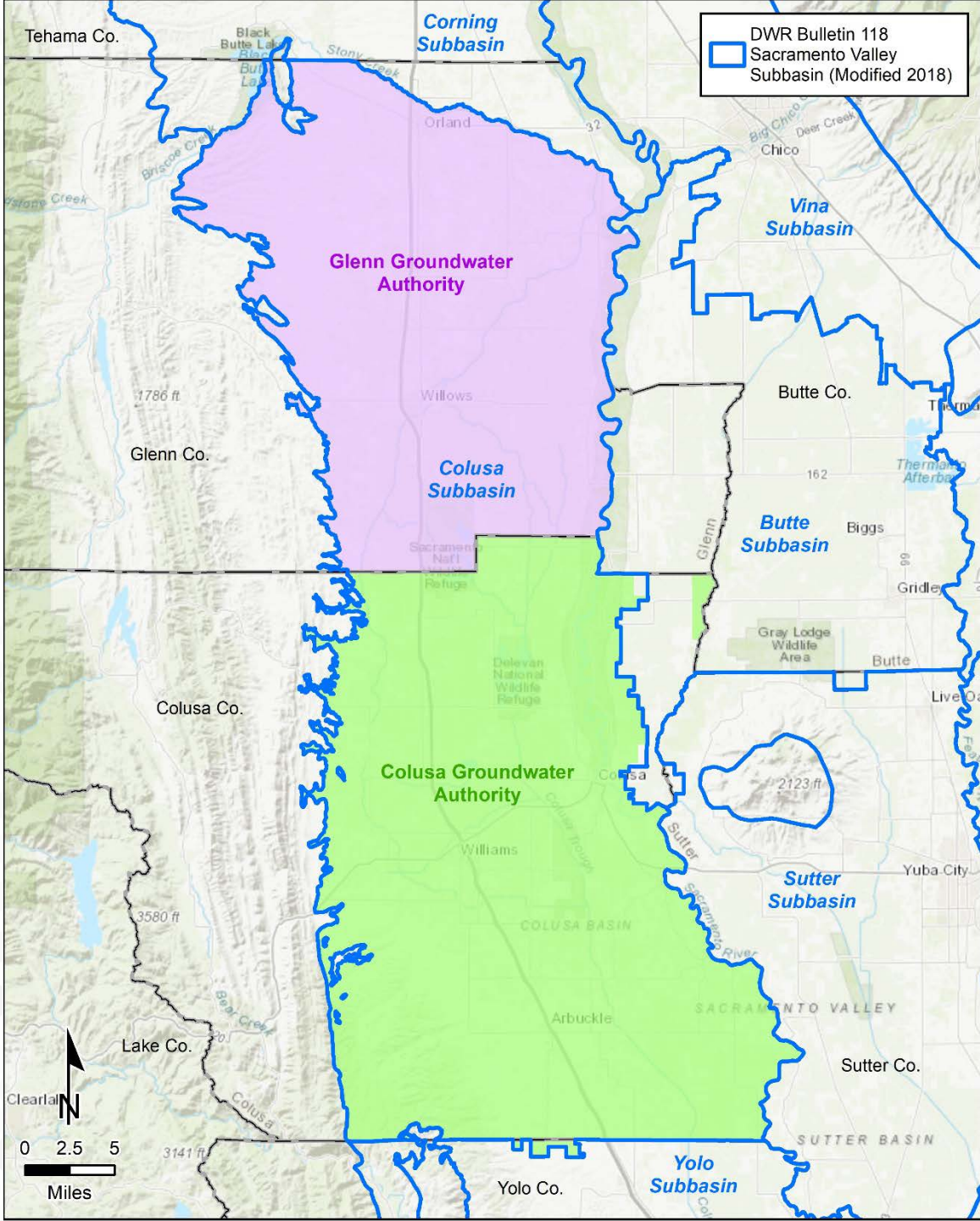
SGMA Foundations



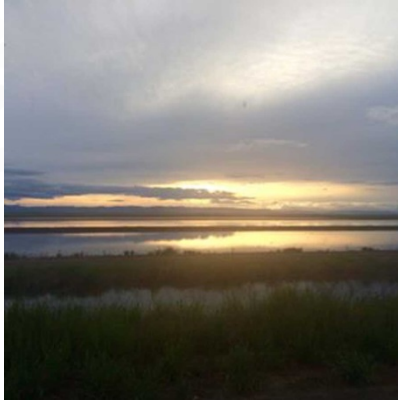
Beneficial Users (Water Code §10723.2)

- All Groundwater Users
- Holders of Overlying Rights (agricultural and domestic)
- Municipal Well Operators
- Public Water Systems
- Tribes
- Local Land Use Planning Agencies
- Counties
- Local Landowners
- Disadvantaged Communities
- Businesses
- Federal Government
- Environmental Users
- Surface Water Users (*if connection between surface and groundwater*)

Colusa Subbasin Map



Colusa Groundwater Authority



Member Agencies / Board of Directors

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Charles Marsh / Alternate: Derick Strain

Colusa Drain Mutual Water Company
Jim Wallace / Alternate: Lynell Pollock

2 Private Pumper Representatives from the Colusa County Groundwater Commission:
Darrin Williams and Jeff Moresco



Glenn Groundwater Authority

Member Agencies / Board of Directors

County of Glenn
John Viegas / Alternate: Vince Minto

City of Orland
Bruce Roundy
Alternate: Pete Carr
2nd Alternate: Ed Vonasek

City of Willows
Gary Hansen / Alternate: Evan Markey

Glenn-Colusa Irrigation District
John Amaro / Alternate: Thaddeus Bettner

Glide Water District
George Nerli
Alternate: Leslie Nerli
2nd Alternate: Michael Alves

Princeton-Codora-Glenn I.D. and Provident I.D.
Gary Enos / Alternate: Lance Boyd

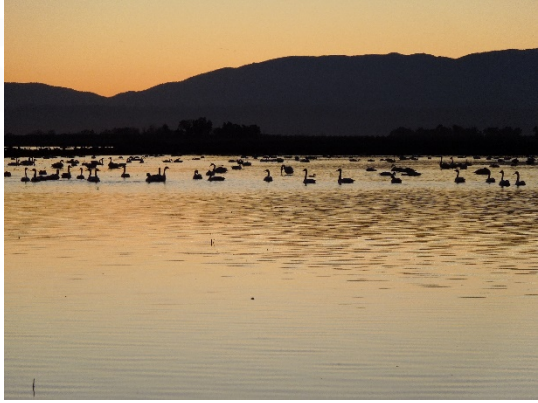
Kanawha Water District
Randy Hansen / Alternate: Wade Danley

Orland-Artois Water District
Charles Schonauer
Alternate: Emil Cavagnolo
2nd Alternate: Andrea Jones

Sustainability Indicators



Example GSP Section Requirements



1. **Administrative Information**
2. **Basin Setting**
3. **Sustainable Management Criteria**
4. **Monitoring Networks**
5. Projects and Management Actions
6. Technical & Reporting Standards
7. Interagency Agreements

Example GSP Section Requirements



- Administrative Information
  - General Description of Area
    - Location, Land Uses, Well Information, Maps, etc.
  - Notice and Communication
  - Public Outreach
  - Beneficial User Information and Input
  - GSA Decision-Making

Example GSP Section Requirements



- Basin Setting
  - –Hydrogeologic Conceptual Model (HCM)
  - –Groundwater Conditions
  - –Water Budget
  - –Management Areas (if applicable and selected by the GSA)

Example GSP Section Requirements



- Sustainable Management Criteria
  - –Sustainability Goal
  - –Undesirable Results
  - –Minimum Thresholds
  - –Interim Milestones
  - –Measurable Objectives

Example GSP Section Requirements



- Monitoring Networks
  - Network Objectives for each Sustainability Indicator
  - Scientific Rationale
  - Monitoring Protocols
  - Locations and Type
  - Data and Reporting Standards
  - Assessment and Improvement Methods

GSP Iterative Process



Thank You

Beneficial User input is essential to GSP development and SGMA planning and implementation.

Please visit the websites or contact Staff to get on the contact list:

Mary Fahey
Water Resources Manager, Colusa Groundwater Authority
530-458-0719
CGA Website: https://colusagroundwater.org/

Lisa Hunter
Program Manager, Glenn Groundwater Authority
530-934-6501
GGA Website: https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority

SGMA Basin Setting
Colusa Subbasin

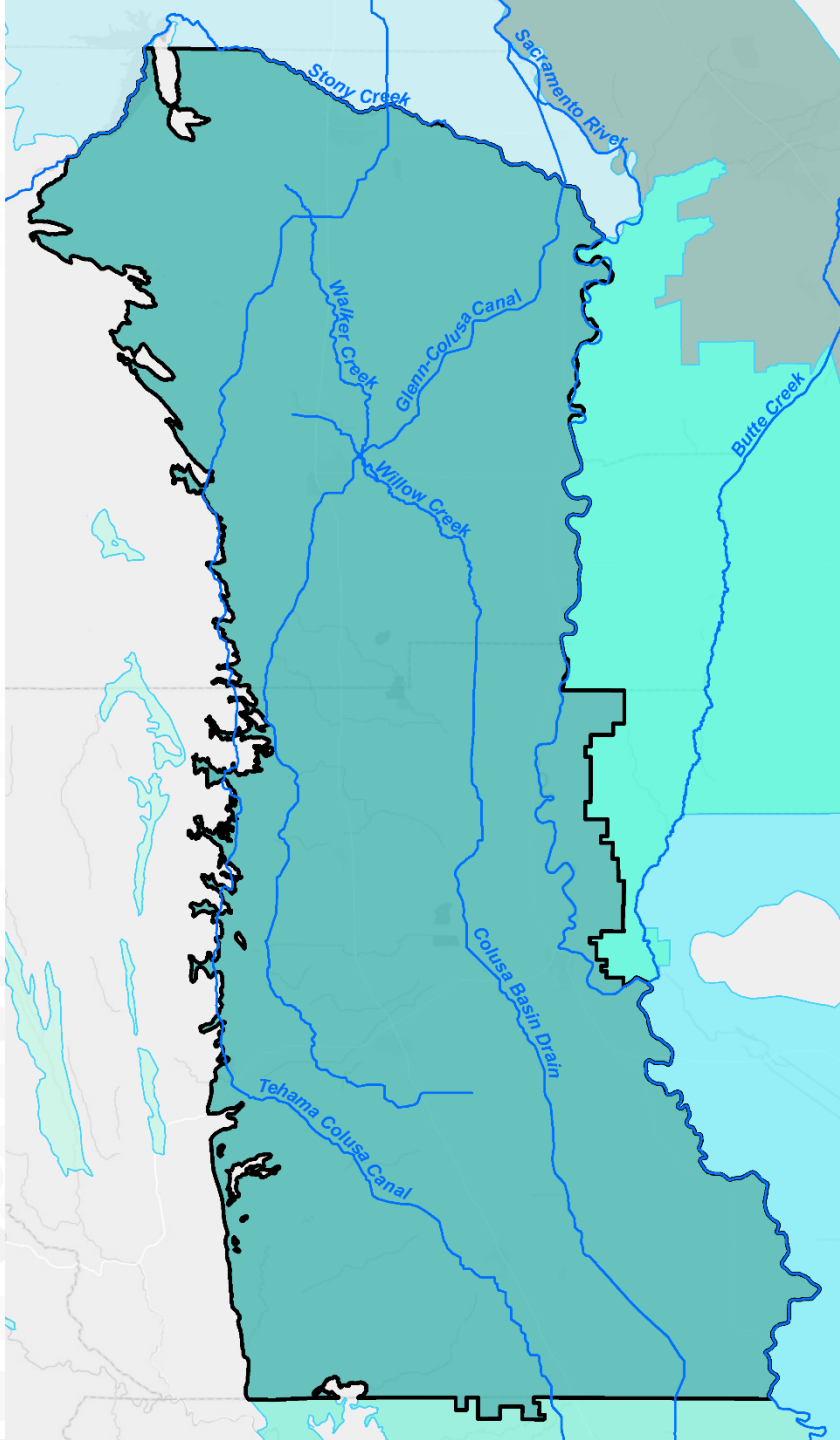
Ken Loy, CHG – West Yost Associates

Dave Ceppos – Facilitator, Sacramento State University

Byron Clark, PE – Davids Engineering

Session Agenda

- Basin Setting Presentation
  - SGMA Definitions
  - Colusa Subbasin Overview
  - Groundwater Flow in Alluvial Basins
  - Stream-Aquifer Interactions
  - Colusa Subbasin HCM
  - Colusa Subbasin Groundwater Conditions
- Small Group Discussions
- Water Budget Update
- Modelling Update



Basin Setting

"Basin Setting"

Definition

(23 CCR § 354.12)

"… physical setting ... characteristics ... and current conditions of the basin … including … **data gaps** and **levels of uncertainty** … that serve as the basis for defining and assessing reasonable **sustainable management criteria** and projects and management actions."

Includes

- Hydrogeologic Conceptual Model (HCM)
- Groundwater Conditions
- Water Budget
- Management Areas (if applicable)

Logical Progression of Basin Activities Needed to Increase Basin Sustainability

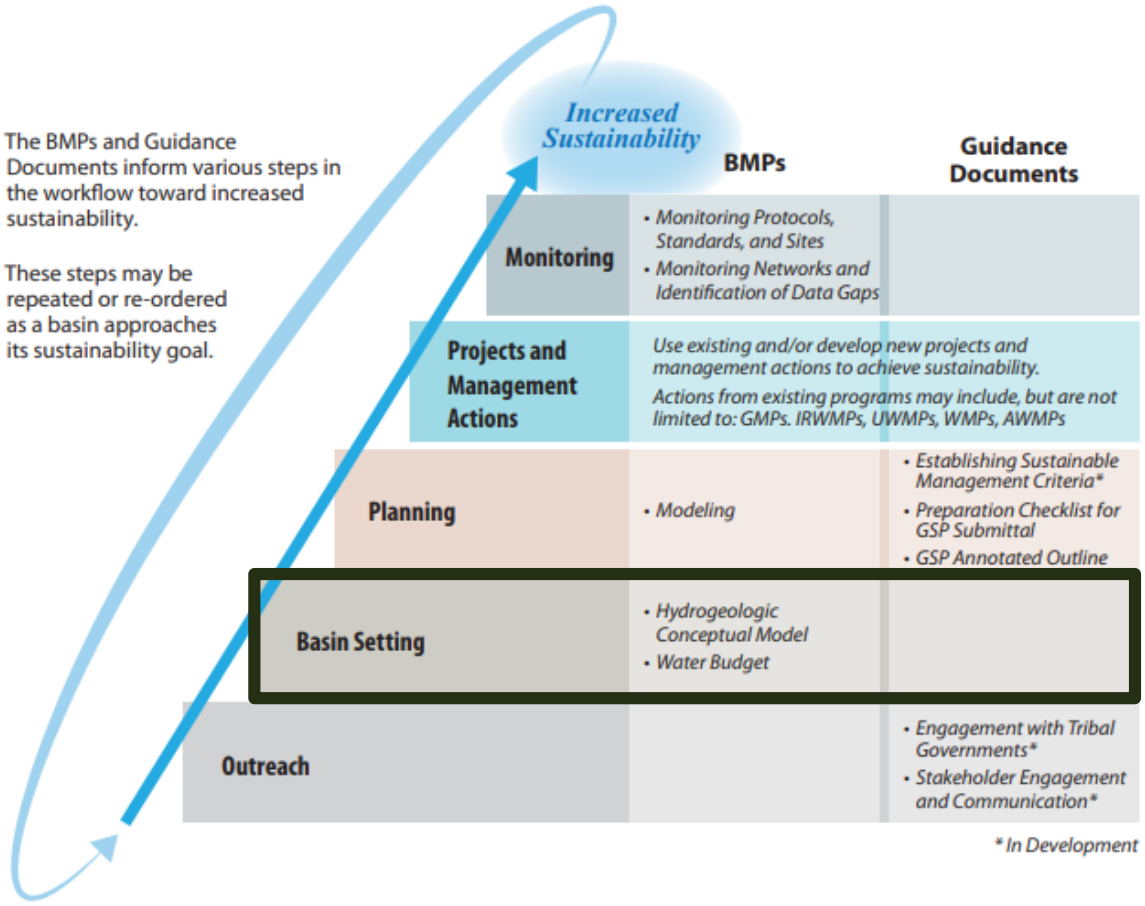


Image Source: DWR, Framework BMP, December 2016.

“Data Gaps” and “Uncertainty”

- **Data Gaps** refer to a lack of information that significantly affects the understanding of the basin setting.
- **Uncertainty** refers to a lack of understanding of the basin setting that affects an Agency's ability to develop sustainable management criteria, appropriate projects, and management actions in a Plan.
- **Data Gaps** and **Uncertainty** may limit the ability to evaluate the efficacy of Plan implementation and to assess whether a basin is being sustainably managed.

"Sustainability Indicators" and Sustainable Management Criteria

- **<u>Sustainability Indicators</u>** refer to any of the effects caused by groundwater conditions that can cause undesirable results with regard to:
  - Groundwater levels
  - Groundwater storage
  - Seawater intrusion
  - Water quality
  - Land subsidence
  - Interconnected surface water

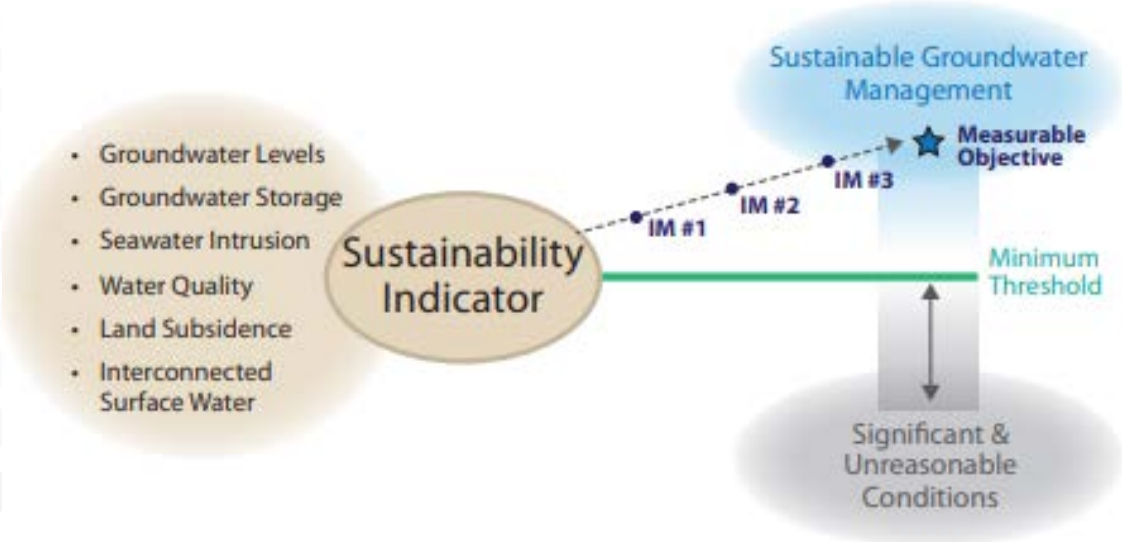
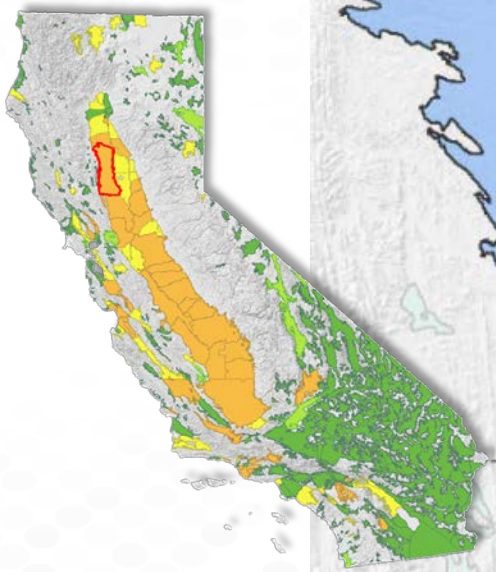
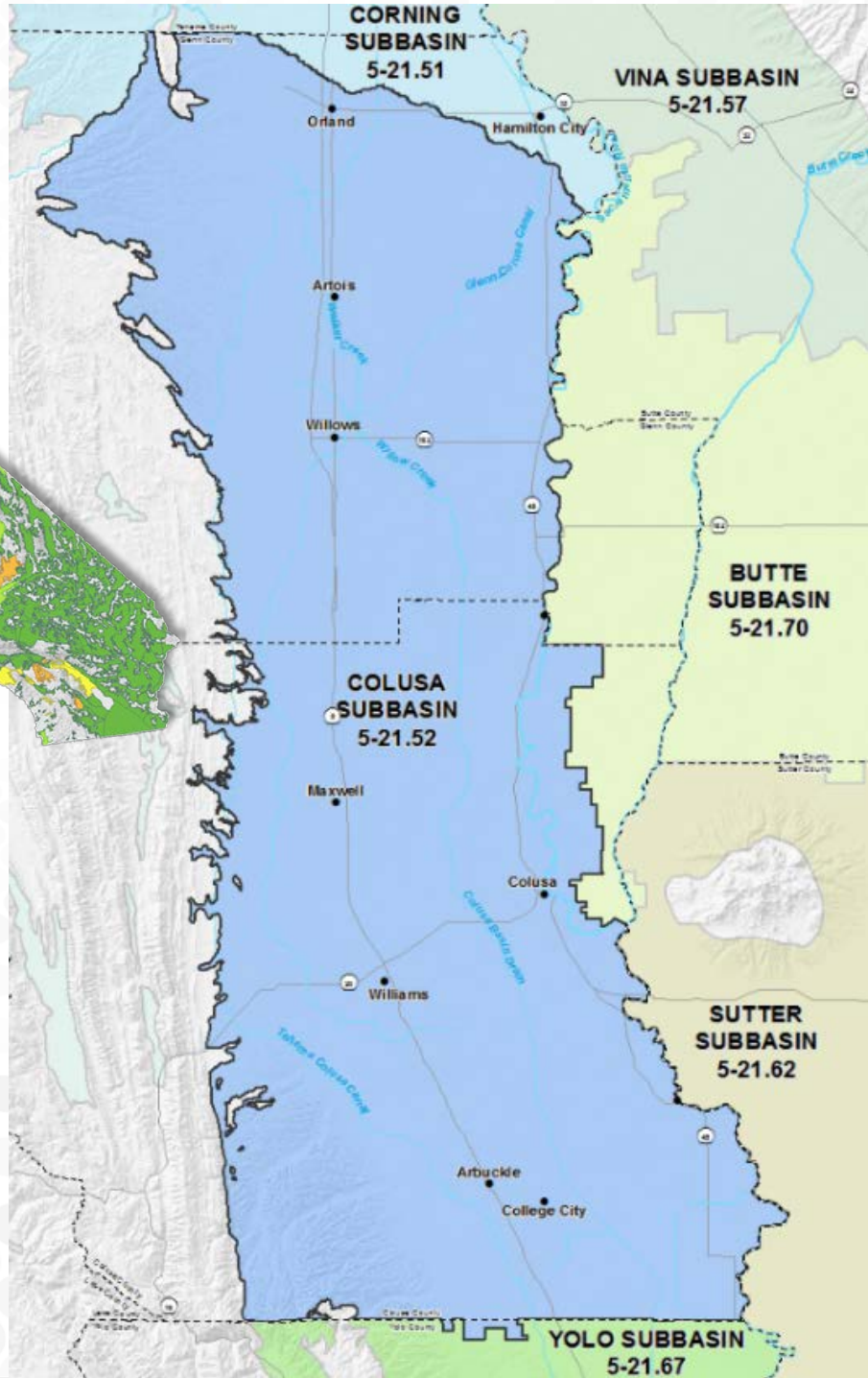


Image Sources: DWR, GSP Emergency Regulations Guide, July 2016.

Colusa Subbasin



- Largest Subbasin in the Sacramento Valley
- 724,000-acre Area
- 60 miles North-South
- 20 miles East-West
- 1,500 ft Thickness



Groundwater Flow in Alluvial Basins

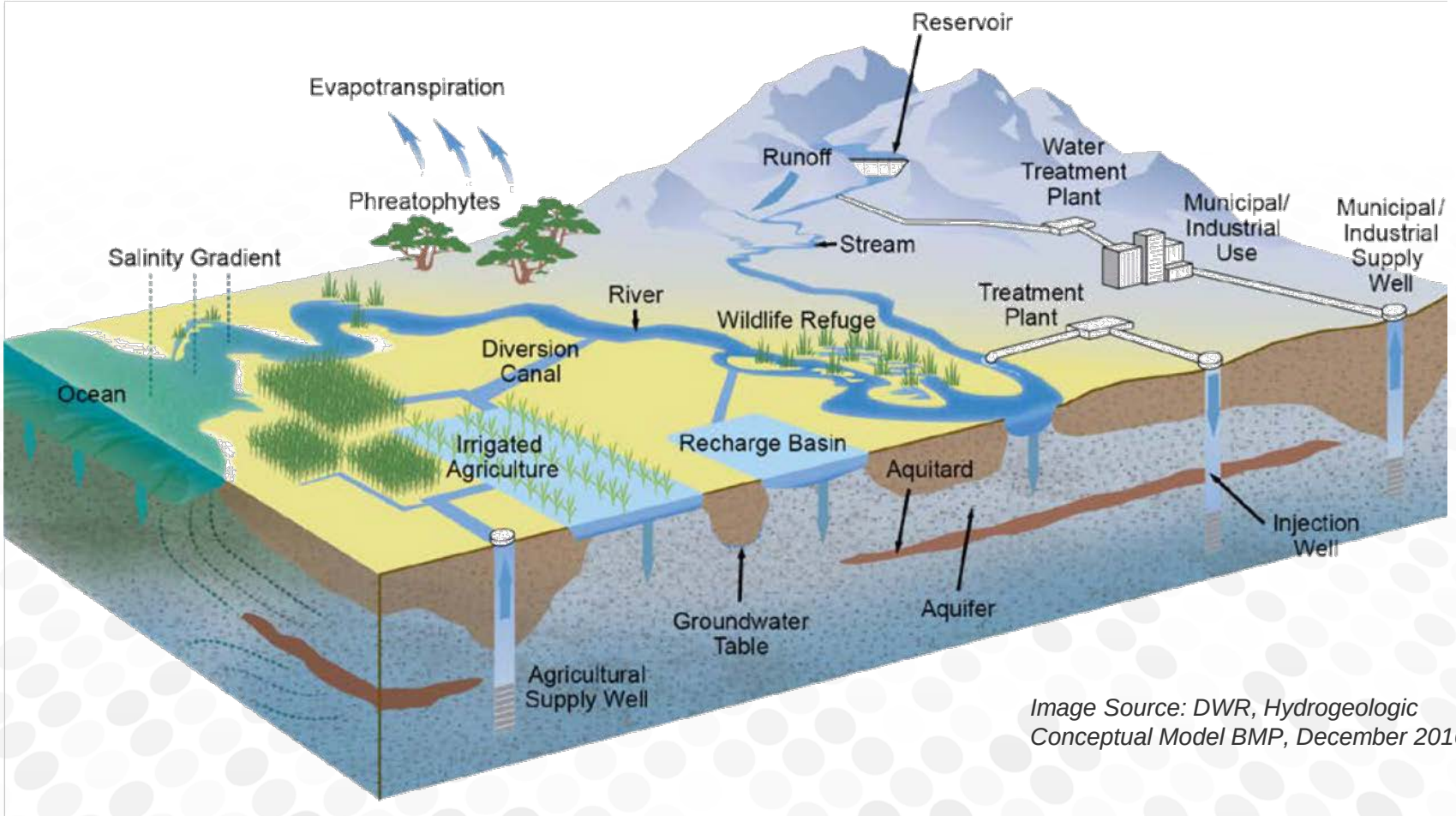
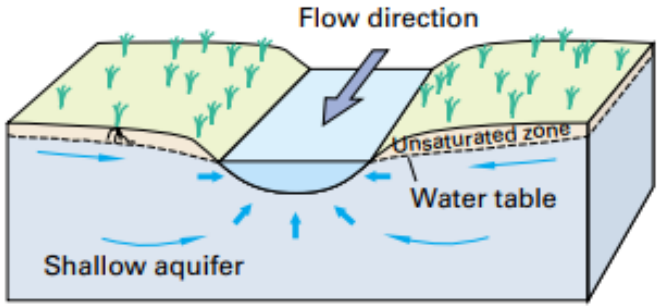


Image Source: DWR, Hydrogeologic Conceptual Model BMP, December 2016.

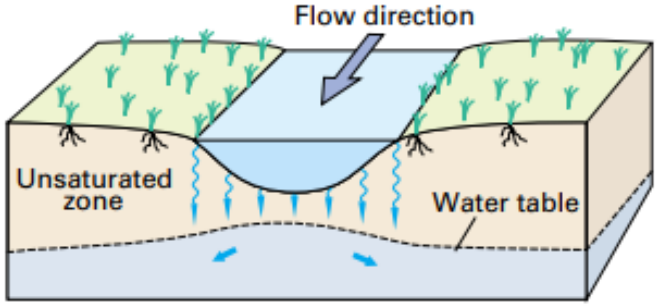
Stream – Aquifer Interactions

GAINING STREAM



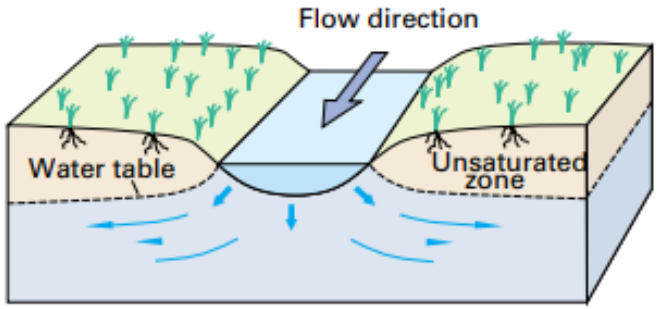
Gaining streams receive water from the groundwater system.

DISCONNECTED STREAM



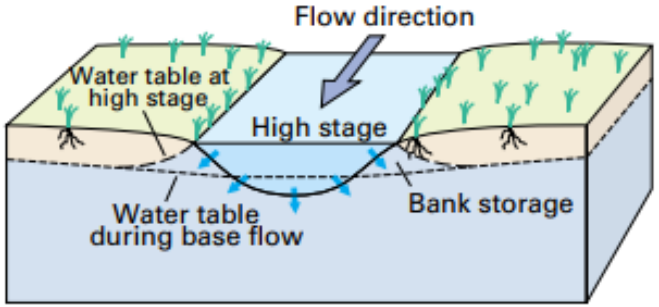
Disconnected streams are separated from the ground water system by an unsaturated zone. For disconnect-ed streams, losses are independent of the groundwater level.

LOSING STREAM



Losing streams lose water to the groundwater system.

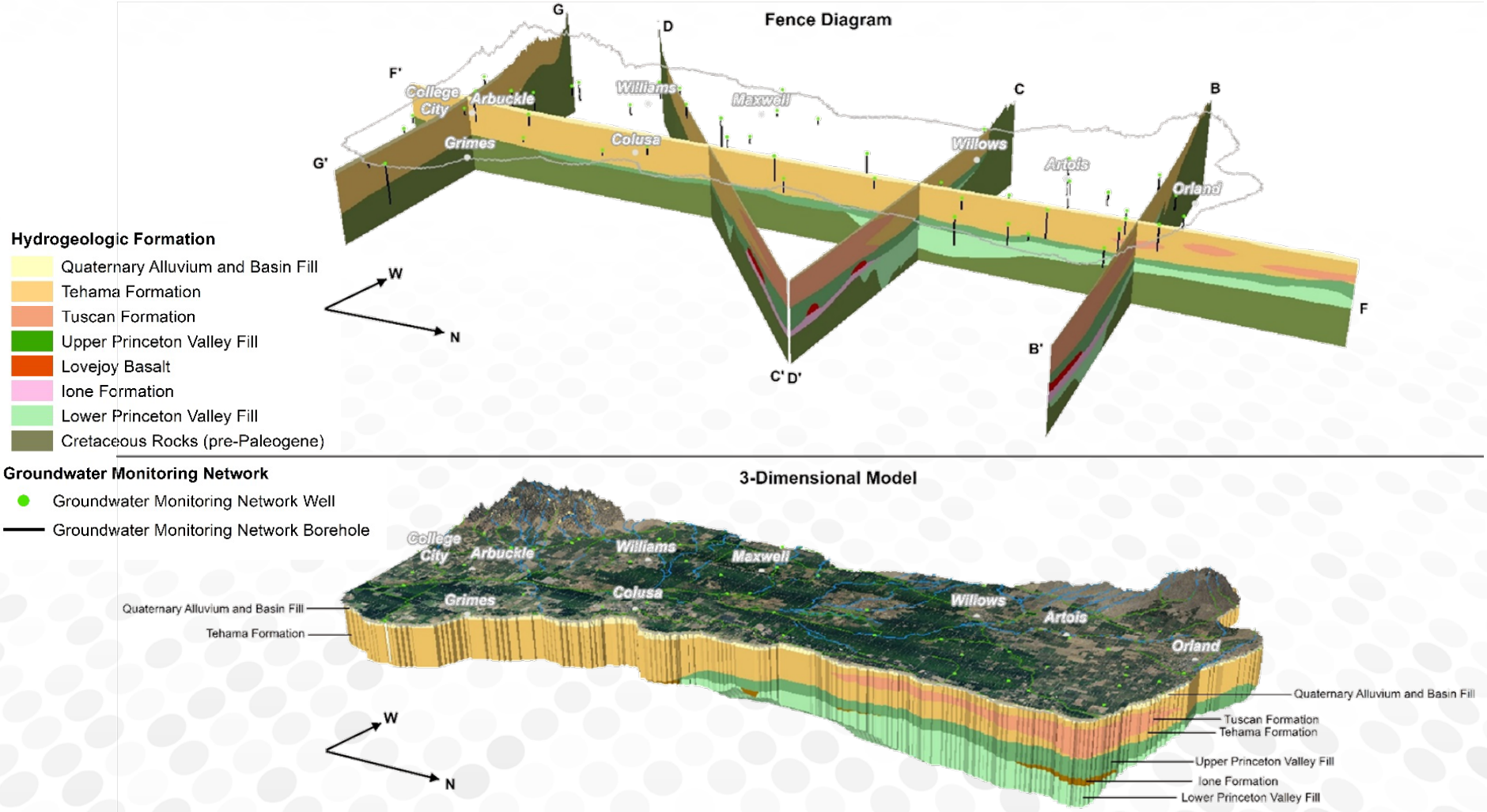
BANK STORAGE



If stream levels ride higher than adjacent groundwater levels, stream water moves into the streambanks as bank storage.

Image Source: Sacramento Valley Groundwater Assessment, prepared for Northern California Water Association, June 2014.

Hydrogeologic Conceptual Model



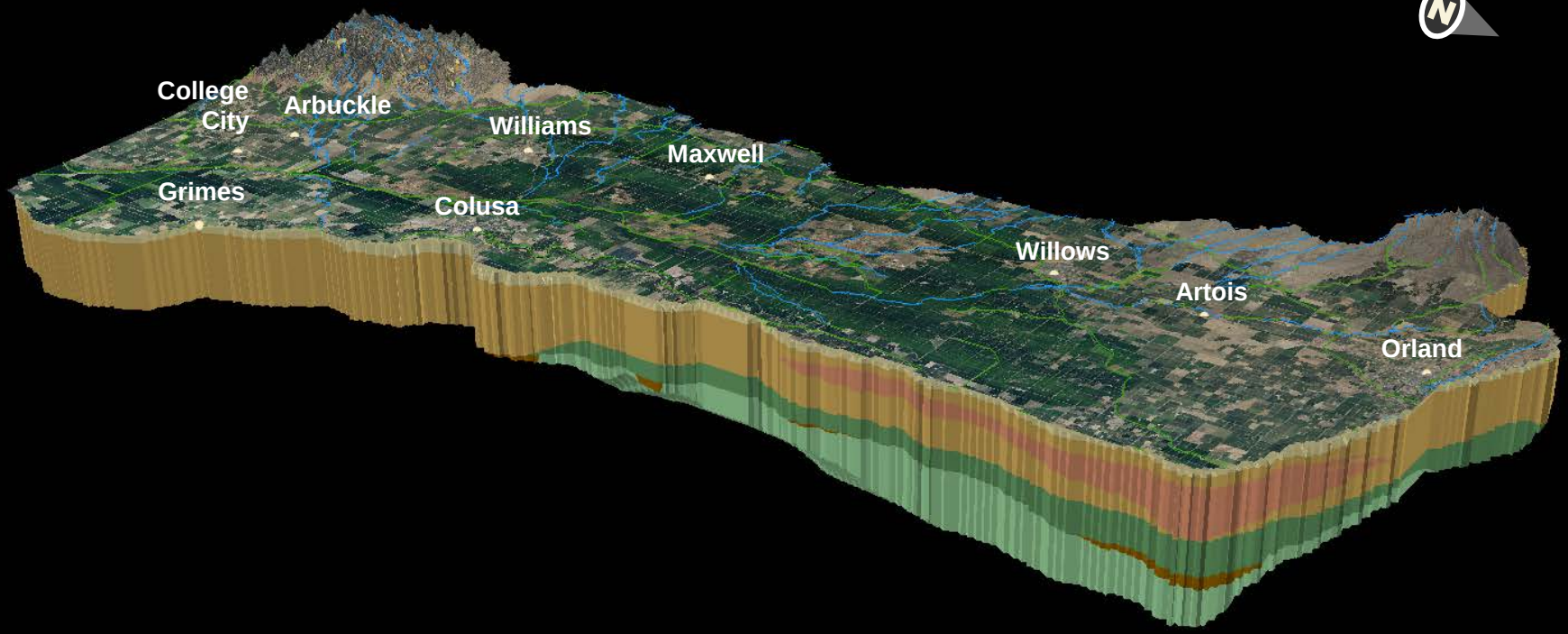
Vertical Exaggeration=10x

Image Source: Hydrogeologic Conceptual Model Report, May 2018.

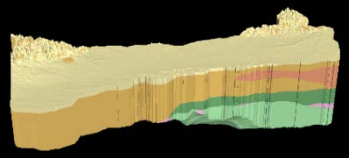
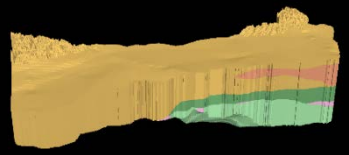
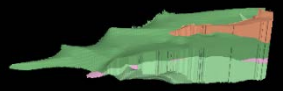
Hydrogeologic Conceptual Model



Hydrogeologic Conceptual Model



Improved Understanding of Principal Aquifers

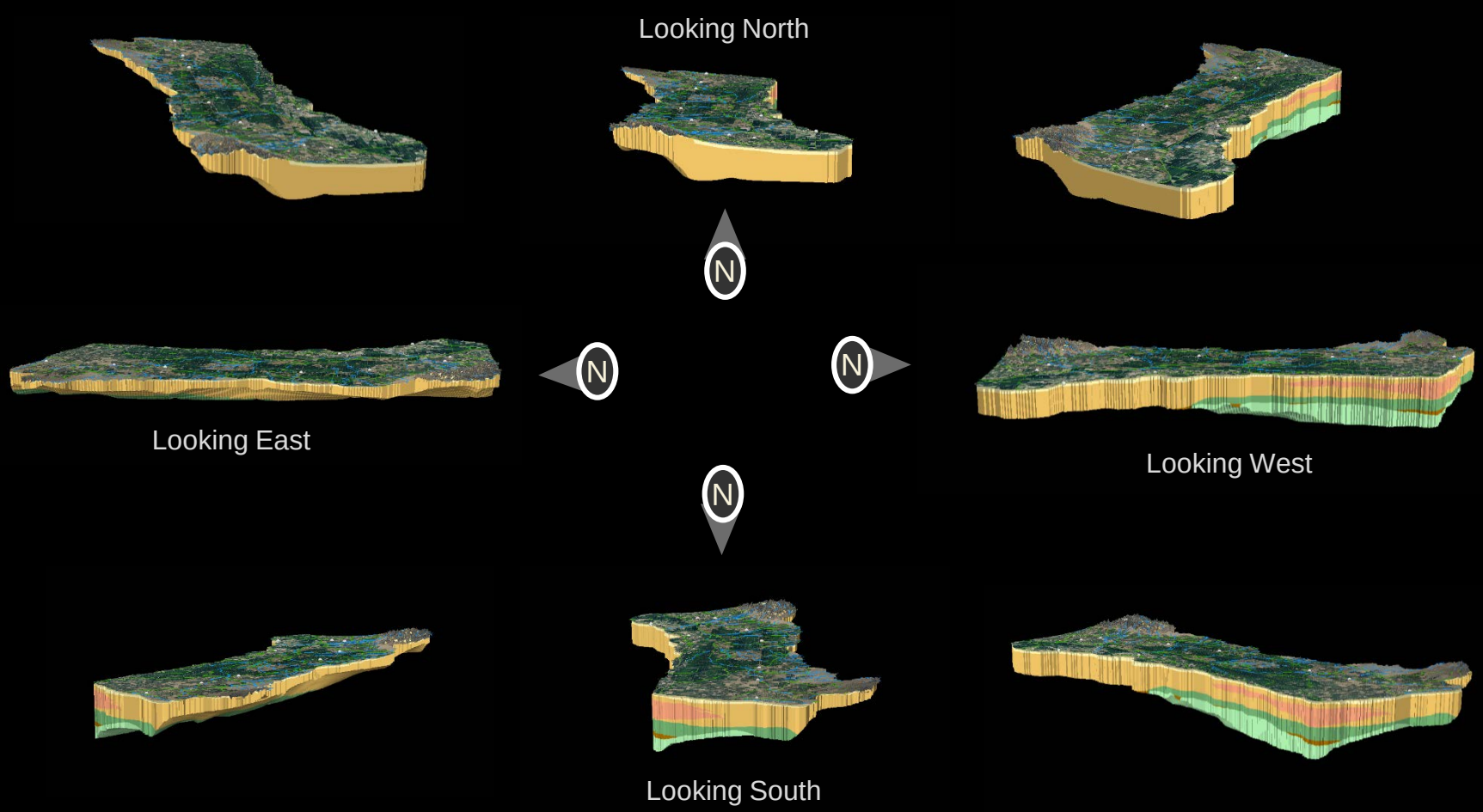
Stacked Formations	Principal Aquifers	Geologic Formation
		Young Alluvium
		Tehama Formation
		Tuscan Formation
Below Geologic Base of Freshwater		
		Upper Princeton Valley Fill Ione Formation Lower Princeton Valley Fill



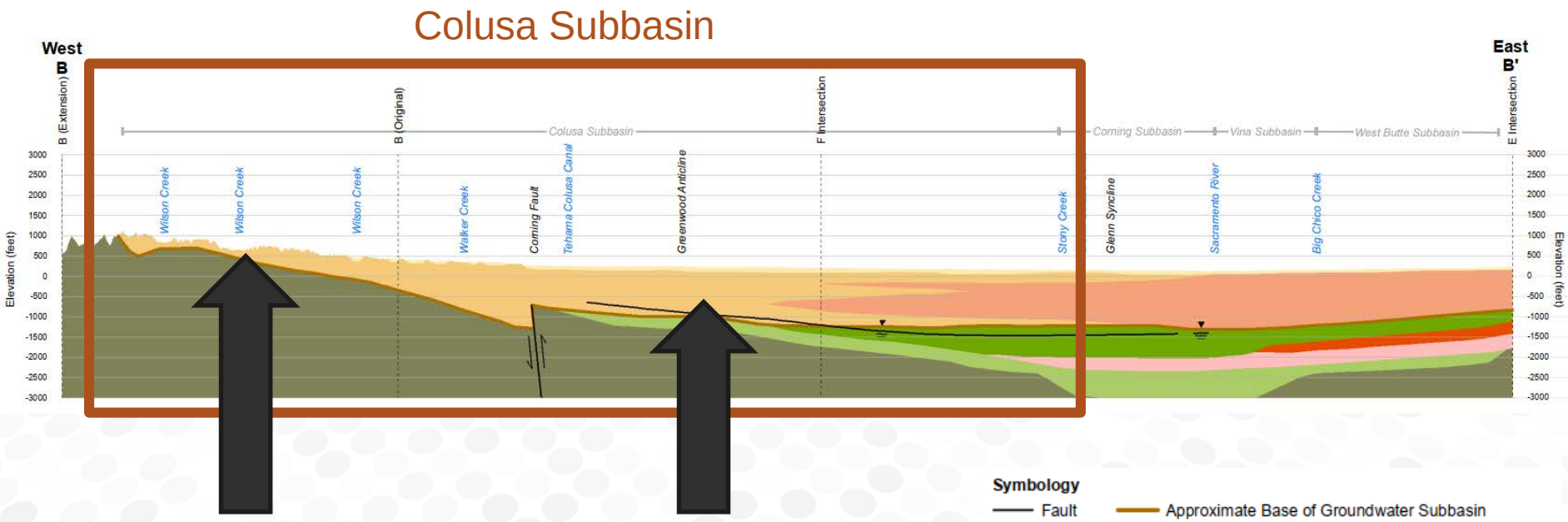
Vertical Exaggeration=10x

- Alluvium
- Tehama Formation
- Tuscan Formation
- Upper Princeton Valley Fill
- Ione Formation
- Lower Princeton Valley Fill

Multi-Directional View of HCM



Cross Section B-B’



Principal aquifers are thinner along the western edge of the basin

Principal aquifers are generally thicker closer to middle of the Sacramento Valley

Symbology

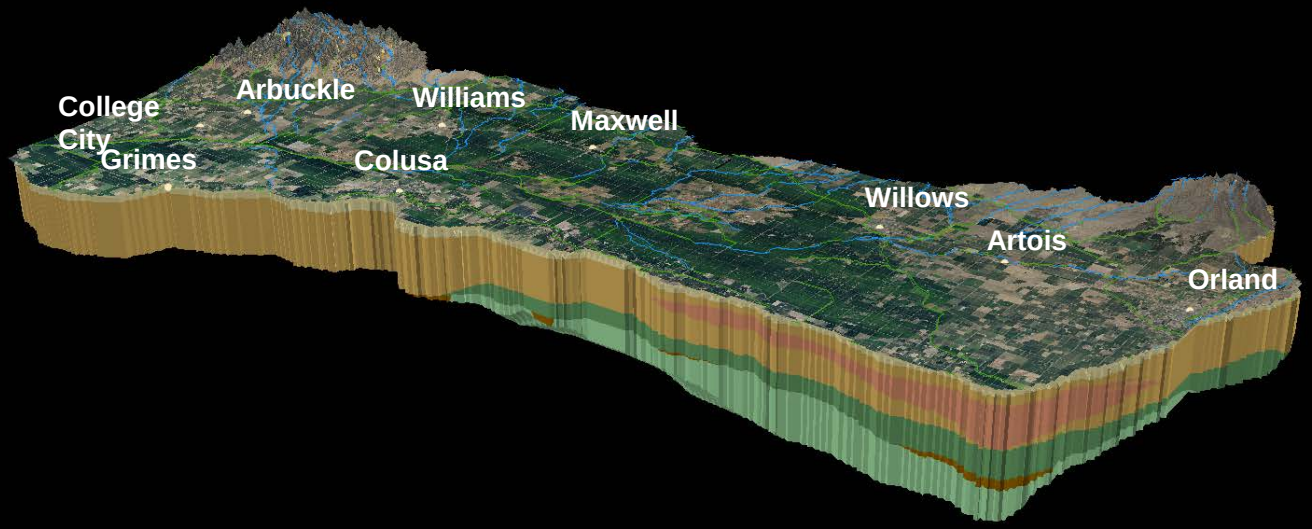
- Fault
- Approximate Base of Groundwater Subbasin
- Base of Fresh Water (~2,000 mg/L TDS)

Geologic Units

- Alluvium
- Tehama Formation
- Tuscan Formation
- Upper Princeton Valley Fill
- Lovejoy Basalt
- Ione Formation
- Lower Princeton Valley FIll
- Cretaceous Rocks (pre-Paleogene)

Image Source: Hydrogeologic Conceptual Model Report, May 2018.

Water Movement Through the HCM



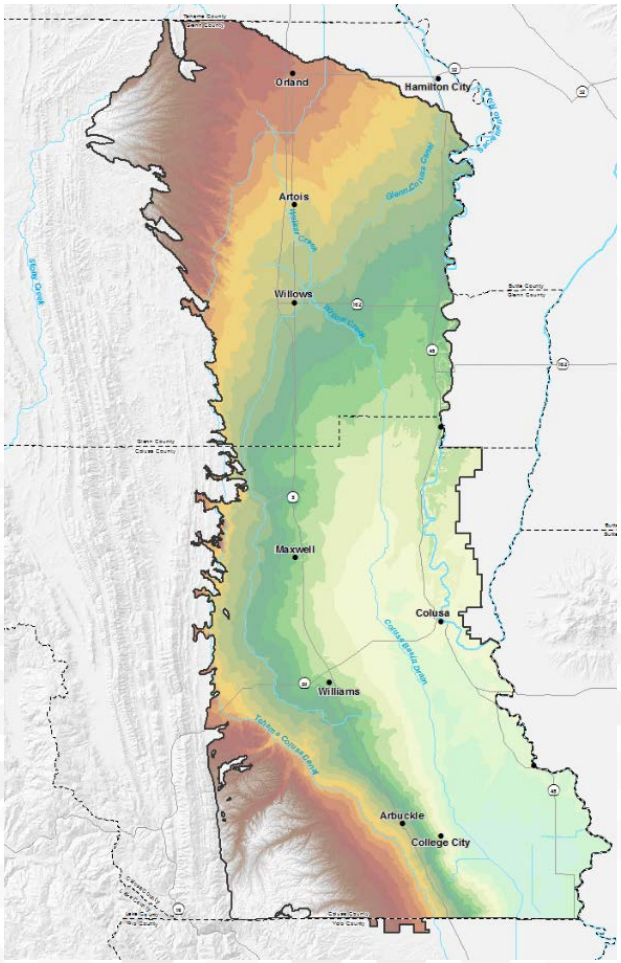
Major Water Budget Components

- Precipitation Recharge
- Applied Water Recharge
- Evapotranspiration
- Pumping & Injection
- Surface Water Inflows & Outflows
- Stream - Aquifer Interactions
- Underflow

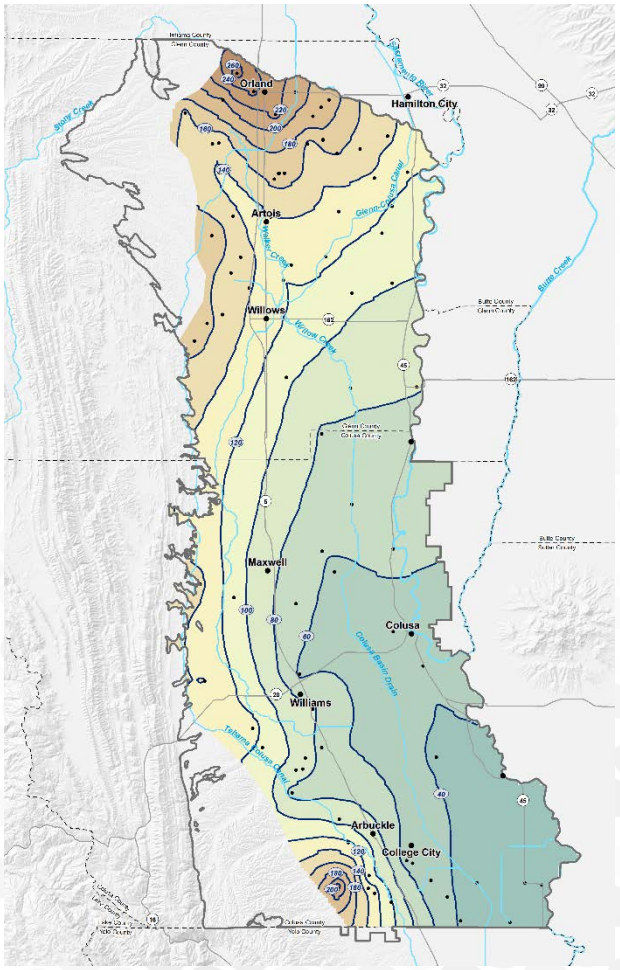
Vertical Exaggeration=10x

Groundwater Flow Trends

Land Surface Elevation

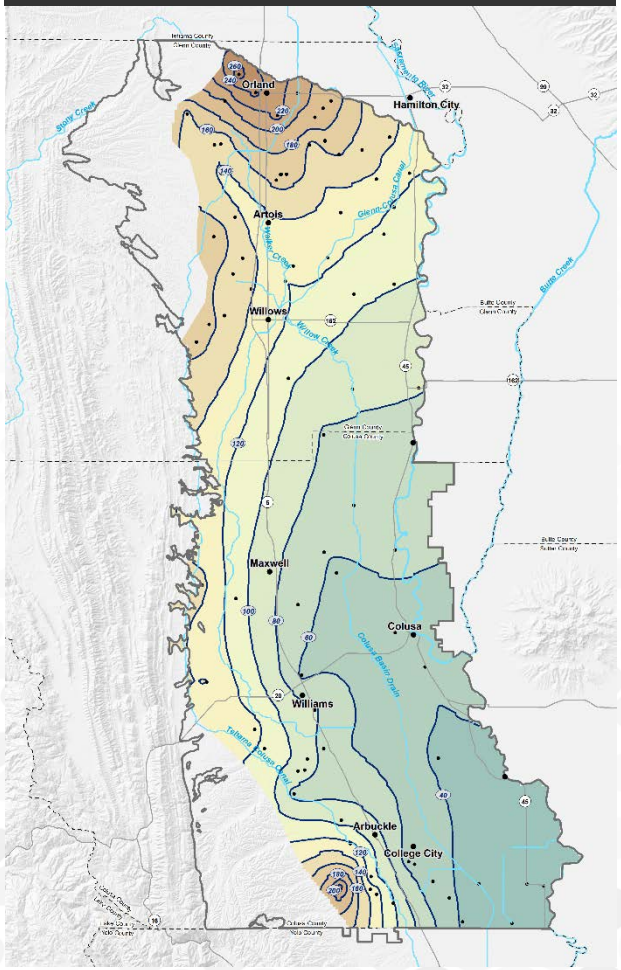


GWE Spring 2006

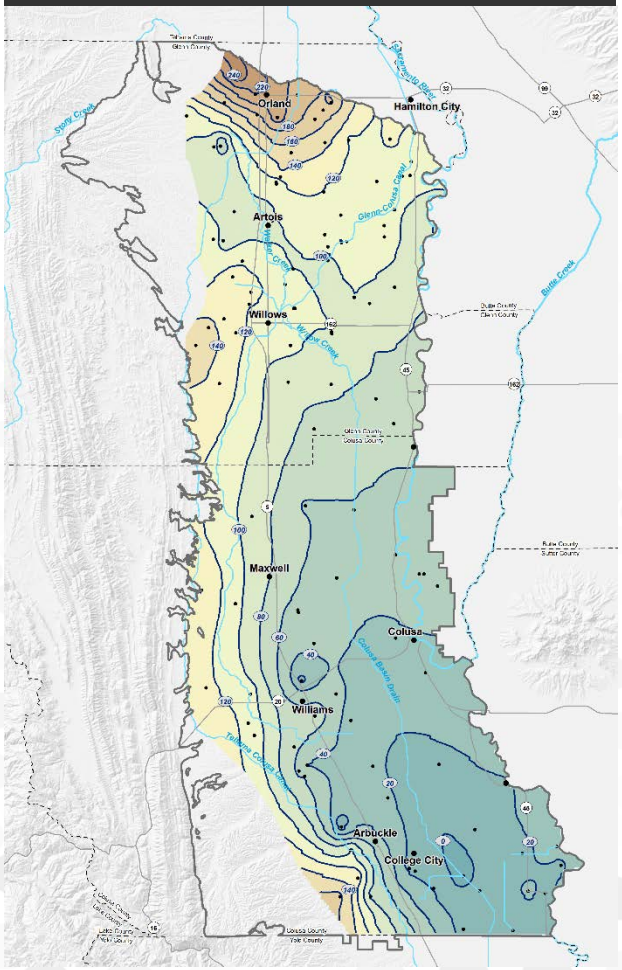


Groundwater Elevation Change - 2006 to 2015

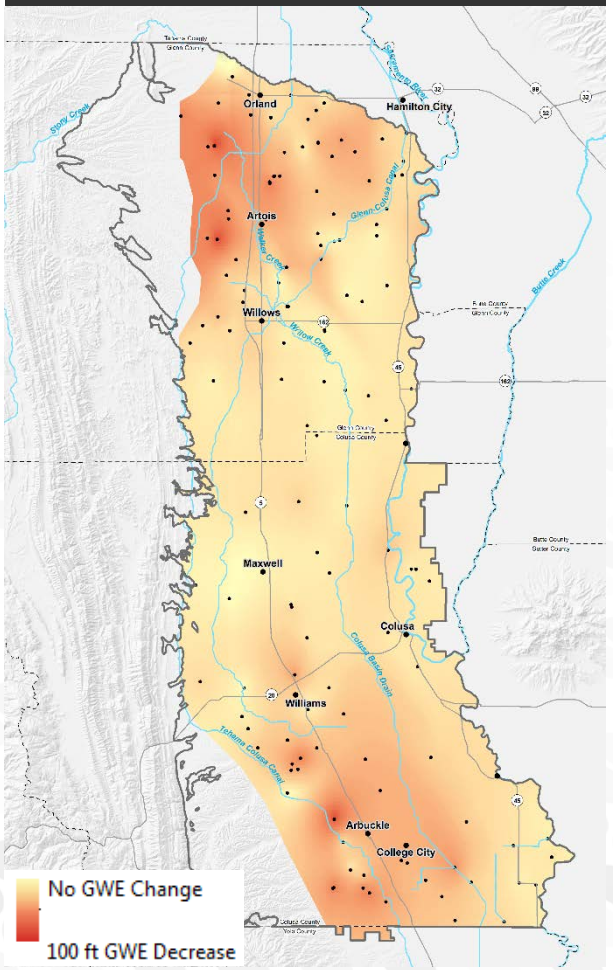
GWE Spring 2006



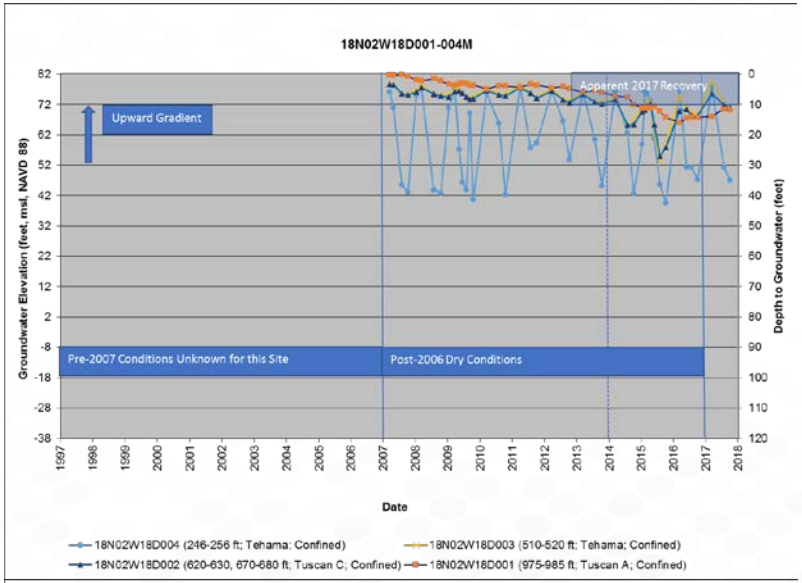
GWE Spring 2015

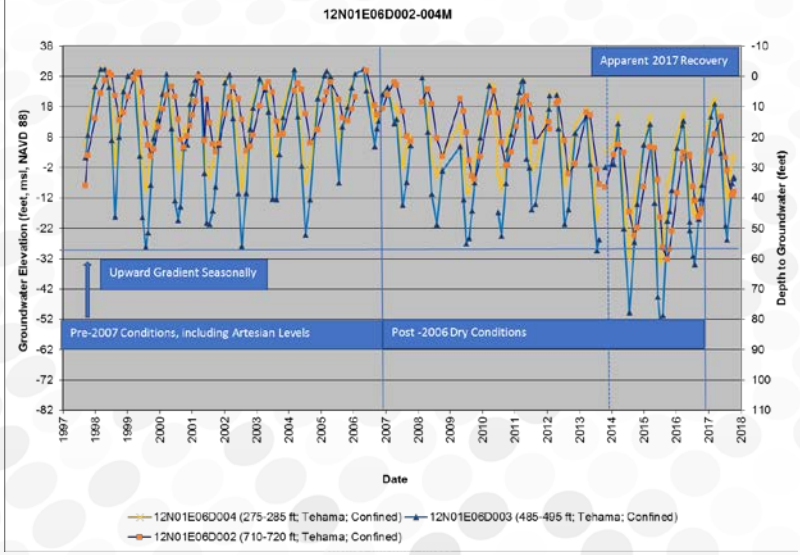


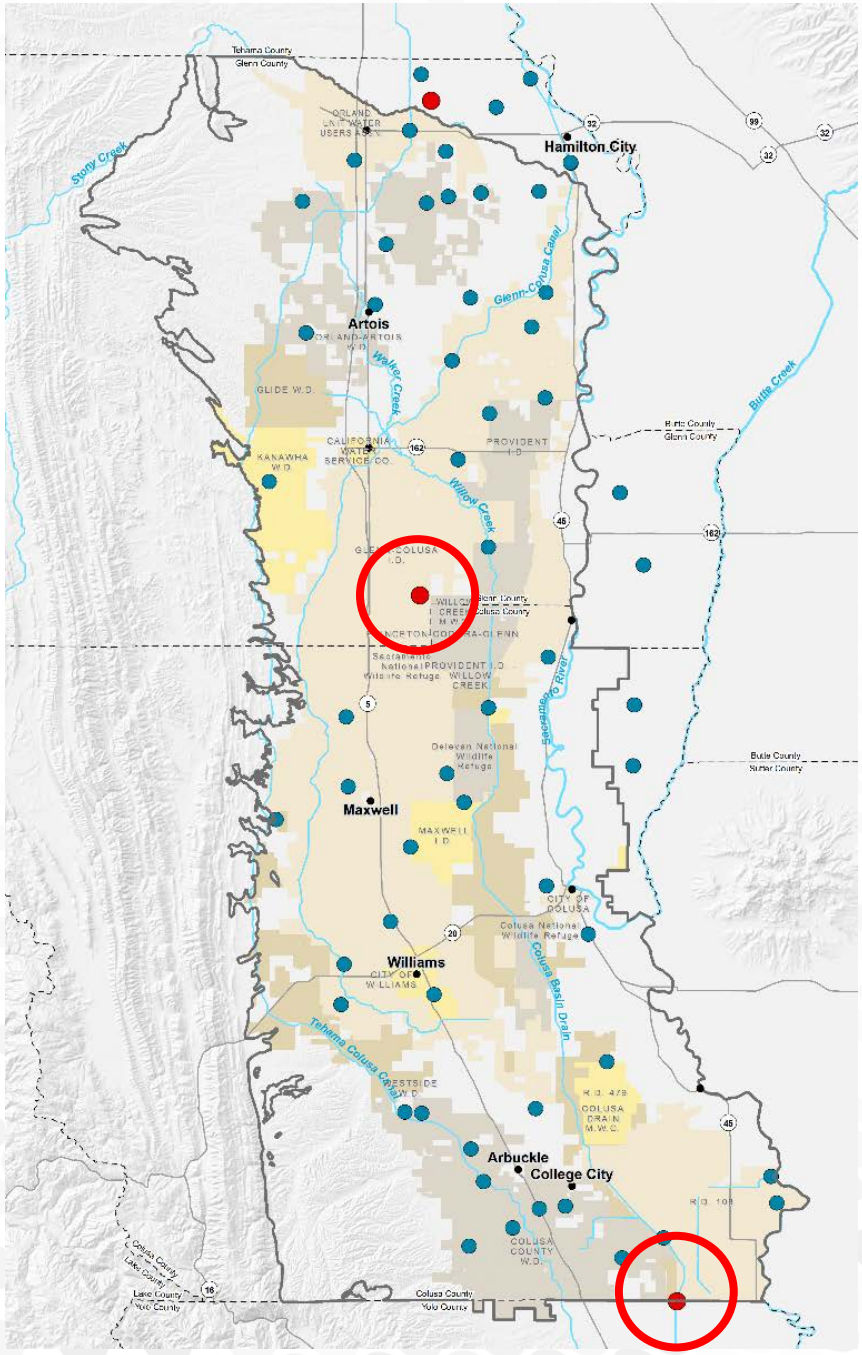
GWE Change



Hydrographs

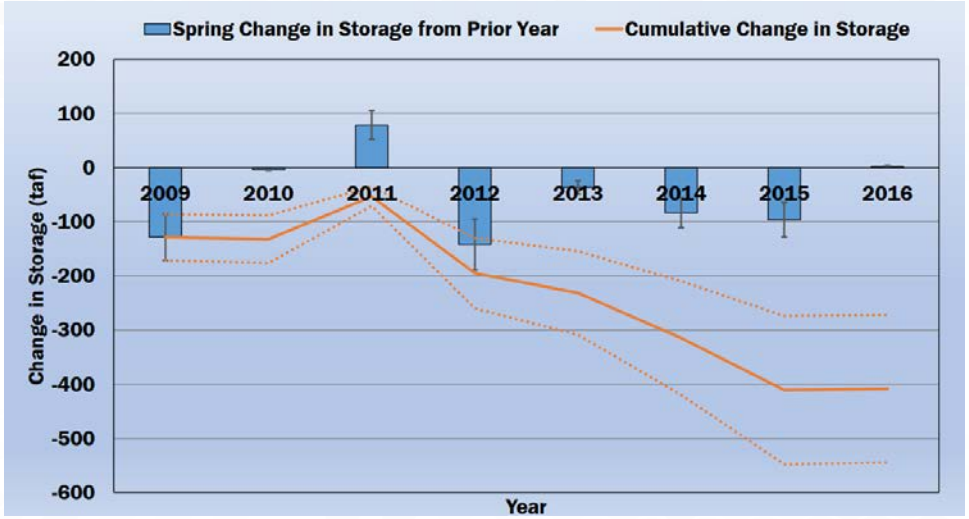






Colusa Subbasin Groundwater Storage

Colusa County



Glenn County

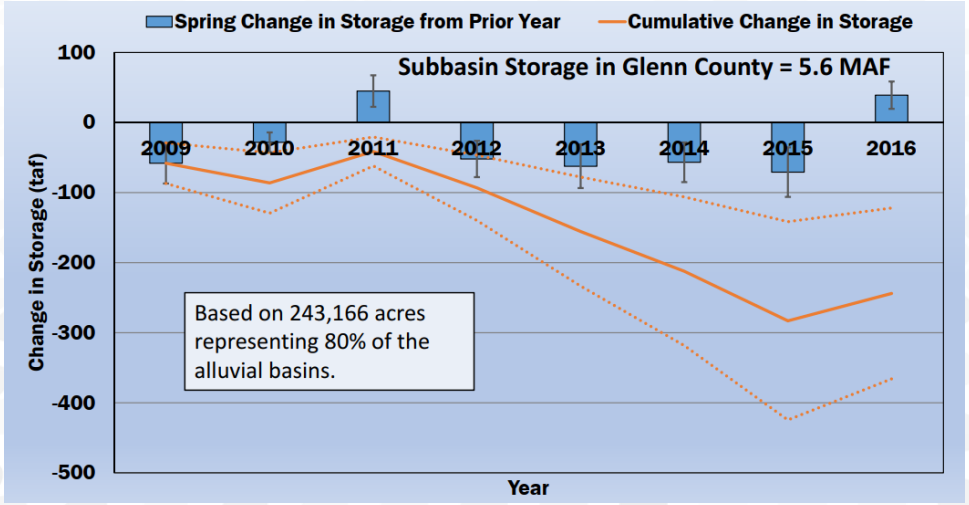


Image Sources:
Groundwater Conditions in Colusa County Relative to Final Groundwater Sustainability Plan Regulations, July 2016.
Glenn County Reconnaissance-Level Groundwater Sustainability Risk Assessment, May 2017.

Groundwater Storage

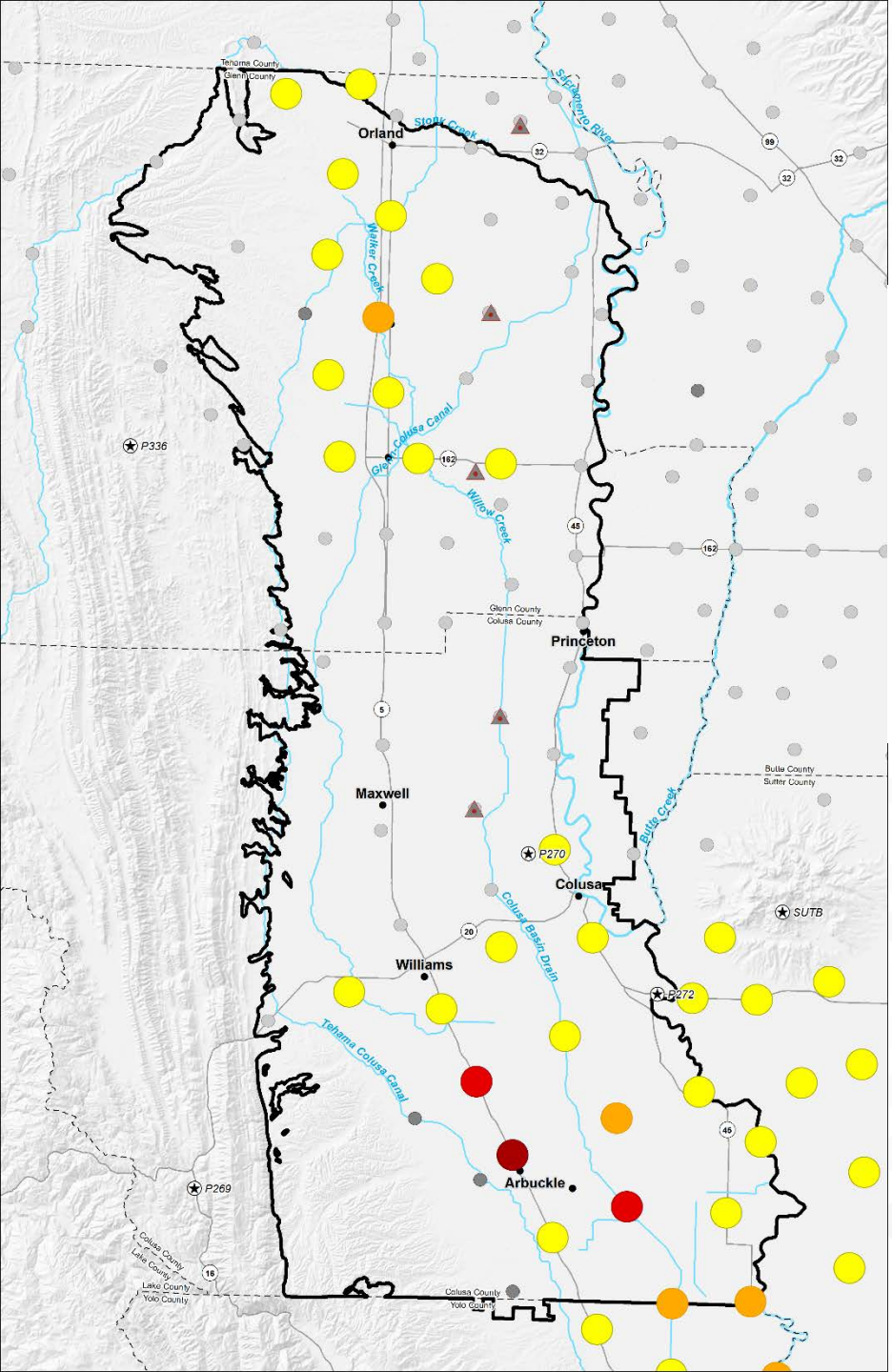
- Storage reduced during multiple-year drought but early analysis indicates recovery.

Groundwater Quality

- Current groundwater quality is generally “good” with potential for some isolated issues.
- Focus will be on impacts to groundwater quality due to activities after implementation of Colusa Subbasin GSP.
- Existing water quality monitoring programs are sufficient and not expected to change due to GSP implementation.



Land Subsidence Survey

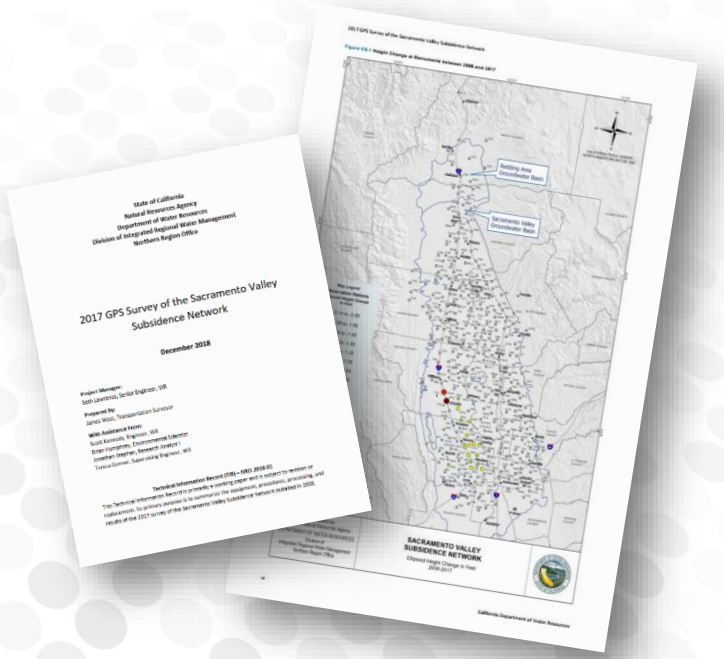


- Continuous GPS Station
- Extensometer

Sacramento Valley Subsidence Benchmarks with 2008 to 2017 Height Difference

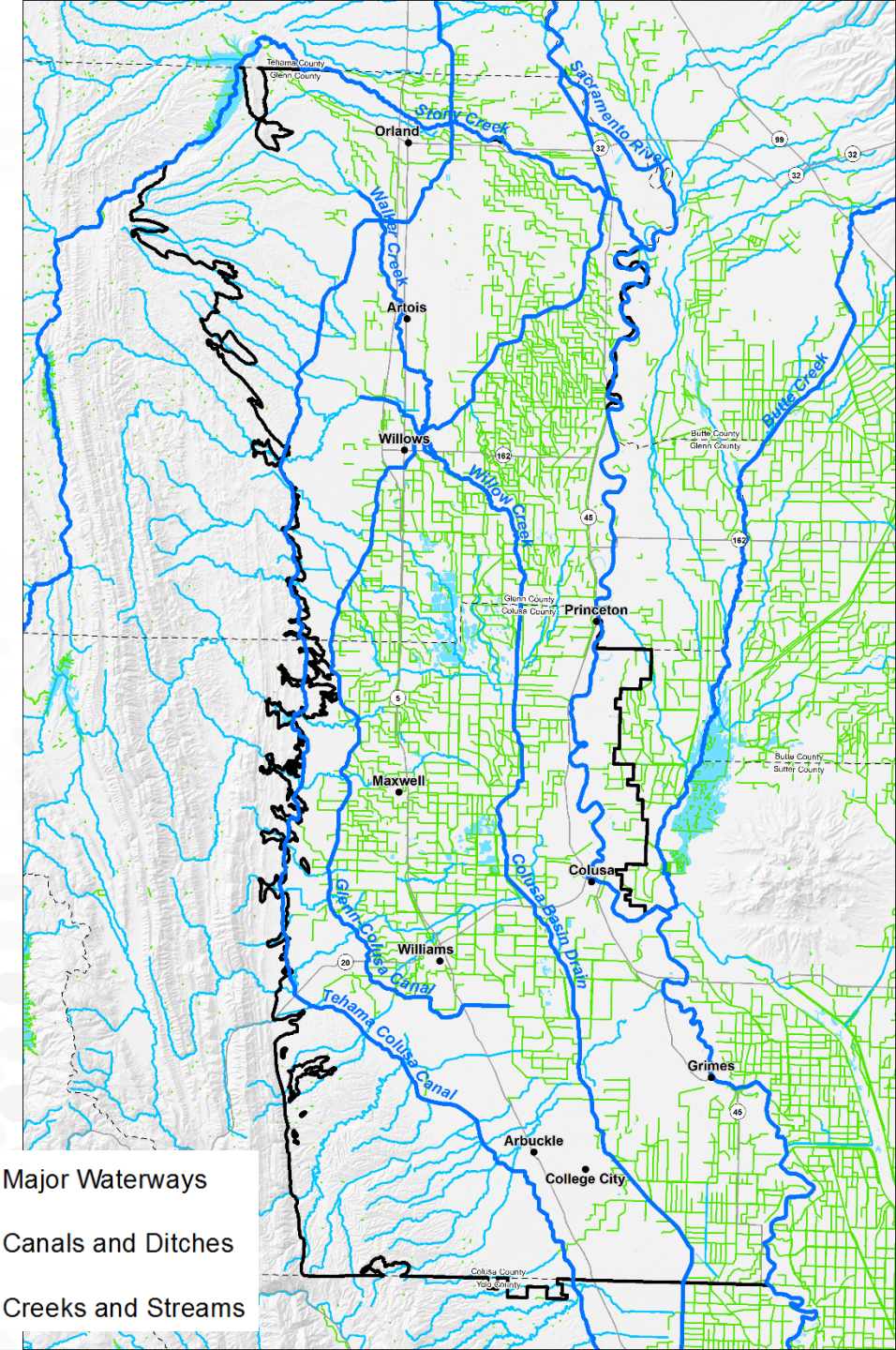
- ≥2 feet
- 1 - <2 feet
- 0.5 - <1 foot
- 2 - <6 inches
- < 2 inches
- New Benchmark or Not Surveyed

2017 GPS Survey Sacramento Valley Subsidence Network, December 2018



Interconnected Surface Waters

- Interconnected surface waters exist within Colusa Subbasin.
- There is uncertainty regarding how groundwater use under the Colusa Subbasin GSP would impact these surface waters.
- Numerical modelling will be used to evaluate impacts to interconnected surface waters.

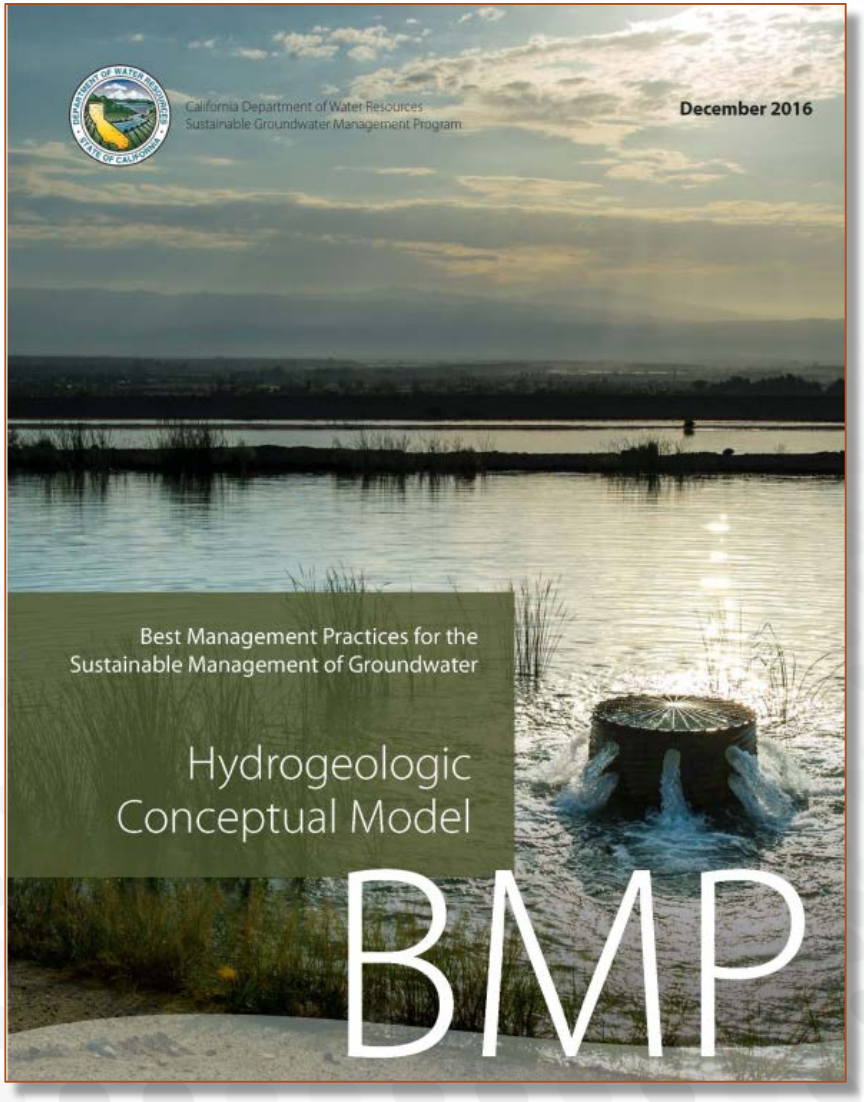


Additional HCM Information

- HCM Fundamentals
- Technical Assistance
- Key Definitions
- Related Materials

- Google:

"SGMA HCM BMP"



Questions?

Ken Loy, CHG

Principal Hydrogeologist - West Yost Associates

kloy@westyost.com

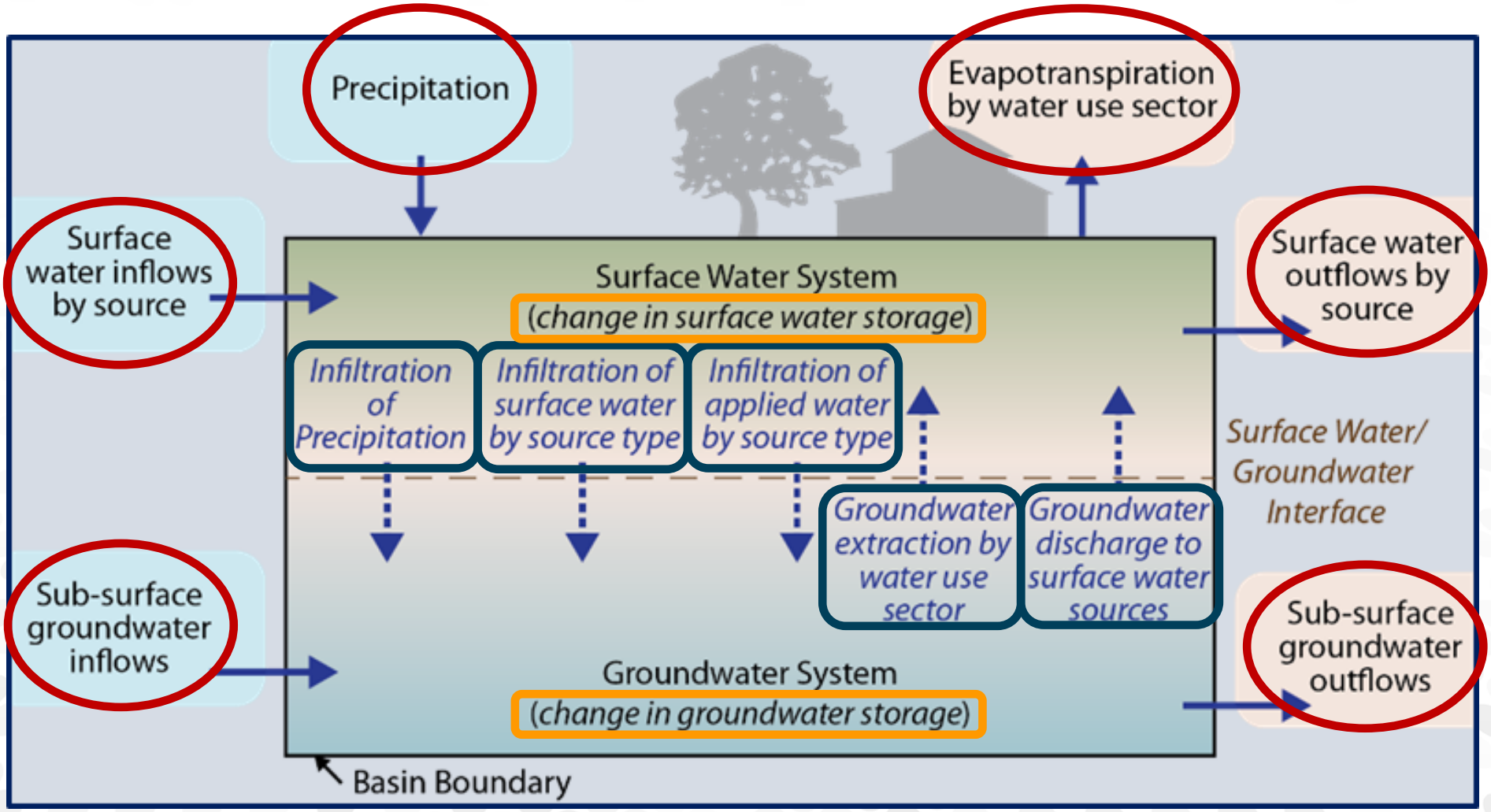
Small Group Discussions – Subbasin Challenges

Water Budget Update

Water Budget Overview

- Explicitly required for inclusion in the GSP (§354.18)
- Complete accounting of inflows, outflows, and change in storage
- Just like a checking account:
  - Deposits – Withdrawals = Balance Change, or
  - Inflows – Outflows = Change in Storage
- Grounded in data
- Must be developed for historical, current, and potential future conditions
- Supported by development of an Integrated Hydrologic Model

Water Budget Components



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- Related Materials

- Google:

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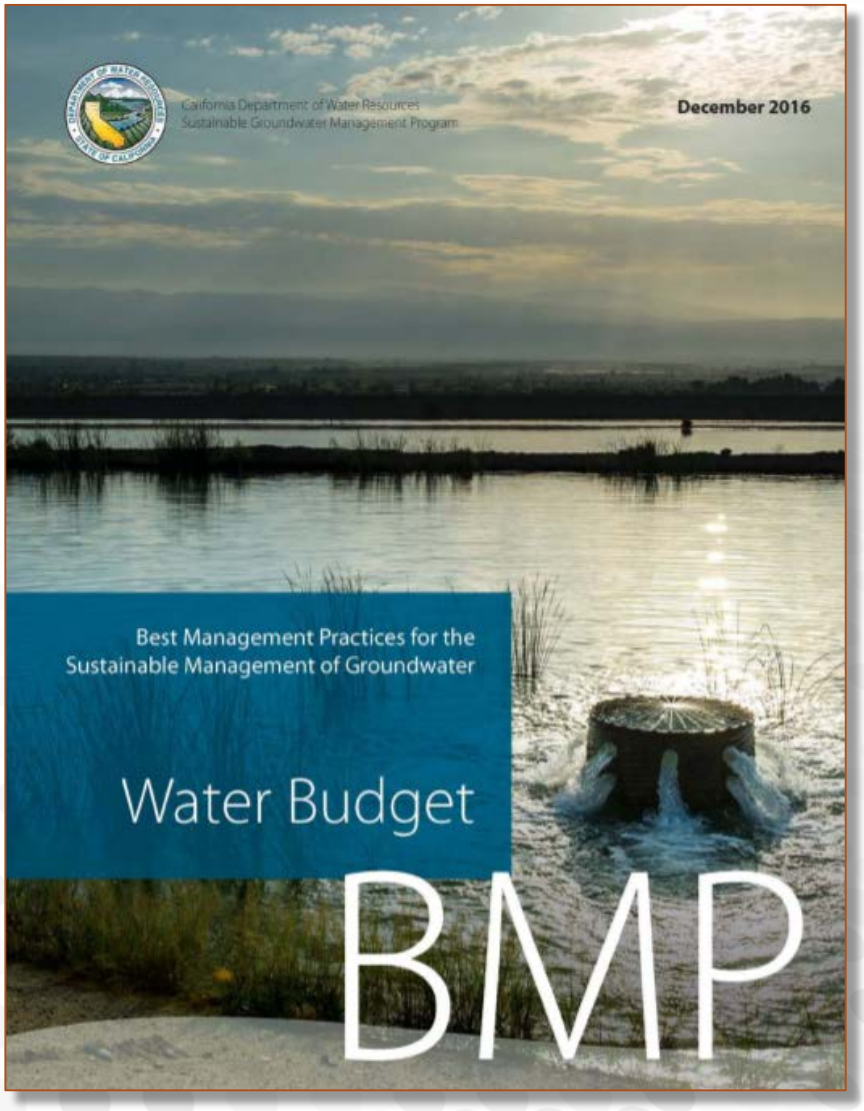


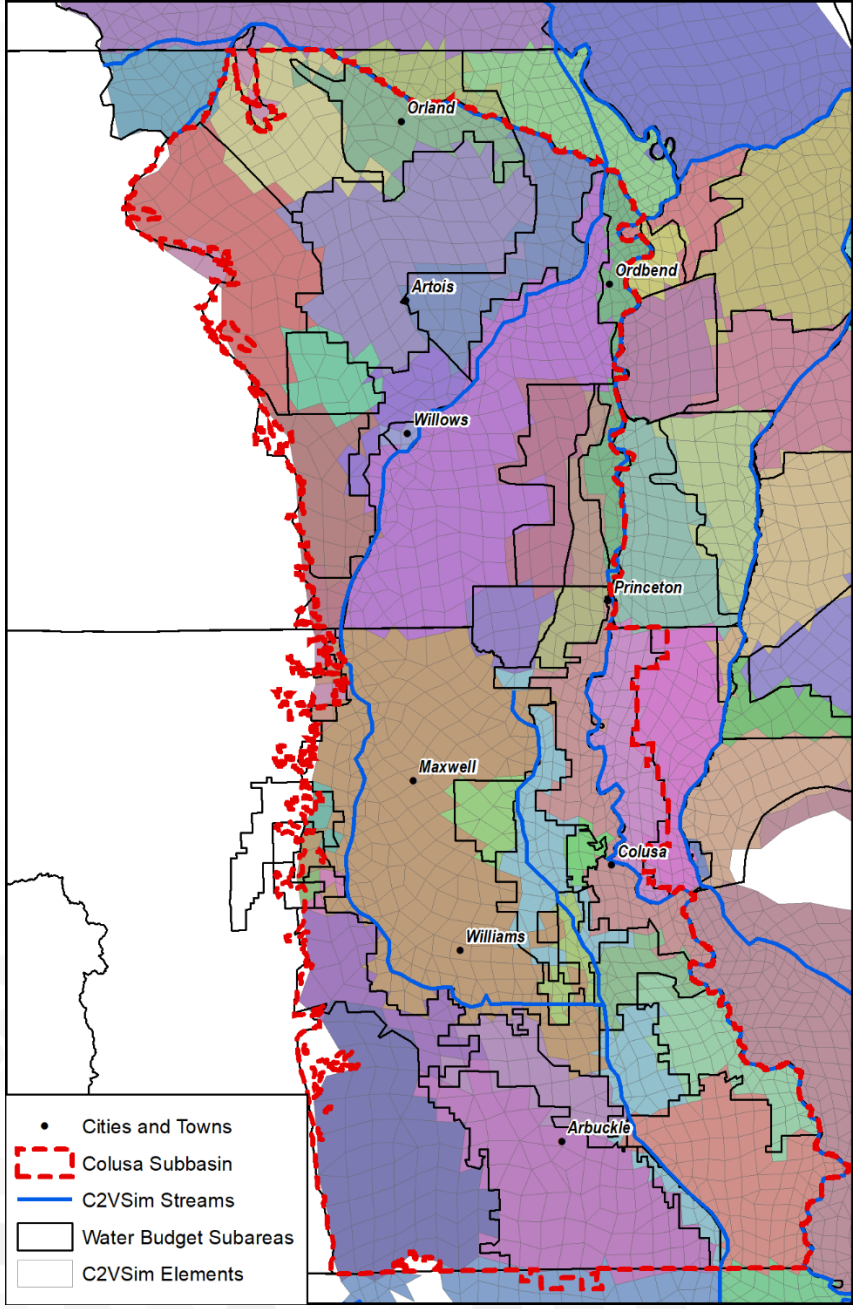
Questions?

Byron Clark, PE
Supervising Engineer – Davids Engineering
byron@davidsengineering.com

Modelling Update

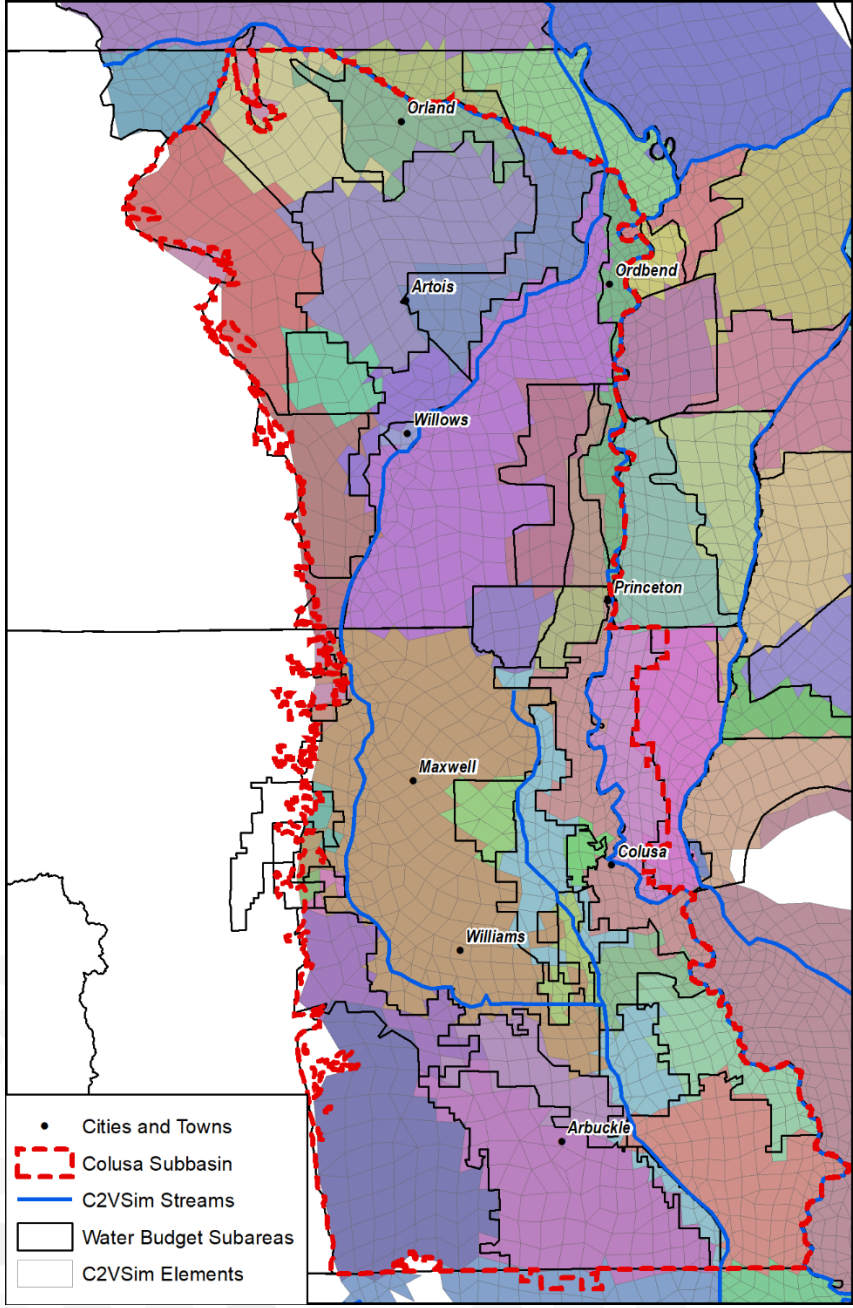
Integrated Hydrologic Model Overview

- Simulates movement of water in the basin over time
- Based on DWR's California Central Valley Groundwater-Surface Water Simulation Model (C2VSim)
- Refined for Local Use
  - Land Use
  - Surface Water Diversions
  - Aquifer Parameters
- Calibrated Based on Measured Data
  - Groundwater levels
  - Streamflows



Integrated Hydrologic Model Uses

- Water Budgets
  - Historical
  - Current
  - Projected
- Sustainable Management Criteria
  - Groundwater levels and storage
  - Stream gains and losses
- Projects and Management Actions
  - Level and storage changes
  - Area of benefit



Additional Modeling Information

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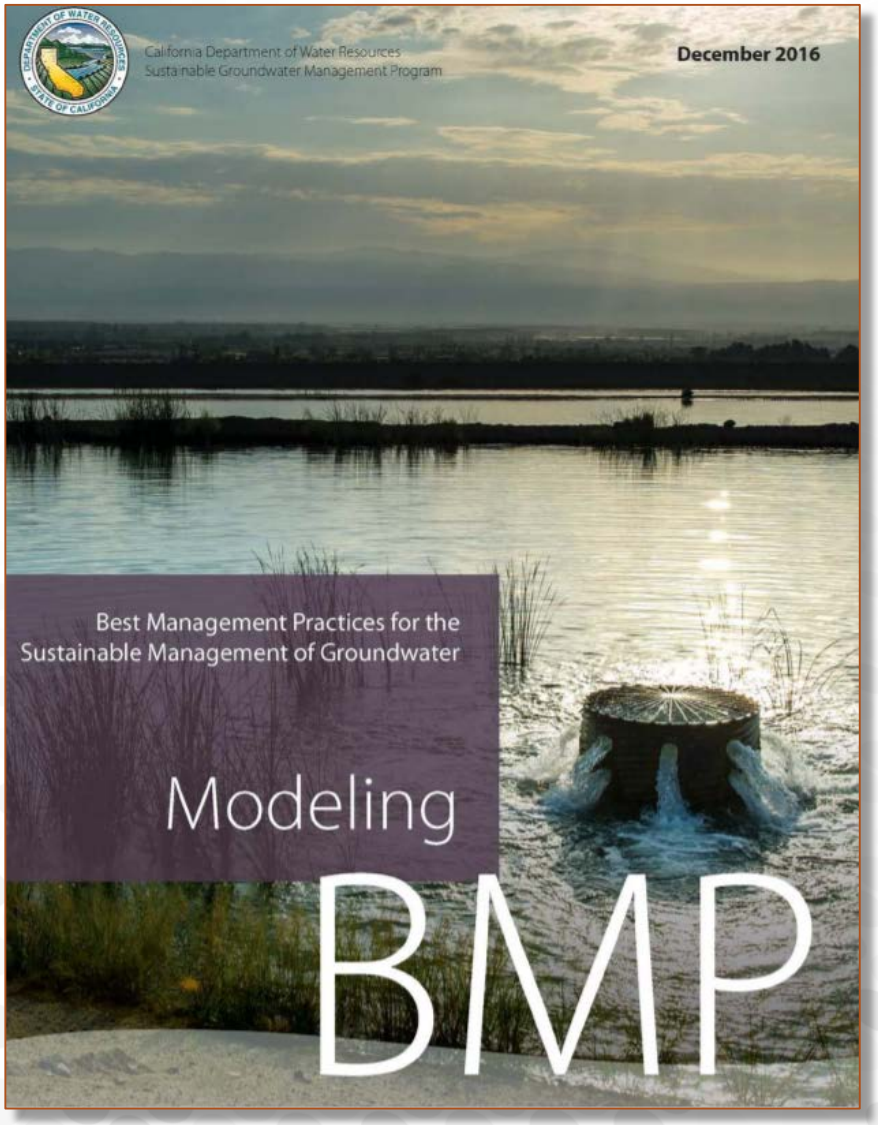
- Technical Assistance
- Key Definitions
- Related Materials

- Google:

"SGMA Modeling BMP"



Questions?

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Supervising Engineer – Davids Engineering
byron@davidsengineering.com

Groundwater Sustainability Planning Next Steps

Dave Ceppos – Facilitator, Sacramento State University

GSP Iterative Process



GSA Question and Answer Session

Closing Remarks

FOR IMMEDIATE RELEASE

Mary Fahey
Program Manager
Colusa Groundwater Authority
mfahey@countyofcolusa.org
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https://colusagroundwater.org/

Lisa Hunter
Program Manager,
Glenn Groundwater Authority
LHunter@countyofglenn.net
530- 934-6501
https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority

PUBLIC WORKSHOP ON LOCAL GROUNDWATER CONDITIONS

The Colusa Groundwater Authority (CGA) and Glenn Groundwater Authority (GGA) (Agencies) will host a pair of public workshops about local groundwater conditions and areas of concern in portions of Colusa and Glenn Counties. Both workshops will cover the same material. Groundwater in the two counties is regulated by the CGA and GGA respectively as per the Sustainable Groundwater Management Act (SGMA). The entire area managed by the Agencies is titled the "Colusa Subbasin" by the California Department of Water Resources, and the Agencies are required to work together to address groundwater problems in the Subbasin. Groundwater conditions that are not sustainable will be subject to a range of future solutions and if these local Agencies are not successful addressing these challenges, the State of California can take over groundwater management in the Subbasin. The Boards of the Agencies are committed to maintain local control of groundwater and regularly update stakeholders about Subbasin conditions and future Agency decisions.

The workshops will provide a brief overview of SGMA and Groundwater Sustainability Plan requirements. Each will then focus on up-to-date, technical information about groundwater conditions and related topics with a focus on sustainability issues in the Colusa Subbasin. Stakeholders will have time to ask questions to Agency Directors, staff, and the technical consulting team. The public is encouraged to attend to learn more about SGMA and the Agencies' next steps. The public will also learn about the importance of Stakeholder participation during Groundwater Sustainability Plan development, and how they can be involved in the process.

"We will have some tough decisions to make in the future" said Supervisor Denise Carter, Chair of the CGA. "We are committed to share everything we know about this Subbasin's groundwater and then develop a program to protect this critical resource".

Similarly, Leslie Nerli representing Glide Water District on the GGA said "We have to hear from our neighbors. This is a big deal. We're going to make decisions soon that will affect groundwater management for the next 20 years. We may not like it but we have some tough challenges in this basin and we need folks to come to the meeting and help provide information to make some of these decisions".

Meeting Dates, Times and Locations:

September 19, 2019
6:00 p.m. – 8:30 p.m.
Colusa VFW Hall
108 East Main Street
Colusa, CA

September 23, 2019
6:00 p.m. – 8:30 p.m.
Glenn Success Square Conference Center
131 East Walker Street,
Orland, CA

AGENDA

COLUSA SUBBASIN GROUNDWATER WORKSHOP

Hosted by the Colusa Groundwater Authority (CGA) and Glenn Groundwater Authority (GGA)

September 19, 2019
6:00 p.m. – 8:30 p.m.
Colusa VFW Hall
108 East Main Street
Colusa, CA

September 23, 2019
6:00 p.m. – 8:30 p.m.
Glenn Success Square Conference Center
131 East Walker Street
Orland, CA

5:30 Sign In

6:00 Welcome and Agenda Review (*Groundwater Sustainability Agency Representative, Dave Ceppos – Facilitator/Sacramento State)*

6:10 Overview - Sustainable Groundwater Management Act (SGMA) (*Facilitator*)

6:30 SGMA Basin Setting (Ken Loy – West Yost, Byron Clark – Davids Engineering)

- Basin Setting Presentation
- Small Group Discussions – Subbasin Challenges
- Water Budget Update
- Modelling Update

8:00 Groundwater Sustainability Planning – Next Steps (Facilitator)

8:10 GSA Question and Answer Session (GSA Board and Staff)

8:25 Closing (Facilitator)

8:30 Adjourn

LOCAL GROUNDWATER PUBLIC WORKSHOPS

Hosted by the Colusa Groundwater Authority and Glenn Groundwater Authority

LEARN ABOUT

- **Local Groundwater Conditions and Concerns**
- **The Sustainable Groundwater Management Act**
- **Groundwater Management Decisions Affecting You**

September 19, 2019	**September 23, 2019**
6:00 p.m. – 8:30 p.m. Colusa VFW Hall 108 East Main Street Colusa, CA	6:00 p.m. – 8:30 p.m. Glenn Success Square Conference Center 131 East Walker Street Orland, CA

For More Information Contact

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https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority

2D-5. SGMA-Series Public Events

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COLUSA SUBBASIN

FOR IMMEDIATE RELEASE

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Lisa Hunter
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530-934-6540
https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority

Well Monitoring Pilot Program Public Workshop

The Colusa Groundwater Authority (CGA) and Glenn Groundwater Authority (GGA) will host an evening online workshop on January 25, 2021. The purpose is to engage and inform growers and landowners who may want to in participate in a Well Monitoring Pilot Program (Pilot Program). This voluntary, non-regulatory program will support gather information about groundwater use in the Colusa Subbasin. It will provide participants near-real time access to information on production and groundwater levels at their wells as a way to support their irrigation management. Interested growers and landowners will work with the CGA and GGA to continuously monitor groundwater use and water levels at participating wells. Funding comes from the *Water Quality, Supply, and Infrastructure Improvement Act of 2014* and the *California Drought, Water, Parks, Climate, Coastal Protection, and Outdoor Access For All Act of 2018 (Proposition 68),* and through an agreement with the California Department of Water Resources

During this workshop, the CGA and GGA will:

- Provide an overview of the Pilot Program
- Describe incentives and responsibilities for interested participants
- Review the application process
- Describe selection criteria for applications received, and
- Answer questions about the Pilot Program

"This is really a win-win for us" said Colusa County Supervisor Denise Carter, Chair of the CGA. "We're required to have the best information to ensure our Groundwater Sustainability Plan is approved and that we can manage our resources locally and avoid State intervention. Many of our neighbors could also really benefit from new technologies to better manage their irrigation sources. This Program gets us both of these."

Meeting Date, Time, and Attendance Information:

January 25, 2021 4:00 p.m. – 5:30 p.m. Join Zoom Meeting https://csus.zoom.us/j/82557753022?pwd=aVBOQTArVGc3WkYwL3h1SWFLMk85QT09 Meeting ID: 825 5775 3022 Passcode: 880156 One tap mobile +16699006833,,82557753022#

ANNOUNCING THE COLUSA SUBBASIN SGMA-Series !!
LOCAL SUSTAINABLE GROUNDWATER
ONLINE WORKSHOPS

Co-Hosted by the Colusa Groundwater Authority and Glenn Groundwater Authority

LEARN and GIVE FEEDBACK about:

- **Local Groundwater Conditions**
- **Approaches to Sustainable Management Criteria**
- **Groundwater Sustainability Project Ideas**

December 9, 2020

5:30 p.m. – 8:30 p.m.

https://csus.zoom.us/j/82305540067?pwd=aUVoTXU4NXZsNktHc3E3ZE90N3pJZz09

Meeting ID: 823 0554 0067

Passcode (Required): 105741

Phone In: 1-669-900-6833,,82305540067# (Not Toll Free)

December 10, 2020

1:00 p.m. – 4:00 p.m.

https://csus.zoom.us/j/89917492421?pwd=bTR4YUxLYzhVMWhFd2I2Ym5vSEgyZz09

Meeting ID: 899 1749 2421

Passcode (Required): 192684

Phone In: 1-669-900-6833,,89917492421# (Not Toll Free)

For More Information Contact

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¡¡ANUNCIANDO LA SUBCUENCA COLUSA SERIE-SGMA!!
AGUA SUBTERRÁNEA LOCAL SOSTENIBLE
TALLERES EN LINEA VIRTUAL

Organizado conjuntamente por Autoridad de Agua Subterránea de Colusa y Autoridad de Agua Subterráneas de Glenn

APRENDA y DE SU COMENTARIOS sobre:

- **Condiciones locales del agua subterránea**
- **Enfoques de los Criterios de Gestión Sostenible**
- **Ideas de Proyectos de Sostenibilidad del Agua Subterránea**

9 de diciembre de 2020

5:30 p.m. - 8:30 p.m.

https://csus.zoom.us/j/82305540067?pwd=aUVoTXU4NXZsNktHc3E3ZE90N3pJZz09

ID de reunión: 823 0554 0067
Contraseña (Necesaria): 105741
Teléfono: 1-669-900-6833,82305540067# (No gratuita)

10 de diciembre 2020

1:00 p.m. - 4:00 p.m.

https://csus.zoom.us/j/89917492421?pwd=bTR4YUxLYzhVMWhFd2I2Ym5vSEgyZz09

ID de reunión: 899 1749 2421
Contraseña (Necesaria): 192684
Teléfono: 1-669-900-6833,,89917492421# (No gratuita)

Para mas información contacte:

Mary Fahey
Directora del Programa
Colusa Groundwater Authority
mfahey@countyofcolusa.org
530-458-0719
https://colusagroundwater.org/

o

Lisa Hunter
Directora del Programa
Glenn Groundwater Authority
LHunter@countyofglenn.net
530-934-6540
https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority

Colusa Subbasin SGMA-Series
July 2021 Public Meetings

COLUSA SUBBASIN

Co-Hosted by:
Colusa Groundwater Authority and Glenn Groundwater Authority

When and Where

Virtual Meeting
July 28, 2021
6:00 p.m. – 8:00 p.m.
https://csus.zoom.us/j/82613933000?pwd=SFNKeW1sL0x6cGJDV2ZlNldiUW1vZz09&from=addon
Meeting ID: 826 1393 3000; Meeting Passcode: 630147
One tap mobile:
+16699006833,,82613933000#,,,,*630147# US

In-Person Meeting
July 29, 2021
6:00 p.m. – 8:00 p.m.
Sites Project Authority
122 Old Hwy 99W
Maxwell, California

For More Information Contact

Mary Fahey
Program Manager
Colusa Groundwater Authority
mfahey@countyofcolusa.org
530-458-0719
https://colusagroundwater.org/

OR

Lisa Hunter
Program Manager
Glenn Groundwater Authority
LHunter@countyofglenn.net
530-934-6540
https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority

LEARN and GIVE FEEDBACK
About draft chapters of the Groundwater Sustainability Plan for the Colusa Subbasin, and methods to submit comments to the Groundwater Authorities

Subcuenca de Colusa, Serie SGMA

Reuniones públicas de julio

Copatrocinado por:
La autoridad de agua subterránea de Colusa y la autoridad de agua subterránea de Glenn

Cuándo y dónde

Reunión presencial

28 de julio de 2021
6:00 p. m. – 8:00 p. m.
https://csus.zoom.us/j/85717001957?pwd=SXhmdjRTd3l6TjlRSnFZa0tid2NTQT09&from=addon
Identificación de la reunión: 857 1700 1957
Contraseña: 632002
+16699006833,,85717001957#,,,,*632002# US

Reunión virtual

29 de julio de 2021
6:00 p. m. – 8:00 p. m.
Autoridad del proyecto de los sitios
122 Old Hwy 99W
Maxwell, CA 95955

Para obtener más información contacte a

Mary Fahey
Directora del proyecto
Autoridad de agua subterránea de Colusa
mfahey@countyofcolusa.org
530-458-0719
https://colusagroundwater.org/

O

Lisa Hunter
Directora del proyecto
Autoridad de agua subterránea de Glenn
LHunter@countyofglenn.net
530-934-6540
https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority

APRENDA y DEJE SU OPINIÓN

Sobre los capítulos del proyecto del Plan de Sustentabilidad de agua subterránea para la subcuenca de Colusa y los métodos para presentar los comentarios ante las autoridades del agua subterránea

COLUSA SUBBASIN

FOR IMMEDIATE RELEASE

Mary Fahey
Program Manager
Colusa Groundwater Authority
mfahey@countyofcolusa.org
530-458-0719
https://colusagroundwater.org/

Lisa Hunter
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Glenn Groundwater Authority
LHunter@countyofglenn.net
530-934-6540
https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority

PUBLIC MEETINGS
GROUNDWATER SUSTAINABILITY PLAN DRAFT CHAPTERS

The Colusa Groundwater Authority (CGA) and Glenn Groundwater Authority (GGA) (Agencies) will host an in-person meeting on July 28 and a virtual meeting on July 29 to discuss the Sustainable Groundwater Management Act (SGMA). The content of these meeting will be the same. Against the backdrop of the critical drought, these meetings will engage the public about future groundwater management to improve long range local sustainable conditions. Under SGMA, the Agencies are required to prepare a Groundwater Sustainability Plan (GSP) for the Colusa Subbasin. Draft Chapters 5 and 6 of the GSP discuss sustainability conditions and potential projects and actions that might be pursued by the Agencies. These chapters will be released on July 16 and the Agencies seek public feedback on these important topics. Agency representatives will provide an overview of the information in these chapters and will outline methods to provide feedback in the near future. The meetings will also include a review of previously released draft chapters and a discussion of next steps in the GSP completion process.

Glenn County Supervisor Grant Carmon said "As a relatively new member of the Glenn Groundwater Authority Board, I can attest that SGMA is a challenging topic. The decisions we will make soon will affect the lives of many people in Glenn and Colusa Counties and the information we will present at these meetings is critically important for stakeholders to consider. I can't stress enough how important it is that our constituents attend one of these meetings".

"We've been at this process a long time and the planning is nearing its end" said CGA Board Member Darrin Williams. "As a Private Well Owner representing similar water users on the CGA Board, we're getting to crunch time for stakeholders to get up-to-speed on SGMA and how it will affect us in the long run. People really need to come to these meetings."

MEETING INFORMATION

Virtual Meeting
July 28, 2021
6:00 p.m. – 8:00 p.m.
https://csus.zoom.us/j/82613933000?pwd=SFNKeW1sL0x6cGJDV2ZINldiUW1vZz09&from=addon
Meeting ID: 826 1393 3000; Meeting Passcode: 630147
One tap mobile: +16699006833,,82613933000#,,,,*630147# US

In-Person Meeting
July 29, 2021
6:00 p.m. – 8:00 p.m.
Sites Project Authority
122 Old Hwy 99W
Maxwell, CA 95955

COLUSA SUBBASIN

SGMA-Series Public Meetings
July 28 and 29, 2021
6:00 pm – 8:00 pm

Virtual Meeting
July 28, 2021
https://csus.zoom.us/j/82613933000?pwd=SFNKeW1sL0x6cGJDV2ZINldiUW1vZz09&from=addon
Meeting ID: 826 1393 3000; Meeting Passcode: 630147
One tap mobile:
+16699006833,,82613933000#,,,,*630147# US

In-Person Meeting
July 29, 2021
Sites Project Authority
122 Old Hwy 99W
Maxwell, California

6:00 **Welcome and Introduction** (Chair, Colusa Groundwater Authority / Glenn Groundwater Authority)

6:05 **Agenda Review and Logistics** (Dave Ceppos, Facilitator – Sacramento State)

6:10 **Groundwater Sustainability Plan Overview** – (Grant Davids, Davids Engineering)

6:25 **Chapter 5: Sustainable Management Criteria** (Ken Loy, West Yost Consultants)

6:50 **Chapter 6: Projects & Management Actions** (G. Davids)

7:10 **Questions and Answers / Public Comment** (Facilitator and all participants)

7:55 **Next Steps / Schedule Review**

8:00 **Adjourn**

Serie SGMA de la Subcuenca de Colusa

Plan de Sostenibilidad del Agua Subterránea - Revisión Pública del Borrador

Reuniones Públicas de Octubre

Co-patrocinado por:
La Autoridad de Agua Subterránea de Colusa y la Autoridad de Agua Subterránea de Glenn
Agencias de Sostenibilidad del Agua Subterránea

Dónde y Cuándo

Reunión Virtual

13 de Octubre, 2021
1:00 p.m. - 3:30 p.m.
Únase a la Reunión de Zoom
https://csus.zoom.us/j/82287631584?pwd=eW1lNGF6aThSOUVwQ3M2ekhjQ1Qrdz09&from=addon
ID de la Reunión: 822 8763 1584 - Código de acceso: 877000
One tap mobile +16699006833,,82287631584#,,,,*877000#
(No es un Número Gratuito)

Reunión Presencial

15 de Octubre, 2021
De 5:30 p.m. a 8:00 p.m.
Autoridad de Sitios del Proyecto
122 Old Hwy 99W
Maxwell, CA 95955

Para más información, póngase en contacto con

Mary Fahey
Directora del Proyecto
Autoridad de Agua Subterránea de Colusa
mfahey@countyofcolusa.org
530-458-0891
https://colusagroundwater.org/

O

Lisa Hunter
Directora del Proyecto
Autoridad de Agua Subterránea de Glenn
LHunter@countyofglenn.net
530-934-6540
https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority

APRENDA y DÉ SU OPINIÓN

Acerca de la Ley de Gestión Sostenible del Agua Subterránea, el Borrador Público del Plan de Sostenibilidad del Agua Subterránea para la Subcuenca de Colusa, y los métodos para presentar comentarios a las Autoridades del Agua Subterránea

Colusa Subbasin SGMA-Series

Groundwater Sustainability Plan-Public Draft Review

October Public Meetings

COLUSA SUBBASIN

Co-Hosted by:
Colusa Groundwater Authority and Glenn Groundwater Authority
Groundwater Sustainability Agencies

When and Where

Virtual Meeting

October 13, 2021
1:00 pm – 3:30 pm
Join Zoom Meeting
https://csus.zoom.us/j/82287631584?pwd=eW1lNGF6aThSOUVwQ3M2ekhjQ1Qrdz09&from=addon
Meeting ID: 822 8763 1584 - Passcode: 877000 One tap mobile
+16699006833,,82287631584#,,,,*877000#
(Not a Toll Free number)

In-Person Meeting

October 15, 2021
5:30 p.m. – 8:00 p.m.
Sites Project Authority
122 Old Hwy 99W
Maxwell, CA 95955

For More Information Contact

Mary Fahey
Program Manager
Colusa Groundwater Authority
mfahey@countyofcolusa.org
530-458-0891
https://colusagroundwater.org/

OR

Lisa Hunter
Program Manager
Glenn Groundwater Authority
LHunter@countyofglenn.net
530-934-6540
https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority

LEARN and GIVE FEEDBACK

About the Sustainable Groundwater Management Act, the Public Draft Groundwater Sustainability Plan for the Colusa Subbasin, and methods to submit comments to the Groundwater Authorities

COLUSA SUBBASIN

Colusa Groundwater Authority and Glenn Groundwater Authority
SGMA-Series Public Meetings
Virtual Meeting

October 13, 2021
1:00 pm – 3:30 pm
Join Zoom Meeting
https://csus.zoom.us/j/82287631584?pwd=eW1lNGF6aThSOUVwQ3M2ekhjQ1Qrdz09&from=addon
Meeting ID: 822 8763 1584 - Passcode: 877000 One tap mobile
+16699006833,,82287631584#,,,,*877000#
(Not a Toll Free number)

Also Available on Facebook LIve

1:00* **Welcome and Introductions** (Chair, Glenn Groundwater Authority)

1:05 **Agenda Review and Logistics** (Dave Ceppos, Facilitator – Sacramento State)

1:10 **Sustainable Groundwater Management Act Overview** (Facilitator)

1:20 **Public Review Draft Groundwater Sustainability Plan (GSP) Overview** – (Grant Davids, Davids Engineering, Inc.)
- History of GSP Development and Public Comment Process
- GSP Status and Document Structure
- Public Input Options

1:35 **Public Draft GSP Chapter Review and Public Input Opportunities** (Consultant Team)
- Background (Chapters 1,2 and 8) – Executive Summary, Introduction, Plan Area, References, Appendices (Grant Davids)
- Basin Setting, Monitoring Network, Sustainable Management Criteria (Ken Loy, West Yost Associates)
  - Chapter 3
  - Chapter 4
  - Chapter 5
- Projects and Management Actions, and Plan Implementation (Grant Davids)
  - Chapter 6
  - Chapter 7

2:15 **Public Comment / Question and Answer Session**

3:25 **Next Steps / Schedule Review**

3:30 **Adjourn**

*All times are approximate

COLUSA SUBBASIN

Colusa Groundwater Authority and Glenn Groundwater Authority
SGMA-Series Public Meetings
In-Person Meeting

October 15, 2021
5:30 p.m. – 8:00 p.m.
Sites Project Authority Office
122 Old Hwy 99W
Maxwell, CA 95955

5:30* **Welcome and Introductions** (Chair, Colusa Groundwater Authority)

5:35 **Agenda Review and Logistics** (Dave Ceppos, Facilitator – Sacramento State)

5:40 **Sustainable Groundwater Management Act Overview** (Facilitator)

5:50 **Public Review Draft Groundwater Sustainability Plan (GSP) Overview** – (Grant Davids, Davids Engineering, Inc.)

- History of GSP Development and Public Comment Process
- GSP Status and Document Structure
- Public Input Options

6:05 **Public Draft GSP Chapter Review and Public Input Opportunities** (Consultant Team)

- Background (Chapters 1,2 and 8) – Executive Summary, Introduction, Plan Area, References, Appendices (Grant Davids)
- Basin Setting, Monitoring Network, Sustainable Management Criteria (Ken Loy, West Yost Associates)
  - Chapter 3
  - Chapter 4
  - Chapter 5
- Projects and Management Actions, and Plan Implementation (Grant Davids)
  - Chapter 6
  - Chapter 7

6:45 **Public Comment / Question and Answer Session**

7:55 **Next Steps / Schedule Review**

8:00 **Adjourn**

*All times are approximate

COLUSA SUBBASIN

FOR IMMEDIATE RELEASE

Mary Fahey
Program Manager
Colusa Groundwater Authority
mfahey@countyofcolusa.org
530-458-0891
https://colusagroundwater.org/

Lisa Hunter
Program Manager
Glenn Groundwater Authority
LHunter@countyofglenn.net
530-934-6540
https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority

PUBLIC MEETINGS
GROUNDWATER SUSTAINABILITY PLAN – PUBLIC DRAFT REVIEW

The Colusa Groundwater Authority (CGA) and Glenn Groundwater Authority (GGA) (Agencies) will host a virtual meeting on October 13 and an in-person meeting on October 15 to discuss the Agencies' release of the Public Draft Groundwater Sustainability Plan (GSP) for the Colusa Subbasin. The content of these meetings will be the same.

Against the backdrop of the last and current critical drought, the California Legislature passed and has required implementation of the Sustainable Groundwater Management Act (SGMA). Under SGMA, the Agencies are required to prepare a GSP for the Colusa Subbasin. The GSP defines what the Agencies will do for the next 20 years to protect the subbasins and ensure groundwater is sustainable. The Agencies have opted to prepare a single, joint GSP for the entire Colusa Subbasin. Prior public events have provided stakeholders the opportunity to learn about and comment on SGMA and the draft GSP chapters. These upcoming meetings will engage the public about the entire draft GSP. Agency representatives will provide an overview of the information in each chapter of the GSP, will outline methods for the public to provide focused input and will provide the public time to ask questions about GSP content.

Colusa County Supervisor and CGA Board Chair Denise Carter said "We're at the culmination of a long process and on the cusp of implementing projects that will better monitor and enhance our groundwater. These meetings and the public comment period are a critical opportunity for stakeholders to give their input to the CGA and GGA before we approve the GSP and submit it to the State. I encourage every affected groundwater user in the subbasin to attend one of these meetings, review the plan and give us your feedback."

Similarly, City of Willows Vice Mayor and GGA Vice Chair Gary Hansen said "As the CGA and GGA Chairpersons noted in their recent Op-Ed, our aquifers provide an essential safety net for our water availability but that safety net is only as good as the tools we create to support it. Our GSP does that and we need public input to confirm if we've done it the right way".

MEETING INFORMATION

Virtual Meeting
October 13, 2021
1:00 pm – 3:30 pm
Join Zoom Meeting
https://csus.zoom.us/j/82287631584?pwd=eW1lNGF6aThSOUVwQ3M2ekhjQ1Qrdz09&from=addon
Meeting ID: 822 8763 1584
Passcode: 877000 One tap mobile
+16699006833,,82287631584#,,,,*877000#
(Not a Toll Free number)

In-Person Meeting
October 15, 2021
5:30 p.m. – 8:00 p.m.

Sites Project Authority Office
122 Old Hwy 99W
Maxwell, CA

COLUSA SUBBASIN

Colusa Subbasin Well Monitoring Pilot Program

Participant Information Form

BACKGROUND

The Colusa Subbasin Groundwater Sustainability Agencies (GSAs) are implementing an incentive-based pilot program to work with interested growers and landowners to continuously monitor groundwater use and water levels at participating wells. This voluntary, non-regulatory program is intended to support the GSAs in gathering information regarding groundwater use in the subbasin while providing participants with near-real time access to information on well production and groundwater levels at their wells to support irrigation management.

PROGRAM DESCRIPTION

Activities

Interested parties are invited to submit a brief application describing contact information, location, cropping, and other information related to the proposed groundwater well. Following the receipt of applications, participants will be selected considering certain criteria. Participants agree that the well location and information collected may be made publicly available. Participants also agree that GSA representatives may make site visits to inspect wells, verify installation, and collect manual measurements as needed.

Incentives

The program will cover the purchase cost of a flowmeter or upgrades to an existing flow meter (up to $2,500), if needed, purchase and installation of a pressure transducer (to monitor groundwater levels), datalogger, solar panel, cellular modem, and a 3-year subscription for web and mobile access to data gathered. Program participation may be extended beyond 3 years, as mutually agreed.

Participants will be responsible for:

- Installation of flow meter per manufacturer specifications
- Installation of access tube for pressure transducer in well casing
- Monthly cellular modem costs (approx. $15 per month)
- Manual reporting of pumping data, in the event of device failure

Timeline

- **January 2021:** Applications Accepted
- **February – March 2021:** Participants Selected, Agreements Executed, Wells Inspected, and Equipment Installed
- **April 2021 – October 2023:** Wells Monitored



Funding for this project has been provided in full or in part from the Water Quality, Supply, and Infrastructure Improvement Act of 2014 and the California Drought, Water, Parks, Climate, Coastal Protection, and Outdoor Access For All Act of 2018 (Proposition 68), and through an agreement with the State Department of Water Resources.

QUESTIONS?

For more information, please contact:

Colusa Groundwater Authority
Mary Fahey, CGA Program Manager
530-458-0719 • mfahey@countyofcolusa.com

Glenn Groundwater Authority
Lisa Hunter, GGA Program Manager
530-934-6540 • lhunter@countyofglenn.net

Colusa Groundwater Authority

Groundwater Sustainability Agency

The Nature Conservancy

Protecting nature. Preserving life.™

On-Farm, Groundwater Recharge Workshop



©Drew Kelly



©Drew Kelly

On-Farm, Groundwater Recharge Glaclrgtc Program

Working in partnership with Colusa Groundwater Authority and the California Department of Water Resources*, The Nature Conservancy is conducting an on-farm, multi-benefit demonstration program, which provides an opportunity for growers to receive financial compensation for recharging groundwater gl the course of normal farming operations while also providing critical shallow wetland habitat for migratory birds.

Farming for Sustainable Groundwater and the Flyway

Uc qcci commitments from growers to irrigate qcjcarcb fields dmp 2+4 ucciq in early fall and late winter 2020-2021. The program compensates growers for field preparation, irrigation and water costs.

Learn More!

Come to the workshop: Wednesday, February 26, 2020, 10:00 a.m.
Colusa Industrial Properties, 100 Sunrise Blvd., Colusa, CA 95932

Presentation: 10:00-10:30 a.m.
Informal Q & A: 10:30-11:30 a.m.

Questions? Call Julia Barfield at (916) 449-2852

*Funding provided in part through DWR's Sustainable Groundwater Management (SGM) Grant Program: The SGM Grant Program provides funding for sustainable groundwater planning and implementation projects through a competitive grant solicitation process. Projects may include the development and implementation of Groundwater Sustainability Plans (GSPs) and those that provide investments in groundwater recharge with surface water, stormwater, recycled water, the prevention of groundwater contamination.







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2D-6. Subbasin Branding

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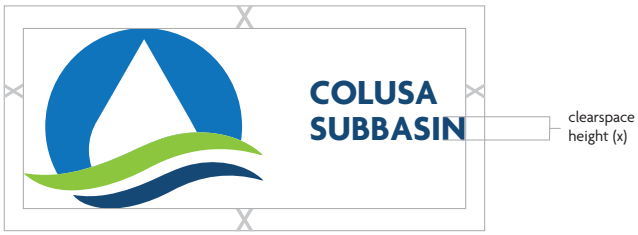
Colusa Subbasin Logo Style Guide

CLEAR ZONE OF LOGO

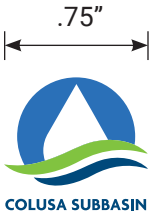
Maintain a clear zone (height of the “P”) around all sides of the logo to ensure visibility of the logo.

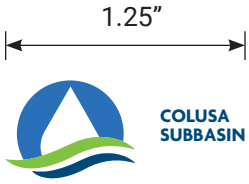




MINIMUM SIZE OF LOGO

Logo should not be smaller than the minimum size to maintain quality and legibility.





ONE COLOR LOGO

One color logos should be used when backgrounds are too colorful and will distract the colored logo.









COLORS

PANTONE 7683 CP
HEX# 3170b7
R49 G112 B183
C83 M55 Y0 K0

PANTONE 376 CP
HEX# 82c341
R130 G195 B65
C54 M0 Y100 K0

PANTONE 7692 CP
HEX# 00497c
R0 G73 B124
C100 M45 Y0 K45

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2D-7. Media Materials

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Article for the Colusa County Farm Bureau "Sodbuster," February, 2016
Sustainable Groundwater Management Act Update from Colusa County
Mary Fahey, Colusa County Water Resources Coordinator

SGMA Background
The Sustainable Groundwater Management Act (SGMA) is a new law that affects all citizens of Colusa County. It offers beneficial opportunities to achieve sustainable groundwater conditions in a manner that will support our vital agricultural economy, as well as other industry, and domestic and public water uses. The law provides for local management of groundwater resources, with the State as an enforcement "backstop" if locals do not successfully implement planning approaches.

The law dictates that Groundwater Sustainability Agencies (GSAs) must be formed to locally implement the law in all high and medium priority groundwater basins (as defined by the California Statewide Groundwater Elevation Monitoring [CASGEM] program). Public agencies with Land or Water Use Authority are eligible to be a GSA. This includes County and City governments, irrigation and reclamation districts, and public water suppliers. A GSA can be made up of one or more local public agencies, and there can be a single GSA or multiple GSAs per groundwater basin. If multiple GSAs exist, they must coordinate planning efforts. GSA(s) must be in place by June 30, 2017, or the State will enforce management responsibilities on all local groundwater users including fees for SGMA implementation.

GSAs are responsible to develop and implement Groundwater Sustainability Plans (GSPs). If there are multiple GSPs in a basin, they must be coordinated, utilize the same data and methodologies, and a Coordination Agreement is required. GSPs must be developed by Jan. 31, 2022, or, again, the state will take on groundwater management responsibilities for the basin.

In Colusa County, we have one high priority CASGEM subbasin (West Butte) and one medium priority CASGEM subbasin (Colusa), both of which are subject to SGMA. Locally, we must reach sustainability by 2042 – 20 years after the GSPs are in place. Measureable objectives must be included in the GSPs, as well as 5-year milestones.

Local Effort
Locally, we are focusing SGMA planning efforts within Colusa County boundaries, while communicating and coordinating with surrounding counties (Glenn, Yolo, Butte, Tehama). The County anticipates being part of a groundwater management partnership that implements SGMA the right way, ensures that we are regional and statewide leaders, and keeps our citizens ahead of the curve on groundwater management policies. We feel we are moving in a positive direction to implement SGMA, as the County has already taken several positive steps, including: acquired professional facilitation services through funding from the Department of Water Resources (to be provided by Sacramento State, Center for Collaborative Policy [CCP]), initiated a county-wide groundwater assessment, and pursued a recent groundwater planning grant through the Water Bond. The County is committed to share these resources with SGMA partners and affected citizens while working with agencies, landowners and other affected parties on GSA and GSP development, and SGMA implementation.

Over the next several months, CCP will coordinate and facilitate several public meetings, including GSA group meetings to determine local GSA structure. CCP will act as a neutral third party at these meetings to ensure that all of the GSA-eligible agencies have an equal voice at the table. Through these meetings, we hope to have a good idea of what our local governance structure will look like by June, 2016. Other efforts will include informational public meetings to ensure that Colusa County citizens are informed and engaged in local groundwater management planning.

Stay Informed

Colusa County and all of its residents need to work together and commit to manage this valuable resource so that we may continue to live here and farm for many generations to come. Here are a few ways you can stay informed:

- Sign up for the Water Resources Mailing List to receive meeting announcements and current news: email mfahey@countyofcolusa.org; or call: 530.458.7709
- Visit the DWR SGMA Website: www.water.ca.gov/groundwater
- Visit the Water Resources Website: www.countyofcolusa.org, under *Departments > Agricultural Administrative Services*

July 11, 2016

Sustainable Groundwater Management Act (SGMA); Introduction, Part 1 of 4

For immediate release
Contact: Mary Fahey, Colusa County Water Resources Coordinator
mfahey@countyofcolusa.com
530-458-7709

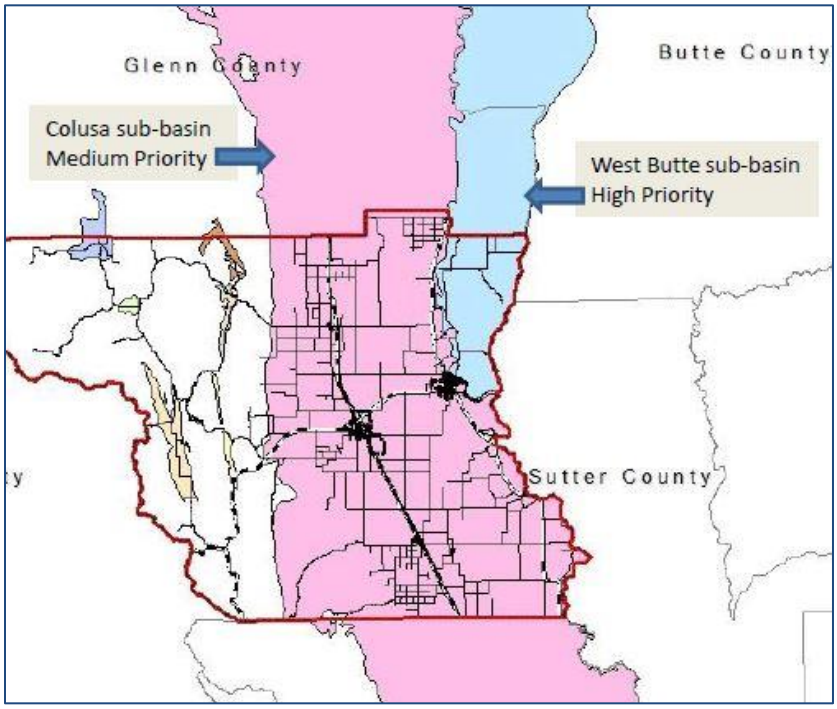
This is the first article in a four-part series to inform groundwater users in Colusa County about new groundwater legislation and the local efforts that are taking place to implement these new laws.

Part 1: The Sustainable Groundwater Management Act (SGMA) – An Overview

What is the Sustainable Groundwater Management Act (SGMA)?

SGMA is comprehensive statewide groundwater legislation that went into effect January 1, 2015. SGMA affects all groundwater users in California. The purpose of the legislation is to achieve sustainable groundwater conditions statewide. Sustainable conditions will support Colusa County's vital agricultural economy, industry, and domestic and public water uses.

SGMA mandates that all high and medium priority groundwater basins in California must be managed sustainably over a 20-year implementation period**.** In Colusa County we have two groundwater basins subject to SGMA: the Colusa subbasin and the West Butte subbasin. Both basins span multiple counties and SGMA implementation efforts must be coordinated basin-wide.



Who Will Be In Charge?

SGMA requires that a local agency, or combination of local agencies, implement SGMA at the local level, with the state as a backstop if necessary. These local agencies are called Groundwater Sustainability Agencies (GSA), and they will be responsible for developing Groundwater Sustainability Plans and ensuring that groundwater is being managed sustainably. GSAs will have many authorities and responsibilities.

According to SGMA, "Any local public agency or combination of local public agencies overlying a groundwater basin may decide to become a groundwater sustainability agency for that basin." "Local agency" means a local public agency that has water supply, water management or land use responsibilities within a groundwater basin. These agencies include counties, cities, irrigation and reclamation districts, and public utility districts, or similar. "Efforts are underway now in Colusa County to determine a local GSA structure, including which agencies will participate in SGMA implementation," said Mary Fahey, Colusa County Water Resources Coordinator. Fahey went on to say, "now is the time for folks to become engaged in local SGMA planning efforts. All of our meetings are open to the public."

What is Sustainability?

Sustainable groundwater management is defined as the management and use of groundwater without causing undesirable results. The California Department of Water Resources has developed Groundwater Sustainability Plan Regulations which define six "Sustainability Indicators" for undesirable results. These conditions must be avoided for a basin to be considered sustainable:

1. Significant and Unreasonable reductions in Groundwater Levels
2. Significant and Unreasonable reductions in Groundwater Storage
3. Significant and Unreasonable Land Subsidence
4. Significant and Unreasonable reductions in Groundwater Quality
5. Significant and Unreasonable reductions in Groundwater-Surface Water Interaction
6. Significant and Unreasonable Seawater Intrusion (we do not have to address this criteria in Colusa County)

Since groundwater conditions vary greatly throughout the state, undesirable results are defined at the basin level (what is undesirable for one area may be acceptable in another area). The bottom line is that the amount of groundwater pumped cannot exceed the amount of water recharged. Cooperation and coordination among agencies and landowners is crucial to successful SGMA implementation, and to maintaining local control over our groundwater resources.

The county would like to remind its citizens that SGMA affects every well owner in California, which is why it is so important for the general public to be informed. Colusa County Supervisor, Denise Carter said, "SGMA planning efforts have been taking place in Colusa County over the past year and a half, and important governance decisions will be made over the next few months. I highly encourage landowners to participate in this process by attending our public meetings and staying informed."

In the next article, we will discuss Groundwater Sustainability Agencies (GSA) and Groundwater Sustainability Plans (GSP) in more detail, and we will also discuss Colusa County's efforts to include private groundwater pumpers in local SGMA planning efforts.

Here's how you can stay informed:

Upcoming Colusa County SGMA Meetings:

July 15, 2016
GSA Working Group Meeting #5
9:00 a.m. – noon
Colusa County Farm Bureau Board Room; 520 Market Street, Colusa, CA 95932
This is the fifth in a series of facilitated working meetings for GSA-eligible agencies to coordinate local governance planning. There will be a presentation on local groundwater conditions and how they relate to the GSP Regulations and sustainability indicators. This presentation will help local agencies determine how they want to participate in local governance. These meetings are open to the public.

SGMA - How to Stay Informed:

- ✓ Get on the Colusa County Water Resources email notification list for updates and meeting announcements - call or email Water Resources Staff: **530.458.7709**; email: mfahey@countyofcolusa.com
- ✓ Visit the Colusa County Water Resources website where you can find meeting announcements, agendas, meeting summaries and presentations as well as information on SGMA: Countyofcolusa.org
- ✓ Visit us on Facebook – Colusa County Groundwater
- ✓ Visit DWR's Groundwater Information Center website for extensive information on SGMA: http://www.water.ca.gov/groundwater/gwinfo/index.cfm
- ✓ Do you have questions? Call or email Colusa County Water Resources Staff

July 25, 2016

Sustainable Groundwater Management Act (SGMA); Groundwater Sustainability Agencies and Groundwater Sustainability Plans, Part 2 of 4

For immediate release
Contact: Mary Fahey, Colusa County Water Resources Coordinator
mfahey@countyofcolusa.com
530-458-7709

This is the second article in a four-part series to inform groundwater users in Colusa County about new groundwater legislation, the Sustainable Groundwater Management Act (SGMA), and the local efforts that are taking place to implement these new laws.

Part 2: Groundwater Sustainability Agencies (GSAs), Private Pumper Advisory Committee (PPAC), and Groundwater Sustainability Plans (GSPs)

What is a Groundwater Sustainability Agency?

As discussed in a previous article, the Sustainable Groundwater Management Act (SGMA) requires that a local agency, or combination of local agencies, implement the legislation at the local level, with the state as a backstop if necessary. These local agencies are called Groundwater Sustainability Agencies (GSA). Any local public agency with water supply, water management and/or land use responsibilities is eligible to be a GSA. Eligible agencies include counties, cities, water districts, reclamation districts, public utility districts and similar.

A GSA is responsible for enforcing all of the requirements of SGMA. GSAs have certain responsibilities and authorities under SGMA. Responsibilities include developing and implementing a Groundwater Sustainability Plan (GSP), conducting studies, providing extensive outreach, monitoring groundwater conditions, and reporting to the state. Authorities that GSAs may use include adopting regulations, levying fees, requiring metering on wells, and regulating groundwater extractions, among others. These authorities are available to GSAs as tools to utilize, if necessary to achieve sustainability.

In Colusa County, we have 28 agencies that are eligible to be a GSA. SGMA allows the local agencies to decide the best governance structure for their basins. Agencies can be a stand-alone GSA covering just their service area, or part of a multi-agency GSA that covers an entire basin or portion of a basin. There can be one or more GSAs in a groundwater basin, but if there are multiple GSAs, they all must work together and coordinate efforts.

GSAs must be established in all of the high and medium priority groundwater basins in the state by June 30, 2017. The GSA-eligible agencies in Colusa County have participated in five governance planning meetings over the last several months. These meetings have been productive and the group continues to make progress in determining a local SGMA governance structure. These meetings are open to the

public and run by professional facilitators from the Center for Collaborative Policy, Sacramento State University.

SGMA and Private Pumpers; Colusa County Private Pumper Advisory Committee (PPAC)

Under SGMA, private landowners are not eligible to be a GSA. Counties are presumed to be the GSA over the "white areas," or "private pumper" areas, which are areas of the county that are not covered by another GSA-eligible agency. This can be seen as problematic because landowners in the private pumper areas rely on groundwater as their sole source of irrigation, making them key players in successful SGMA implementation.

Colusa County has given our private pumpers a greater voice in SGMA planning and implementation by forming a Private Pumper Advisory Committee (PPAC). The PPAC is made up of 7 members and 3 alternates. Members of the PPAC are private pumper individuals from throughout the County, chosen by the Colusa County Groundwater Commission.

PPAC responsibilities include two main tasks; they are advisory to the County on the concerns and issues of the private pumpers, and they are also responsible to provide SGMA outreach to their neighbors. The PPAC is also very engaged in Colusa County's governance planning.

What is a Groundwater Sustainability Plan (GSP)?

SGMA requires one or more Groundwater Sustainability Plans (GSP) be prepared for all high and medium priority groundwater basins in the state. Local GSAs will be responsible for developing GSPs by January 31, 2022 (January 31, 2020 for basins in overdraft). If there are multiple GSPs in a basin, they must be coordinated and must utilize the same data and methodologies.

The GSPs will be the road map to achieving sustainable groundwater management. GSPs must include, among other elements: a description of the plan area, sustainability goals for each of the six Sustainability Indicators (see below), measurable objectives and milestones, a monitoring and data management program, projects and management actions to achieve/maintain sustainability, a water budget detailing projected water supplies and demands, a description of how the Plan will affect other surrounding plans, and many more details. SGMA requires yearly reporting and every-five-year Plan evaluation to ensure that progress is being made.

The Groundwater Sustainability Plan Regulations define six "Sustainability Indicators" for undesirable results. These conditions must be avoided for a basin to be considered sustainable:

- Significant and Unreasonable reductions in Groundwater Levels
- Significant and Unreasonable reductions in Groundwater Storage
- Significant and Unreasonable Land Subsidence
- Significant and Unreasonable reductions in Groundwater Quality
- Significant and Unreasonable reductions in Groundwater-Surface Water Interaction
- Significant and Unreasonable Seawater Intrusion (we do not have to address this criteria in Colusa County)

The California Department of Water Resources (DWR) developed GSP Regulations which were adopted June 1, 2016. You can find these on their website at:
http://www.water.ca.gov/groundwater/sgm/gsp.cfm

Upcoming Colusa County SGMA Meetings:

August 26, 2016
Private Pumper Advisory Committee Meeting
10:00-noon
Colusa Industrial Properties Conference Room
100 Sunrise Blvd., Colusa, CA 95932

SGMA - How to Stay Informed:

- ✓ Get on the Colusa County Water Resources email notification list for updates and meeting announcements - call or email Water Resources Staff: 530.458.7709; email: mfahey@countyofcolusa.com
- ✓ Visit the Colusa County Water Resources website where you can find meeting announcements, agendas, meeting summaries and presentations as well as information on SGMA: countyofcolusa.org
- ✓ Visit DWR's Groundwater Information Center website for extensive information on SGMA: http://www.water.ca.gov/groundwater/gwinfo/index.cfm
- ✓ Do you have questions? Call or email Colusa County Water Resources Staff

August 1, 2016

Sustainable Groundwater Management Act (SGMA); Implementing SGMA in Colusa County, Part 3 of 4

For immediate release
Contact: Mary Fahey, Colusa County Water Resources Coordinator
mfahey@countyofcolusa.com
530-458-7709

This is the third article in a four-part series to inform groundwater users in Colusa County about new groundwater legislation, called the Sustainable Groundwater Management Act (SGMA), and the local efforts that are taking place to implement these new laws.

Part 3 – Implementing SGMA in Colusa County

Forming Governance

The County of Colusa and other local agencies and stakeholders have been working cooperatively on a proactive approach to SGMA implementation since early 2015. The County wants to be part of a partnership that implements SGMA the right way, ensures that we are regional and statewide leaders, and keeps our citizens ahead of the curve on groundwater management policies.

Formation of local Groundwater Sustainability Agencies (GSAs) is the first major task required by local agencies. GSAs are the governing bodies that will be responsible for developing a Groundwater Sustainability plan (GSP) and implementing SGMA locally. GSA-eligible agencies in Colusa County have formed a Governance Workgroup that has been meeting regularly to determine the best approach to form one or more GSAs in the county. The Governance Workgroup includes various water management districts, and public water suppliers. Groundwater users from the County's Private Pumper Advisory Committee are also participating in these meetings.

GSA-eligible agencies will have to make very important decisions regarding their level of participation in governance. Implementing SGMA will will require significant resources from GSAs. Some agencies may not have the necessary resources, yet they don't want to be left out of the process. Other agencies may not want to participate and prefer to leave decision making to other agencies. The Governance Workgroup is discussing options to include different levels of engagement from agencies.

Recognizing the delicate nature of bringing agencies together to form a new political governing body, the Department of Water Resources (DWR) developed a program to provide facilitation support services to counties. Colusa County acquired these services and the Center for Collaborative Policy (CCP) at California State University, Sacramento, has been facilitating the Governance Workgroup meetings. The facilitators act as a neutral third party so that each agency has an equal voice at the table. They also work closely with DWR to ensure that accurate and current information regarding SGMA is shared with the group.

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Five facilitated Governance Workgroup meetings have taken place in Colusa County with a sixth meeting being scheduled in August. The group continues to make progress at the county leve. Plans for the near future include coordinating with Glenn and Butte Counties who share subbasins with Colusa County. These meetings are open to the public and are noticed at the project website (see web links below).

Next Steps

The Colusa SGMA Governance Workgroup will continue to convene regular planning meetings over the next year. In the next few months, the group will begin to coordinate with Glenn and Butte Counties on basin-wide governance planning. By the end of 2016, and possibly sooner, we anticipate that the Colusa County portions of the Colusa Subbasin and West Butte Subbasin will have a defined governance structure. Once that structure is agreed upon, legal agreements, such as Joint Powers Authority (JPA) Agreements and Coordination Agreements will be drawn up.

Important Dates:

12/30/2016	Governance Structure defined in Colusa County
Jan. 2017-June, 2017	Legal Agreements are developed
6/30/2017	GSAs must be in place for all high and medium priority groundwater basins that are not in critical overdraft
1/31/2022	GSPs must be completed for all high and medium priority groundwater basins that are not in critical overdraft

SGMA - How to Stay Informed:

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- ✓ Visit the Colusa County Water Resources website where you can find meeting announcements, agendas, meeting summaries and presentations as well as information on SGMA: countyofcolusa.org
- ✓ Visit DWR's Groundwater Information Center website for extensive information on SGMA: http://www.water.ca.gov/groundwater/gwinfo/index.cfm
- ✓ Do you have questions? Call or email Colusa County Water Resources Staff

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Sustainable Groundwater Management Act (SGMA); Introduction, Part 4 of 4

For immediate release
Contact: Mary Fahey,
Colusa County Water Resources Coordinator
mfahey@countyofcolusa.com
530-458-7709

NOTE: Part 4 of 4 was ultimately not finalized nor published by media outlets in the Colusa Subbasin.

Colusa Groundwater Authority

Groundwater Sustainability Agency

100 Sunrise Blvd., Suite A | Colusa, CA 95932 | 530.458.7709

FOR IMMEDIATE RELEASE

Contact: Mary Fahey, Colusa Groundwater Authority Program Manager
Email: mfahey@countyofcolusa.com
Phone: (530) 458-0719
Date: April 27, 2018

Sustainable Groundwater Management Act (SGMA) Groundwater Sustainability Planning

ATTENTION ALL USERS OF GROUNDWATER WELLS IN COLUSA, AND/OR GLENN COUNTY:
The State of California under the Sustainable Groundwater Management Act (SGMA) law requires all groundwater well users to live under a Groundwater Sustainability Plan developed by Groundwater Sustainability Agencies that must be completed by January 31, 2022. This Plan will require all groundwater well use to be sustainable for all parts of the basins throughout California, and will potentially require meters and records on groundwater use. Also required will be a plan for recharging the aquifers if groundwater falls into an overdraft situation.

Development of the Groundwater Sustainability Plans by Groundwater Sustainability Agencies is just getting underway in Colusa and Glenn Counties. Each groundwater user has the opportunity to help develop these Plans which all users will have to live by. It would behoove all groundwater users to get involved in this process.

Please attend Groundwater Sustainability Agency meetings and other local water management meetings including the Colusa Groundwater Authority, Glenn Groundwater Authority, and Colusa County Groundwater Commission meetings, and add your name to email notification lists. You can find more information and sign up for the email lists on the websites at:

Colusa Groundwater Authority:
www.colusagroundwater.org
Contact the office: 530-458-0719 or email: mfahey@countyofcolusa.com

Glenn Groundwater Authority:
http://www.countyofglenn.net/dept/ag-commissioner/water-resources/glenn-groundwater-authority
Contact the office: 530-934-6501 or email: lhunter@countyofglenn.net

Other Groundwater Sustainability Agencies within Colusa and Glenn County include the Corning Sub-basin GSA, Glenn County, Reclamation District 1004, Reclamation District 2106, and Western Canal Water District.
More information can also be found on the Department of Water Resources website at:
https://www.water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management

July 2018

USDA United States Department of Agriculture

Farm Service Agency Electronic News Service

BULLETIN

GovDelivery

Colusa County FSA Updates

Colusa County FSA Office
100 Sunrise Blvd., Suite D
Colusa, CA 95932
Phone: 530-458-5131 Ext.2
Fax: 844-206-6975

County Executive Director:
Denise Nannen

Farm Loan Manager:
Shaleen Hogan

Program Technicians:
Kristen Correa-Fernandez
Stephanie Cotter
Cynthia Pearson

County Committee:
Mary Anne Azevedo
Craig Felix
Joseph Kalfsbeek

Next County Committee Meeting: TBD

Elections for the 2018 County Committee

Elections for USDA's Farm Service Agency's (FSA) Colusa County Committee is underway.

It is important that every eligible producer participate in these elections because FSA county committees are a link between the agricultural community and the USDA. The 2018 election in Colusa County will be conducted for the representative Local Administrative Area (LAA) 3 located west of Interstate 5.

County committee members are a critical component of FSA operations. Committees should be comprised of members who reflect the diversity of producers involved in production agriculture in Colusa County. This means that producers representing underserved groups or communities should be on the committee to speak on behalf of their constituency.

Underserved producers are beginning, women and other minority farmers and ranchers and land owners and/or operators who have limited resources. Other minority groups including Native American and Alaska Natives; persons under the poverty level, and persons that have disabilities are also considered underserved.

County committee election ballots will be mailed to eligible voters on Nov. 5, 2018. The last day to return completed ballots to the Colusa County USDA service center is Dec. 3, 2018.

For more information on eligibility to serve on FSA county committees, visit: **www.fsa.usda.gov/elections**.

Heading 2 HereSustainable Groundwater Management Act

(SGMA) Groundwater Sustainability Planning

ATTENTION ALL USERS OF GROUNDWATER WELLS IN COLUSA, AND/OR GLENN COUNTY

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Development of the Groundwater Sustainability Plans by Groundwater Sustainability Agencies is just getting underway in Colusa and Glenn Counties. Each groundwater user has the opportunity to help develop these Plans which all users will have to live by. It would behoove all groundwater users to get involved in this process.

Please attend Groundwater Sustainability Agency meetings and other local water management meetings including the Colusa Groundwater Authority, Glenn Groundwater Authority, and Colusa County Groundwater Commission meetings, and add your name to email notification lists. You can find more information and sign up for the email lists on the websites at:

Colusa Groundwater Authority:

www.colusagroundwater.org

Contact the office: 530-458-0719 or email: mfahey@countyofcolusa.com

Glenn Groundwater Authority:

http://www.countyofglenn.net/dept/ag-commissioner/water-resources/glenn-groundwater-authority

Contact the office: 530-934-6501 or email: lhunter@countyofglenn.net

Other Groundwater Sustainability Agencies within Colusa and Glenn County include the Corning Sub-basin GSA, Glenn County, Reclamation District 1004, Reclamation District 2106, and Western Canal Water District.

More information can also be found on the Department of Water Resources website at:

https://www.water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management

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Persons with disabilities who require accommodations to attend or participate in this meeting should contact Denise Nannen at 530-458-5131 extension 2 or Federal Relay Service at 1-800-877-8339.

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Colusa Groundwater Authority (CGA)

Groundwater Sustainability Agency

100 Sunrise Blvd., Ste. A, Colusa, CA 95932 | 530-458-0719
www.colusagroundwater.org

SEPTEMBER 4, 2018 SPECIAL BASIN BOUNDARY MODIFICATION (BBM) EDITION NEWSLETTER

The purpose of this newsletter is to inform the public about the basin boundary modification proposals being considered in the Colusa and West Butte groundwater subbasins in Colusa County.

BASIN BOUNDARY MODIFICATIONS (BBM)

The Sustainable Groundwater Management Act (SGMA) established a process for local Groundwater Sustainability Agencies (GSAs) to request that the California Department of Water Resources (DWR) revise the boundaries of Bulletin 118 groundwater basins or subbasins in order to promote sustainable groundwater management. DWR completed the first round of Basin Boundary Modifications (BBMs) under SGMA in 2016. On January 1, 2018, DWR opened the second and current round of BBM modifications. Proposals are due September 28, 2018. Once a BBM request is submitted and deemed complete by DWR, a 30-day public comment period is opened. It is anticipated that DWR will release the initial results of round two BBMs in late 2018, after which another 30-day public comment period will open.

The purpose of this newsletter is to describe two basin boundary modification proposals being considered in the basins that lie in, and adjacent to, Colusa County:

1. The Colusa Groundwater Authority is proposing modifications to the West Butte and Colusa Subbasins.

2. The County of Butte is proposing modifications to the Vina, West Butte and East Butte Subbasins.

These proposed modifications are discussed in detail on the following pages.

More information on BBMs

You can find a map of statewide groundwater basins by accessing DWR's online Basin Boundary Assessment tool: https://gis.water.ca.gov/app/bbat/

You can find more information about Basin Boundary Modifications, including a list of proposed modifications and submitted BBM proposals by accessing DWRs online SGMA Portal: https://sgma.water.ca.gov/basinmod/

More information on BBMs can be found on DWR's website: https://water.ca.gov/Programs/Groundwater-Management/Basin-Boundary-Modifications

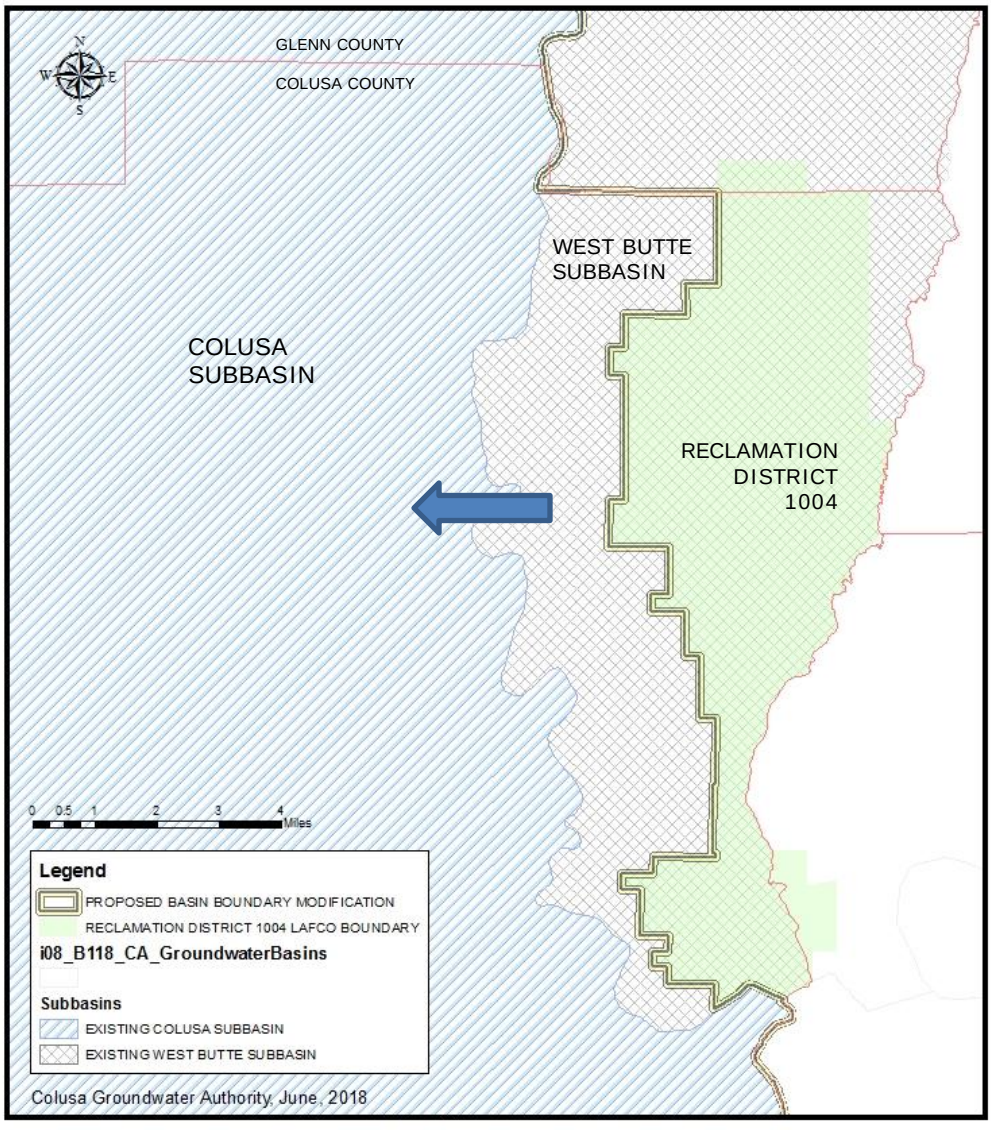
LOCAL BASIN BOUNDARY MODIFICATION (BBM) PROPOSALS

Colusa Groundwater Authority Proposed Basin Boundary Modification (BBM)

In May, 2018, the Colusa Groundwater Authority (CGA) submitted an initial notification to DWR of a proposed jurisdictional Basin Boundary Modification that would consolidate a portion of the West Butte Subbasin (5-21.58) with the Colusa subbasin (5-21.52). This jurisdictional consolidation would bring the Colusa County portion of the West Butte Subbasin that lies on the west side of the legal service area boundary of Reclamation District 1004 into the Colusa Subbasin.

A **Jurisdictional Basin Boundary Modification** involves the addition, deletion, or relocation of a basin or subbasin boundary that is not a scientific modification but promotes sustainable groundwater management.

COLUSA GROUNDWATER AUTHORITY
PROPOSED BASIN BOUNDARY MODIFICATION 2018
Colusa Subbasin (5-21.52); West Butte Subbasin (5-21.58)



Data Sources:
1. Groundwater Basins from DWR's final 2016 Bulletin 118 Groundwater Basin Boundaries, downloaded
2. GSA Boundaries from DWR SGMA GSA Map Viewer, downloaded
3. California Counties from DWR SGMA GSA Map Viewer, downloaded
4. Reclamation District 1004 Boundaries from Colusa County LAFCO

A **Management Area** is defined in the GSP Regulations as:

"… an area within a basin for which the Plan may identify different minimum thresholds, measureable objectives, monitoring or projects and management actions based on water use sector, water source type, geology, aquifer characteristics, or other factors."
§ 351 (r)

"Each Agency may define one or more management areas within a basin if the Agency has determined that creation of management areas will facilitate implementation of the plan."

The Colusa Groundwater Authority identified that this proposed jurisdictional basin boundary modification would improve the efficiency and cost-effectiveness of sustainable groundwater management within these basins. The current Bulletin 118-defined basin boundaries split the CGA into two subbasins, which will require the CGA to participate in the development and implementation of two separate Groundwater Sustainability Plans. The majority of the CGA's jurisdiction lies in the Colusa Subbasin, where we have achieved very effective sustainable groundwater management planning, in close coordination with the Glenn Groundwater Authority. Consolidation of the CGA's jurisdiction would allow this coordinated effort to continue seamlessly through GSP development.

The CGA intends, through development of the Groundwater Sustainability Plan, to delineate **Management Areas** in the Colusa Subbasin. Management Areas are tools that GSAs can use to define areas in the basin where more localized groundwater management can take place. Management Areas can be defined by unique hydrological conditions, or other parameters. It is anticipated that the area in the West Butte Subbasin proposed to be consolidated into the Colusa Subbasin would become its own Management Area in the Colusa Subbasin GSP.

The proposed Basin Boundary Modification does not alter any landowner's water rights - the CGA does not have that authority. Additionally, the proposed BBM does not have any bearing on groundwater transfers - Colusa County's Groundwater Ordinance remains in place and the GSA cannot override any County Ordinance.

Opportunities to Provide Input

The CGA is interested in receiving feedback regarding the proposed BBM from local agencies and landowners in the Colusa and West Butte Subbasins. In May, 2018, a notification of the proposed BBM was distributed to the CGA's email distribution list and a notification was posted on the DWR SGMA Portal website. The proposed modification has been discussed at several public CGA Board meetings, Colusa County Farm Bureau Board meetings, Northern Sacramento Valley IRWMP meetings, RD 1004 Board meetings, West Butte Subbasin Workgroup meetings, and other various public meetings. Information is also posted on the CGA website.

A presentation and discussion regarding the CGA's proposed Basin Boundary Modification will be held at the next **Colusa Groundwater Authority Board Meeting:**

September 25, 2018
1:00 p.m. – 3:00 p.m.
Colusa Industrial Properties Conference Room
100 Sunrise Blvd., Colusa, CA 95932

Members of the public that wish to learn more are encouraged to attend this meeting. Additionally, comments and questions can be sent to CGA Staff via email to Mary Fahey at mfahey@countyofcolusa.com, mail: **100 Sunrise Blvd., Suite A, Colusa, CA 95932**, or by phone: **530-458-0719**.

Colusa Groundwater Authority Staff and Butte County Staff communicate regularly and share information related to SGMA implementation. There is a high level of coordination between all of the GSAs in the local groundwater basins.

Butte County's Proposed Basin Boundary Modification

Butte County is working toward submitting a BBM request to DWR in coordination with the Feather River Water Districts (Western Canal Water District, Richvale Irrigation District, Biggs West Gridley Water district, and Butte Water District) and other GSAs to modify the Vina, West Butte, and East Butte Subbasins. The proposed modification would create a new "Butte Subbasin" by consolidating large portions of the West Butte and East Butte Subbasins. The "Butte Subbasin" would include Butte County GSA areas, RD 2106, RD 1004, the Feather River Districts, the City of Biggs, the City of Gridley and small portions of the Glenn County GSA and Colusa Groundwater Authority. The southern boundary would mostly align with the Butte-Sutter County line. As a result of these modifications, the Vina Subbasin expands to the south to include Butte County GSA areas and Durham Irrigation District.

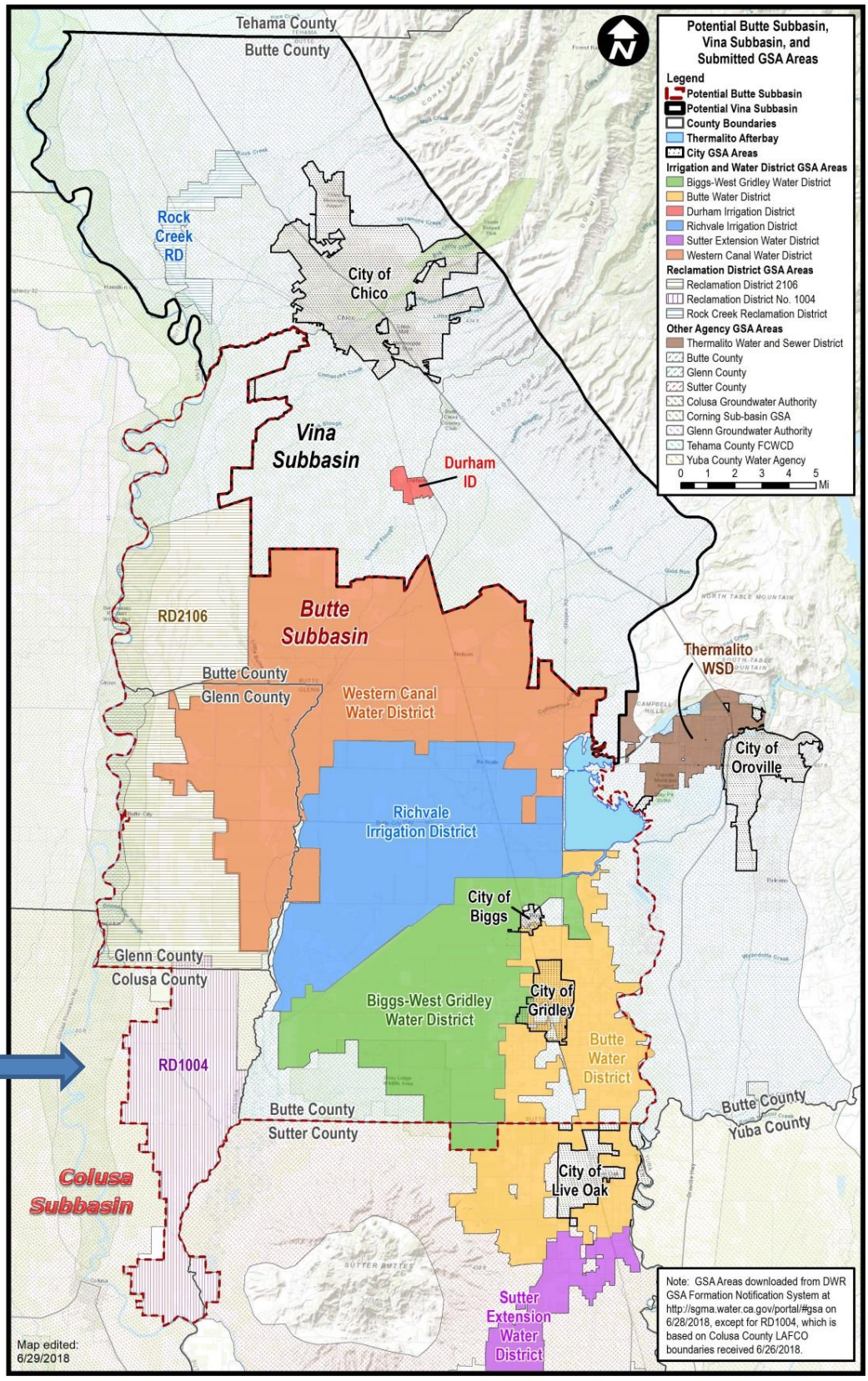
This modification, combined with the CGA's proposed modification would remove the West Butte Subbasin, and reduce the number of subbasins in Butte County from four down to three. Similar to the CGA's proposed BBM, Butte County's proposal provides greater efficiency and will reduce costs for long-term governance of groundwater in these subbasins and for development and implementation of Groundwater Sustainability Plans.

See map of the proposed "Butte Subbasin" on Page 5.

For questions or additional information regarding Butte County's Basin Boundary Modification, please contact Christina Buck at (530) 552-3593 or cbuck@buttecounty.net



Butte County Proposed Basin Boundary Modification in the West Butte, East Butte and Vina Subbasins



The area outlined in the dashed red line is the proposed Butte Subbasin BBM.

The CGA's proposed BBM aligns with the proposed Butte Subbasin boundary in Colusa County.

DWR's BBM Public Comment Opportunity

Once the Basin Boundary Modification proposals are posted to the California Department of Water Resources' (DWR) online Basin Boundary Modification Request System, public comments can be submitted pursuant to Article 4, Section 343.12 of the Basin Boundary Modification Emergency Regulations (see below). Public comments will be accepted by DWR for 30 days after the BBM request is posted.

Written comments regarding any Basin Boundary Modification proposal can be submitted to DWR within 30 days of the BBM proposal being posted on DWR's website.

§ 343.12. Public Input

(a) Any person may provide information to support or oppose a proposed boundary modification request as follows:

(1) Public input must be submitted by written notice to the California Department of Water Resources within 30 days after the Department posts a notice that the request is complete pursuant to Section 343.10(c), and provide the requesting agency a duplicate copy of that information the same day.

(2) Public input must include the name, address, and electronic mail address of the person or entity providing that input.

(3) Public input must include a clear statement of the basis for the support of or opposition to the proposed boundary modification.

(4) The level of detail provided by public input need not be as comprehensive as that contained in the request, but must rely on similar scientific and technical information as the particular boundary modification request to which it is addressed, and will be evaluated by the Department using the same criteria.

(b) The Department shall post all public input on the Department's Internet Web site.

(c) The Department is not required to respond to comments received through public input, but will consider such comments as part of its evaluation of a boundary modification request.

(d) The Department shall give the requesting agency a reasonable opportunity to respond to public input, including the opportunity to modify the boundary modification request.

Note: Authority cited: Section 10722.2, Water Code. Reference: Section 10722.2, Water Code.

A **Groundwater Sustainability Agency (GSA)** is responsible for performing the duties and exercising the necessary powers to implement the Sustainable Groundwater Management Act at the local level. A single agency can be a GSA, or a combination of local agencies can form a GSA through a Joint Powers Agreement or other legal Agreement. SGMA law required GSAs to be in place by June 30, 2017.

Any "unmanaged areas" (areas not covered by a GSA) in a groundwater basin that is subject to SGMA will come under management of the State Water Resources Control Board.

The Colusa Groundwater Authority was formed to ensure that the groundwater resources in Colusa County are managed locally and State intervention is avoided.

ABOUT THE COLUSA GROUNDWATER AUTHORITY

The Colusa Groundwater Authority (CGA) was formed on June 29, 2017 to comply with the Sustainable Groundwater Management Act (SGMA) regulations and ensure that groundwater is managed locally. The CGA is a Joint Powers Authority and is recognized by DWR as the Groundwater Sustainability Agency (GSA) for the Colusa County portion of the Colusa Subbasin, and portions of the West Butte Subbasin outside of Reclamation District 1004. (see map, page 8).

Members of the Colusa Groundwater Authority Board:

1. County of Colusa
2. City of Colusa
3. City of Williams
4. Glenn Colusa Irrigation District
5. Maxwell Irrigation District and Westside Water District (1 seat)
6. Princeton-Codora-Glenn Irrigation District and Provident Irrigation District (1 seat)
7. Colusa County Water District
8. Reclamation District 108
9. Reclamation District 479
10. Colusa Drain Mutual Water Company
11. Private Pumper Representative from Colusa County Groundwater Commission
12. Private Pumper Representative from Colusa County Groundwater Commission



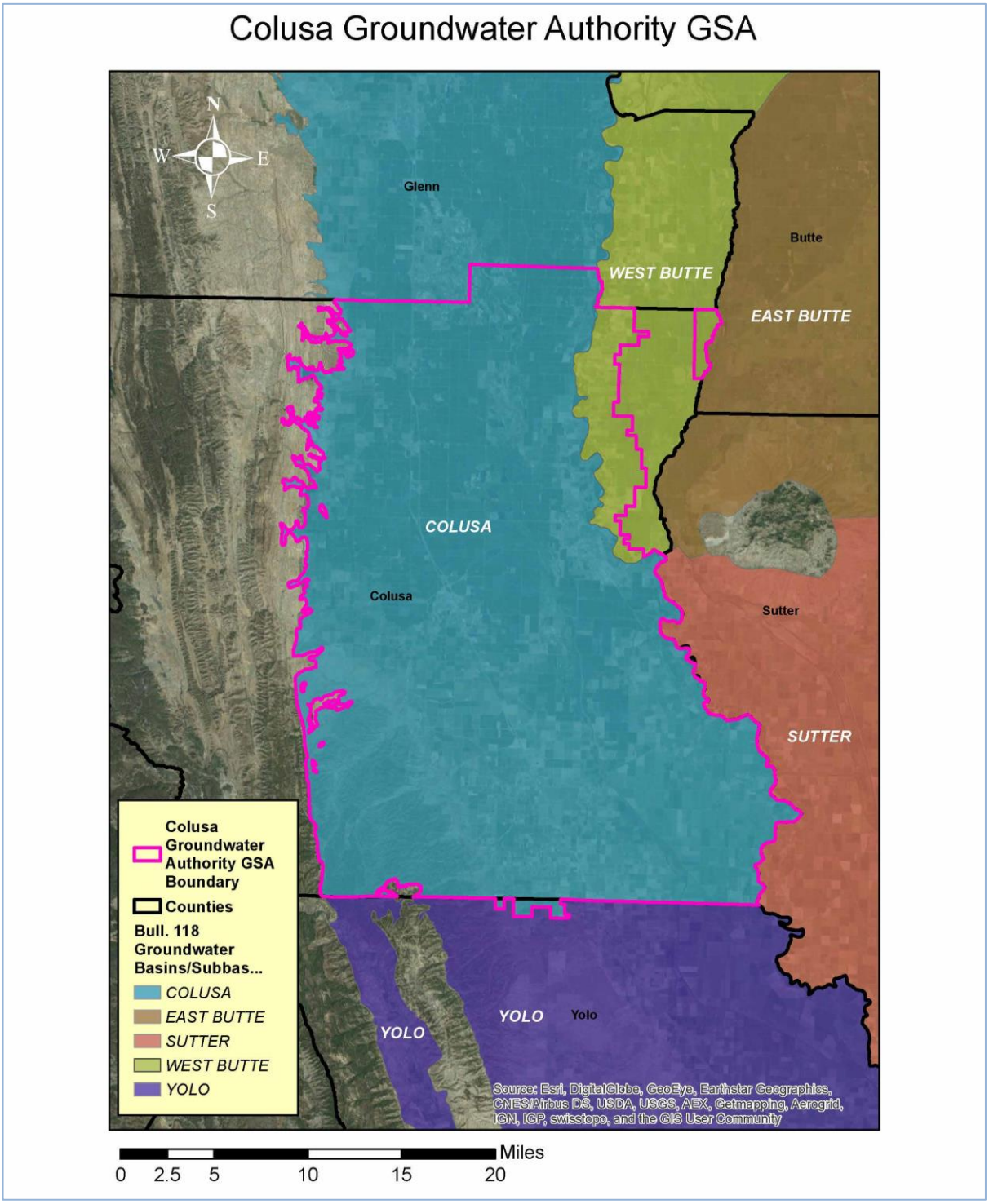
Get to know the Colusa Groundwater Authority, and keep up with the latest SGMA news.

Visit the website:

Colusagroundwater.org

Colusa Groundwater Authority Jurisdiction

The Colusa Groundwater Authority covers the areas outlined in pink on this map. The Blue area is the Colusa Subbasin and the green area is the West Butte Subbasin. A map of statewide GSAs can be found on the DWR GSA Map Viewer.



STAY INFORMED!
All beneficial uses and users of groundwater (Water Code Section 10723.2) must be taken into consideration during SGMA planning and implementation. There will continue to be ample opportunities for public engagement during GSP development. If you are not on the CGA's email list, please contact Water Resources staff to ensure you receive meeting notices and other relevant information, and please share this information with your friends and neighbors.

SGMA – STAY INFORMED:

Between now and January 31, 2022, the CGA will be developing the Groundwater Sustainability Plan for the Colusa Subbasin. **If you have not been involved in local SGMA planning, now is the time!**

There are many opportunities to be engaged and informed about local groundwater management planning:

- ✓ Get on the CGA email notification list for updates and meeting announcements - call or email Staff (see contact info below), or sign up on the website: https://colusagroundwater.org/contact-us/
- ✓ Visit the CGA Website regularly: http://colusagroundwater.org
- ✓ Attend Colusa Groundwater Authority Board meetings
- ✓ Visit DWR's Groundwater Information Center website: https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management
- ✓ Visit the DWR SGMA Portal: https://sgma.water.ca.gov/portal/#intro

The next meeting of the CGA Board is **September 25, 2018** at 1:00 p.m. at Colusa Industrial Properties. The full Board meeting schedule can be found on the CGA website: https://colusagroundwater.org/meetings/

All CGA Board meetings are open to the public.

Staff contact:
Mary Fahey, CGA Program Manager
100 Sunrise Boulevard, Suite A, Colusa, CA 95932
email: mfahey@countyofcolusa.org
Phone: 530.458.0719



Colusa Groundwater Authority, Article for October, 2018 Family Water Alliance "Green Ribbon" Newsletter

Submitted by Mary Fahey, Program Manager, Colusa Groundwater Authority / 530-458-7709

The Sustainable Groundwater Management Act – Time for Landowners to Get Involved!

With a myriad of water-related issues dominating the headlines these days, it's difficult for landowners to know where to focus and when to get involved. While all of the issues are important, now is definitely the time to get up to speed and involved with local Sustainable Groundwater Management Act (SGMA) efforts.

As the Colusa Groundwater Authority (CGA) moves into its second year of operations, the Board is working on important projects that all landowners in Colusa County should be aware of, including development of the Groundwater Sustainability Plans that will dictate the future of groundwater management in the local basins. Development of these plans is just getting underway in the basins in Colusa County, and surrounding counties, and Stakeholder input is critical to development of these plans. The Plans must be completed by January 31, 2022.

The Colusa Groundwater Authority is also working on a Long-term Funding plan to maintain its day to day operations. The Agencies that make up the Board of the CGA agreed to fund the effort for the first two years, through June 30, 2019. The CGA is beginning a Proposition 218 Assessment process for long-term funding. Similar processes are taking place in other basins throughout the State, including the Glenn County portion of the Colusa Subbasin.

And finally, the CGA has submitted a request to the California Department of Water Resources (DWR) for a Basin Boundary Modification. This modification would bring the Colusa County portion of the West Butte Subbasin that lies on the west side of the legal service area of Reclamation District 1004 into the Colusa Subbasin. This proposed modification will create greater efficiency and will reduce costs for long-term governance of groundwater in these subbasins, and for development and implementation of Groundwater Sustainability Plans. The proposal is posted on DWR's online Basin Boundary Modification Request System: https://sgma.water.ca.gov/basinmod/init/preview/162. Public comments can be submitted on the DWR online Portal: https://sgma.water.ca.gov/basinmod/modrequest/comments/243 pursuant to Article 4, Section 343.12 of the Basin Boundary Modification Emergency Regulations. The Deadline for public comment is 11:59 p.m. October 28, 2018.

All of this information and more can be found on the **Colusa Groundwater Authority website: http://colusagroundwater.org**

You can also sign up on the CGA email notification list for updates and meeting announcements:

- Sign up on the website: https://colusagroundwater.org/contact-us/
- Or call or email Staff: Mary Fahey, Program Manager, 530-458-0719; email: mfhahey@countyofcolusa.com

If you have not been involved in local SGMA planning, now is the time!

Colusa Groundwater Authority, Article for October, 2018 Colusa County Farm Bureau "Sodbuster" Newsletter

Submitted by Mary Fahey, Program Manager, Colusa Groundwater Authority / 530-458-7709

The Sustainable Groundwater Management Act – Time for Landowners to Get Involved!

With a myriad of water-related issues dominating the headlines these days, it's difficult for landowners to know where to focus and when to get involved. While all of these issues are important, now is definitely the time to get up to speed and involved with local Sustainable Groundwater Management Act (SGMA) efforts.

As the Colusa Groundwater Authority (CGA) moves into its second year of operations, the Board is working on important projects that all landowners in Colusa County should be aware of, including development of the Groundwater Sustainability Plans that will dictate the future of groundwater management in our local basins. In the Northern Sacramento Valley basins, Groundwater Sustainability Plans must be completed by January 31, 2022. Development of these plans is just getting underway in the basins in Colusa County, and surrounding counties, and Stakeholder input is critical to development of these plans.

The Colusa Groundwater Authority is also working on a Long-term Funding plan to maintain its day to day operations. The Agencies that make up the Board of the CGA agreed to fund the effort for the first two years, through June 30, 2019. The CGA is beginning a Proposition 218 Assessment process for long-term funding. Similar processes are taking place in other basins throughout the State, including the Glenn County portion of the Colusa Subbasin.

And finally, the CGA intends to submit a request to the California Department of Water Resources (DWR) for a Basin Boundary Modification. This modification would bring the Colusa County portion of the West Butte Subbasin that lies on the west side of the legal service area of Reclamation District 1004 into the Colusa Subbasin. This proposed modification will create greater efficiency and will reduce costs for long-term governance of groundwater in these subbasins, and for development and implementation of Groundwater Sustainability Plans.

All of this information and more can be found on the **Colusa Groundwater Authority website: http://colusagroundwater.org**

You can also sign up on the CGA email notification list for updates and meeting announcements:

- Sign up on the website: https://colusagroundwater.org/contact-us/
- Or call or email Staff: Mary Fahey, Program Manager, 530-458-0719; email: mfhahey@countyofcolusa.com

If you have not been involved in local SGMA planning, now is the time!

Colusa Farm Bureau

Sodbuster December 2020

Sustainable Groundwater Management Act Update in the Colusa Subbasin

The big news in local groundwater management right now is Groundwater Sustainability Plan (GSP) development to comply with the Sustainable Groundwater Management Act (SGMA). Local GSPs are due January 31, 2022 and groundwater agencies throughout the region are working hard to achieve that milestone.

The Colusa Groundwater Authority (CGA) and Glenn Groundwater Authority (GGA) are jointly launching a focused "*SGMA –Series*" of GSP-related events, starting with two online public meetings in December. The meetings will be identical and will cover the status of the GSP for the Colusa Subbasin. Stakeholders will learn about work completed, work in progress, and next steps as the agencies continue their mandate to regulate groundwater use through implementation of SGMA. The meetings will be an opportunity for stakeholders to give the CGA and GGA Boards and their consultant team critically important feedback on how groundwater should be managed in the future. Stakeholders will also learn about future *SGMA-Series* opportunities and how to be involved in GSP development over the next year.

The CGA and GGA Boards hope you can participate in one of these public meetings in December:

- **Wednesday, December 9 at 5:30 p.m.**
- **Thursday, December 10 at 1:00 p.m.**

Over the next several months, CGA and GGA will release the Colusa Subbasin GSP in draft sections for public review and comment. The entire Public Draft GSP will be released for a final round of public comments in August, 2021. The *SGMA-Series* meetings will occur at strategic intervals between now and August to provide information on GSP development and to solicit Stakeholder input. Additionally, both the CGA and GGA Boards of Directors and Technical Advisory Committees hold monthly meetings that are open to the public and everyone is welcome to attend.

For more information about local SGMA planning, please visit:

- Colusa Groundwater Authority website: https://colusagroundwater.org
- Glenn Groundwater Authority website: https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority

COLUSA SUBBASIN

Drought has returned. Severe. Unrelenting. Undiscriminating.

As we face a long, frustrating summer and fall in the Sacramento Valley, everyone…farmer, homeowner, rancher, environmental advocate, businessperson, water deliverer, etc. will be profoundly affected by our current and pending drought conditions. In the immediate, there are no easy answers. Scarce resources inevitably create conflict. However, such conditions can also create uncommon partnerships and with the right tools, powerful solutions. In 2014, the State Legislature passed the Sustainable Groundwater Management Act (SGMA); a sweeping law that foundationally changes how groundwater is and will be managed. Our part of California is unique and we need groundwater management methods that will work for us and for our communities. We have answered the call and the requirements of SGMA and are finalizing a locally driven, locally focused Groundwater Sustainability Plan for the Colusa Groundwater Subbasin (covering most of Colusa and Glenn Counties).

SGMA is hard. It is cumbersome, expensive, complicated, intrusive and far reaching. Few people, regardless of where they sit on the ideological spectrum, like it when legislation is created that dramatically affects them. As water users in this region we are no exception. But it is undeniable that SGMA was written for just this circumstance. It forces us to build local solutions and partnerships to achieve and maintain sustainable groundwater conditions for the future, particularly during droughts. In an era of water uncertainty, it is an uncomfortable reality that being forced to be more resilient to drought may not be what we wanted; but it is what we need.

Think about why we live in this region. Why our relatives settled here and put down roots. Why we stayed or came, raising families, building homes, businesses and futures. Whether it is the productivity of the soils, the charm of our communities, the beauty of our natural resources, we hope to pass these attributes on to the next generations. Then think about this region without a resilient water supply.

We need to think about “sustainability” not as a title forced on us from people in Sacramento but instead, as a way of life that protects what we hold dear. Like it or not, SGMA helps or will help us do what we have not been able to do on our own across the State. It created new, regulating groundwater agencies, vested with powerful authorities to guarantee that groundwater is protected. It gives us the ability to manage these resources locally and to bring a diverse collection of affected parties together to make this happen. In our case, SGMA led us to create the Glenn Groundwater Authority (GGA) and Colusa Groundwater Authority (CGA). Multi-organization, multi-person public agencies represented by your neighbors, colleagues and friends. We shop in the same stores, send our kids to the same schools, and love the same communities and natural resources that you do. And we are dedicated to building the necessary solutions that in time, can help protect us from drought.

We have a robust surface water supply in the Sacramento Valley. One that has historically supported water needs and the groundwater beneath us. But we know all too well that some of these sources are being challenged and have proved legally uncertain and beyond our control to protect. Within the groundwater aquifers lies a safety net. That safety net however, is only as good as the tools we create to support it. In the case of SGMA, this comes in the form of the aforementioned Groundwater Sustainability Plan that the GGA and CGA are jointly preparing. The Plan defines our current

groundwater situation, and describes what we will do in the future to better understand and protect these resources. The Plan describes the conditions we are obligated to address. Important factors like preserving and enhancing groundwater levels, minimizing potentially damaging subsidence, avoiding adverse water quality impacts and protecting natural resources that depend on the connection between groundwater and surface water. Once the Plan is adopted and submitted to the State, the GSAs will then have the authority to implement the actions in the Plan.

By State law, we are nearing the end of the period to prepare the Plan. In the coming weeks and months, the CGA and GGA will host and encourage you to attend, public meetings to discuss the draft Plan and provide written comments to us. The CGA and GGA will consider comments received and then finalize and adopt the Plan by January 2022. The projects and management actions described in the Plan won't be easy to achieve. They may require new investments, an unfailing commitment to collaboration, uncomfortable options we haven't wanted to discuss in the past, and potential sacrifice in the future. They will reflect a continued commitment to work collaboratively for the common good of our region, rather than as individual water users and organizations competing for limited resources. The Plan will not be ready in time to help us through the current drought. We won't even be able to begin to implement aspects of the Plan until February 2022 at the earliest. But we will learn from the current and recent water crises and that will inform our Plan and actions. Over time, SGMA will live up to its promise, warts and all, to support resilience as best we can locally and to ensure that we work together to achieve successful outcomes.

In closing, on July 28 and 29 from 6 – 8 p.m, the CGA and GGA will hold the next round of public meetings in our "SGMA-Series".

The meeting on the 28th will be held virtually. See the following websites for more information:

- https://colusagroundwater.org
- https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority/gga

The meeting on the 29th will be held at:

- Sites Project Authority Office - 122 Old Highway 99W, Maxwell, CA 95955.

These meetings will focus on the sustainability conditions we have been studying for the Plan, and the potential projects and management actions that we refer to above. We encourage you to attend these meetings and to visit our websites and related social media to learn more about SGMA and the GGA and CGA. We need you to participate in upcoming meetings, to embrace the need for these collaborative changes and to work with us to forge a new resilient groundwater future in the Sacramento Valley.

On behalf of the Colusa Groundwater Authority Board and Glenn Groundwater Authority Board

Signed,

Ms. Denise Carter
Chair
Colusa Groundwater Authority

Mr. John Amaro
Chair
Glenn Groundwater Authority

Historically, because of the lack of beds in Colusa County,

Colusa County has agreed to purchase the former nursing

once the purchase closes and the repairs are completed, Tyler said. ■

Groundwater Sustainability Plan meetings scheduled

PIONEER REVIEW
news@colusacountynews.com

The Colusa Groundwater Authority and Glenn Groundwater Authority will host two meetings this month to discuss the recently-released Draft Groundwater Sustainability Plan for the Colusa Subbasin.

The content of the two meetings will be the same, although one will be held "virtually" and the other, in person, officials said.

The virtual meeting will be held from 1-3:30 PM on Wednesday, Oct. 13, via Zoom. The in-person meeting will be held from 5:30-8 PM at the Sites Project Authority Office, 122 Old Highway 99W, in Maxwell.

Against the backdrop of the last drought, the California Legislature passed the Sustainable Groundwater Management Act, which requires local groundwater agencies to define and implement measures that ensure groundwater is sustainable for the next 20 years, officials said.

Glenn and Colusa authorities have worked together to prepare a single joint plan for the Colusa Subbasin.

CGA Chair Denise Carter said the agency representative will provide an overview of each chapter of the plan at the two meetings, allowing members of the public to ask questions and provide focused input about the sustainability methods that will be used.

"We're at the culmination of a long process and on the cusp of implementing projects that will better monitor and enhance our groundwater," Carter said in a joint press release.

GGA Vice-Chair Gary Hansen said the Colusa Subbasin aquifers provide an essential safety net for water availability, but that safety net is only as good as the tools that can be created to support it.

"Our GSP does that and we need public input to confirm if we've done it the right way," Hansen said.

The draft Groundwater Sustainability Plan and online meeting instructions can be viewed on the CGA's website at colusagroundwater.org. ■

Local students receive PG&E scholarship

Turn to KIRKWOOD / 8



David Wilson/Sun-Herald
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Sustainability plan for Colusa Subbasin nearly complete

Community input sought to finalize GSP

By Lynzie Lowe
llowe@appealdemocrat.com
Tri-County News

In one of the final steps to complete a Groundwater Sustainability Plan (GSP) for the Colusa Subbasin, the Colusa Groundwater Authority (CGA) and the Glenn Groundwater Authority (GGA) hosted a virtual public meeting on Wednesday to review the plan and gather community input.

The GSP is a roadmap for how groundwater will be managed over the next two decades, according to meeting facilitator Dave Ceppos, and is being prepared by the CGA and GGA in response

Turn to SUBBASIN / 8

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of study at colleges and universities in California and throughout the country.

Recipients of this year's scholarship from Colusa County include Ashlyn Wooldridge of Arbuckle, Kathryn Williams of Arbuckle and Laynee Haywood of Maxwell.

Recipients from Glenn County include Madalyn Nissen of Willows and Matthew Freitas of Glenn.

Since 2011, the Blue Diamond Foundation has awarded nearly 150 scholarships to help students in our local communities achieve their dreams of a college education.

OMES NEW MEMBERS



Courtesy photo/Rotary Club

service group, such as Tiffany Dietz, superintendent of the eiving a certificate of membership from Rotary Club Vice pecial luncheon. For more infor[redacted]n on the Rotary Club

ng Scenario at Richfield lementary School (when tudents are not in atten-ance) during which all irst responders in the ounty attend.

"It is a sad fact that such training has to take place," Fears said. "But in today's atmosphere, it is essential to protecting our children."



municipal, tribal, agricultural, industrial and environmental uses," said Ceppos.

According to Ceppos, avoiding adverse impacts is based on the evaluation of six sustainability indicators, including surface water depletion, reduction of storage, regraded quality, land subsidence and lowering groundwater levels. The final indicator, seawater intrusion, was determined to not be applicable in the Colusa Subbasin.

The development of the Colusa Subbasin GSP, like many others throughout California, has coincided with one of the most severe and extensive droughts that has ever gripped the western United States, with drought conditions throughout most of California, including the area in and around the Colusa Subbasin, classified as "exceptional" – the most extreme classification, according to the U.S. Drought Monitor.

During the meeting John Amaro, chairperson of the GGA, said at this point in time it is likely too late to make any major and immediate changes to the way aquifers are managed within the Colusa Subbasin and the entire Sacramento Valley region to mitigate the effects of the current drought.

"We will have to work collaboratively together through this current water emergency and then prepare for the next drought with the lessons we learned and the tools we've built as a result of our new, almost completed, groundwater sustainability plan," said Amaro.

According to the draft, technical work and related public involvement processes supporting development of the Colusa Subbasin GSP began in earnest in May 2020 and is now nearing completion.

"Development of the GSP has utilized the best available science and tools, with the most sufficient and credible information and data available for the decisions being made and the time frame available for making those decisions," read the draft. "Current and historical groundwater conditions and water budgets have been evaluated for the subbasin in alignment with the GSP regulations. The technical work is based primarily on historical records of surface water and groundwater conditions from 1966 through 2015, which includes the prior 2014-2015 drought, but not the current 2020- 2021 drought."

The Colusa Subbasin has been designated by the Department of Water Resources as a high priority subbasin, which means Colusa Subbasin GSAs must develop, adopt, and submit a GSP covering the entire subbasin to DWR by January 31, 2022.

Another public meeting to discuss the Public Draft Colusa Subbasin Groundwater Sustainability Plan will be held in person today (Friday) at the Sites Project Authority office, 122 Old Highway 99W, Maxwell, from 5:30-8 p.m.

"Your participation today andover the past few years has been incredibly important to guide our approach as we prepare the GSP in a way that reflects your needs, " said Amaro. "Of many things we are proud of, one and most particular is the unprecedented opportunities we have had for you to participate in this process."

According to Amaro, the GCA and the GGA have collectively sponsored, publicized and conducted 236 separate meetings in various formats since Jan. 2016 to give the community the opportunity to learn about this "challenging law and the steps to comply with it."

The Draft GSP is available for public review and comment through Oct. 31.

Those located in the Glenn Groundwater Authority can get more information by contacting Lisa Hunter, program manager for the Glenn Groundwa-

Appendix 2E

Communication & Engagement Plan

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Colusa Subbasin

Final Stakeholder Communication and Engagement Plan

Version: August 2019

Prepared for:

Colusa Groundwater Authority
Glenn Groundwater Authority

Prepared by:

California State University Sacramento
College of Continuing Education
Consensus and Collaboration Program

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Colusa Subbasin
Final Stakeholder Communication and Engagement Plan

Version: August 2019

Purpose

The purpose of this Stakeholder Communication and Engagement Plan is to assist Colusa Subbasin Groundwater Sustainability Agencies (GSAs) (respectively the Colusa Groundwater Authority [CGA] and the Glenn Groundwater Authority [GGA]) in their efforts to develop general and strategic communications to engage stakeholders in groundwater management activities.

Overview and Background

California's Sustainable Groundwater Management Act (SGMA) of 2014 requires broad and diverse stakeholder involvement in GSA activities, and the development and implementation of Groundwater Sustainability Plans (GSPs) for groundwater basins around the state, including the Colusa Subbasin. The intent of SGMA is to ensure successful, sustainable management of groundwater resources at the local level. Success will require cooperation by all stakeholders, and cooperation is far more likely if stakeholders have consistent messaging of valid information and are provided with opportunities to help shape the path forward. Further, to ensure trust and cooperation from stakeholders, all activities of the GSA's should be conducted in as transparent a manner as possible. The California Department of Water Resources (DWR) has designated the Colusa Subbasin as a high priority basin (2019), and subject to SGMA.

To that end, the intention of the Plan is to:

- Provide the GSAs, community leaders, and other beneficial users a roadmap to follow to ensure consistent messaging of SGMA requirements and related Colusa Subbasin information and data.
- Provide a roadmap for the GSAs and community leaders to ensure stakeholders have meaningful input into GSA decision-making, including GSP development.
- Ensure the roadmap demonstrates a process that is widely seen by stakeholders as fair, transparent and respectful to the range of interested parties.
- Provide a transparent and easily-accessible process for stakeholders to contribute to the development of a GSP that can effectively address groundwater management within the Colusa Subbasin.
- Ensure that information reaches all beneficial users who have an interest in the Subbasin.

Communication Plan Goals

The Plan supports the following goals:

1. Educate stakeholders about:

A. SGMA and its requirements,

B. The CGA and GGA,

C. Groundwater resources in the Colusa Subbasin and the benefits of sustainable groundwater management

D. Potential changes to current groundwater management under SGMA

E. How stakeholders will be represented in their GSAs, and

F. How stakeholders can participate in SGMA planning and decision-making efforts.

2. Communicate important SGMA deadlines and dates.
3. Coordinate outreach and engagement activities between the GSAs to ensure efficiency and to support stakeholders in GSP development.
4. Support individual GSA outreach and engagement activities.
5. Articulate strategies and channels for obtaining ongoing stakeholder input and feedback to inform GSP design and development.
6. Provide a roadmap to the GSAs on ways to effectively and efficiently reach all beneficial users.
7. Encourage stakeholder engagement (e.g., by establishing dedicated SGMA outreach strategies and channels, communicating information about meeting and workshop dates and content, and highlighting all opportunities for stakeholders to provide input in the GSA decision-making process and GSP planning process).

Major Audiences

A Colusa Subbasin stakeholder is a "beneficial user" as described by SGMA. Under the requirements of SGMA, all beneficial uses and users of groundwater must be considered in the development of GSPs, and GSAs must encourage the active involvement of diverse social, cultural, and economic elements of the population. Beneficial users, therefore, are any stakeholders who have an interest in groundwater use and management in the Colusa Subbasin. Their interest may be related to GSA activities, GSP development and implementation, and/or water access and management in general.

To assist in determining who the specific SGMA stakeholders and beneficial users are, DWR has created a Stakeholder Engagement Chart for GSP development in their 2017 *GSP Stakeholder Communication and Engagement Guidance Document*. The following table (Table 1) is based on the DWR chart, modified to fit the circumstances and stakeholders of the Colusa Subbasin. It will continue to be updated during the GSP planning process.

Table 1. Stakeholder Engagement Chart for GSP Development

Category of Interest	Examples of Stakeholder Groups	Engagement Purpose
General Public	• Citizens groups • Community leaders • Interested individuals • Universities/Academia	Inform to improve public awareness of sustainable groundwater management
Land Use	• Municipalities • Local land use agencies • Regional land use agencies • Community Service Districts	Consult and involve to ensure land use policies are supporting GSPs and there are no conflicting policies between the GSAs / GSP and said local government agencies
Private Users	• Private pumpers (domestic and agricultural) • Schools and colleges • Hospitals	Inform and involve in assessing impacts to groundwater users
Urban/ Agricultural Users	• Water agencies • Irrigation districts • Municipal water companies • Mutual water companies • Resource conservation districts • Farmers/Farm Bureaus • Water Districts • Water users associations • Irrigated Lands Regulatory Program Coalition	Collaborate to ensure sustainable management of groundwater
Industrial Users	• Commercial and industrial self-suppliers • Local trade associations or groups	Inform and involve in assessing impacts to users
Environmental and Ecosystem Uses	• Federal and State agencies • Wetland managers • Environmental groups	Inform and involve to consider/incorporate potential ecosystem impacts to GSP process
Surface Water Users	• Irrigation Districts • Water Districts • Water users associations • Agricultural users	Inform and involve to collaborate to ensure sustainable water supplies
Economic Development	• Chambers of commerce • Business groups/associations • Elected officials • State Assembly members • State Senators • Economic Development Team	Inform and involve to support a stable economy
Human Right to Water	• Disadvantaged communities • Small water systems • Environmental justice groups/community-based organizations	Inform and involve to provide safe and secure groundwater supplies to all communities reliant on groundwater

Category of Interest	Examples of Stakeholder Groups	Engagement Purpose
	• De minimis well owners	
Tribes	• Federally Recognized Tribes • Non-Federally Recognized Tribes	Inform, involve and consult with tribal government
Federal Lands	• U.S. Fish and Wildlife Service • U.S. Bureau of Reclamation • U.S. Army Corps of Engineers	Inform, involve and collaborate to ensure basin sustainability
Integrated Water Management	• Regional water management groups (IRWM regions) • Flood agencies	Inform, involve and collaborate to improve regional sustainability

Key Messages

Beneficial users have been engaged in Subbasin-scale SGMA activities since shortly after enactment of the Act through the convening of governance work groups in each county to define governance in the Subbasin and establish GSAs. Each work group publicized all meetings and held initial SGMA information public meetings. As the GSAs expand the process of reaching out to stakeholders to inform and engage them in GSP development, and to conduct general communication about groundwater management issues and items, it is critical that GSAs share clear and consistent key messages to avoid confusion and misunderstanding. Key messages include:

1. The CGA and GGA are the exclusive GSAs in the Colusa Subbasin
2. Management responsibilities of the CGA and GGA include GSP preparation and approval, funding, SGMA implementation, and SGMA enforcement.
3. The CGA and GGA have committed to prepare a single GSP for the Colusa Subbasin.
4. The Colusa Subbasin GSP will inform and regulate groundwater usage. It will account for groundwater use and impacts on diverse groups of beneficial users, including, disadvantaged communities, agricultural users, residential users, municipal users, Tribes, and environmental water uses.
5. The CGA and GGA will proactively and sustainably managing groundwater in the Colusa Subbasin, and shall ensure compliance with SGMA to prevent State intervention.
6. The CGA and GGA will coordinate efforts with surrounding GSAs and subbasins in managing their respective portions of the Subbasin to achieve compliance with SGMA.
7. The CGA and GGA are committed to proactive and transparent outreach and engagement with all beneficial users during the GSP preparation process, and future SGMA implementation.
8. All beneficial users have an equal opportunity, either directly or through appropriate representation on the governing boards of the GSAs, to participate in GSP development and SGMA implementation.
9. Extensive outreach is a priority of both GSAs, to inform beneficial users about

implementation and potential effects of SGMA, and to ensure beneficial users are involved in the process.

10. Sustainable groundwater conditions in the Colusa Subbasin are critical to support, preserve, and enhance the economic viability, social well-being and culture of all beneficial uses and users, including tribal, domestic, municipal, agricultural, and industrial users.
11. Implementation and enforcement of the GSP should take place at the most local level possible and should allow each GSA member maximum input to any GSP chapter or section applicable to the Member and the beneficial uses and users that exist or will exist in a Member's service area or jurisdiction, and should reflect the Member's authority and desire to manage the water resources available to its constituents or customers, provided such management is consistent with sustainability requirements of SGMA and the GSP.
12. The Members agree that the GSP should encourage board members of each GSA to act on behalf of and represent all beneficial users within their service areas to ensure collective compliance with the Act.

Decision-Making

The CGA and GGA operate under respective Joint Powers Agreements (JPA). The JPAs can be found respectively at the following weblinks:

- https://colusagroundwater.org/mdocs-posts/cga-joint-powers-agreement-v1/
- https://www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority

Regarding decision-making, each GSA has identified in their respective JPA, the following text regarding decision-making:

> *"Except as to actions identified in Section 4.7, the Board of Directors will conduct all business by vote of a majority of the Directors present, if a quorum shall be established, and each Director shall have one (1) vote. Prior to voting, Board members shall endeavor in good faith to reach consensus on the matters to be determined such that any subsequent vote shall be to confirm the consensus of the Board. If any Board member or Member strongly objects to a consensus-based decision prior to a vote being cast, the Board shall work in good faith to reasonably resolve such strong objection, and, if the same is not resolved collaboratively, then the matter will proceed to a vote for final resolution under this Article 4.6 or Article 4.7 below, as applicable."*

Furthermore, each GSA JPA includes an attached Memorandum of Agreement (MOA) that represents negotiated guiding principles adopted by the respective GSA members during the development of their respective governance. These MOAs include the following stated principle regarding decision-making and engagement with beneficial users.

> *"A partnered approach should be fostered for sustainable groundwater management in the Colusa Subbasin that, among other things, supports the Act;*

achieves sustainable conditions in the Subbasin; reflects mutual respect for each Party's discretion, governmental authority, expertise, knowledge of groundwater conditions, rights, needs and concerns; and ensures appropriate representation of all Beneficial Uses and Users."

Regarding advisory and coordinating committees, the CGA and GGA have each created a Technical Advisory Committee that meets periodically and is expected to have a significant role during the GSP development period as a venue for key technical discussions and subsequent recommendations to technical consultants, and to the respective GSA Boards. The CGA TAC and the GGA TAC generally meet jointly to facilitate basin-wide technical discussions and recommendations. These meetings are open to the public.

Each GSA has also formed other committees such as Executive Committees, Long-Term Funding Committees, and Public Engagement Committees. Some committees, such as standing committees are Brown Act compliant while ad hoc committees are generally formed for a limited time and purpose and do not require Brown Act compliance, although open meetings are commonly encouraged.

Recommended Communication Strategies and Mechanisms

This Plan is designed to meet the needs of the Subbasin as a whole. To maximize efficiency and support consistent messaging, it is appropriate that some outreach activities be conducted on a basin-wide level. However, it is also important to recognize that under SGMA each GSA has its own responsibility for engagement of the beneficial users within its boundaries, and individual GSA representatives and staff will need to engage with their own stakeholders and will be responsible for tracking the needs of their local communities. GSAs will consider stakeholder input gathered from outreach efforts as they move through GSP development and implementation processes. Three sets of strategies are important to consider when planning outreach and engagement activities, included in the following categories:

1. SGMA-required activities: The law requires GSAs to undertake specific types of outreach and engagement activities.
2. Essential strategies centrally communicated at the Subbasin and GSA service area level: Activities proven to successfully engage stakeholders.
3. Secondary strategies locally communicated at the GSA service area and beneficial user level: Activities that will enhance engagement efforts on a local and as-needed basis. These strategies are recommended for engaging specific stakeholder groups.

SGMA-Required Strategies

SGMA strongly encourages broad stakeholder engagement in development and implementation of GSPs. According to SGMA:

- *"The groundwater sustainability agency shall encourage the active involvement of diverse social, cultural, and economic elements of the population within the groundwater basin prior to and during the development and implementation of the groundwater sustainability plan."* [CA Water Code Sec. 10727.8(a)]

- "*The groundwater sustainability agency shall consider the interests of all beneficial uses and users of groundwater."* [CA Water Code Sec. 10723.2]

GSAs are given broad discretion in the methods and processes utilized to meet engagement requirements. DWR has provided recommended phasing of engagement activities from the start of SGMA governance through long-term SGMA implementation however these recommendations are not prescriptive and are subject to GSA-specific discretion as to the timing and sequence of activities. (See Appendix 3 for graphical descriptions of generalized, sequential engagement strategies, phases and statutory and regulatory citations)

Centralized Outreach and Engagement Strategies

In the interest of collaboration as well as efficiency, the two GSAs in the Subbasin are conducting and will continue to conduct various joint outreach and engagement activities (as also stated above), including:

- Joint public outreach and education meetings and workshops
- Joint CGA/GGA Board meetings and workshops
- Joint CGA/GGA Executive Committee meetings
- Joint CGA/GGA Technical Advisory Committee meetings
- Potentially other joint CGA/GGA committees as developed
- Development of outreach materials

Localized Outreach and Engagement Strategies

1. Develop and Maintain Lists of Interested Parties

A list of stakeholders and beneficial users (interested parties) has been developed by each GSA and will be updated throughout the GSP planning, implementation and enforcement processes. Each GSA will maintain its own list.

Timely notification of opportunities for interested parties to participate in the development and implementation of the GSP will be given via the channels and strategies described in detail throughout this document.

Additional options for engagement will be considered during specific engagement opportunities and include: (and in some cases are described further below)

- GSA Websites
- Flyers
- Direct mailers
- Newsletters
- Fact Sheets
- Print Media (Newspaper notifications and SGMA articles)
- Social Media

- Surveys
- Articles in agency newsletters/websites (e.g. Farm Bureau, RCDs, Farm Service Agency, Cooperative Extension, etc.)
- Notifications on GSA Member Agency websites/newsletters
- Engagement Partner events (e.g. community workshops, community meetings, etc.)
- Educational tours/field trips

To assist in determining the topics, types, and sequencing of outreach vis-à-vis specific stakeholder interests, DWR has recommended conducting a "Lay of the Land" exercise. In the Colusa Subbasin, although many of the major interests are represented on the GSA boards or advisory committees, there are still some interests (e.g., de minimis- users, small agriculturally-allied businesses) that need to be engaged. Table 2, below, presents this "lay of the land" analysis as recommended by DWR.

Table 2. SGMA GSA/GSP Stakeholder Constituency "Lay of the Land" Exercise

Organization or Individual	Type of Stakeholder	Key Interests	Key Issues	Expected GSP Sections of Interest	Rationale
Small urban/domestic (non-agricultural) water users	Domestic well users/Municipal well operators	Access to safe and affordable drinking water	Encourage active participation in the process	• Basin Setting • Projects and Management Actions (PMA)	Not represented directly on GSA board
De minimis users	Private well users	Access to safe and affordable drinking water	Encourage active participation in the process Financial impacts from SGMA implementation	• Basin Setting • Sustainable Management Criteria (SMC) • Monitoring Networks • PMA	Not represented directly on GSA board
Agricultural workers	Disadvantaged communities	Water availability, quality, fees, fallowing	Difficult to reach. Transient and housing insecure population	• Basin Setting • SMC • Monitoring Networks • PMA	Extensive and potentially underrepresented community of beneficial users
Businesses	Private users	Water availability, quality, fees	Economic and financial impacts from SGMA implementation	• Basin Setting • PMA	Not commonly associated or active with water policy issues
Ag-allied users (e.g. tractor	Private users	Access to safe and affordable drinking	Economic and financial impacts	• Basin Setting • PMA	Direct economic benefits and impacts

Organization or Individual	Type of Stakeholder	Key Interests	Key Issues	Expected GSP Sections of Interest	Rationale
leasing and maintenance)		water	from SGMA implementation		associated with water availability
Tribes	California Native American Tribes	Equitable use and availability of groundwater resources. Avoidance of negative redirected effects from groundwater extraction	Respect of cultural backgrounds, norms and needs	• Basin Setting • SMC • Monitoring Networks • PMA	Underrepresented community of beneficial users.
Environmental interests	Environmental users of groundwater	Water availability for environmental purposes	Ecological health of tributaries and groundwater dependent ecosystems. Equitable and balanced use of groundwater	• Basin Setting • SMC • Monitoring Networks • PMA	
Small surface water diverters (including private wetlands	Agricultural users, and environmental users of	Water availability, quality, fees, fallowing	Water resource availability Financial impacts from SGMA	• Basin Setting • SMC • Monitoring Networks	Direct economic benefits and impacts associated with water availability

Organization or Individual	Type of Stakeholder	Key Interests	Key Issues	Expected GSP Sections of Interest	Rationale
managers)	groundwater		implementation	• PMA	
Surface Water Suppliers and Diverters	Agricultural water suppliers and irrigators	Opportunities for conjunctive use and groundwater recharge projects,	Protecting surface water rights. Acknowledgement for additional groundwater recharge created from agricultural irrigation and MAR projects	• Basin Setting • SMC • Monitoring Networks PMA	GW and Surface water are connected
Sites Reservoir JPA	Surface water users	Opportunities for conjunctive uses	Conjunctive use	• Basin Setting • SMC • Monitoring Networks • PMA	New and potentially influential agency of local and statewide interests

2. Provide Regular Public Notices and Updates; Ensure Brown Act Compliance

The GSAs will provide public notices about their open meetings to ensure all stakeholders are informed and all Brown Act noticing requirements are fulfilled. The GSAs will also coordinate consistent messaging and outreach regarding basin-wide SGMA information and updates as they relate to the Colusa Subbasin.

A. Topics to be noticed include and are not limited to:
    i. GSP development and planning updates
    ii. GSP implementation and enforcement updates
        - GSP work plan and timeline
        - Funding/financing plans
    iii. General GSA updates, including:
        - GSA Board meetings
        - Executive Committee meetings
        - Technical Advisory Committee meetings
        - Public outreach and education meetings and workshops
        - GSA annual reports
        - Other SGMA related updates

B. Schedule notices to be sent on a regular schedule, for example bi-monthly, monthly, or as needed
    i. Meetings subject to the Brown Act, such as GSA Board meetings, must provide public notice and agendas must be posted 72 hours in advance of each regularly scheduled meeting (special meetings require 24-hour advance notice)

C. Develop content appropriate to audiences and their interests, ensuring information is articulated in a way that is easily understood
    i. Communication to beneficial users with less SGMA or technical experience should be easily understood, with streamlined, relatable, and repetitive information
    ii. Updates and messages should be condensed to one page when possible, providing a succinct summary of the issues discussed, and including links for further or additional information
    iii. As applicable, specific items should have an estimated timeline and a designated point of contact, including the person's position, email and telephone number
    iv. Updates and information should be provided in both English and Spanish if possible

D. Designate responsible staff and appropriate resources for ongoing inter-agency coordination regarding joint messaging, consistent outreach, and communication with stakeholders

E. Determine appropriate dissemination channels by considering the following:
    i. Utilize Constant Contact or a similar email marketing platform for management of interested party stakeholder lists or utilize GSA interested parties lists for email communications

ii. Utilize member agency listservs delivered via standard email and/or U.S. Mail, e.g., inclusion in water bills, tax assessor documents, etc.

iii. Utilize updated interested party stakeholder list for the Colusa Subbasin, including organizations and agencies such as Farm Bureaus, RCDs, DAC groups, Tribes, schools, hospitals, utilities, mutual water companies, neighborhood groups, and local non-profits

3. Provide Notices and Updates in Local Newspapers and Periodicals

Notices can take the form of public notices, op-ed articles, letters to the editor, advertisements or earned media.

A. Send information and/or media releases to regional and local media outlets and contacts

i. Print Media
ii. Organization and community newsletters and periodicals
iii. Identify trusted bi-lingual and/or Spanish speaking media outlets

B. Provide follow-up or wrap-up articles written by staff when appropriate

C. Include notices for appropriate public meetings (as described throughout this Plan):

4. Create and Manage Social Media Content

Social media is not considered to be a primary mode for beneficial users to get information in the Subbasin (when compared to other more traditional means). However, recognizing changing trends in information access and exchange, the GSAs will consider expanding their outreach to include some of the more common social media platforms as long as said engagement proves beneficial (in terms of verifiable uses) and does not create an undo impact on staff time and GSA resources.

5. Institute Regular Stakeholder Outreach and Engagement Opportunities

It is critical that stakeholders and beneficial users are provided regular opportunities for their input to be incorporated into GSA decision-making processes, and that they understand exactly how they are able to contribute to the GSP planning and implementation processes.

Stakeholder engagement opportunities include but are not limited to:

A. Standing Operations Meetings

i. GSA Board meetings
ii. Advisory Committee meetings

B. Public Workshops and Stakeholder meetings

The following should be considered when planning workshops and stakeholder meetings:

i. Schedule workshops in evenings, or times that work well for the target audience, and/or near easily-accessible community areas as feasible and avoid busy seasons (i.e. planting and harvest)

ii. Provide translation and facilitation services in English and Spanish (when feasible)

iii. Public workshop (or similar) content includes but is not limited to:

a) Updates on GSA coordination activities
b) SGMA information
c) Updates on GSP development and planning activities
d) Opportunities for interested parties to participate in the development and implementation of the GSP (e.g. technical workshops on specific GSP components)
e) Notice of GSA intent to adopt or amend a GSP
f) Updates on groundwater management activities in the Subbasin, including projects
g) Notice to impose fees
h) Updates on SGMA activities in surrounding basins
i) Information on legislative activities related to SGMA, and groundwater and surface water management

6. Develop Consistent, Coordinated Messages and Talking Points

Define the key messages needed to effectively convey SGMA-related information to various audiences, and ensure consistency in a coordinated and meaningful outreach effort to all stakeholders.

A. For each topic being discussed (see work plan), develop a set of talking points that can be used by GSA members when speaking to specific stakeholder groups or audiences. Talking points and messaging may be customized to specific stakeholder groups as appropriate.
B. Develop tools, such as a glossary and a SGMA information piece, that contain easy-to-understand information as well as responses to anticipated questions from stakeholder groups. Consider developing simple brochures, infographics, and short videos.
C. Identify and communicate opportunities for public engagement and/or public comment during meetings on GSP development.
D. Provide clear messaging that GSAs retain legal responsibility for final GSA- and GSP-related decisions.

Additional Outreach and Engagement Strategies

While engagement opportunities can be created by GSAs, there are also opportunities for engagement that already exists in the Subbasin community.

The most effective way to inform and engage many stakeholders and beneficial users regarding SGMA requirements and soliciting feedback is through trusted local agencies and community organizations with standing meetings and established communication channels.

A. Support local agencies and community organizations in disseminating information and engaging stakeholders in the following ways:

i. During standing board and/or community meetings
ii. Through monthly information pieces in newsletters or included in mailings

iii. By disseminating information in both English and Spanish when appropriate

B. Local trusted agencies and community organizations include but are not limited to:
   i. Boards of Supervisors
   ii. City Councils
   iii. Environmental conservation groups
   iv. Farm Bureaus
   v. Growers associations and industry organizations
   vi. Irrigation Districts
   vii. Leaders in DAC communities
   viii. Local hospitals and schools
   ix. Local non-profits
   x. Mutual Water Companies
   xi. RCDs
   xii. Tribal Council meetings
   xiii. Water Districts

C. Leverage local, trusted resources for community meetings, such as fairgrounds, firehouses, schools, churches, and community centers

D. Organize public meetings around concrete impacts to specific stakeholders, including:
   i. SGMA informational workshop(s) to inform stakeholders of important changes in groundwater management and how it will impact them
   ii. Meetings that detail when and how opportunities to provide input to the GSA decision-making and GSP development processes will occur
   iii. Public meetings regarding fee structures to help stakeholders understand how to interpret the impacts on them

E. Make information and meetings accessible to various stakeholder groups
   i. Provide information in easy-to-understand and streamlined terms
   ii. Provide information and facilitation in both English and Spanish, when appropriate and as feasible
   iii. Hold meetings during hours that do not conflict with regular work schedules (i.e., nights and weekends), or during prime planting and harvesting seasons

Recommended Milestones for Engaging Stakeholders

To employ the Stakeholder Communication and Engagement Plan effectively, Colusa Subbasin GSAs will need to develop a schedule for outreach and engagement activities. The below table (Table 3) identifies milestones required by SGMA, as well as centralized and localized engagement strategies that will be considered during each timeframe. This schedule, or similar, is expected to be updated into a task-oriented work plan and timeline as communication and engagement tasks are allocated and a more specific workplan for GSP development is prepared.

Table 3. Summary of Engagement Opportunities and Milestones

Timeframe	Milestone or Stage	Required Community Engagement Under SGMA	Centralized & Localized Communication Strategies
Shortly after GSA formation	After identification of outreach responsibilities among GSA member agencies	Notification of GSA formation	• Provide notice of GSA outreach resources: website, email listserv, calendar of GSA Board and subcommittee meetings • Develop and continue to update list of interested parties
Before GSP Planning Activities	Prior to beginning GSP development	Provide to the public and State, notice of intent to begin GSP planning and description of opportunities for interested parties to participate in GSP development and implementation	• Public workshop (s) • GSA Board meetings • Email notices and updates • Newspaper notice of public workshop(s)
Between Notice of GSP Planning and January 31, 2022	During GSP development	Public workshops, public meetings, TAC meetings, GSA Board meetings and other opportunities providing stakeholder avenues to participate in GSP development	*Centralized:* • Public workshops and/or public meetings on GSP development. • Email notice of public workshops / meetings • Newspaper notices of public workshops / meetings *Localized:* • Updates and information on GSP development at standing meetings • Disseminate updates via newsletter, websites and social media
	During GSP development	Active involvement of diverse social, cultural, and economic	*Centralized:* • Provide monthly email notices and updates

Timeframe	Milestone or Stage	Required Community Engagement Under SGMA	Centralized & Localized Communication Strategies
		elements of the population within the Subbasin	• Update website regularly • Convene monthly or bimonthly meetings of GSA Coordination Committee and Technical Advisory Committee • Convene quarterly or monthly meetings of GSA Board • Identify and communicate opportunities for public engagement on GSP development, (providing clear messages that GSAs retain legal responsibility for final GSA and GSP related decisions) • Develop consistent, coordinated messages and talking points • Arrange for technical support to stakeholder groups through presentations or workshops conducted by GSA representatives/staff • Develop content appropriate to the audience and their interests, ensuring information can be easily understood • Update area legislative bodies at strategic mileposts (and any other groups upon request) • Utilize updated interested party stakeholder list, member agency listservs delivered via email and/or U.S. Mail, and other media outlets such as newspaper and radio to provide notices • Strategically engage local, special SGMA identified groups *Localized:* • Utilize local channels and meetings to identify and

Timeframe	Milestone or Stage	Required Community Engagement Under SGMA	Centralized & Localized Communication Strategies
			communicate opportunities for public engagement and/or public comment during meetings on GSP development • Leverage and support local agencies and community organizations in disseminating information and engaging stakeholders, including through existing community meetings, newsletters, websites, and social media • Organize public meetings around concrete impacts to specific stakeholders • Develop additional, locally-targeted communication strategies to engage difficult-to-reach communities and community members
GSP adoption no later than January 31, 2022	Prior to GSP adoption or amendment	○ Provide notice to cities and counties within Plan area ○ Consider comments provided by the cities and counties ○ Accommodate requests for consultation received from the cities and counties within 30 days	SEE ABOVE
GSP adoption no later than January 31, 2022	Prior to GSP adoption or amendment	No sooner than 90 days following public notice, hold public hearing/ public workshop	SEE ABOVE

Evaluation and Assessment

Any communication strategy should include opportunities to check in at various points during implementation to ensure that it is meeting the communication and engagement goals and complying with SGMA law. These check-ins can include:

- What worked well
- What didn't work as planned
- Meeting recaps with next steps
- Listing lessons learned and developing mid-course corrections
- (As relevant) Communications budget analysis

Educational Materials

DWR and the State Water Resources Control Board have developed various educational materials about SGMA and GSA/GSP development. In addition to State materials, academic institutions and foundations have published useful reports about SGMA implementation. While not comprehensive, Table 4 lists some essential SGMA educational and reference materials.

Table 4. Educational and Reference Documents for SGMA Implementation

Educational/Reference Document Titles	Publishing Entity	Date/Year of Publication
Groundwater Sustainability Agency Frequently Asked Questions http://www.water.ca.gov/groundwater/sgm/pdfs/DWR_GSA_FAQ_2016-01-07.pdf	DWR	January 7, 2016
Groundwater Sustainability Plan (GSP) Emergency Regulations Guide http://www.water.ca.gov/groundwater/sgm/pdfs/GSP_Final_Regs_Guidebook.pdf	DWR	July 2016
Collaborating for Success: Stakeholder Engagement for Sustainable Groundwater Management Act Implementation http://www.cleanwateraction.org/files/publications/ca/SGMA_Stakeholder_Engagement_White_Paper.pdf	Community Water Center Clean Water Fund Union of Concerned Scientists	July 2015

Educational/Reference Document Titles	Publishing Entity	Date/Year of Publication
The 2014 Sustainable Groundwater Management Act: A Handbook to Understanding and Implementing the Law http://www.watereducation.org/sites/main/files/file-attachments/groundwatermgthandbook_oct2015.pdf	Water Education Foundation	October 2015
SGMA Engagement With Tribal Governments https://www.water.ca.gov/LegacyFiles/groundwater/sgm/pdfs/GD_Tribal_Final_2017-06-28.pdf	DWR	June 2017
California's Sustainable Groundwater Management Act (SGMA): Understanding the Law https://www.cfbf.com/storage/app/media/documents/Issues/SGMA_Brochure.pdf	California Farm Bureau Federation	2018

Appendix 1: Opportunities for Engagement

The following table is a template for the regularly updated schedule of meetings that provide opportunities for engagement. This table (or similar) should be isolated as a standalone portion of the GSAs' respective administrative records for GSP preparation and SGMA implementation to ensure accurate comprehensive memorialization of engagement events.

Table A. Scheduled Meetings and Workshops

Date	Meeting Purpose/Topics	Time & Location	Meeting Type

Appendix 2: Tribal Engagement

There are two Tribes in the Colusa Subbasin: The Colusa Indian Community and the Cortina Rancheria. Both Tribes have been engaged and active in SGMA planning and implementation activities from the beginning, and they have been welcomed into the process. The GSAs will continue to engage with these entities throughout GSP development and beyond.

Relevant DWR Information

SGMA Section 10720.3. …any federally recognized Indian Tribe, appreciating the shared interest in assuring the sustainability of groundwater resources, may voluntarily agree to participate in the preparation or administration of a groundwater sustainability plan or groundwater management plan under this part through a joint powers authority or other agreement with local agencies in the basin. A participating Tribe shall be eligible to participate fully in planning, financing, and management under this part, including eligibility for grants and technical assistance, if any exercise of regulatory authority, enforcement, or imposition and collection of fees is pursuant to the Tribe's independent authority and not pursuant to authority granted to a groundwater sustainability agency under this part.
Draft Discussion Paper Tribal Participation with Groundwater Sustainability Agencies http://www.water.ca.gov/groundwater/sgm/pdfs/SGMA_Tribal_GSAs.pdf
Must a local agency exclude federal and tribal lands from its service area when forming a GSA? No, federal lands and tribal lands need not be excluded from a local agency's GSA area if a local agency has jurisdiction in those areas; however, those areas are not subject to SGMA. But, a local agency in its GSA formation notice shall explain how it will consider the interests of the federal government and California Native American tribes when forming a GSA and developing a GSP. DWR strongly recommends that local agencies communicate with federal and tribal representatives prior to deciding to become a GSA. As stated in Water Code §10720.3, the federal government or any federally recognized Indian tribe, appreciating the shared interest in assuring the sustainability of groundwater resources, may voluntarily agree to participate in the preparation or administration of a GSP or groundwater management plan through a JPA or other agreement with local agencies in the basin. Water Code References: §10720.3, §10723.2, §10723.8

Tribal Outreach Resources

The following are links to agency Tribal outreach resources and considerations, each of which captures important principles and resources for Tribal outreach. A short summary of key outreach principles can be found below.

- Draft Discussion Paper Tribal Participation with Groundwater Sustainability Agencies

- CalEPA Tribal Consultation Policy Memo (August 2015)
- DWR Tribal Engagement Policy (May 2016)
- CA Natural Resources Agency Tribal Consultation Policy (November 2012)
- SWRCB Proposed Tribal Beneficial Uses
- Butte County Associate of Governments: Policy For Government-To-Government Consultation With Federally Recognized Native American Tribal Governments *(a model from the transportation sector)*
- CA Court Tribal Outreach and Engagement Strategies
- Traditional Ecological Knowledge resources
- Water Education Foundation Tribal Water Issues

Key Outreach Principles

- Engage early and often
- Consider tribal beneficial uses in decision-making (identified by region here); identify and seek to protect tribal cultural resources
- Share relevant documentation with tribal officials
- Conduct meetings at times convenient for tribal participation with ample notification
- Request relevant process input/data/information from tribes
- Empower tribes to act as tribal cultural resources caretakers
- Designate a tribal liaison(s) where appropriate
- Share resources for tribal involvement as is feasible
- Develop MOUs where relevant
- Be mindful of the traditions and cultural norms of tribes in your area

Appendix 3: DWR Guidance: General Engagement Phases and Requirements

Phase 1: 2015 - 2017

Phase 1 Engagement Requirements

- **Establish and Maintain List of Interested Parties** §10723.4
- **GSA Formation Public Notice** §10723(b)
- **GSA Formation Public Hearing** §10723(b)
- **GSA Formation (due 6/30/17)** §10723(b)
  Notify DWR:
  - Include list of interested parties
  - Explain how parties' interests will be considered
- **Pre-GSP Development** §10727.8
  Provide a written statement describing how interested parties may participate to:
  - DWR
  - Cities within the GSA boundary
  - Counties within the GSA boundary

Relevant DWR Information

Phase 2: 2017 - 2022

Phase 2 Engagement Requirements

- **GSP Initial Notification** §353.6*
  - GSAs are required to submit GSP Initial Notifications through the SGMA Portal - GSP Initial Notification System at http://sgma.water.ca.gov/portal/#gsp
  - Public can comment on the submitted GSP notification
- **GSP Preparation** §10727.8 and §10723.2
  - Encourage active involvement
  - Consider beneficial uses and users of groundwater when describing *Undesirable Results, Minimum Thresholds, and Projects & Actions*
- **GSP Communications Section** §354.10*
  - GSA decision-making process
  - Opportunities for engagement and how public input is used
  - How GSA encourages active involvement
  - Method of informing the public
- **Public Notice of Proposed Adoption** §10728.4
- **GSP Adoption Public Hearing** §10728.4
- **GSP Submittal** §354.10*
  - Include a summary of communications: description of beneficial uses/users, list of public meetings, comments received/responses

Phase 3: 2018

Phase 3 Engagement Requirements

- **60 Day Comment Period** §353.8*
  - Any person may provide comments to DWR regarding a proposed or adopted GSP via the SGMA Portal at http://sgma.water.ca.gov/portal/
  - Comments will be posted to DWR's website

Phase 4: 2022+

Phase 4 Engagement Requirements

- **Public Notices and Meetings** §10730
  - Before amending a GSP
  - Prior to imposing or increasing a fee
- **Encourage Active Involvement** §10727.8

Engagement Requirements Applicable to ALL PHASES

- **Beneficial Uses and Users** §10723.2
  Consider interests of all beneficial uses and users of groundwater
- **Advisory Committee** §10727.8
  GSA may appoint and consult with an advisory committee
- **Public Notices and Meetings** §10730
  - Before electing to be a GSA
  - Before adopting or amending a GSP
  - Prior to imposing or increasing a fee
- **Encourage Active Involvement** §10727.8
  Encourage the active involvement of diverse social, cultural, and economic elements of the population within the groundwater basin
- **Native American Tribes** §10720.3
  - May voluntarily agree to participate
  - See Engagement with Tribal Government Guidance Document
- **Federal Government** §10720.3
  - May voluntarily agree to participate

Appendix 3A

Monitoring Network Groundwater Elevation Hydrographs

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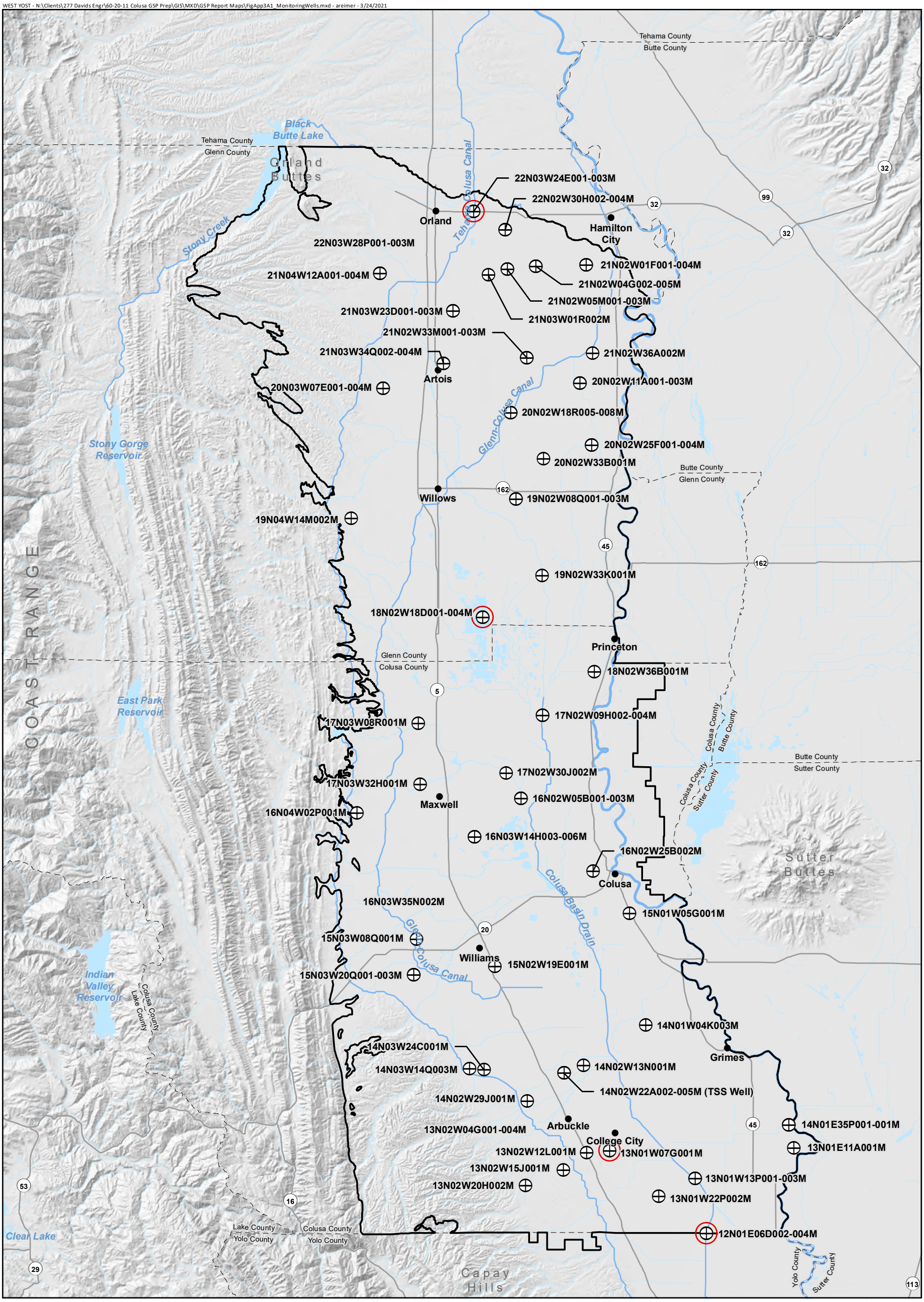

Figure 3A-1

Groundwater Monitoring Wells with Hydrographs

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

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Figure 3A-2. 12N01E06D002-004M Active Observation Well Cluster
Ground Surface Elevation 27.94 feet msl, NAVD 88

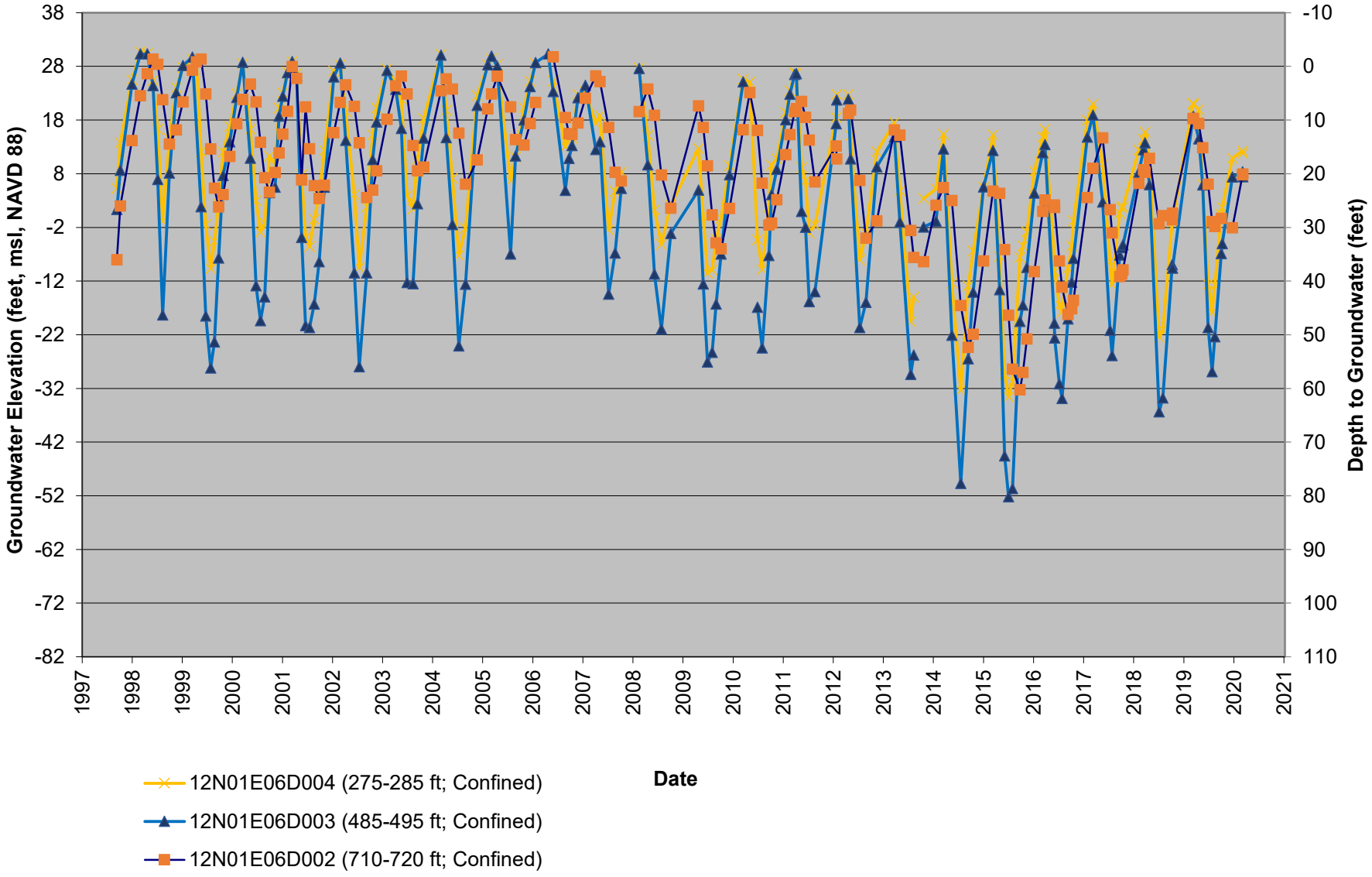


Figure 3A-3. 13N01E11A001M Active Residential Well
Ground Surface Elevation 34.19 feet msl, NAVD 88

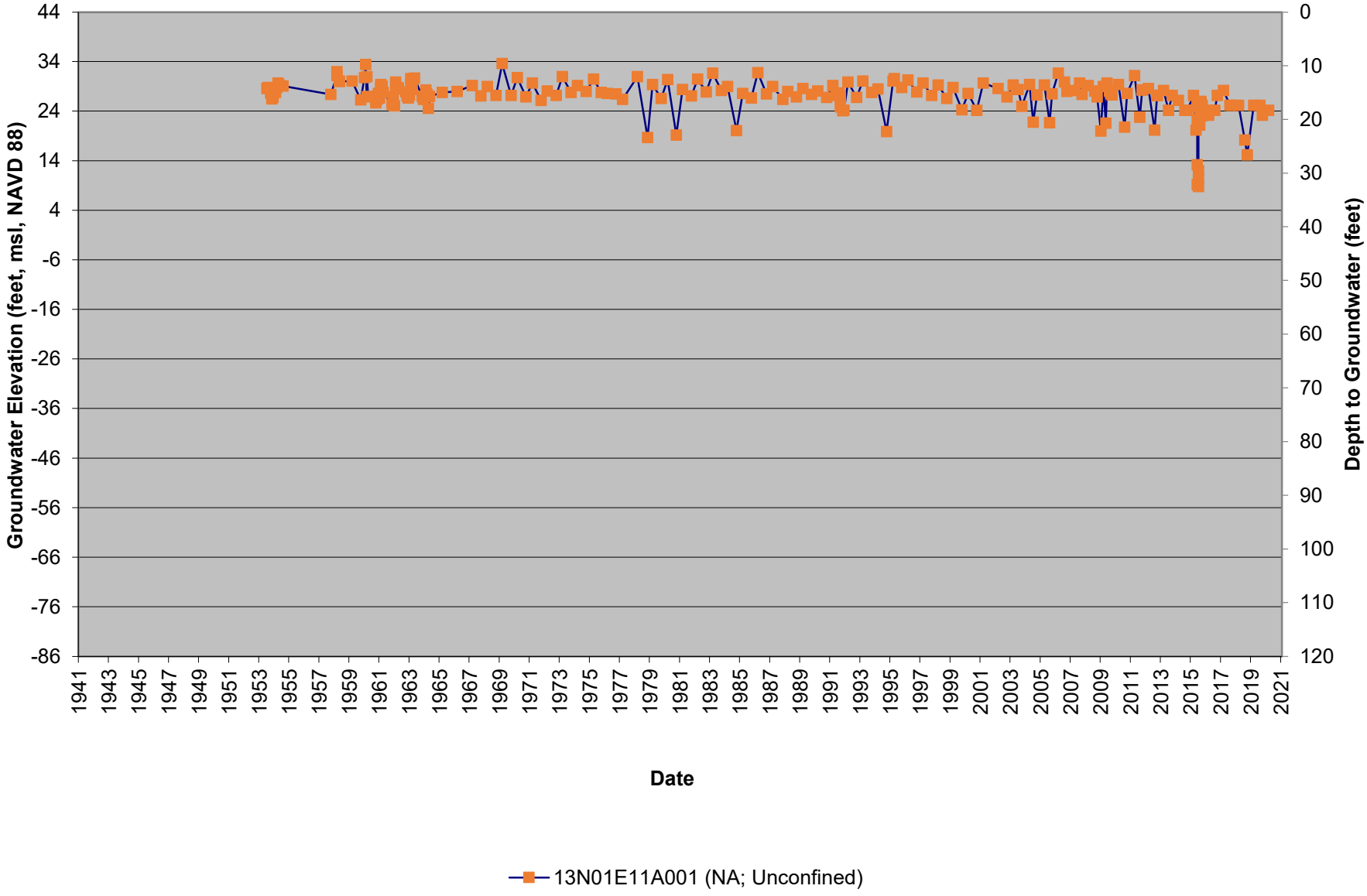


Figure 3A-4. 13N01W07G001M Active Irrigation Well
Ground Surface Elevation 90.47 feet msl, NAVD 88

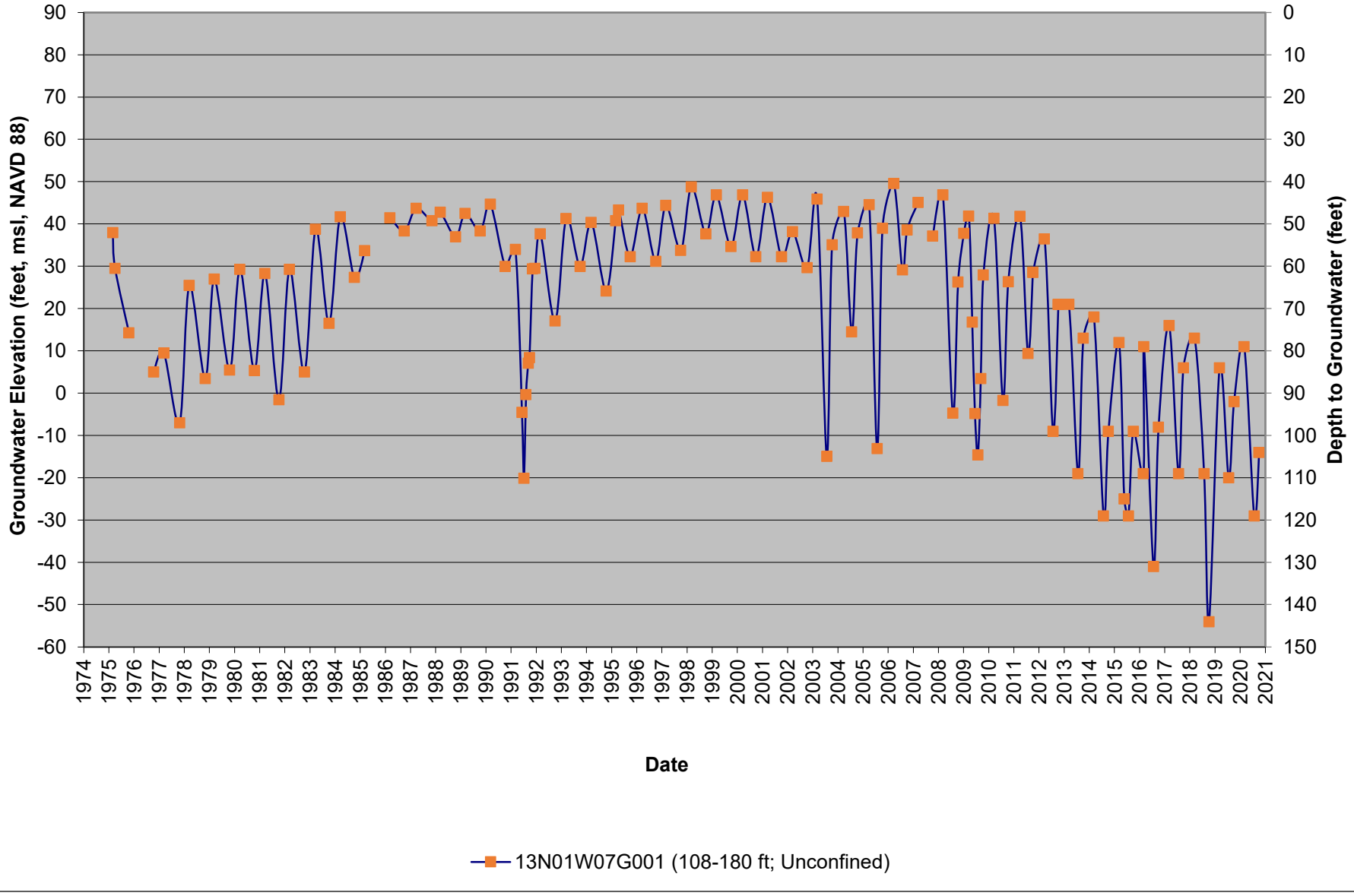


Figure 3A-5. 13N01W13P001-003M Active Observation Well Cluster
Ground Surface Elevation 32.23 feet msl, NAVD 88

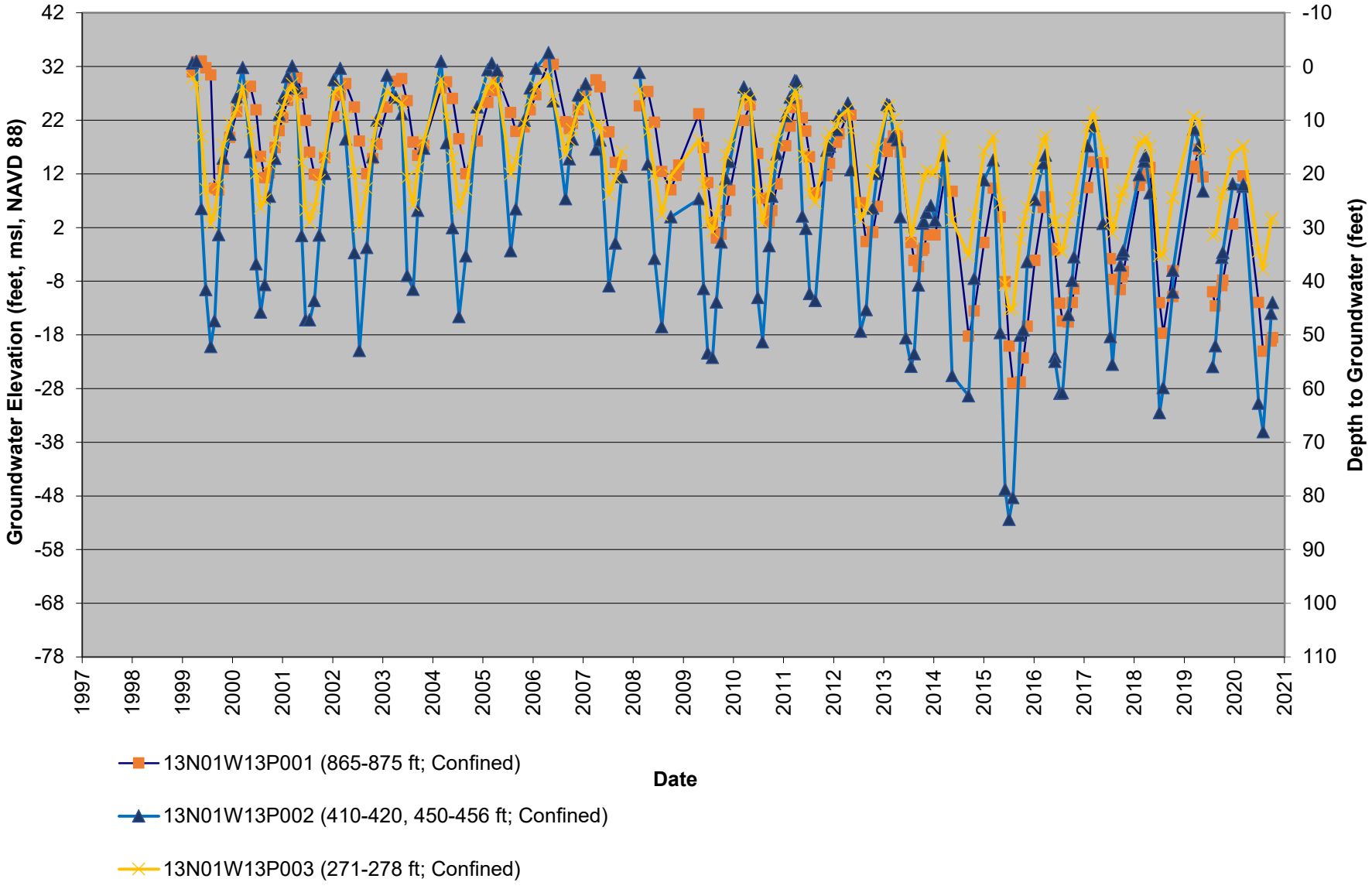


Figure 3A-6. 13N01W22P002M Active Irrigation Well
Ground Surface Elevation 60.46 feet msl, NAVD 88

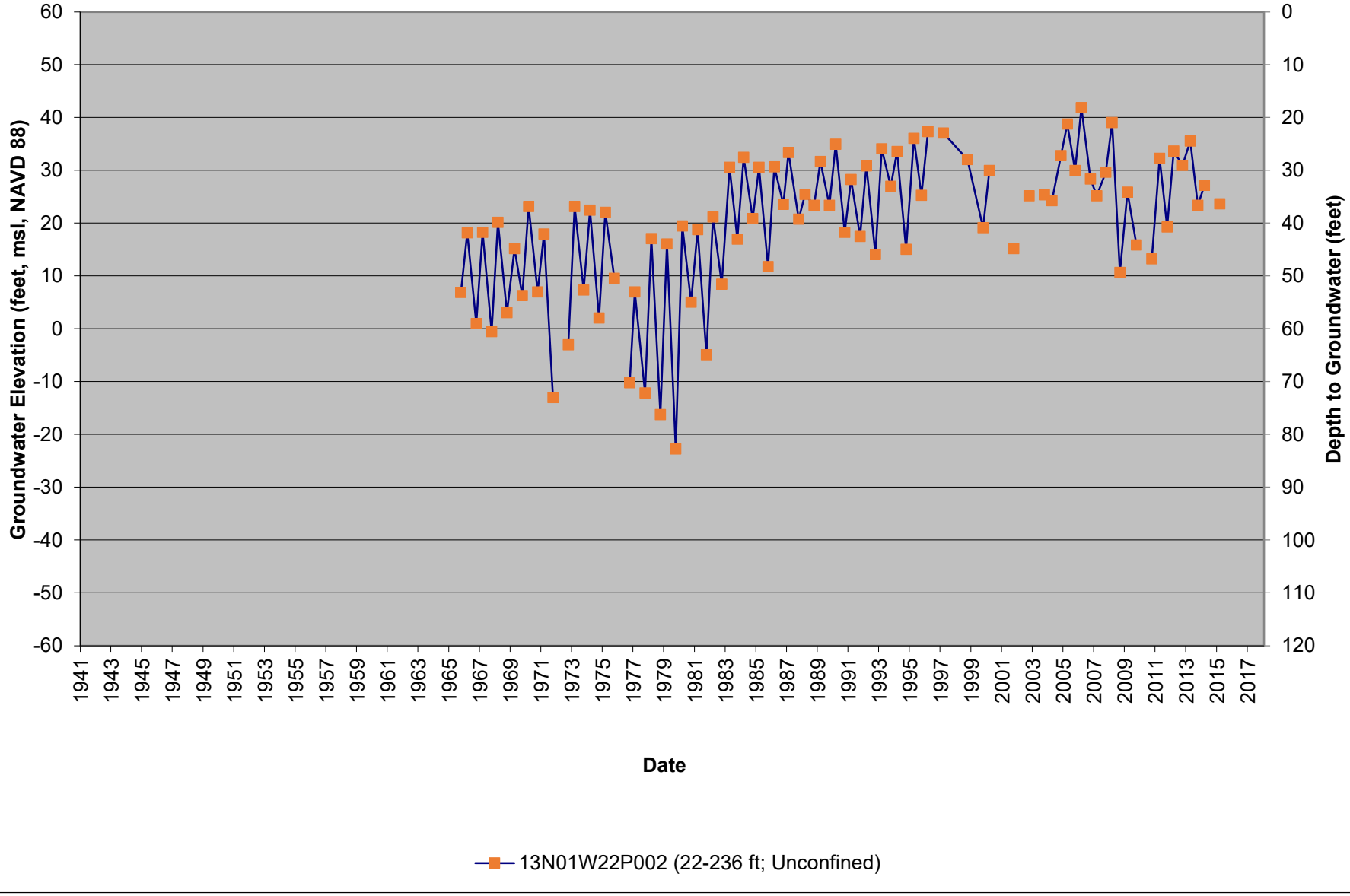


Figure 3A-7. 13N02W04G001M, 003M, 004M Active Observation Well Cluster
Ground Surface Elevation 188.81 feet msl, NAVD 88

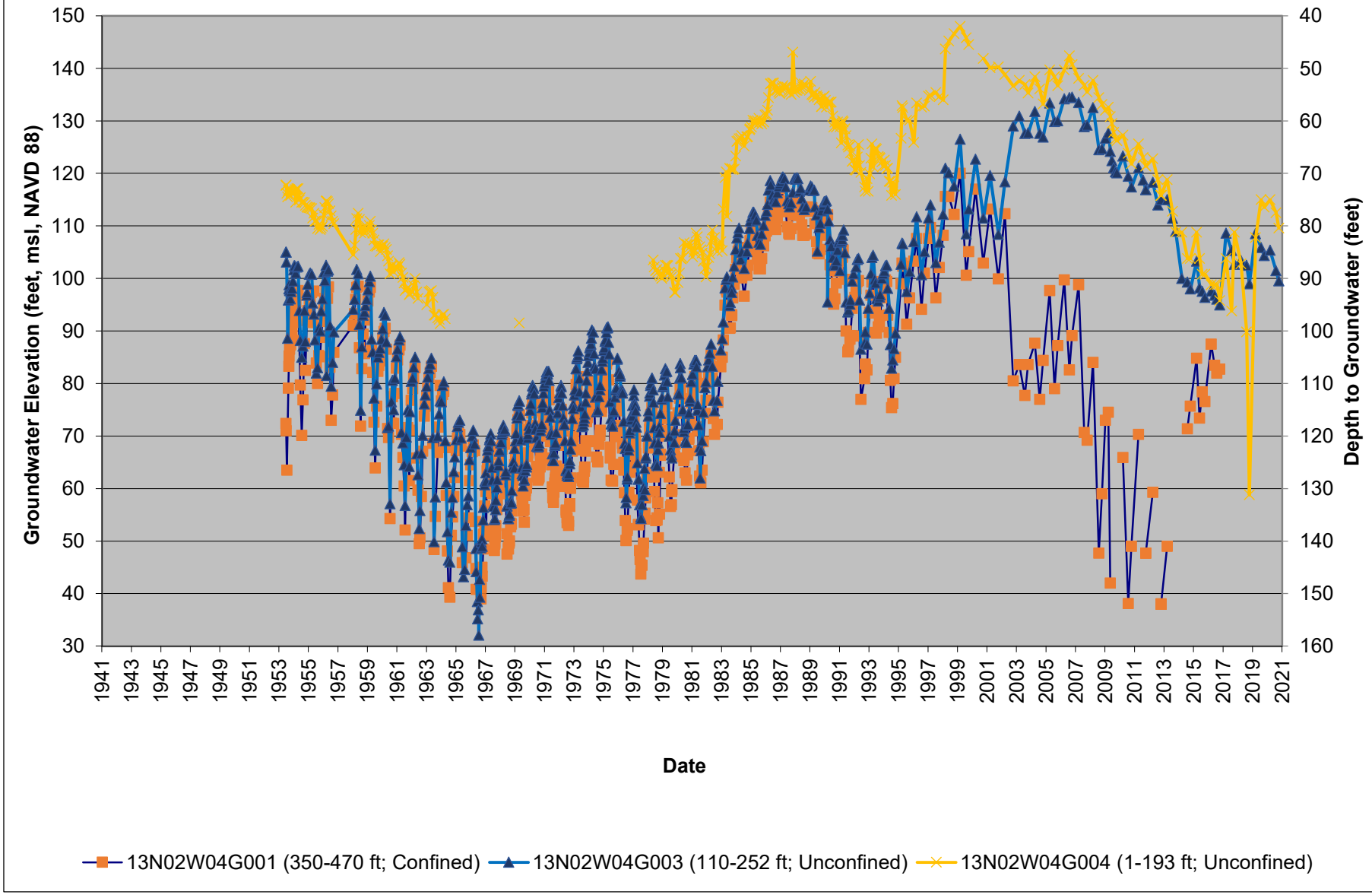


Figure 3A-8. 13N02W12L001M Active Irrigation Well
Ground Surface Elevation 135.49 feet msl, NAVD 88

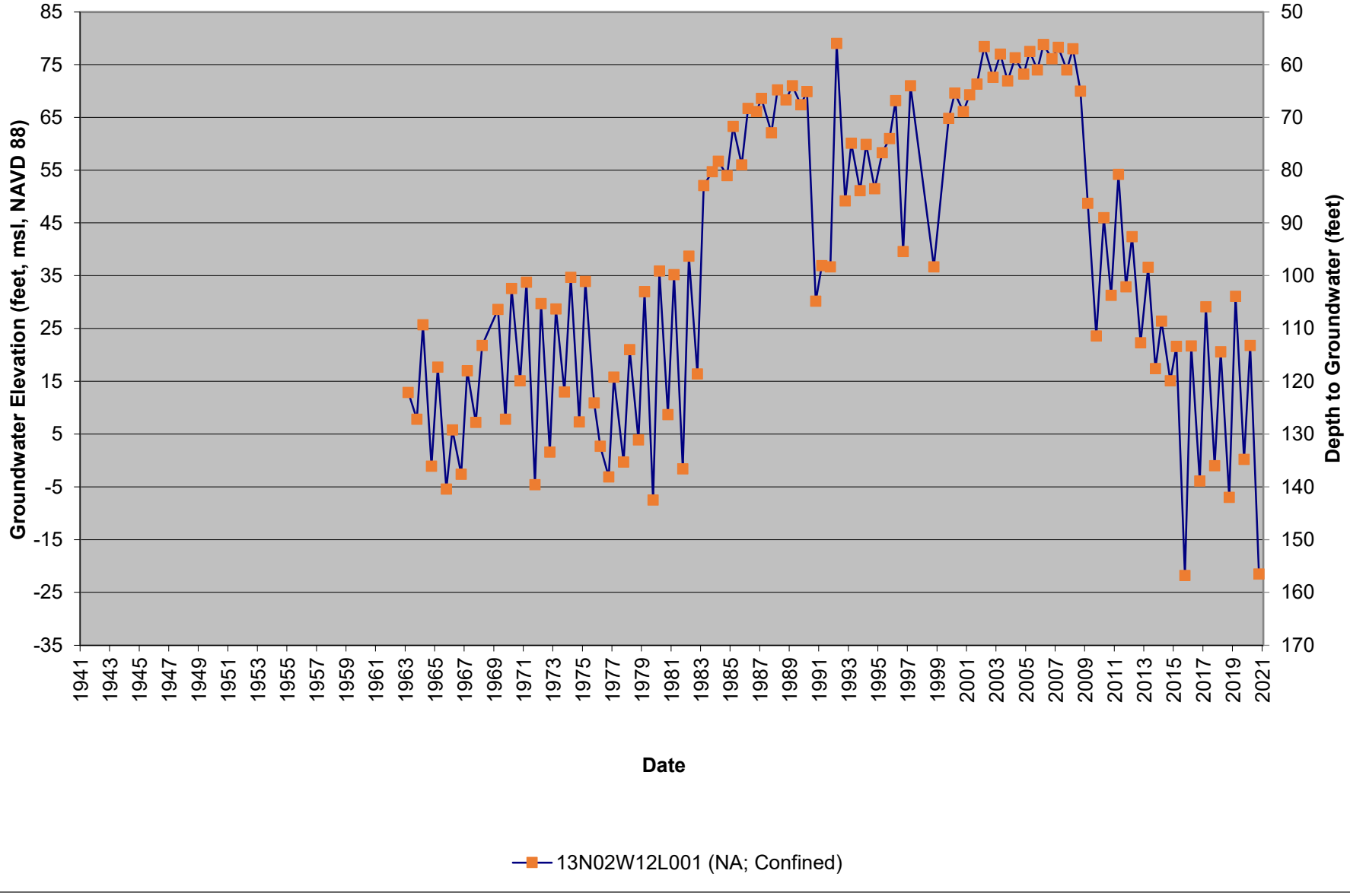


Figure 3A-9. 13N02W15J001M Active Residential Well
Ground Surface Elevation 212.52 feet msl, NAVD 88

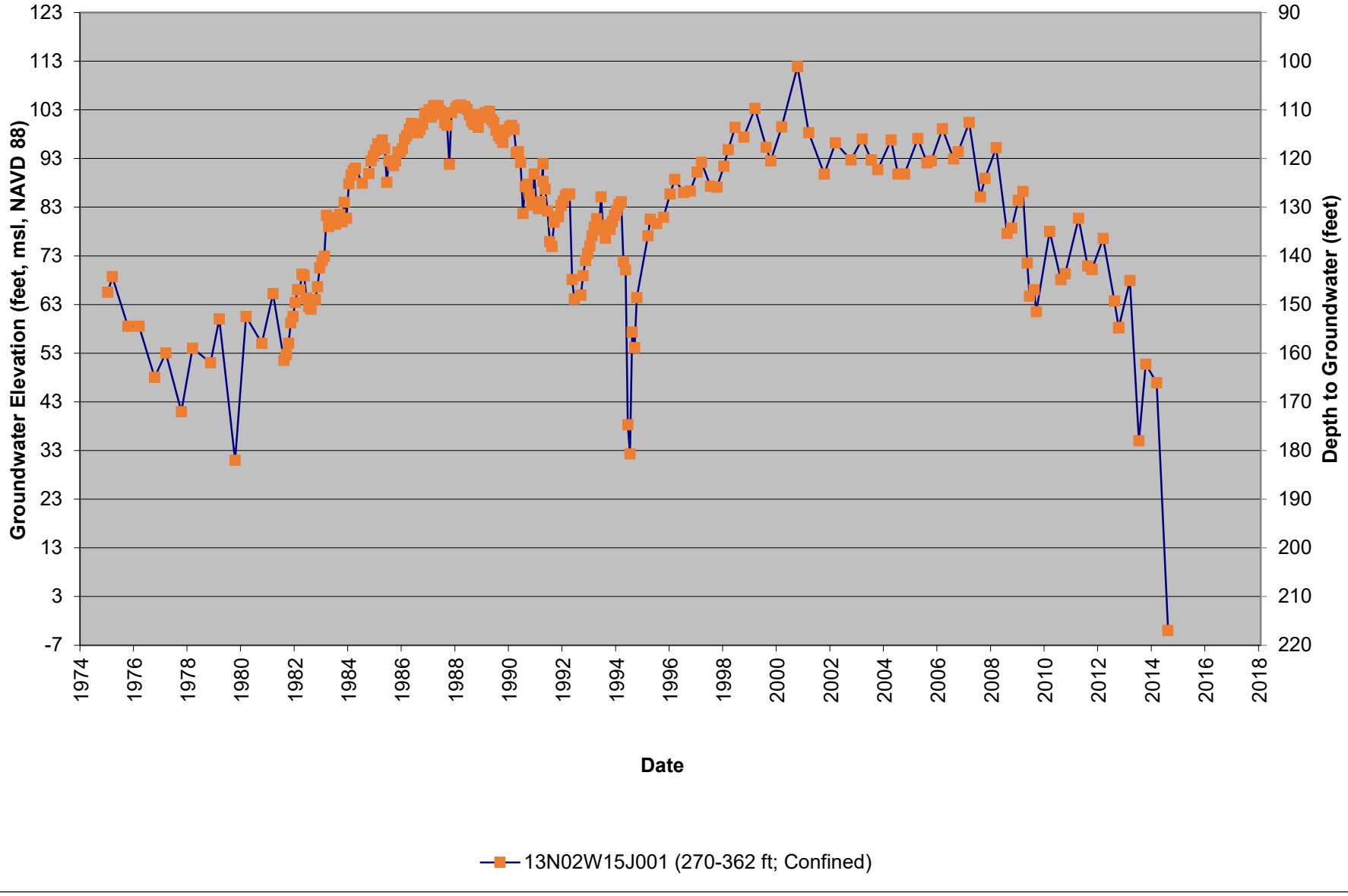


Figure 3A-10. 13N02W20H002M Active Residential Well
Ground Surface Elevation 342.58 feet msl, NAVD 88



Figure 3A-11. 14N01E35P001-004M Active Observation Well Cluster
Ground Surface Elevation 46.88 feet msl, NAVD 88

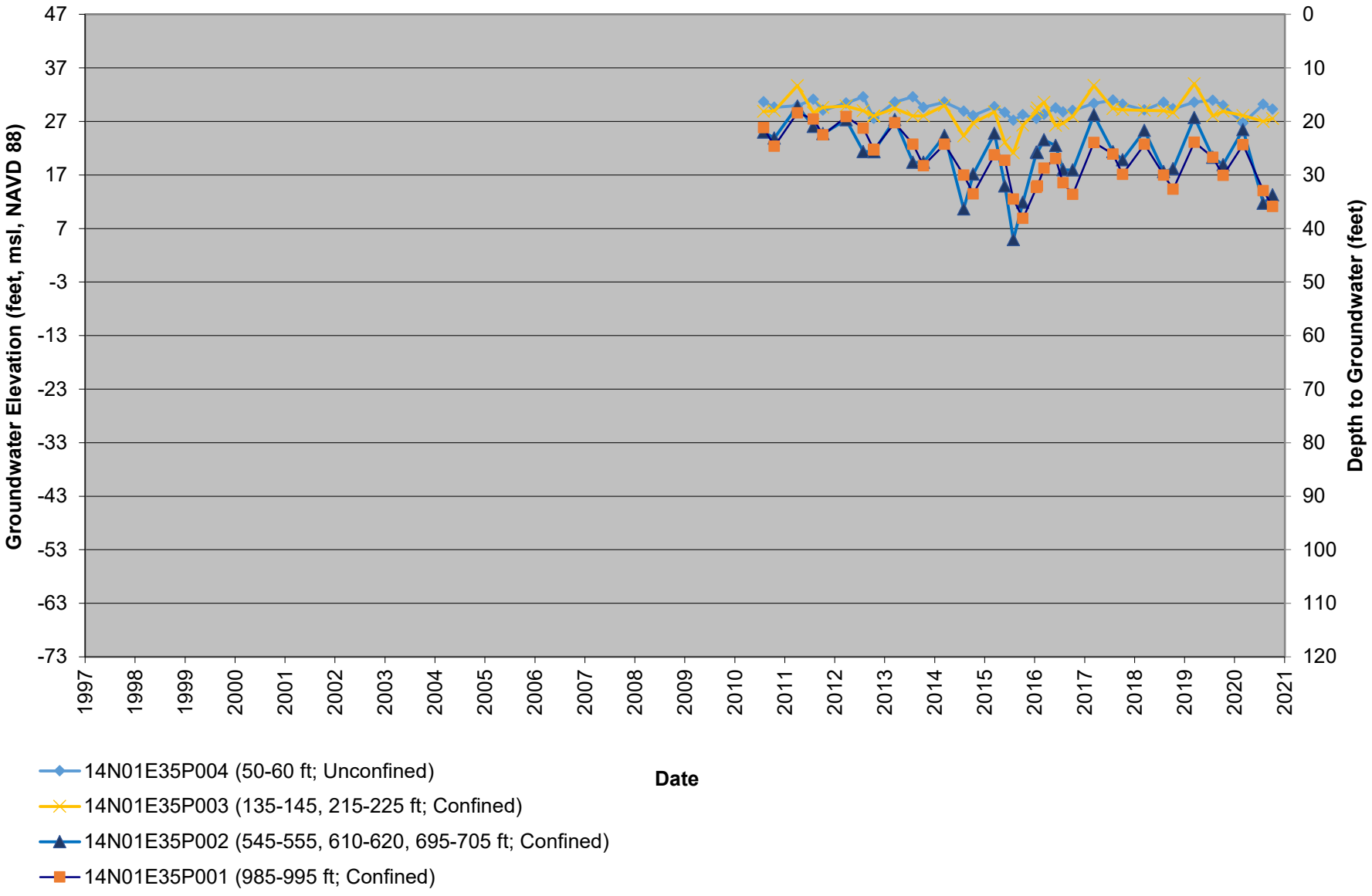


Figure 3A-12. 14N01W04K003M Active Irrigation Well
Ground Surface Elevation 37.43 feet msl, NAVD 88

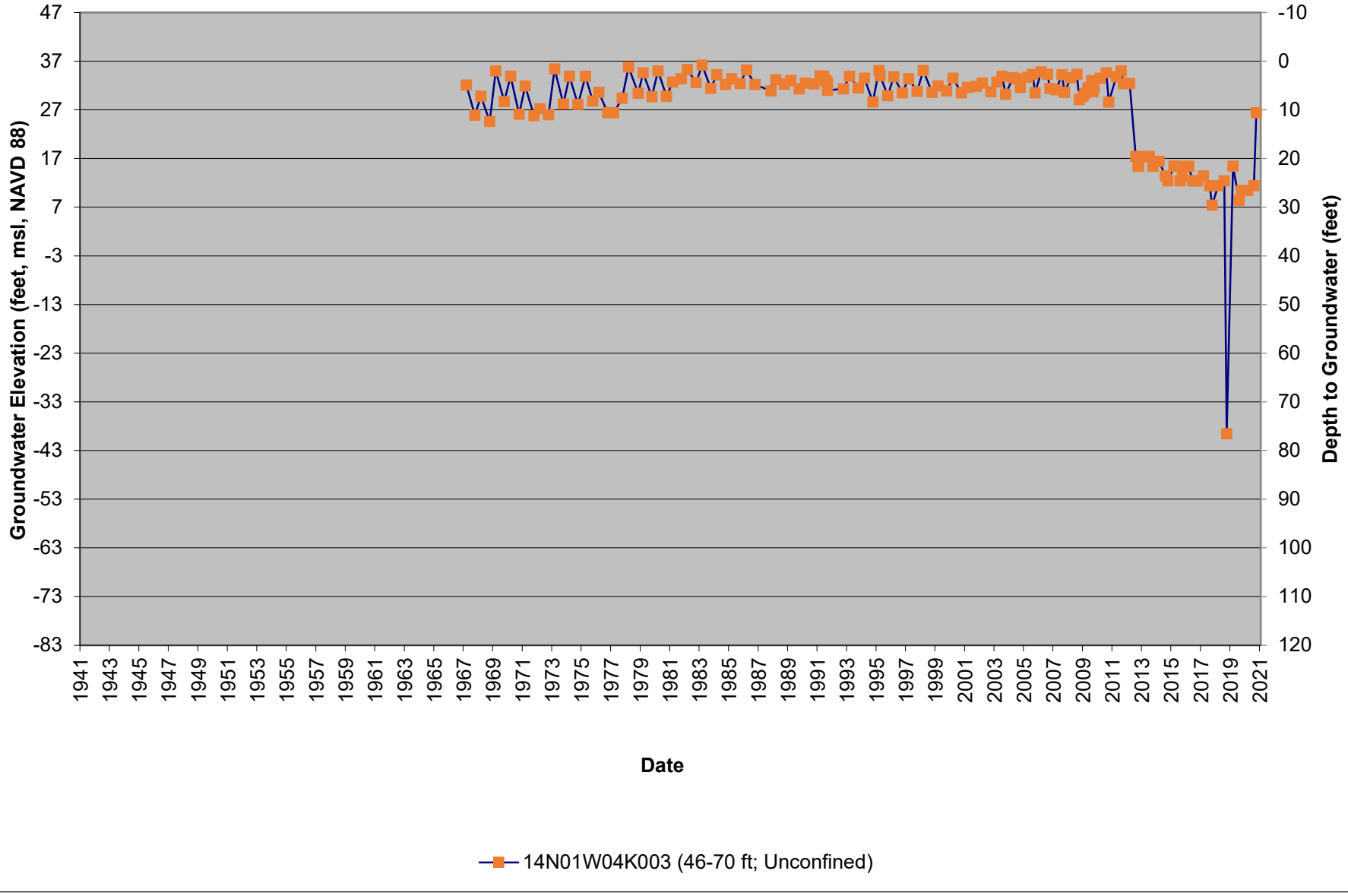


Figure 3A-13. 14N02W13N001M Active Irrigation Well
Ground Surface Elevation 62.45 feet msl, NAVD 88

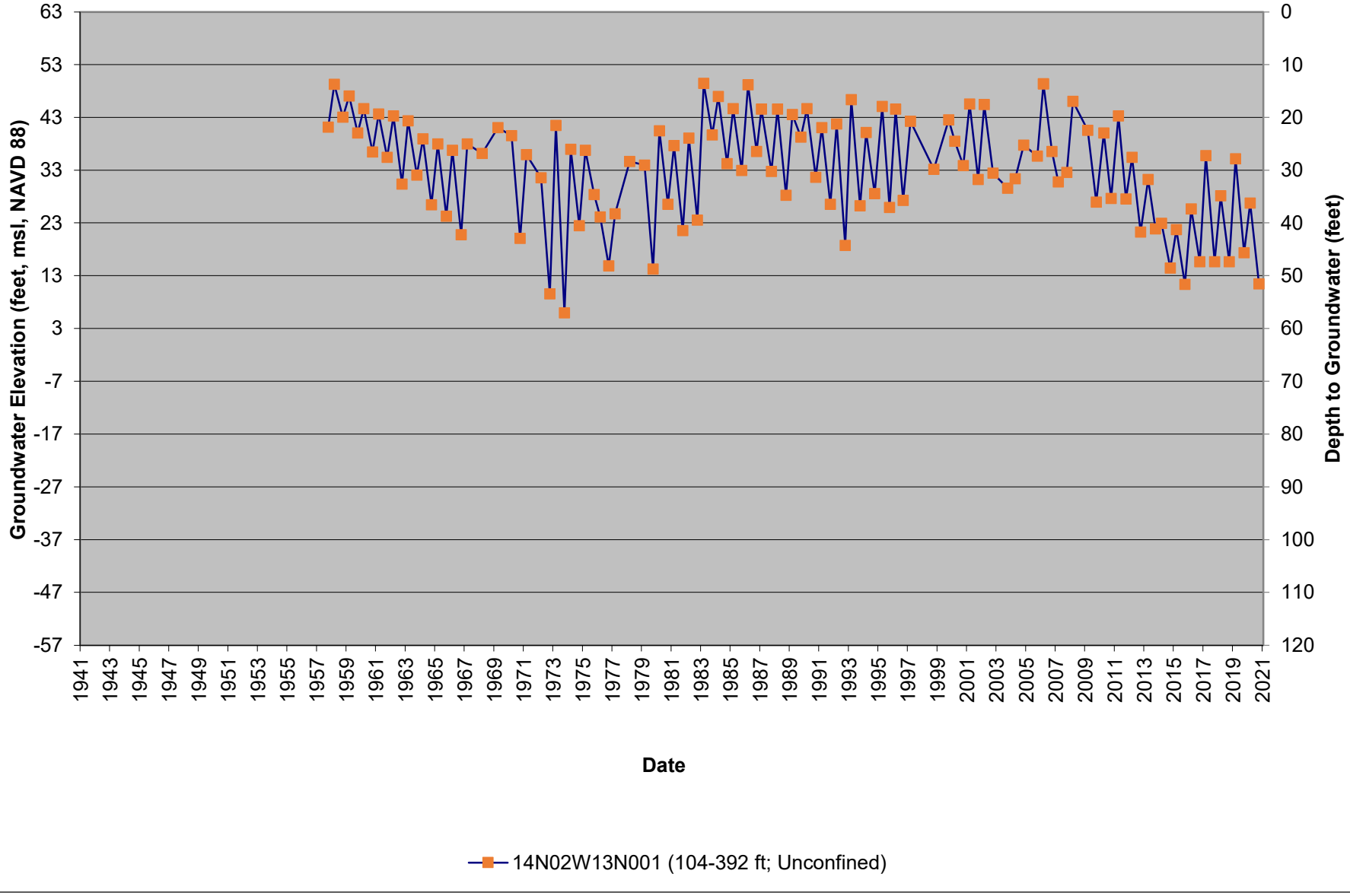


Figure 3A-14. 14N02W29J001M Active Irrigation Well
Ground Surface Elevation 162.50 feet msl, NAVD 88

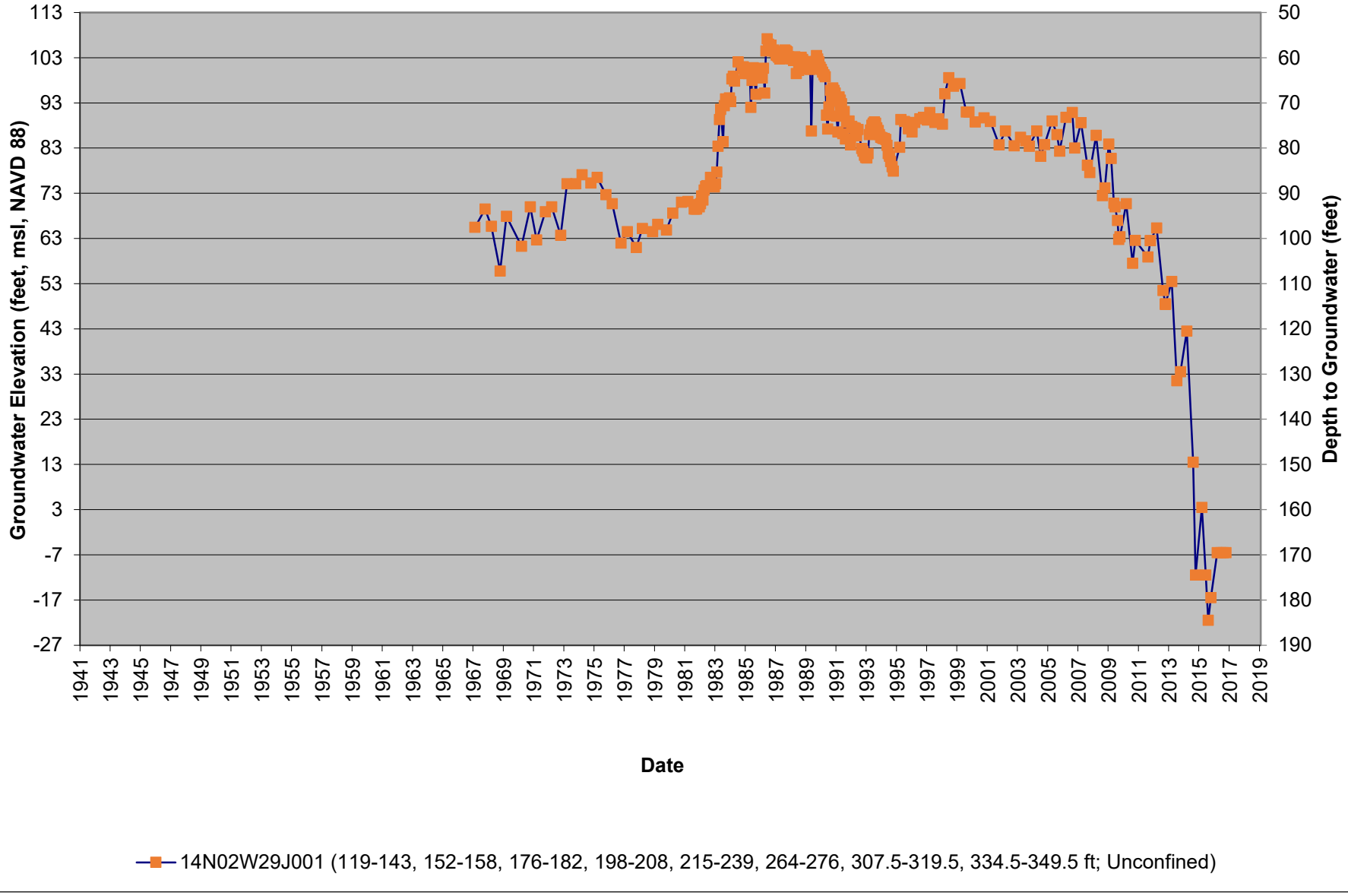


Figure 3A-15. 14N03W14Q003M Active Irrigation Well
Ground Surface Elevation 172.52 feet msl, NAVD 88

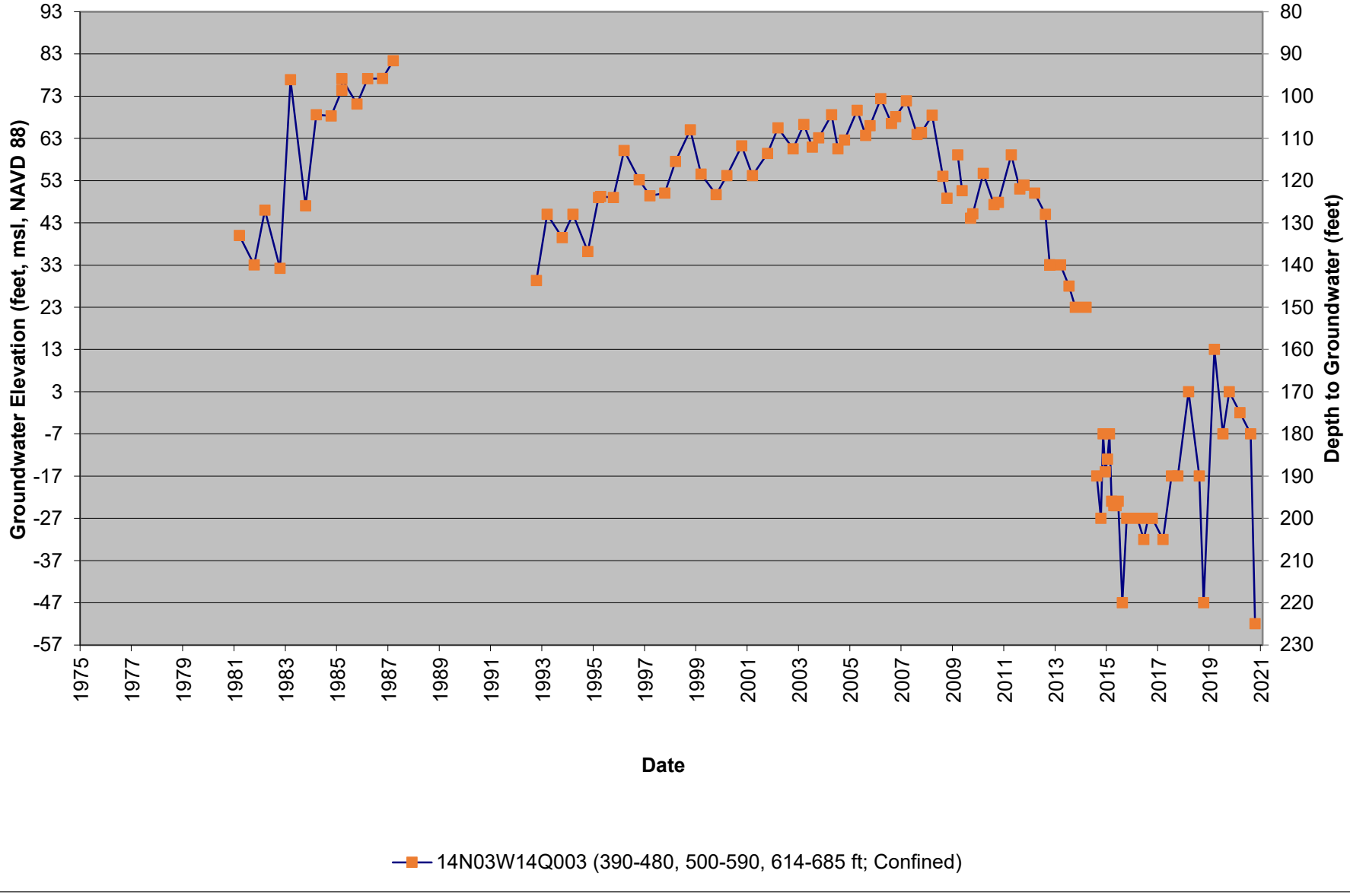


Figure 3A-16. 14N03W24C001M Active Residential Well
Ground Surface Elevation 172.51 feet msl, NAVD 88

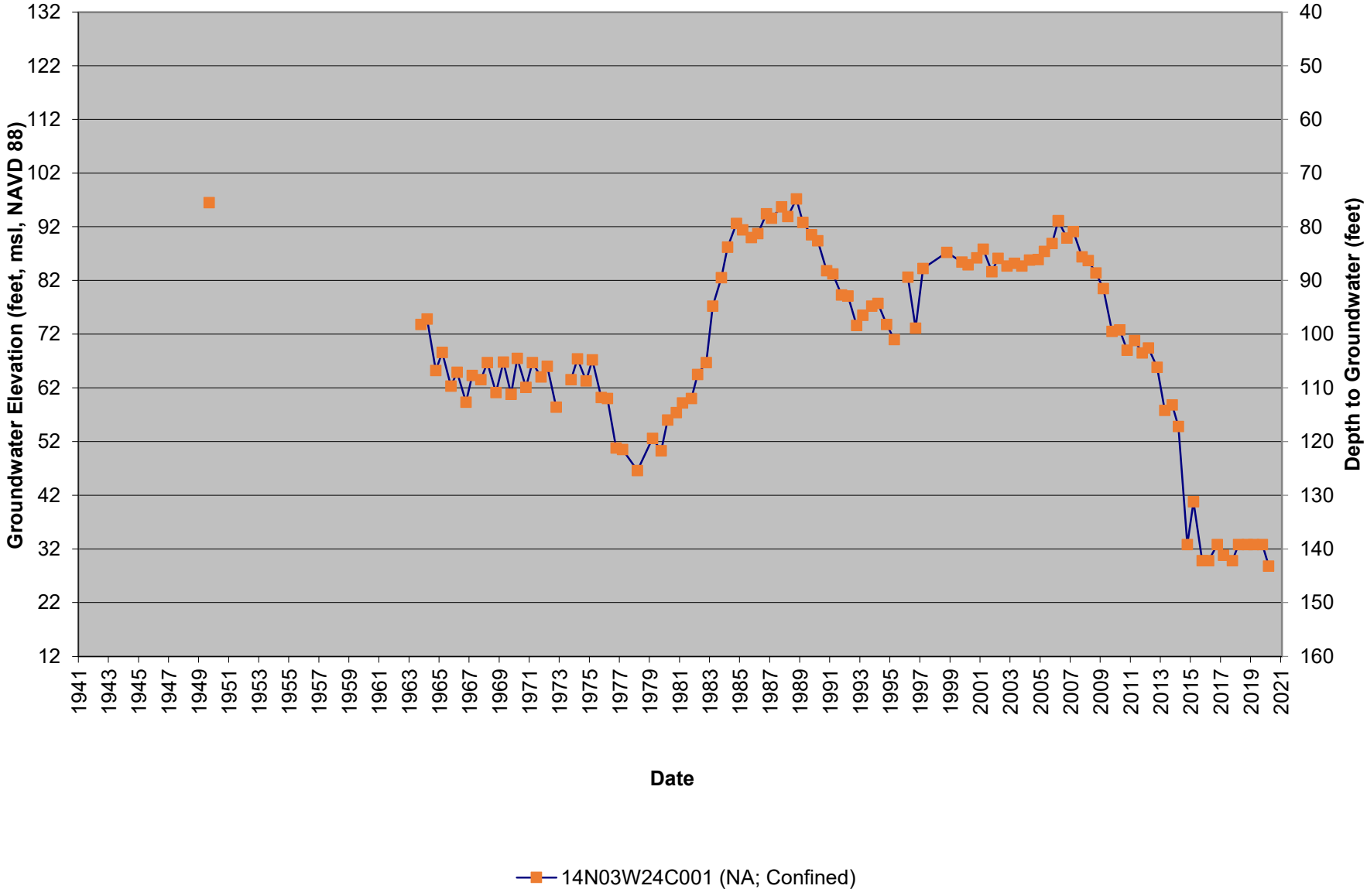


Figure 3A-17. 15N01W05G001M Active Residential Well
Ground Surface Elevation 47.42 feet msl, NAVD 88

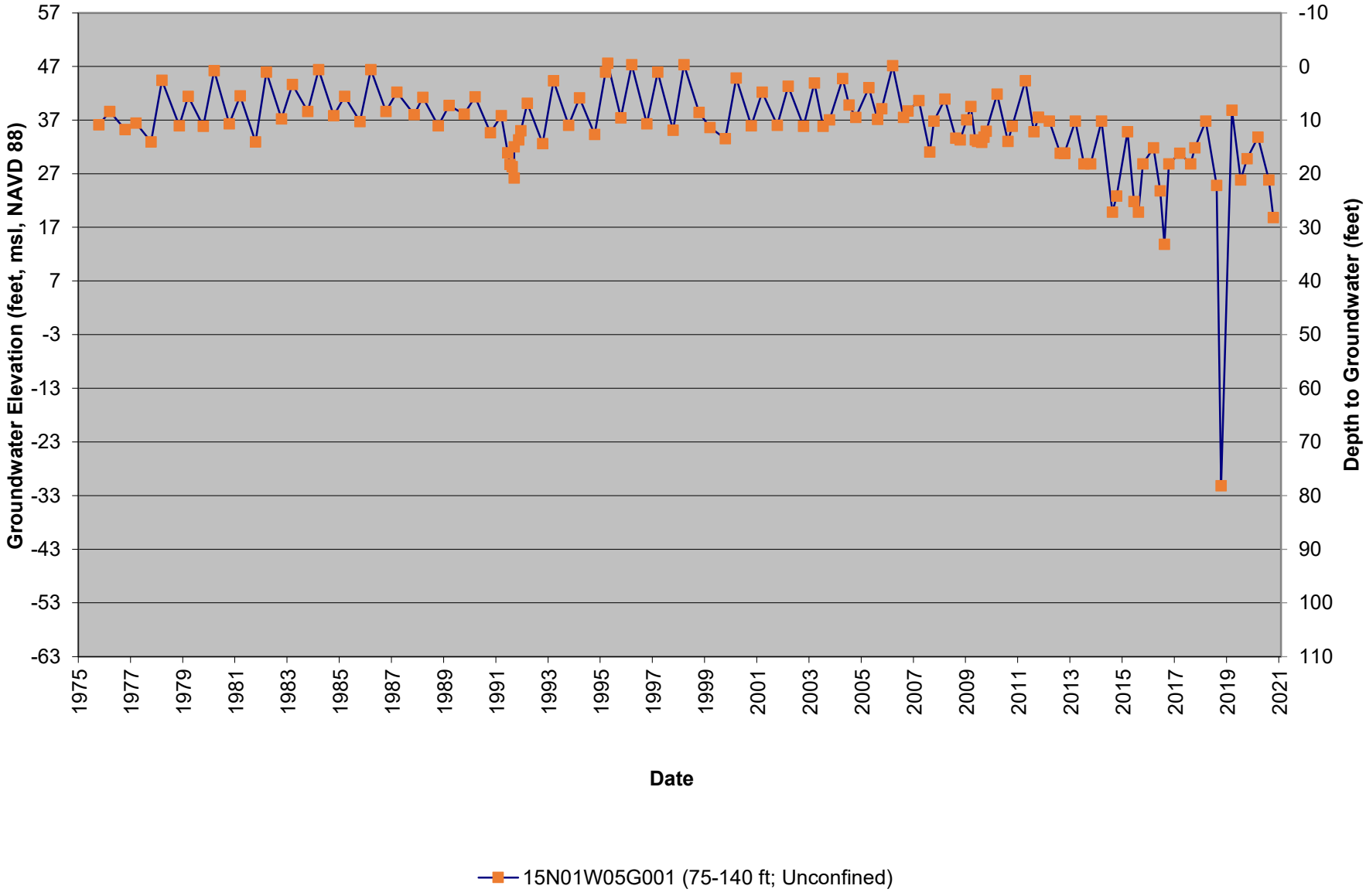


Figure 3A-18. 15N02W19E001M Active Irrigation Well
Ground Surface Elevation 87.46 feet msl, NAVD 88

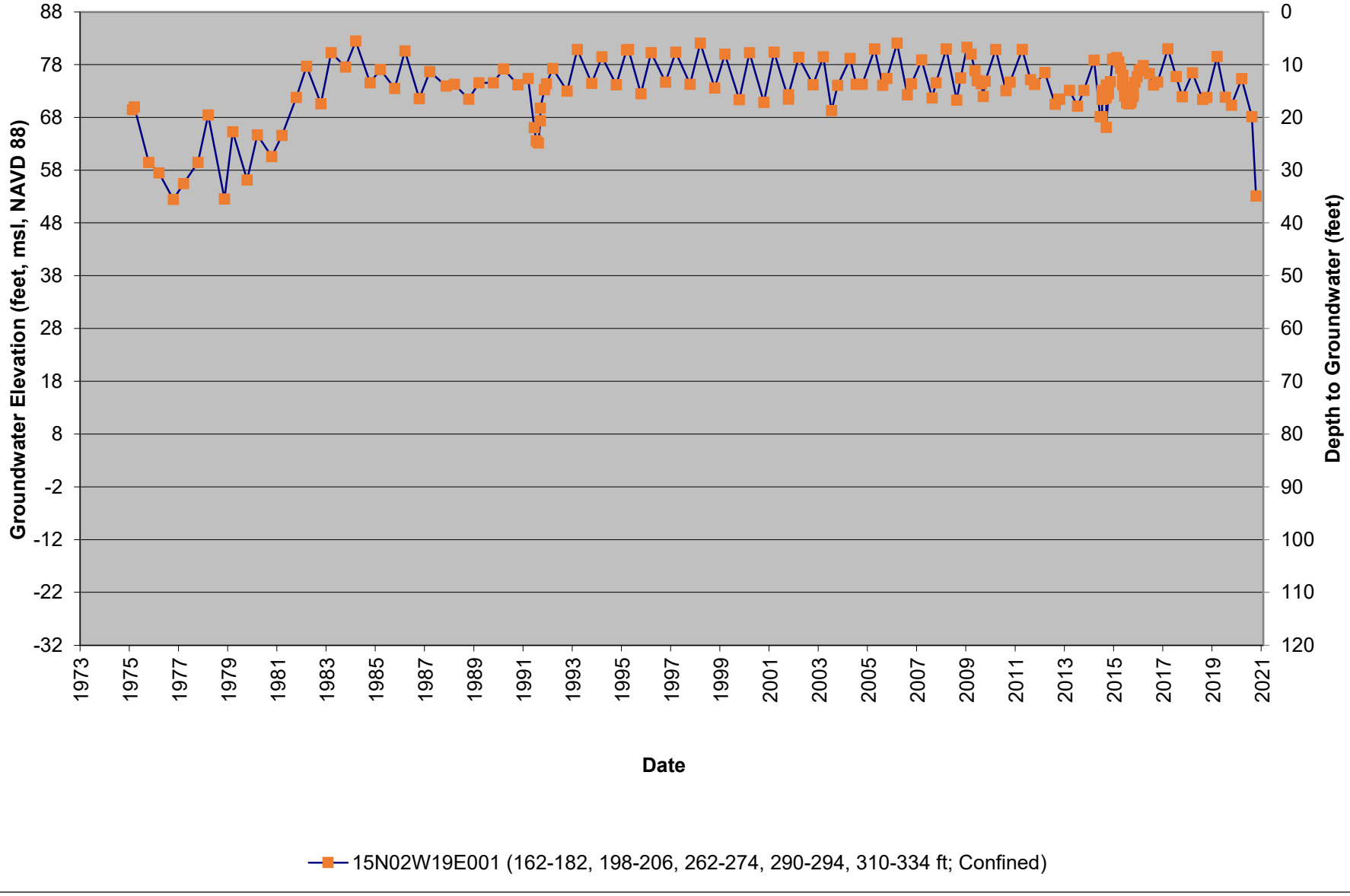


Figure 3A-19. 15N03W08Q001M Active Irrigation Well
Ground Surface Elevation 115.58 feet msl, NAVD 88

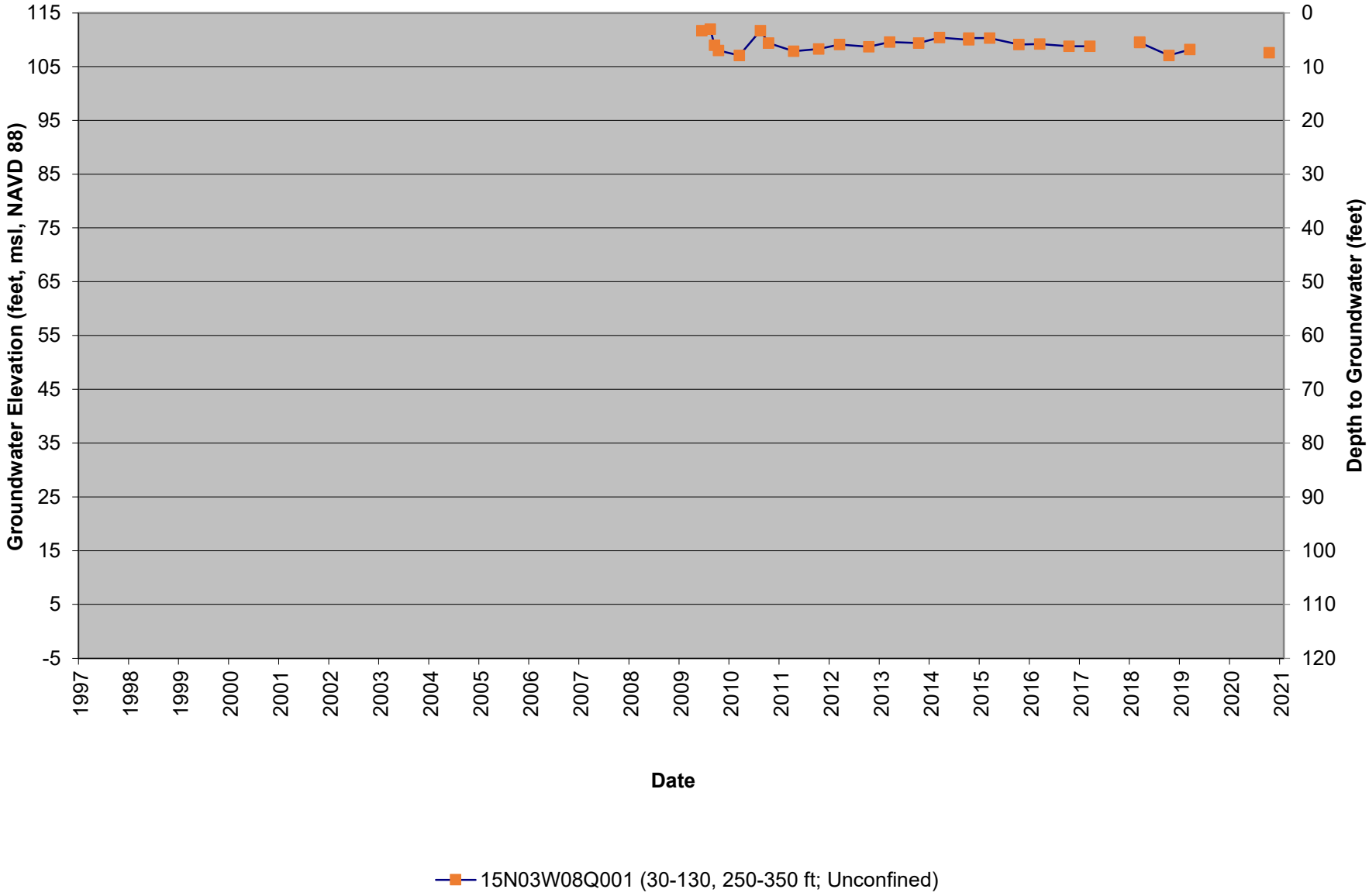


Figure 3A-20. 15N03W20Q001-003M Active Observation Well Cluster
Ground Surface Elevation 128.56 feet msl, NAVD 88

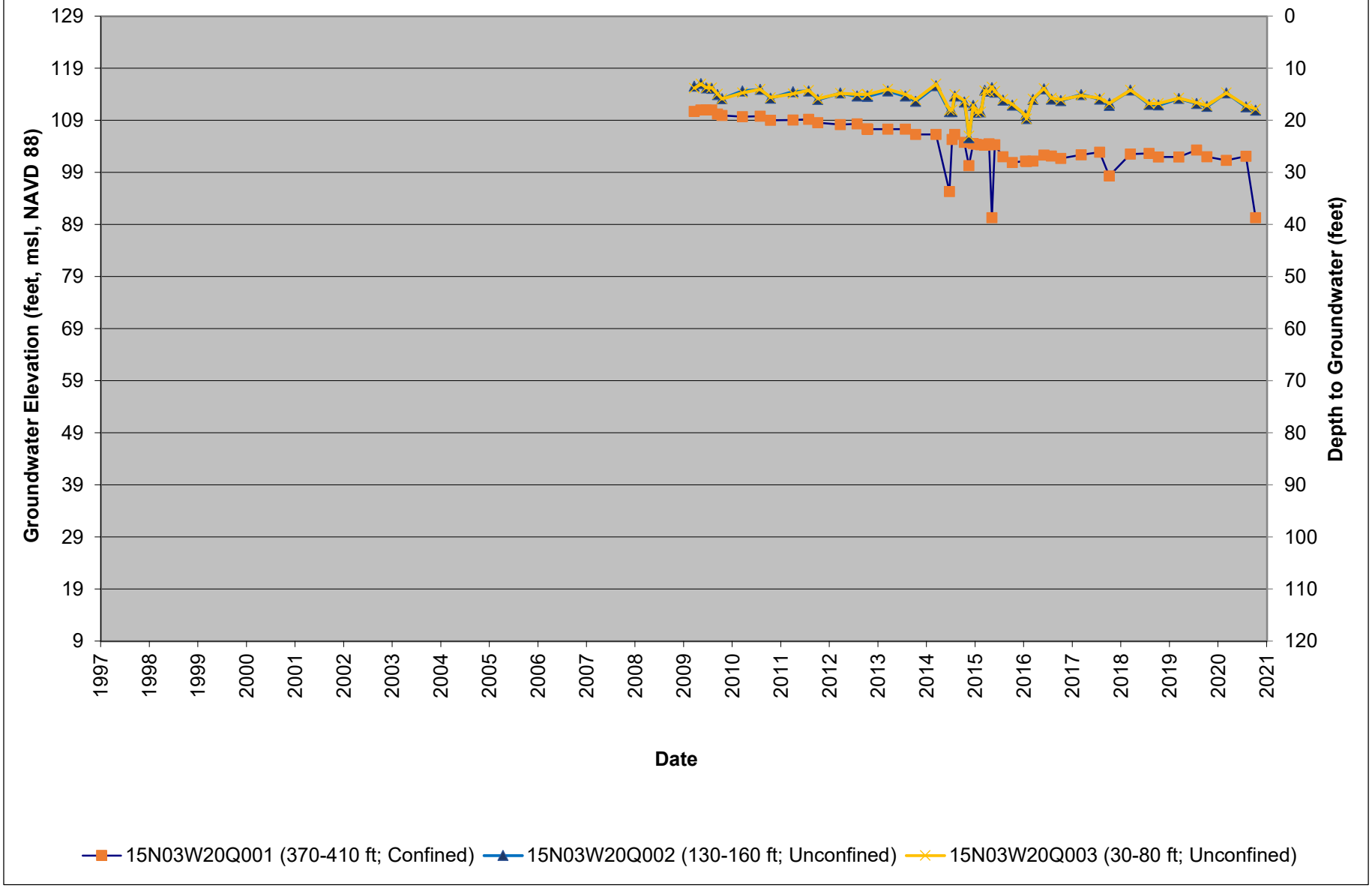


Figure 3A-21. 16N02W05B001-003M Active Observation Well Cluster
Ground Surface Elevation 65.00 feet msl, NAVD 88

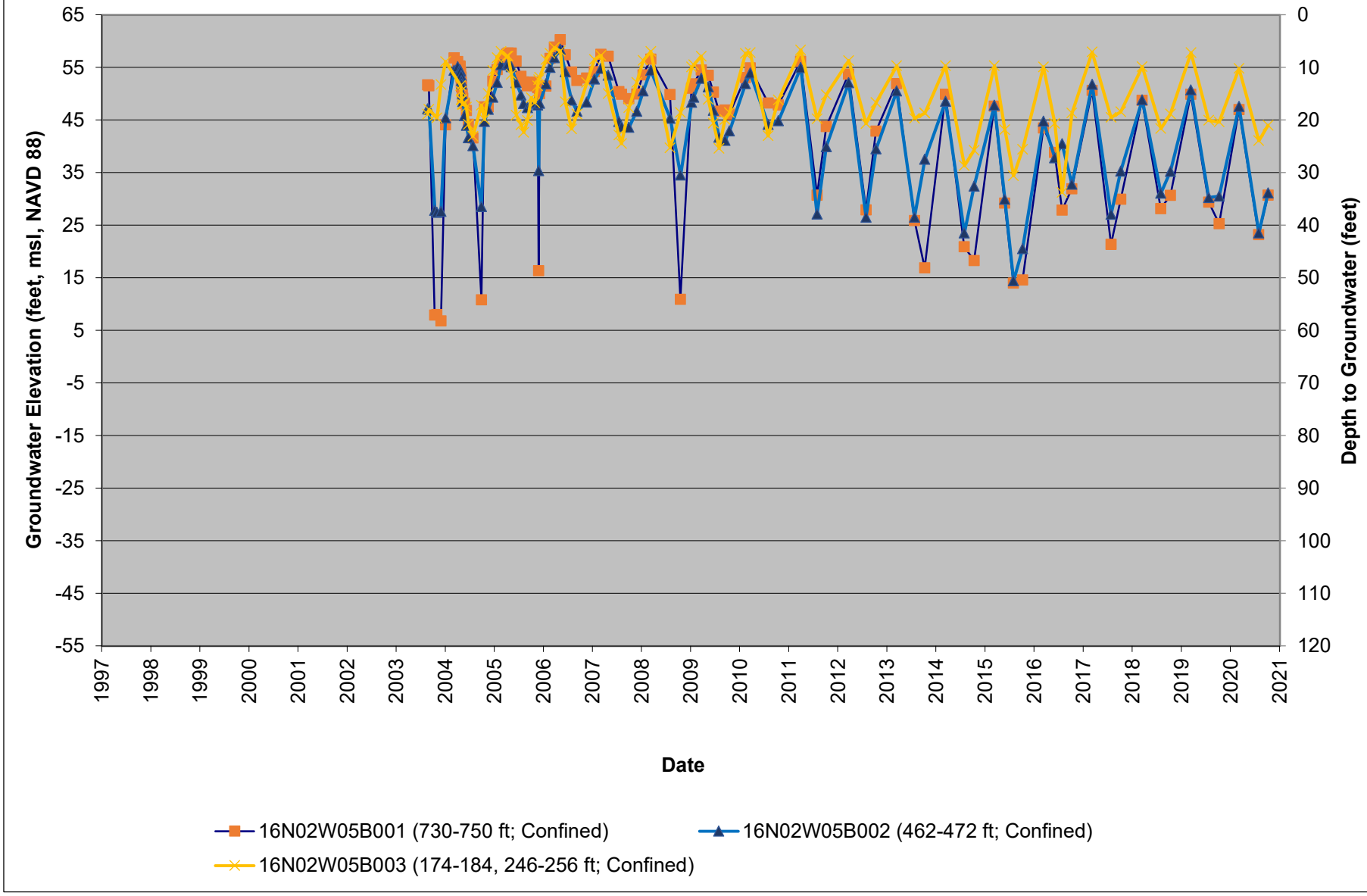


Figure 3A-22. 16N02W25B002M Active Residential Well
Ground Surface Elevation 55.42 feet msl, NAVD 88

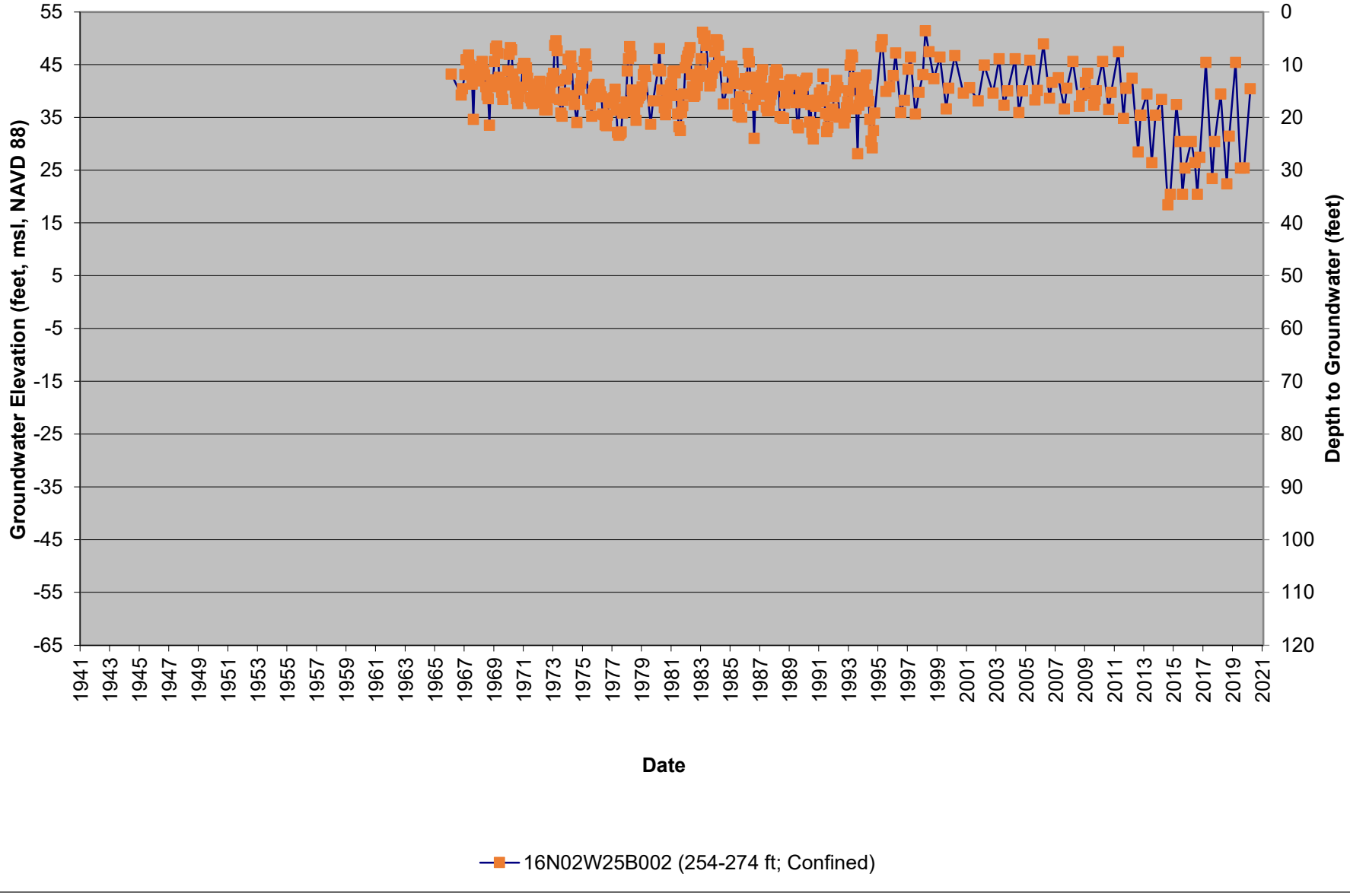


Figure 3A-23. 16N03W14H003-006M Active Observation Well Cluster
Ground Surface Elevation 65.70 feet msl, NAVD 88

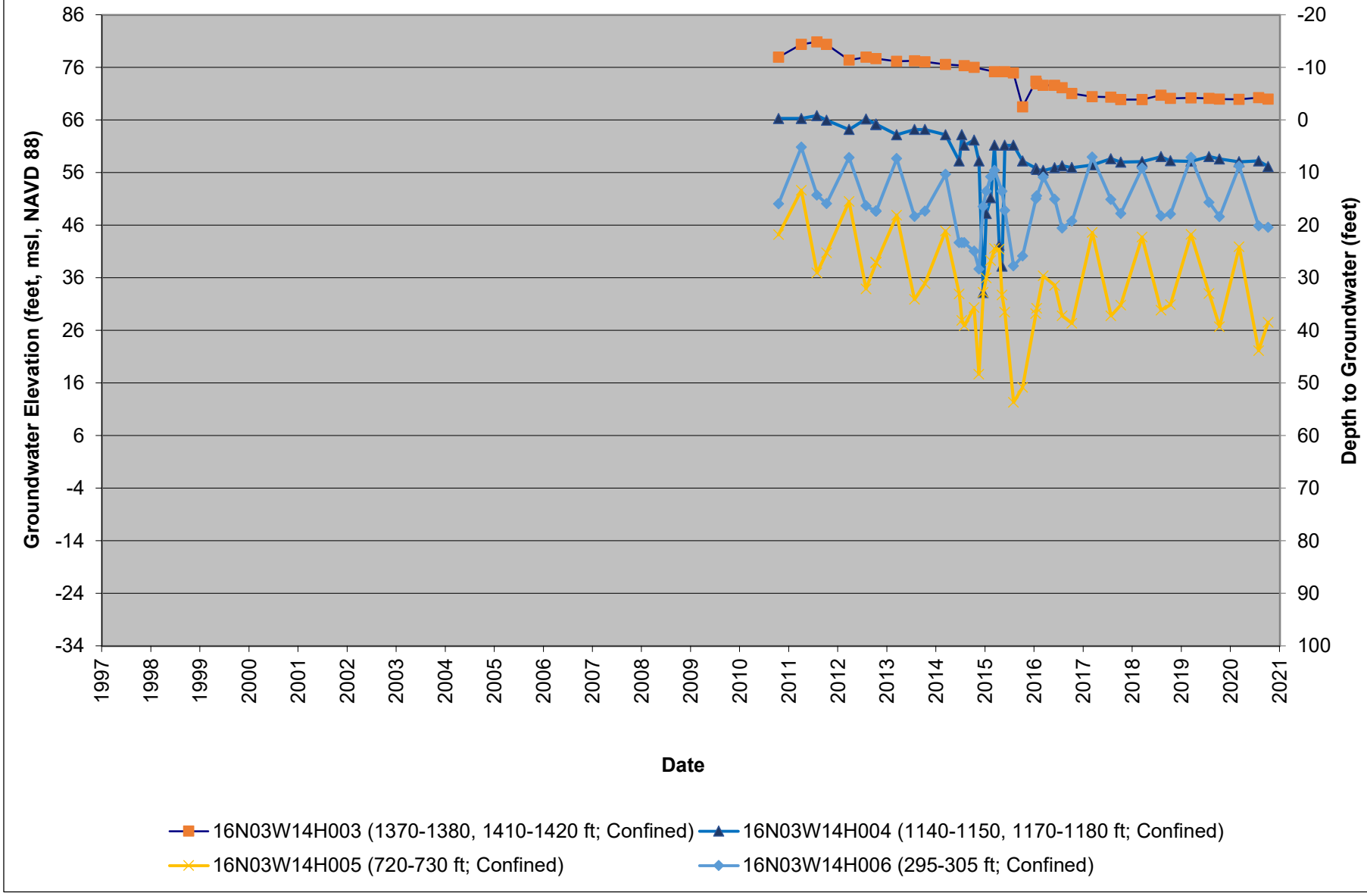


Figure 3A-24. 16N03W35N002M Inactive Residential Well
Ground Surface Elevation 75.47 feet msl, NAVD 88

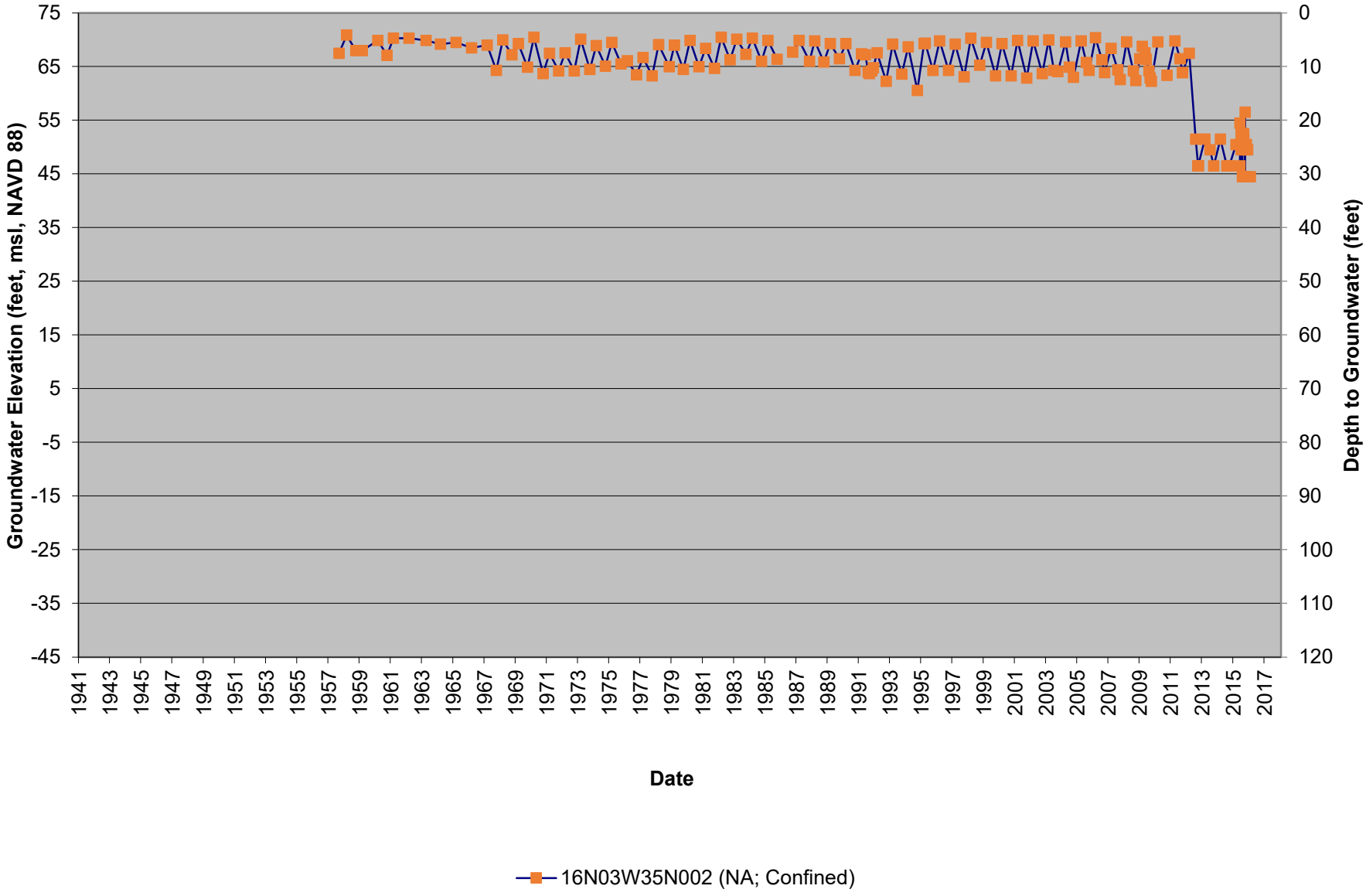


Figure 3A-25. 16N04W02P001M Active Stockwatering Well
Ground Surface Elevation 162.53 feet msl, NAVD 88

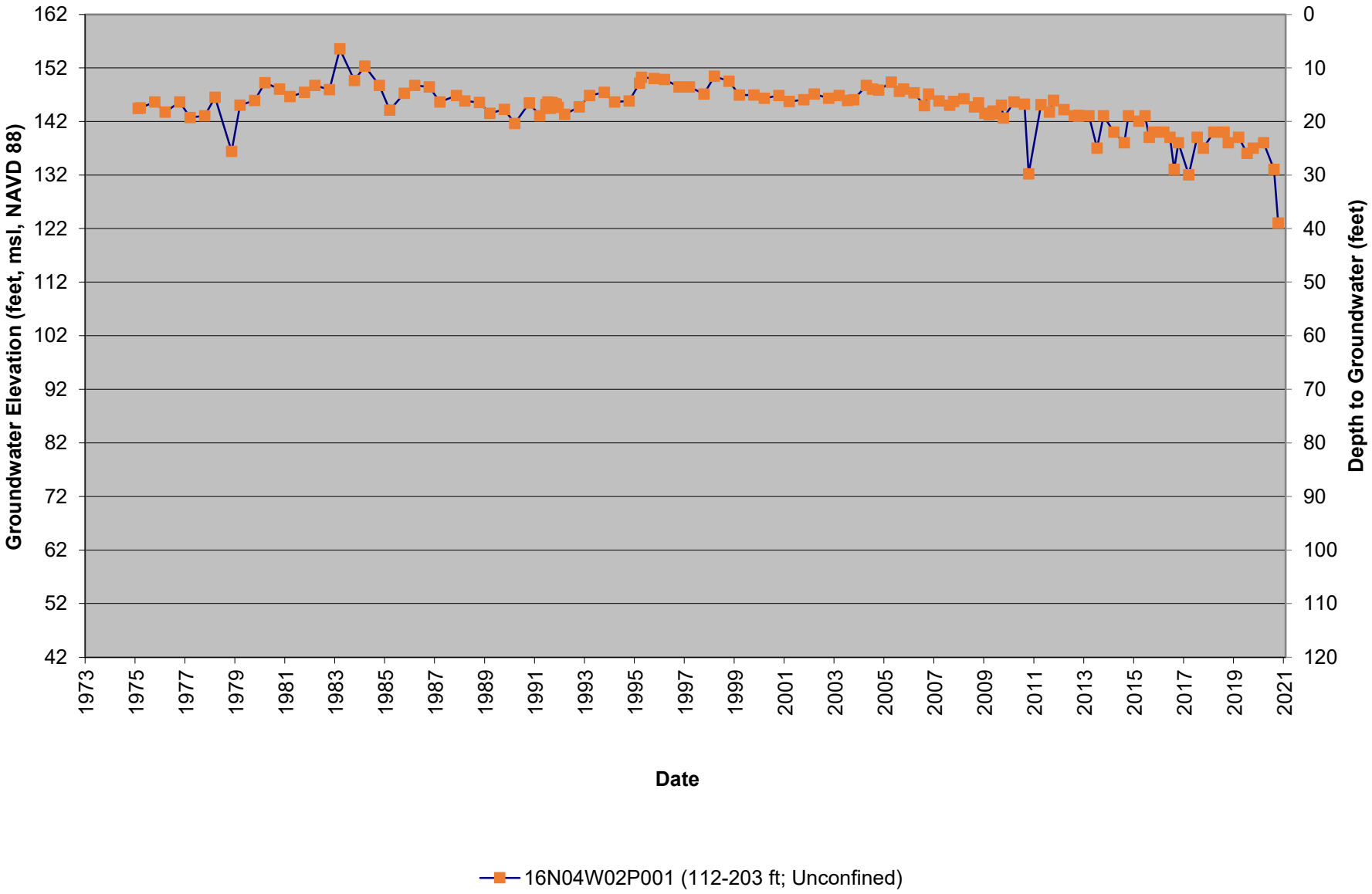


Figure 3A-26. 17N02W09H002-004M Active Observation Well Cluster
Ground Surface Elevation 67.00 feet msl, NAVD 88

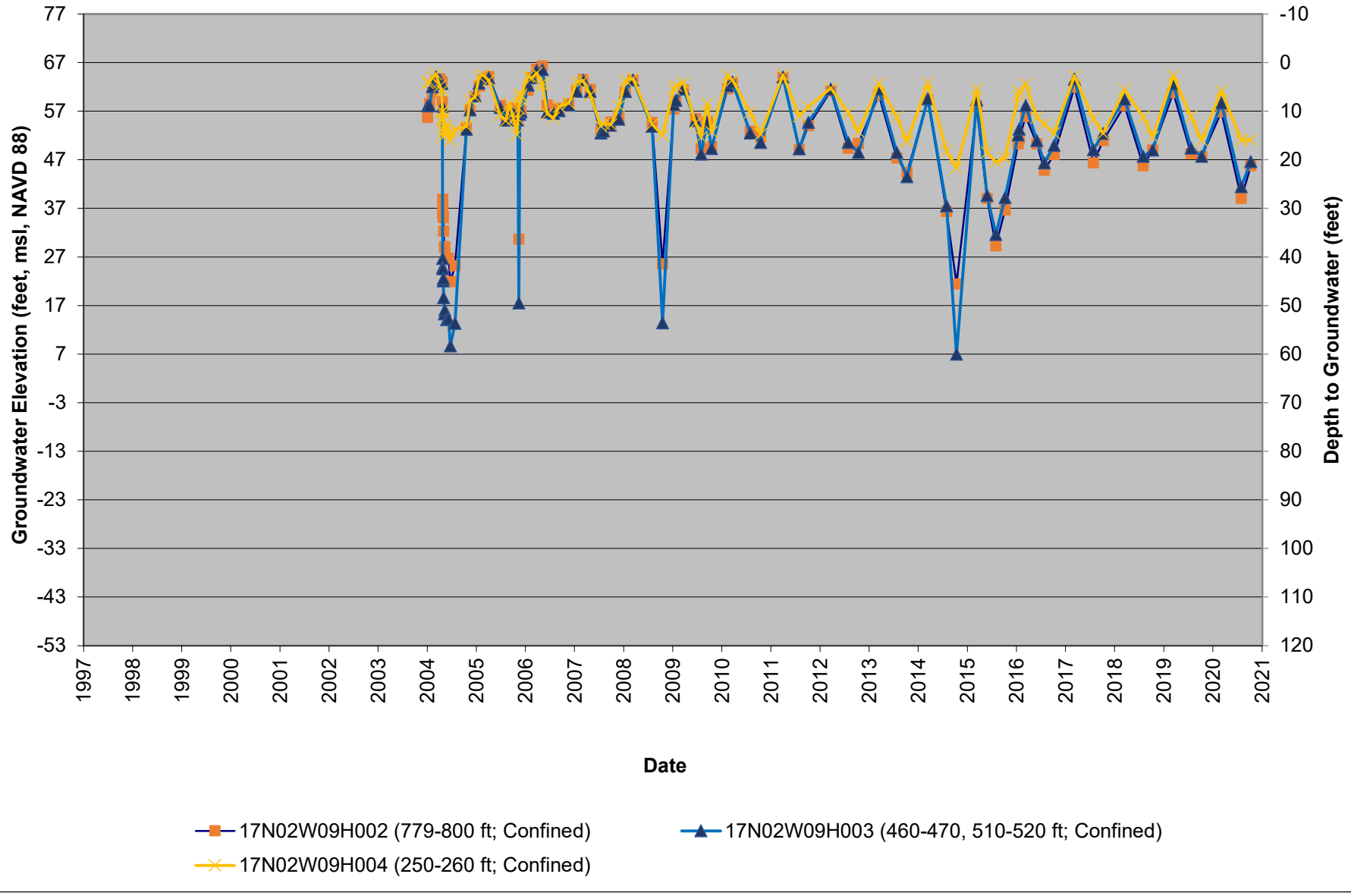


Figure 3A-27. 17N02W30J002M Active Residential Well
Ground Surface Elevation 63.43 feet msl, NAVD 88

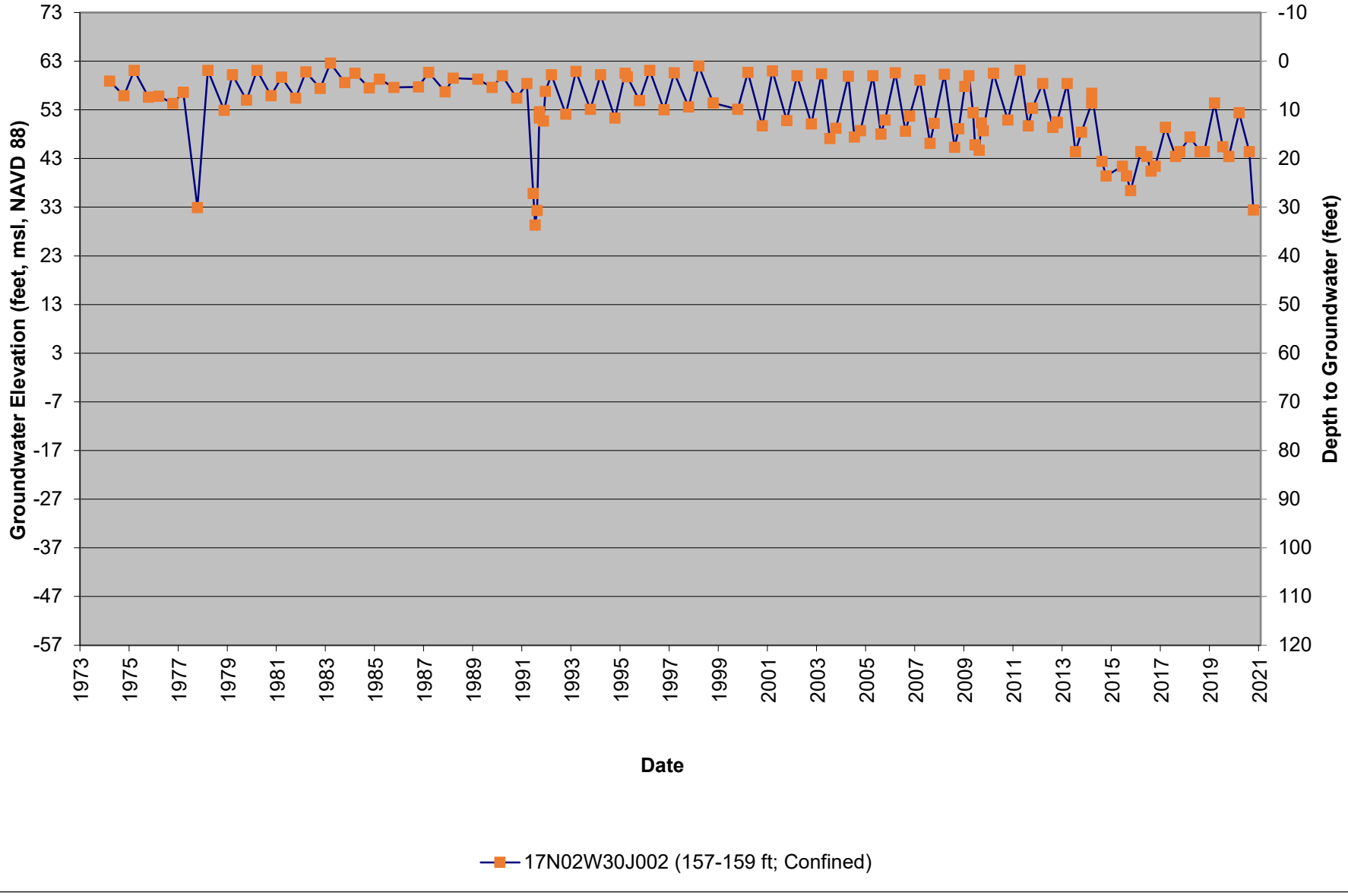


Figure 3A-28. 17N03W08R001M Active Residential Well
Ground Surface Elevation 107.46 feet msl, NAVD 88

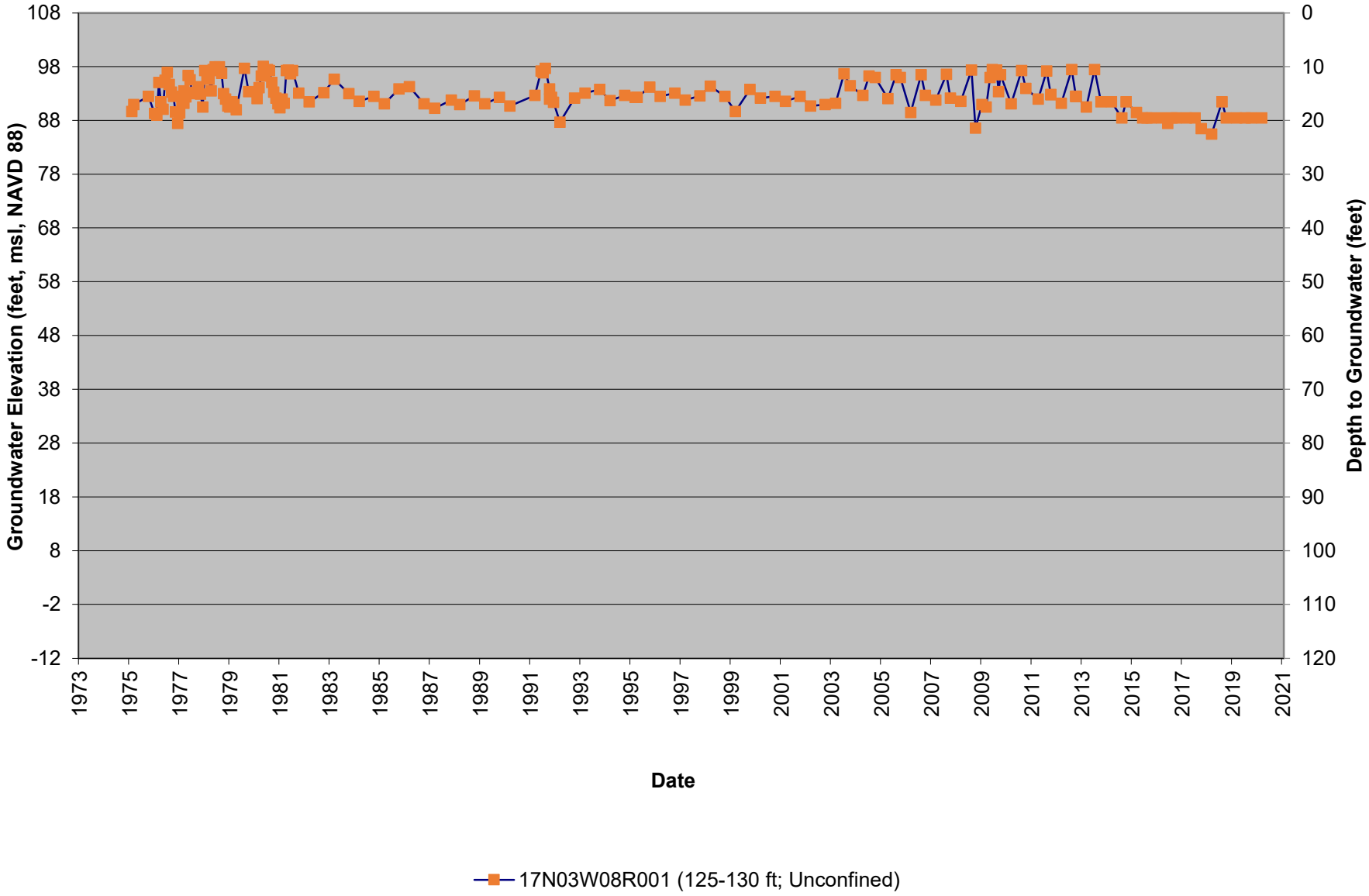


Figure A-30. 17N03W32H001M Active Residential Well
Ground Surface Elevation 100.47 feet msl, NAVD 88

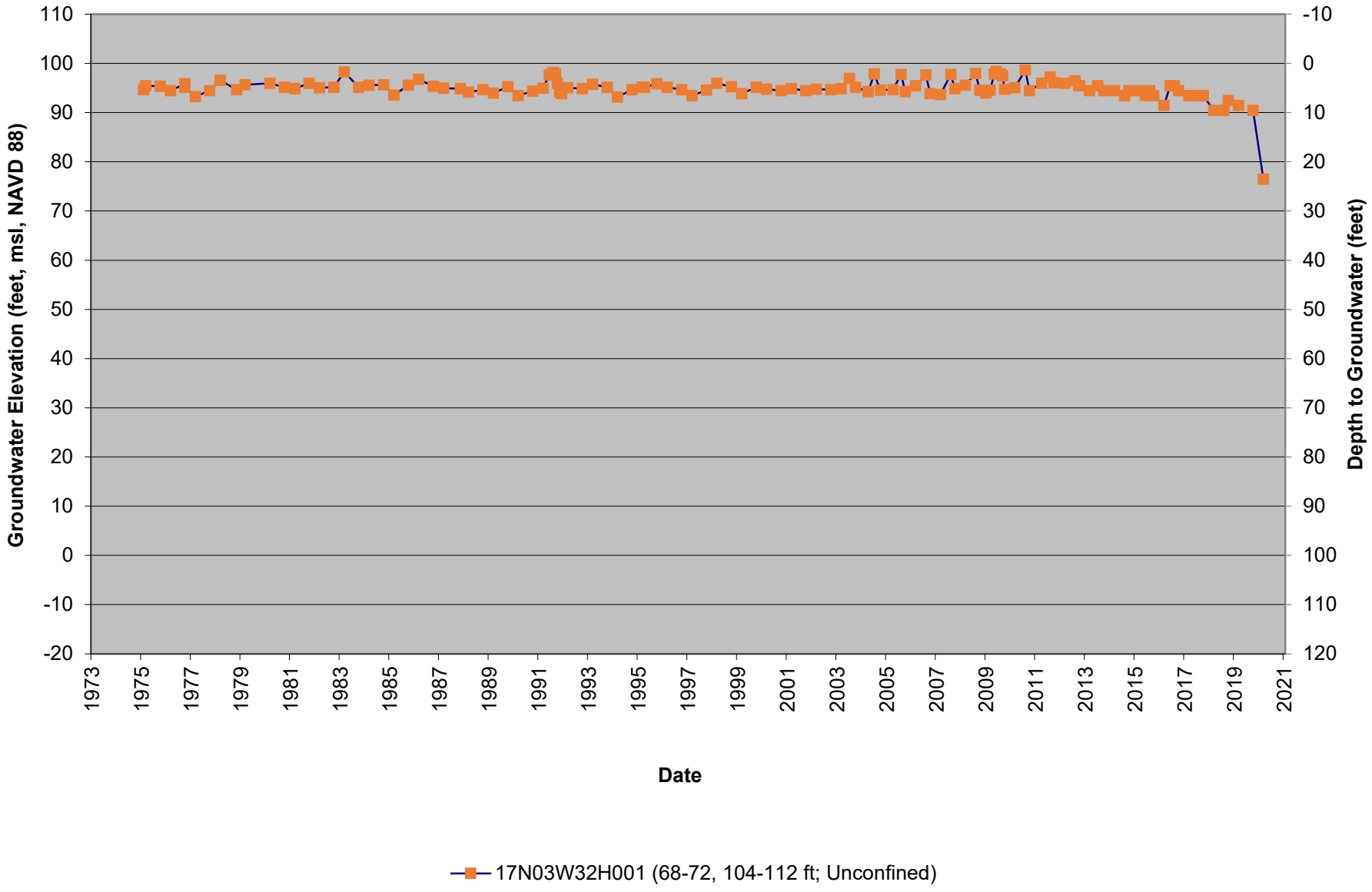


Figure 3A-30. 18N02W18D001-004M Active Observation Well Cluster
Ground Surface Elevation 82.43 feet msl, NAVD 88

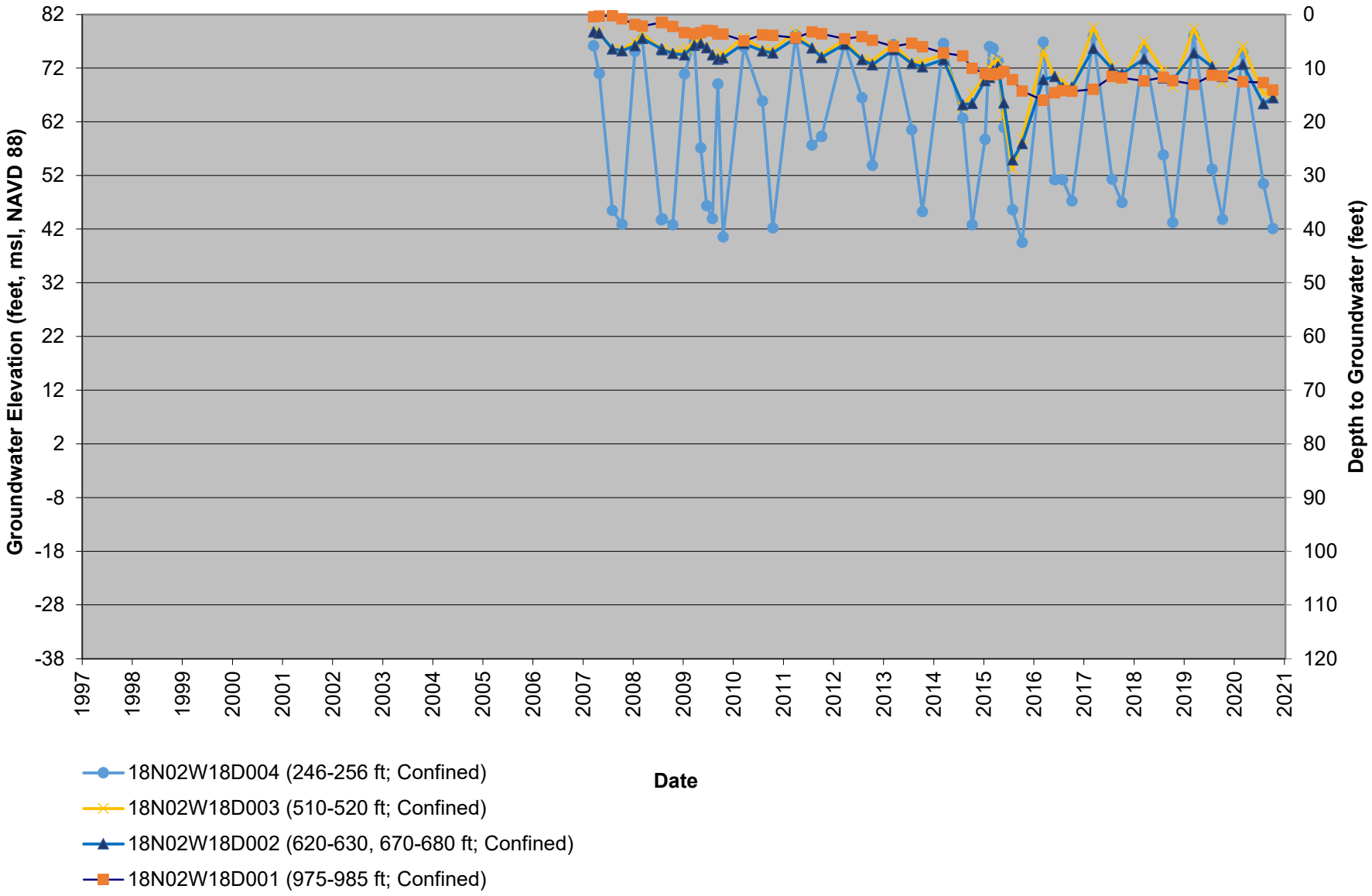


Figure 3A-31. 18N02W36B001M Active Irrigation Well
Ground Surface Elevation 75.40 feet msl, NAVD 88

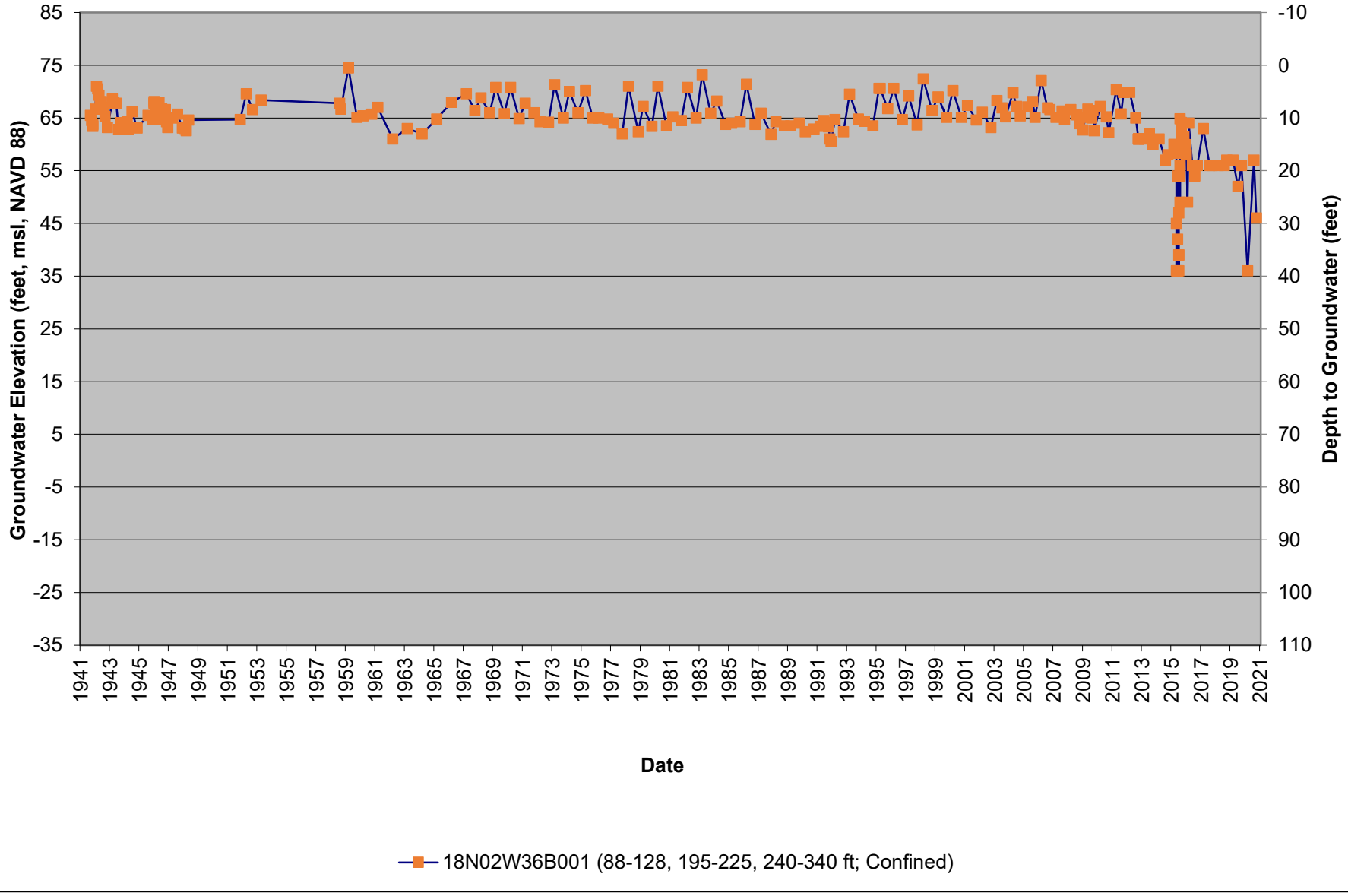


Figure 3A-32. 19N02W08Q001-003M Active Observation Well Cluster
Ground Surface Elevation 108.36 feet msl, NAVD 88

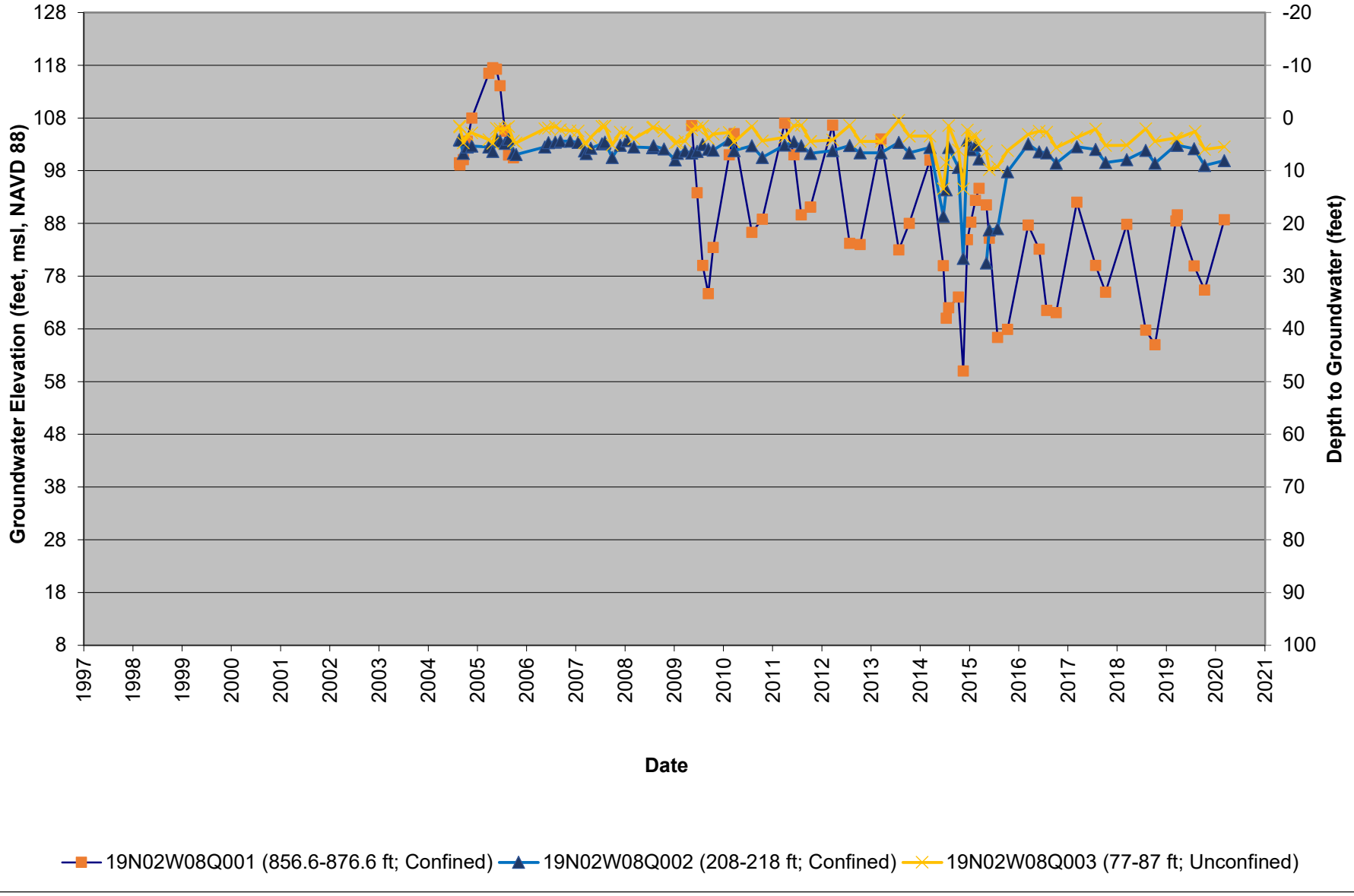


Figure 3A-33. 19N02W33K001M Active Irrigation Well
Ground Surface Elevation 87.41 feet msl, NAVD 88

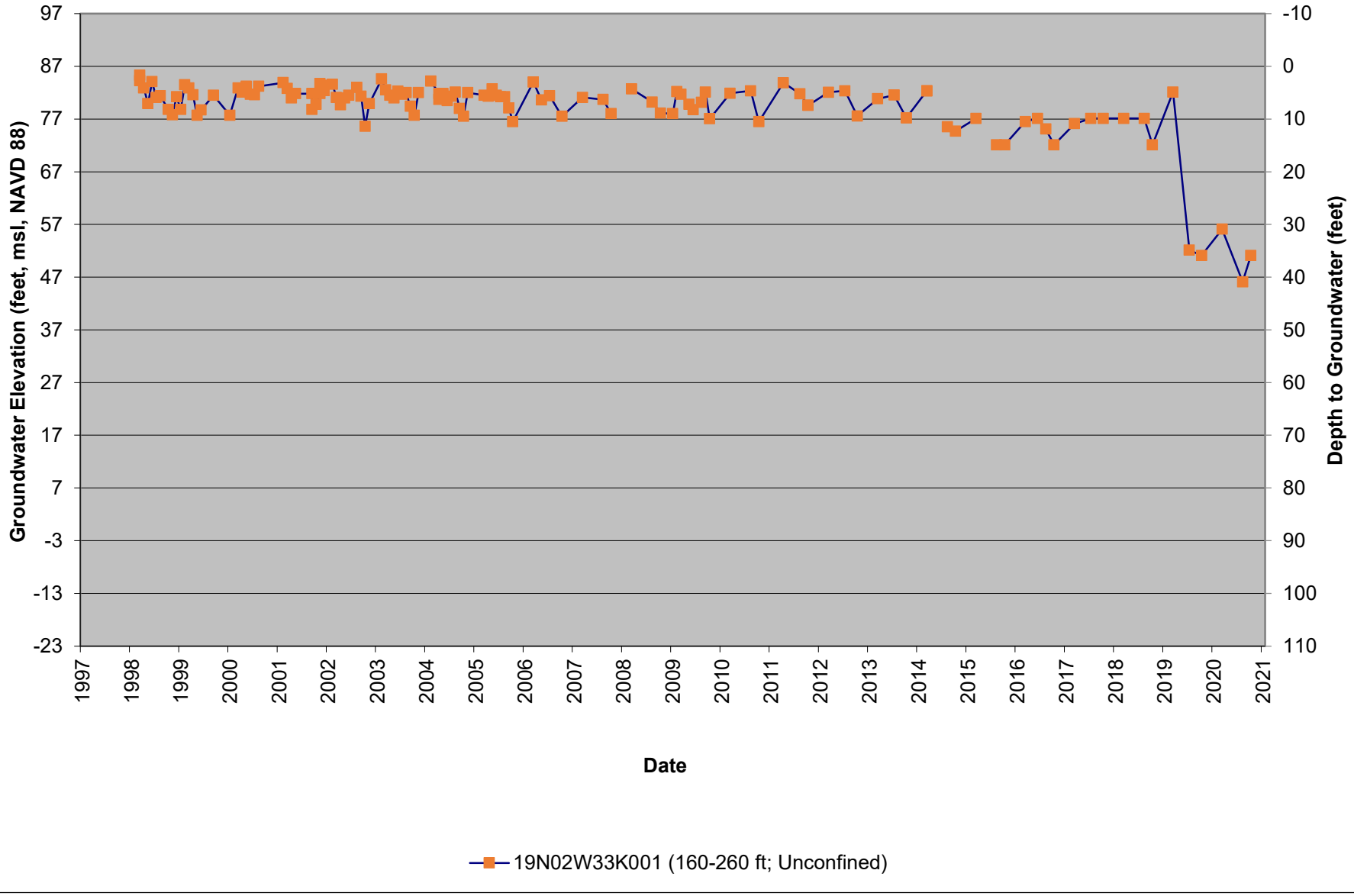


Figure 3A-34. 19N04W14M002M Active Observation Well
Ground Surface Elevation 185.83 feet msl, NAVD 88

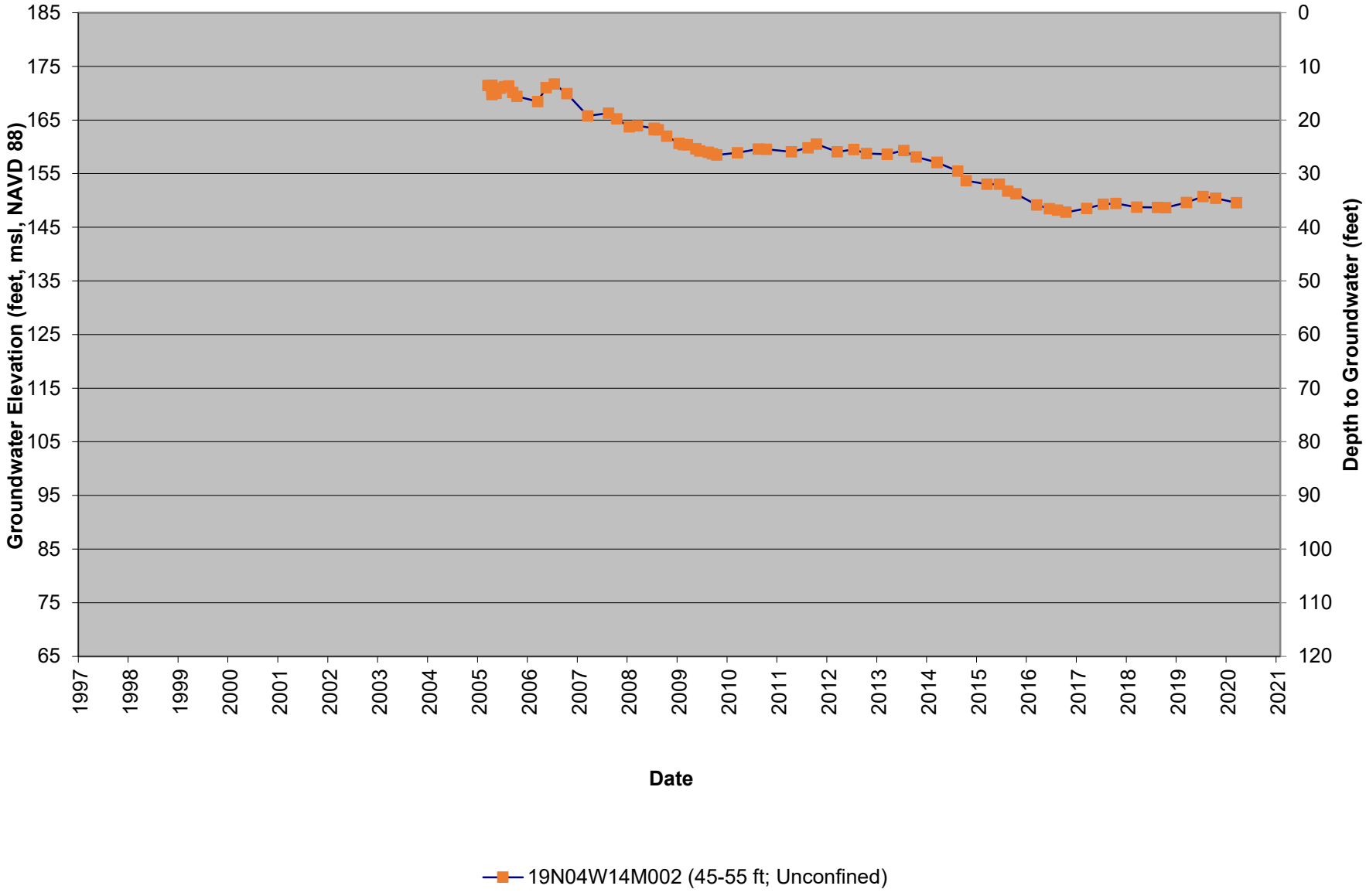


Figure 3A-35. 20N02W11A001-003M Active Observation Well Cluster
Ground Surface Elevation 125.40 feet msl, NAVD 88

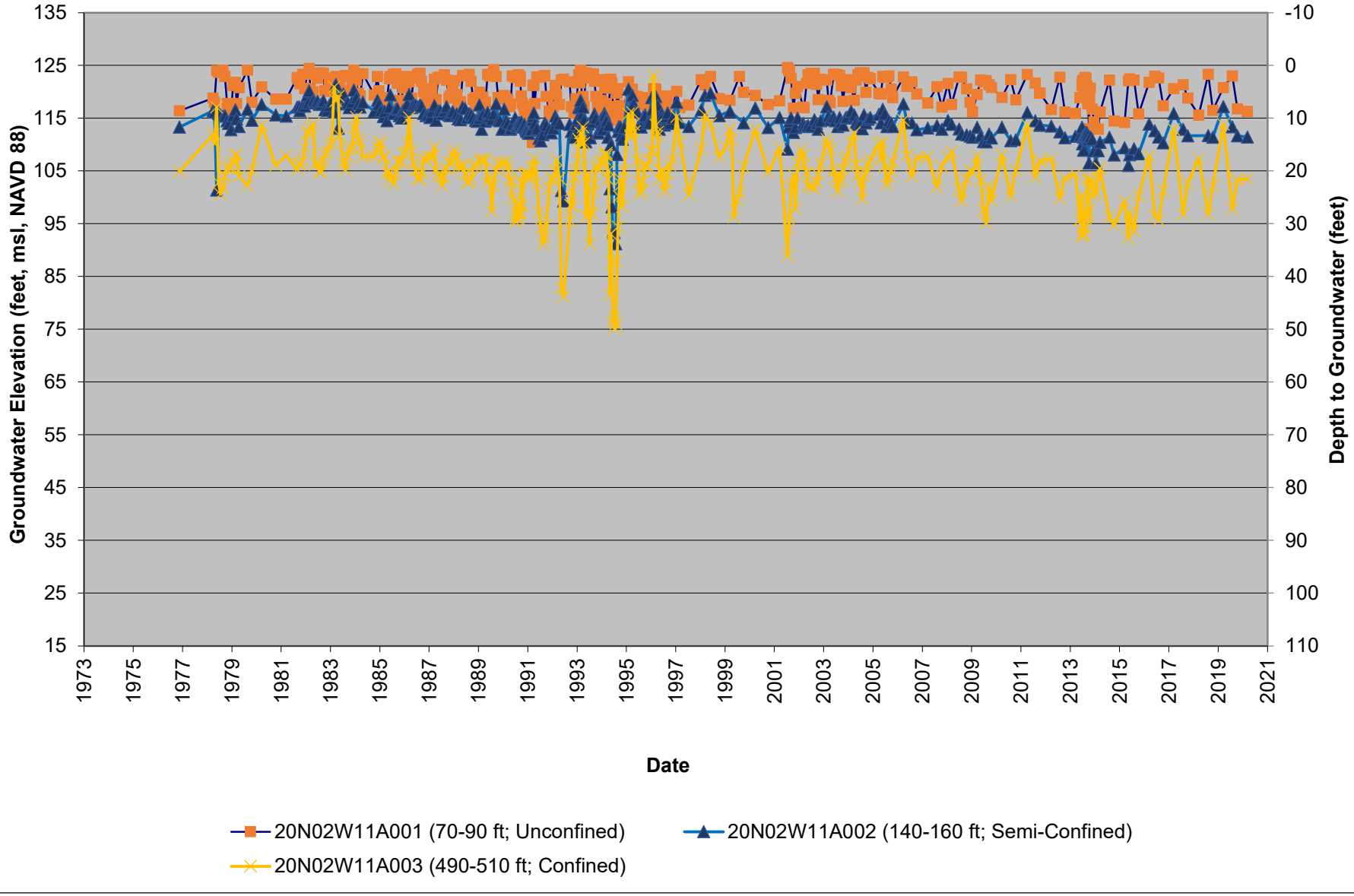


Figure 3A-36. 20N02W18R005-008M Active Observation Well Cluster
Ground Surface Elevation 131.38 feet msl, NAVD 88

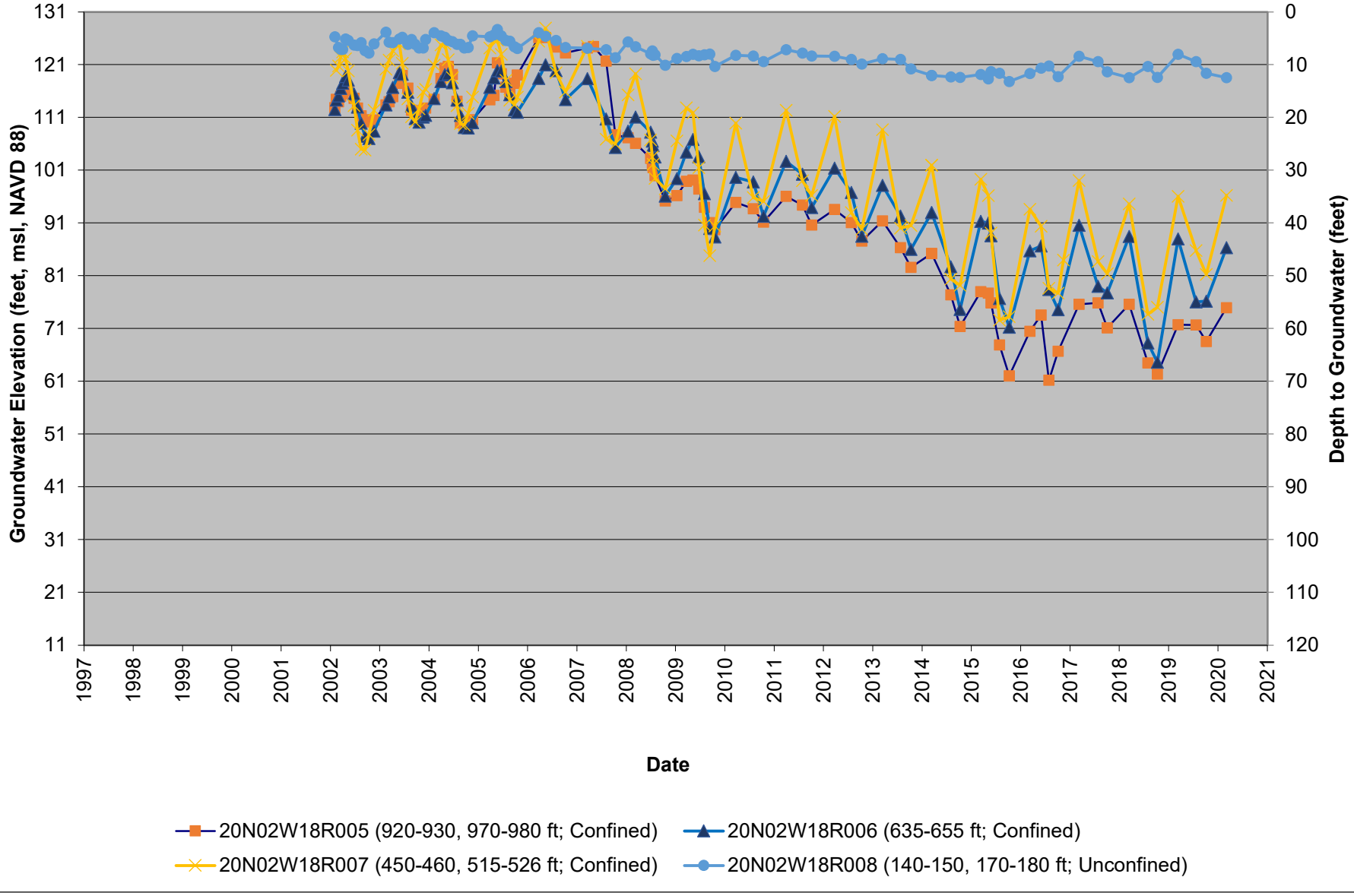


Figure 3A-37. 20N02W25F001-004M Active Observation Well Cluster
Ground Surface Elevation 102.20 feet msl, NAVD 88

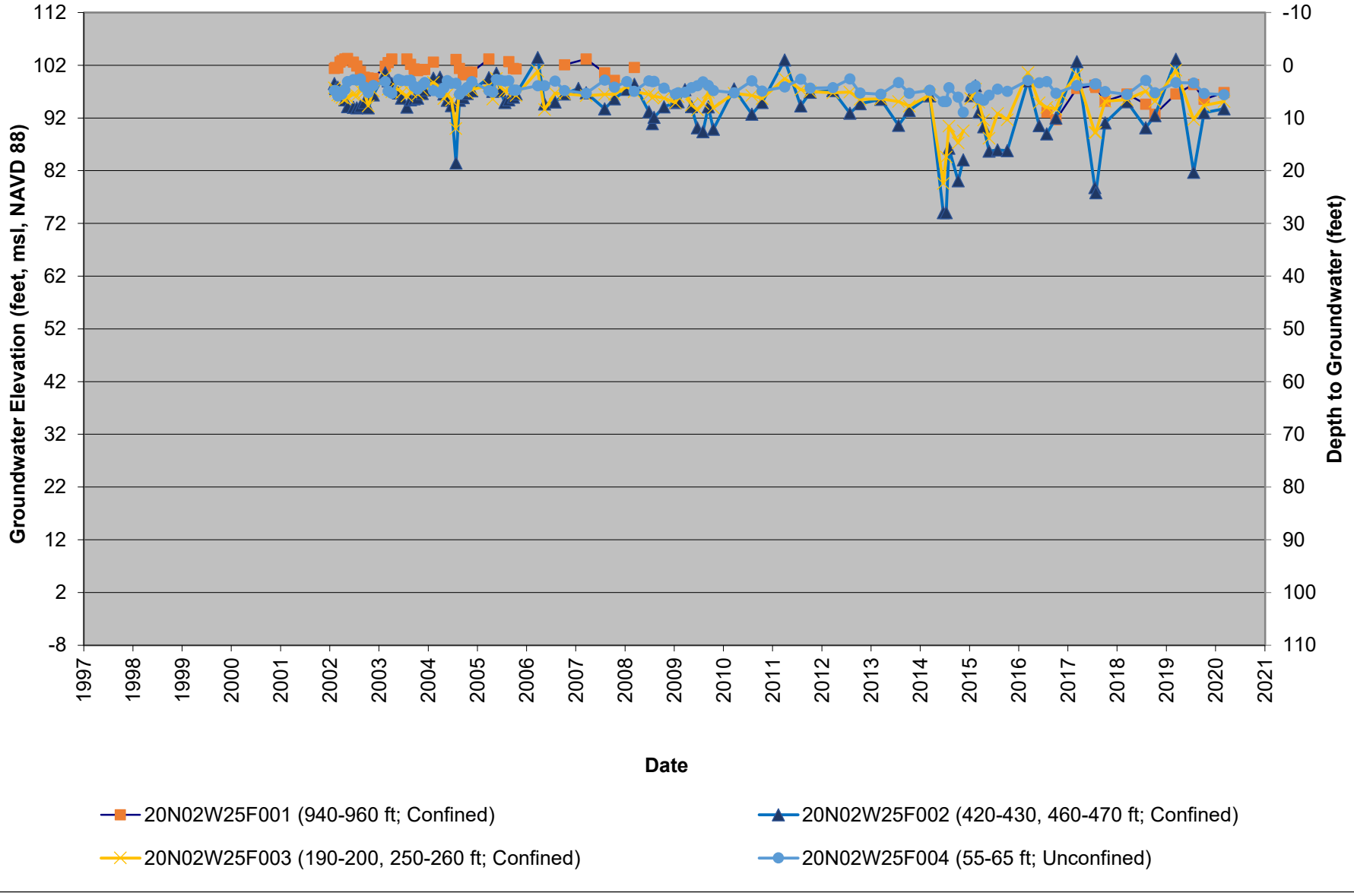


Figure 3A-38. 20N02W33B001M Active Observation Well
Ground Surface Elevation 105.41 feet msl, NAVD 88

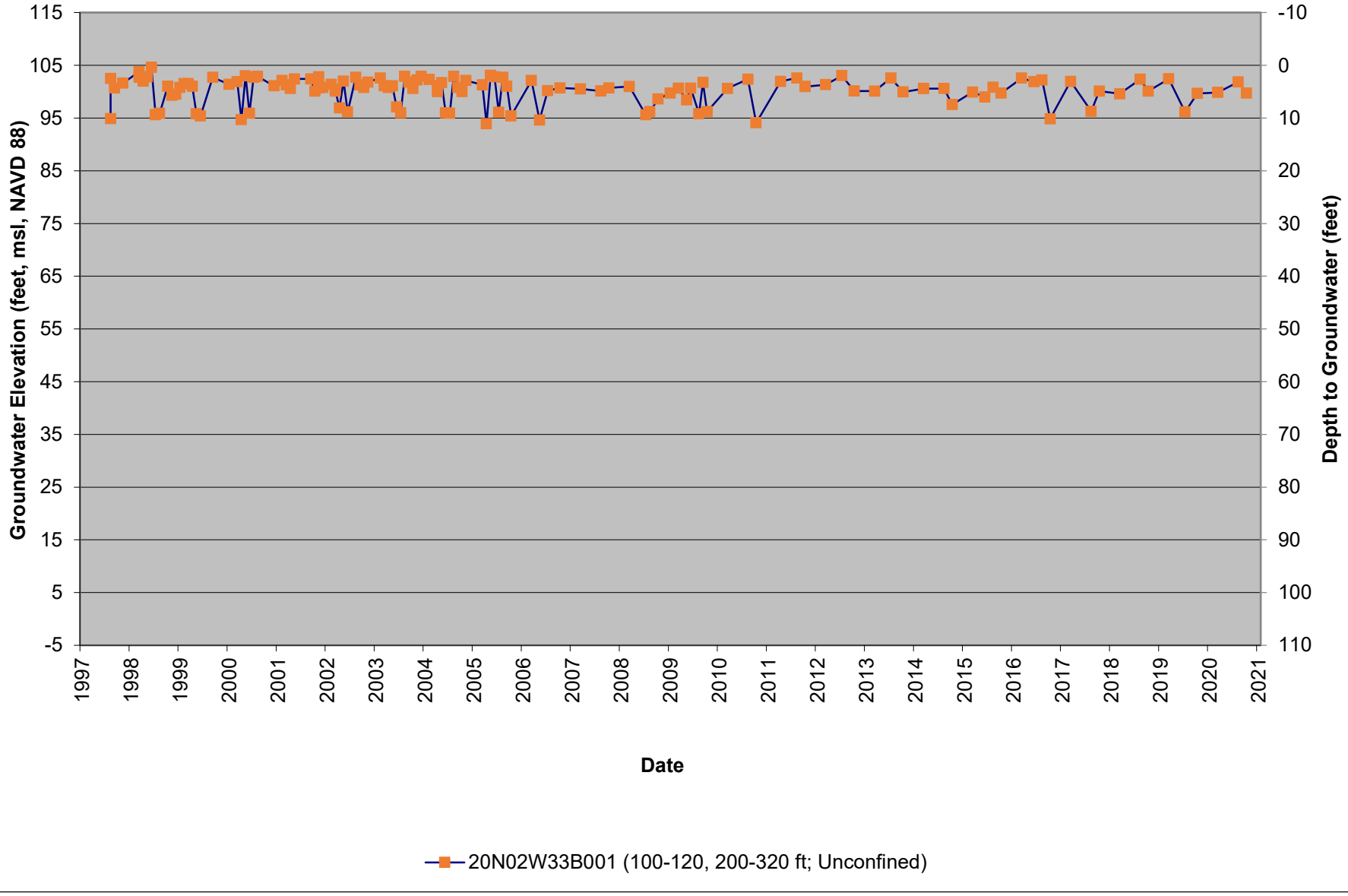


Figure 3A-39. 20N03W07E001-004M Active Observation Well Cluster
Ground Surface Elevation 179.17 feet msl, NAVD 88

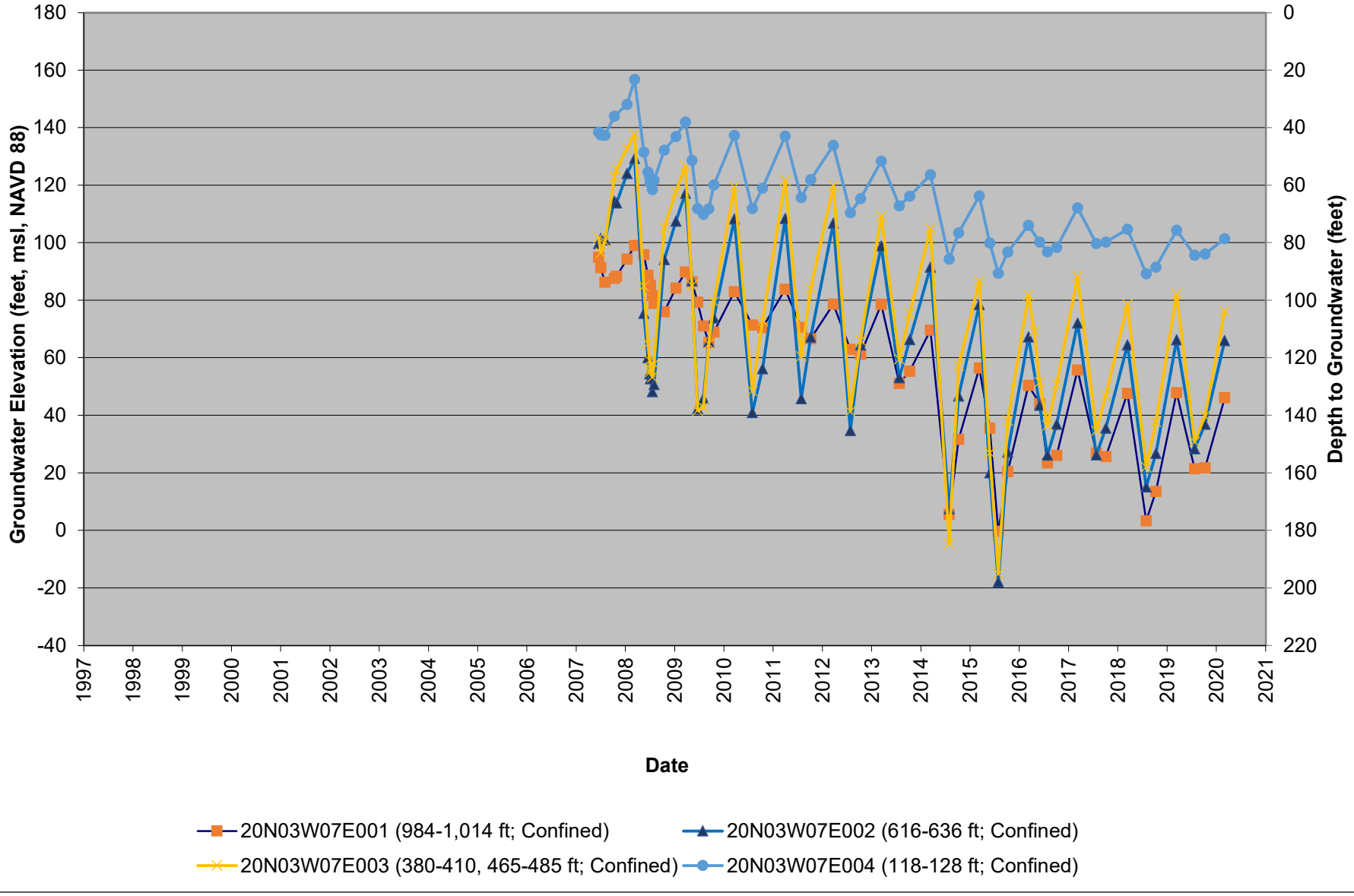


Figure 3A-40. 21N02W01F001-004M Active Observation Well Cluster
Ground Surface Elevation 160.88 feet msl, NAVD 88

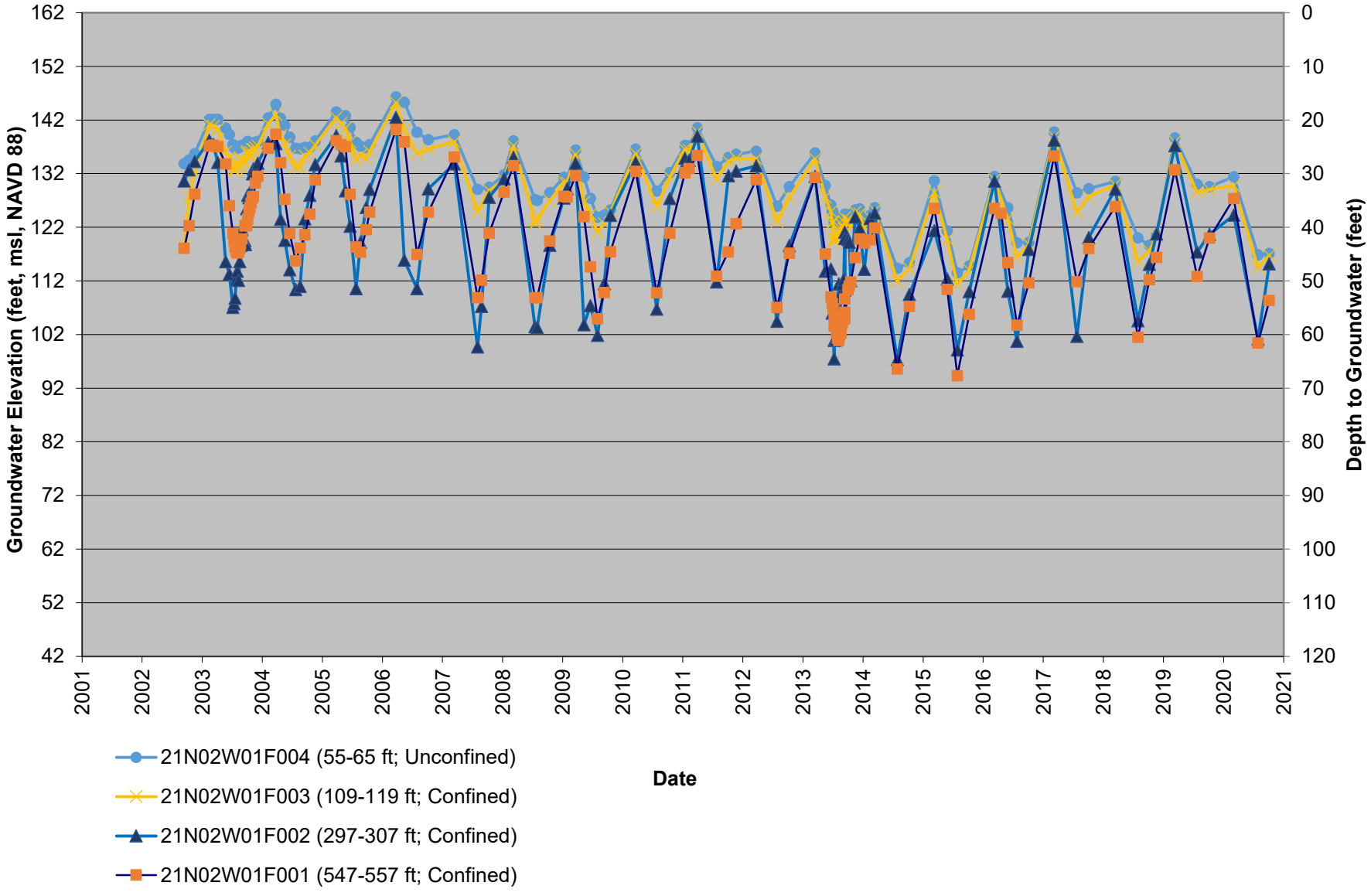


Figure 3A-41. 21N02W04G002-005M Active Observation Well Cluster
Ground Surface Elevation 178.41 feet msl, NAVD 88

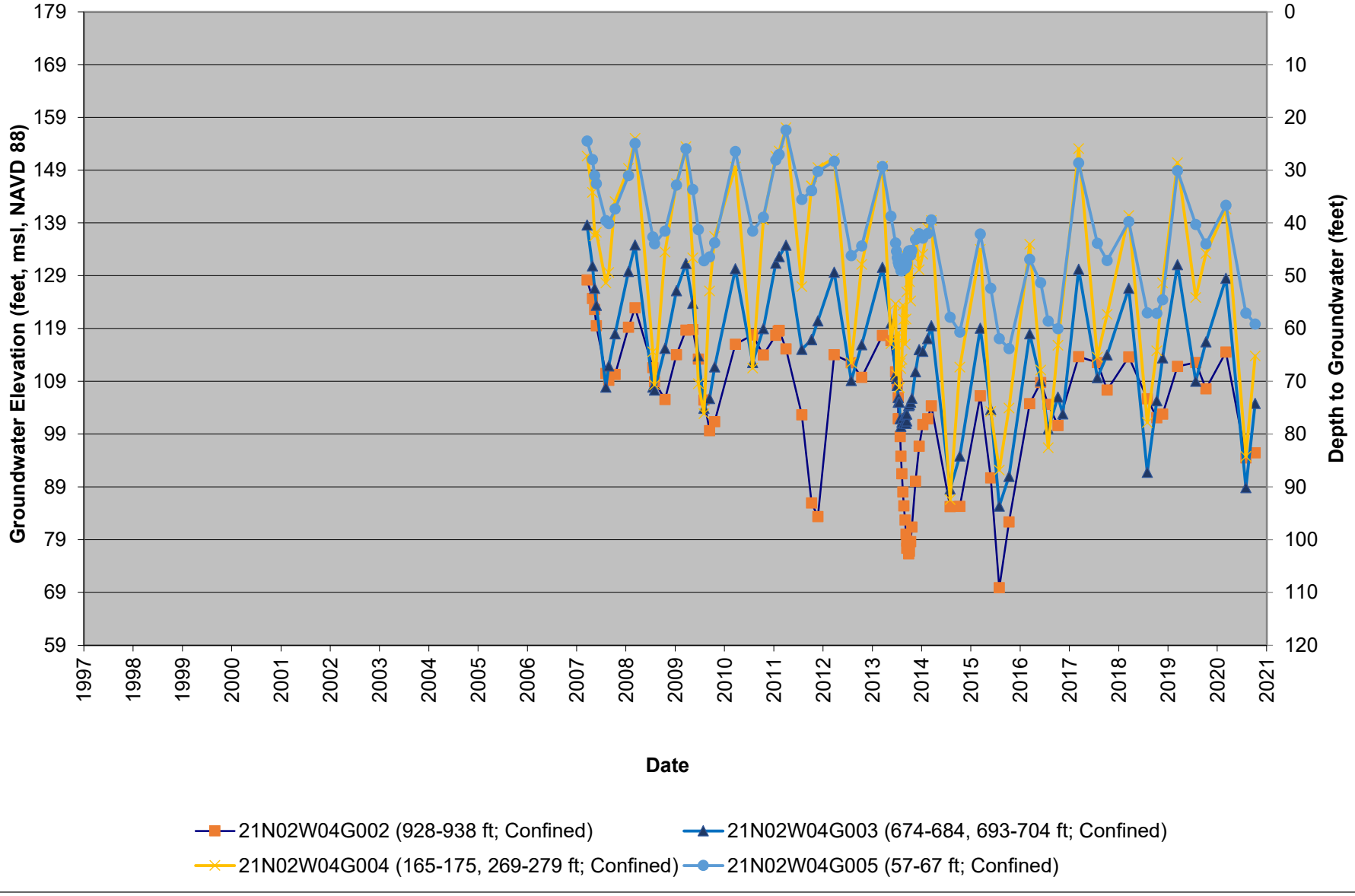


Figure 3A-42. 21N02W05M001-003M Active Observation Well Cluster
Ground Surface Elevation 188.93 feet msl, NAVD 88

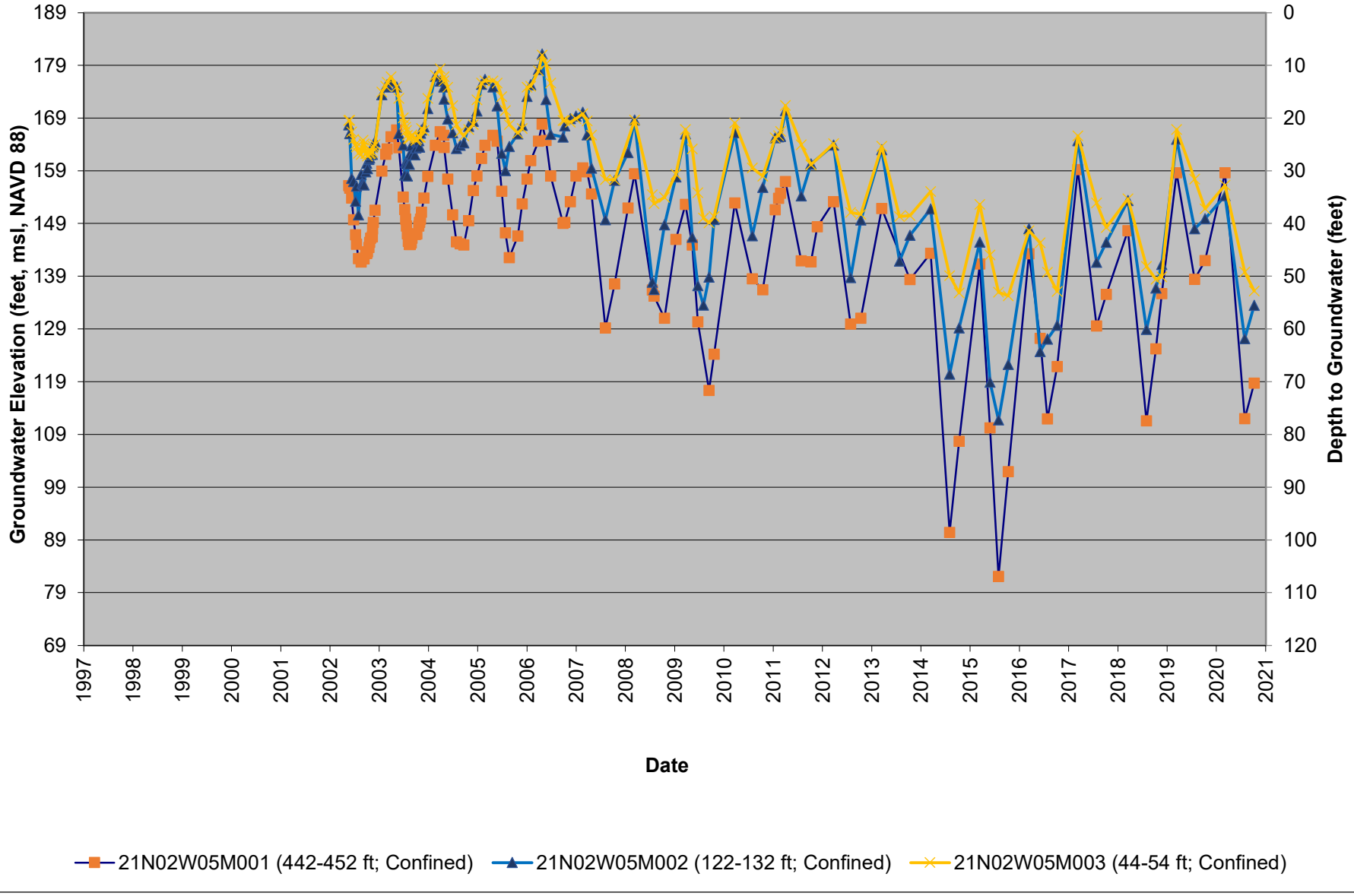


Figure 3A-43. 21N02W33M001-003M Active Observation Well Cluster
Ground Surface Elevation 149.00 feet msl, NAVD 88

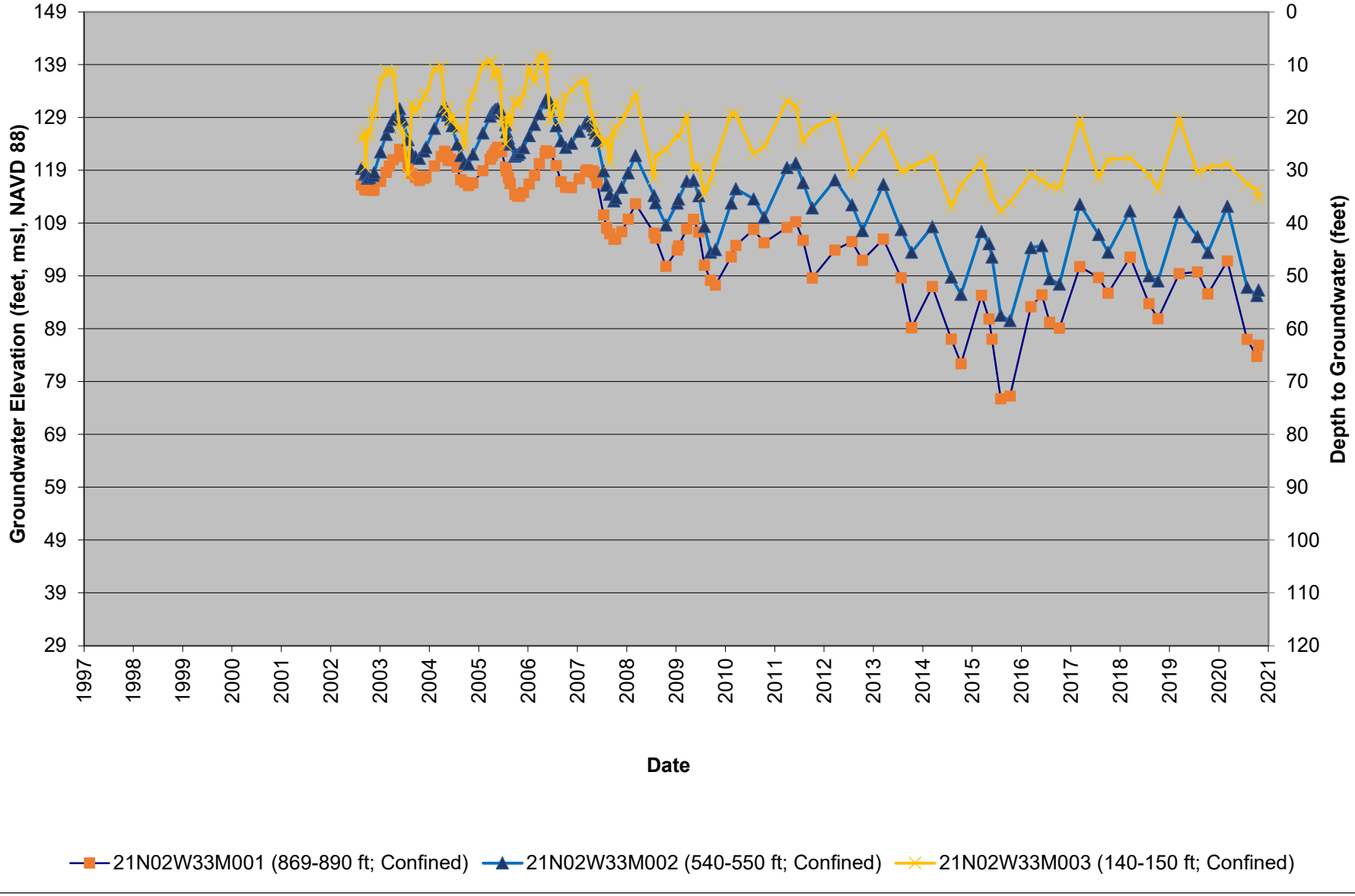


Figure 3A-44. 21N02W36A002M Active Observation Well
Ground Surface Elevation 135.39 feet msl, NAVD 88

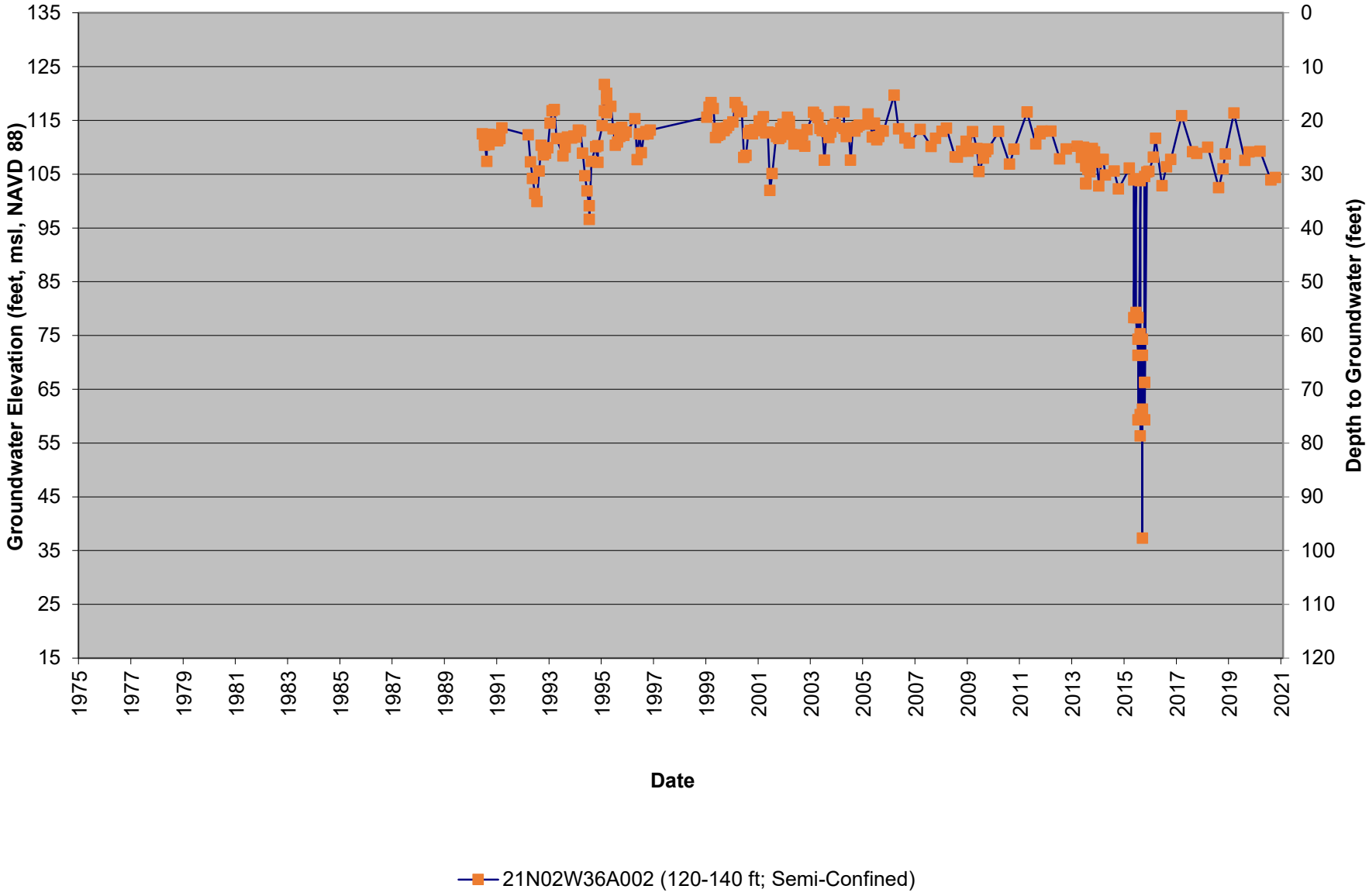


Figure 3A-45. 21N03W01R002M Active Observation Well
Ground Surface Elevation 203.32 feet msl, NAVD 88

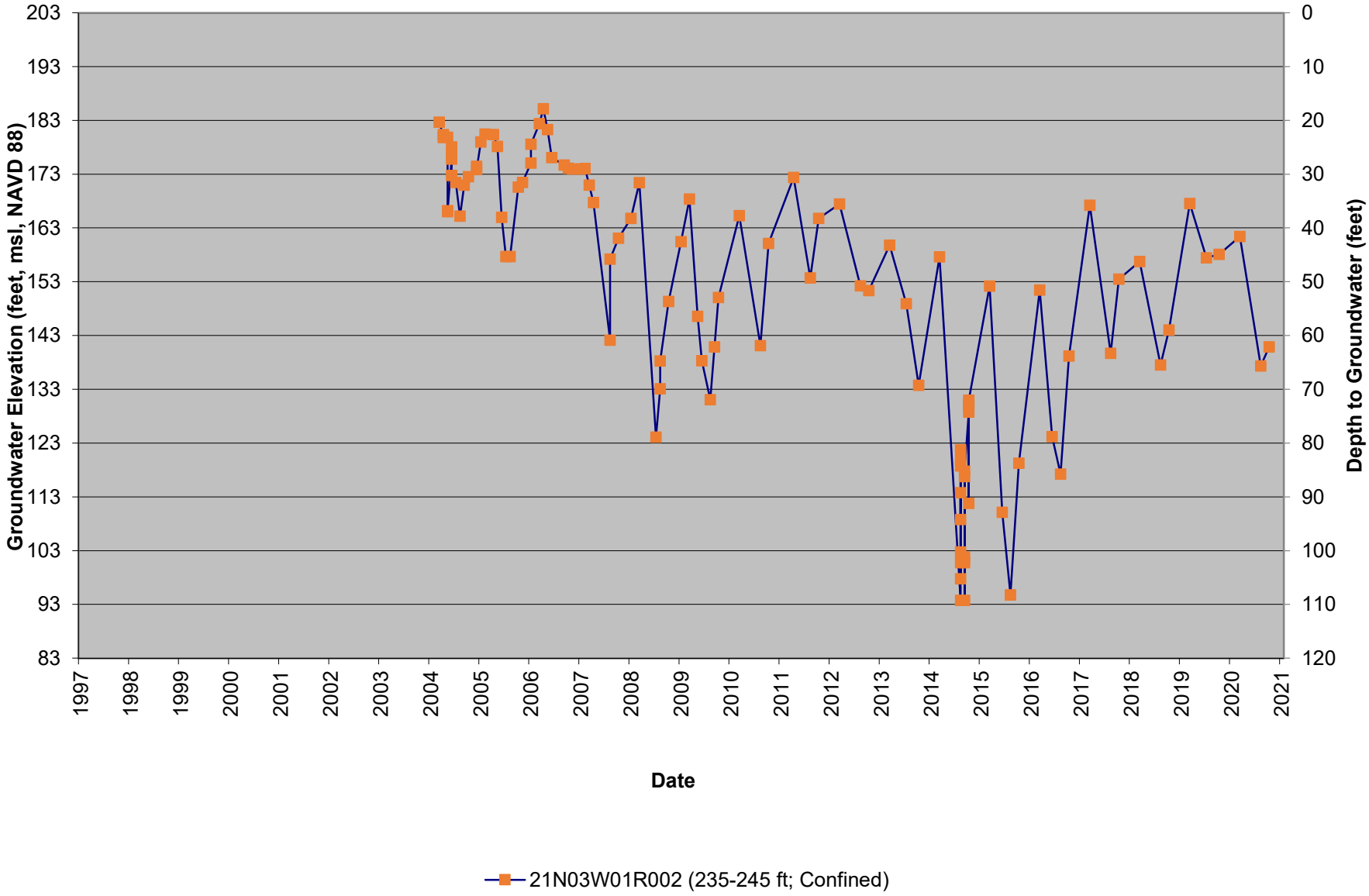


Figure 3A-46. 21N03W23D001-003M Active Observation Well Cluster
Ground Surface Elevation 204.76 feet msl, NAVD 88

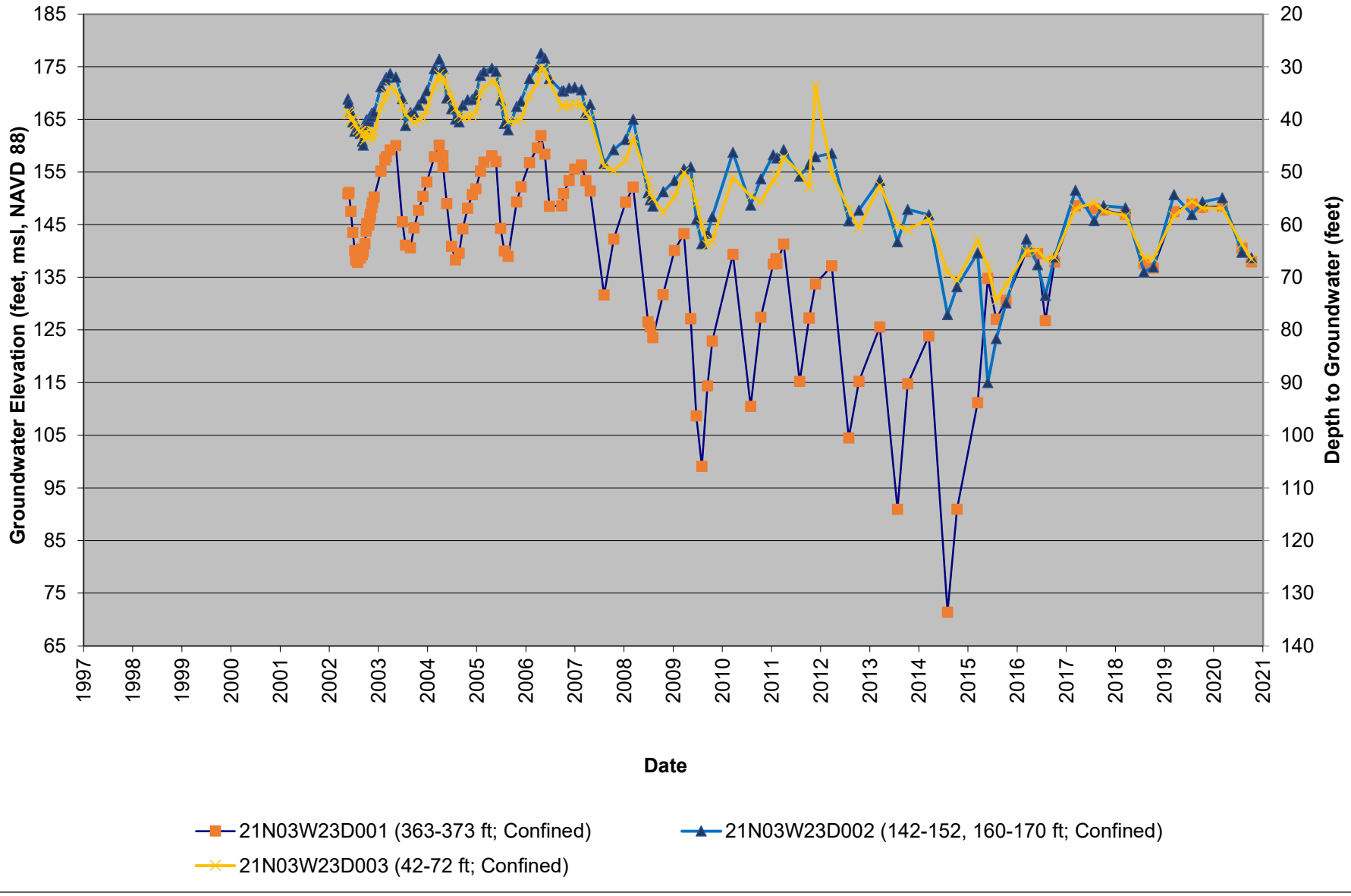


Figure 3A-47. 21N03W34Q002-004M Active Observation Well Cluster
Ground Surface Elevation 166.65 feet msl, NAVD 88

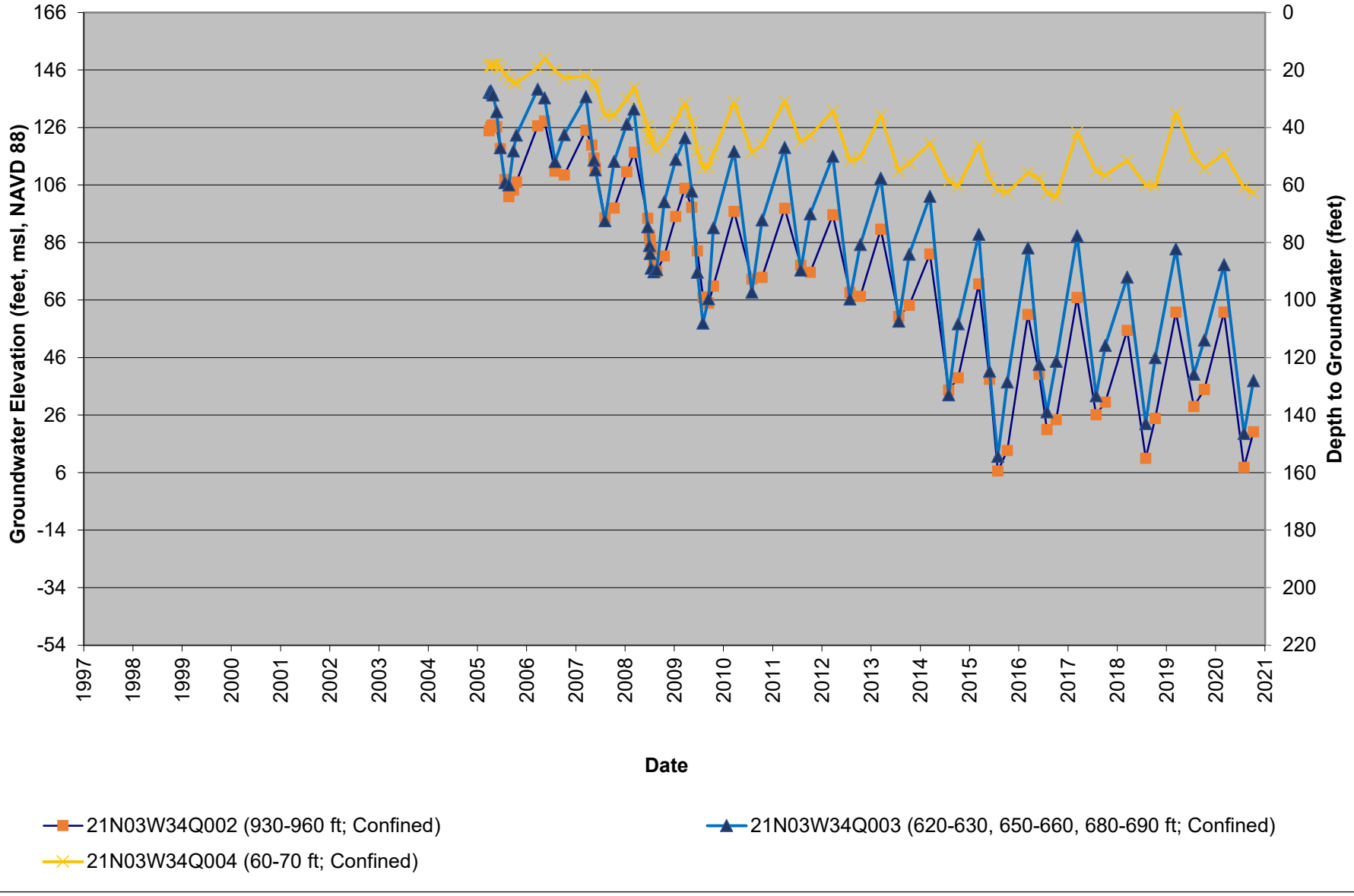


Figure 3A-48. 21N04W12A002-004M Active Observation Well Cluster
Ground Surface Elevation 247.88 feet msl, NAVD 88

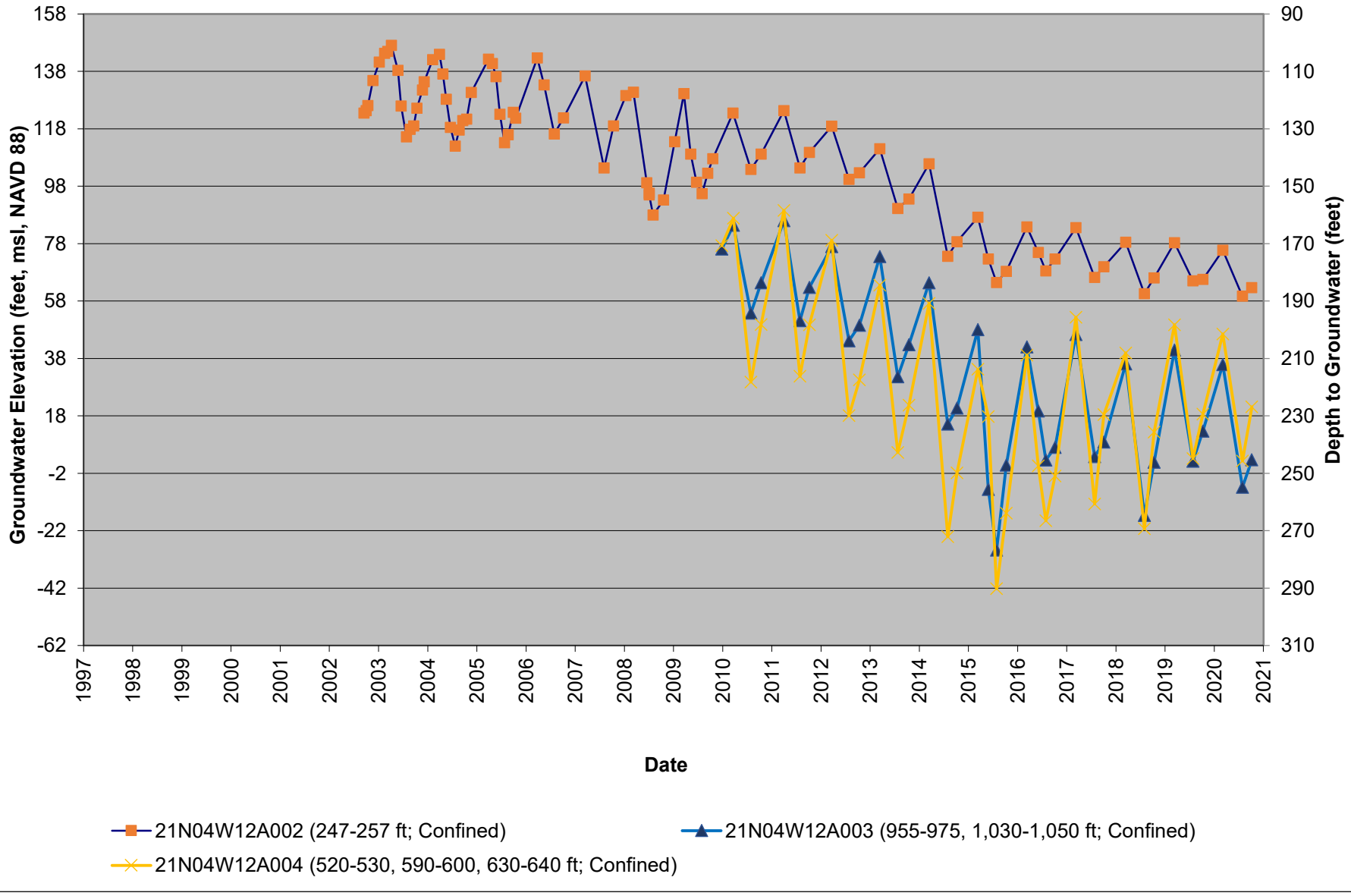


Figure 3A-49. 22N02W30H002-004M Active Observation Well Cluster
Ground Surface Elevation 204.43 feet msl, NAVD 88

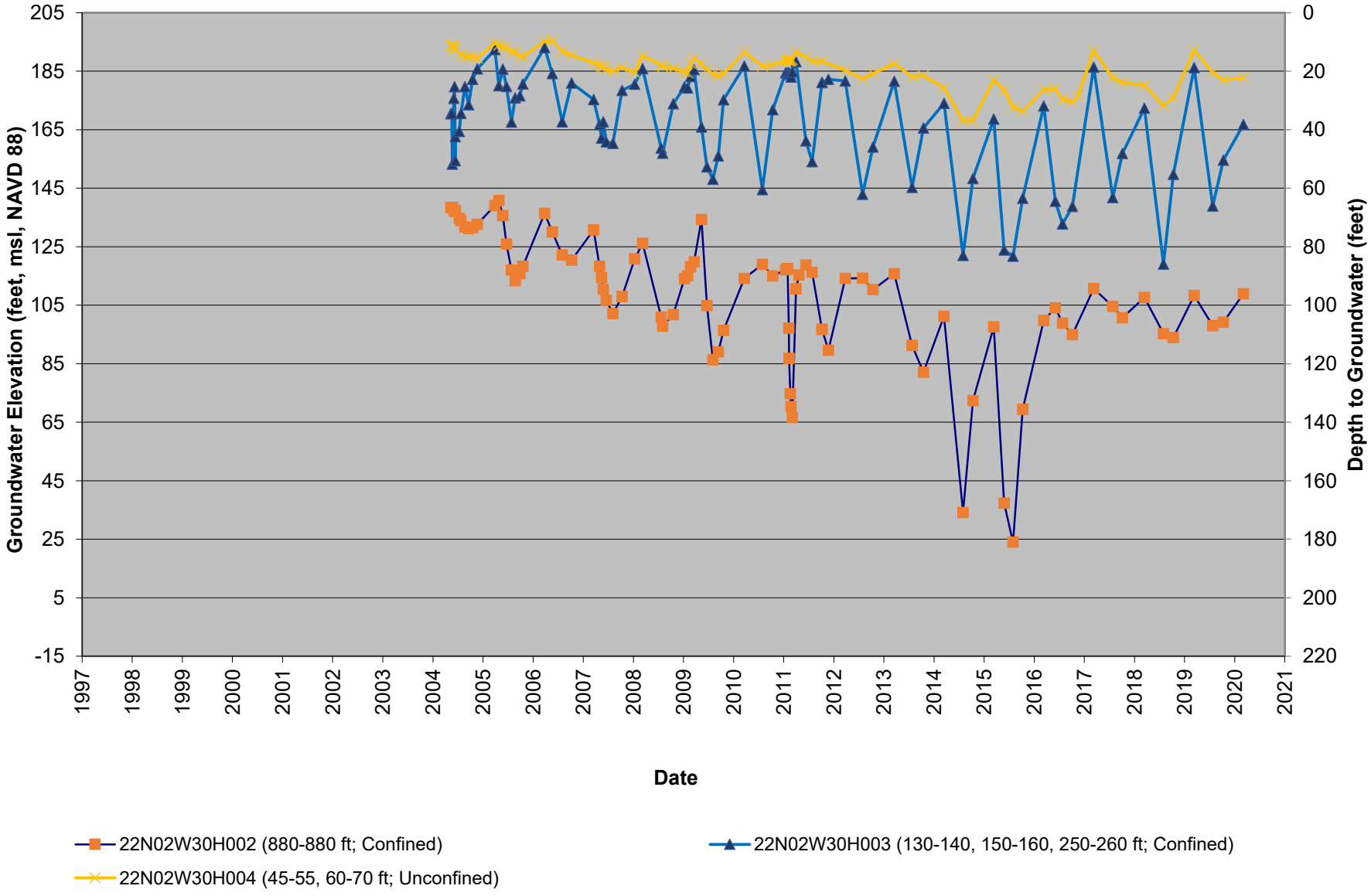


Figure 3A-50. 22N03W24E001-003M Active Observation Well Cluster
Ground Surface Elevation 230.51 feet msl, NAVD 88

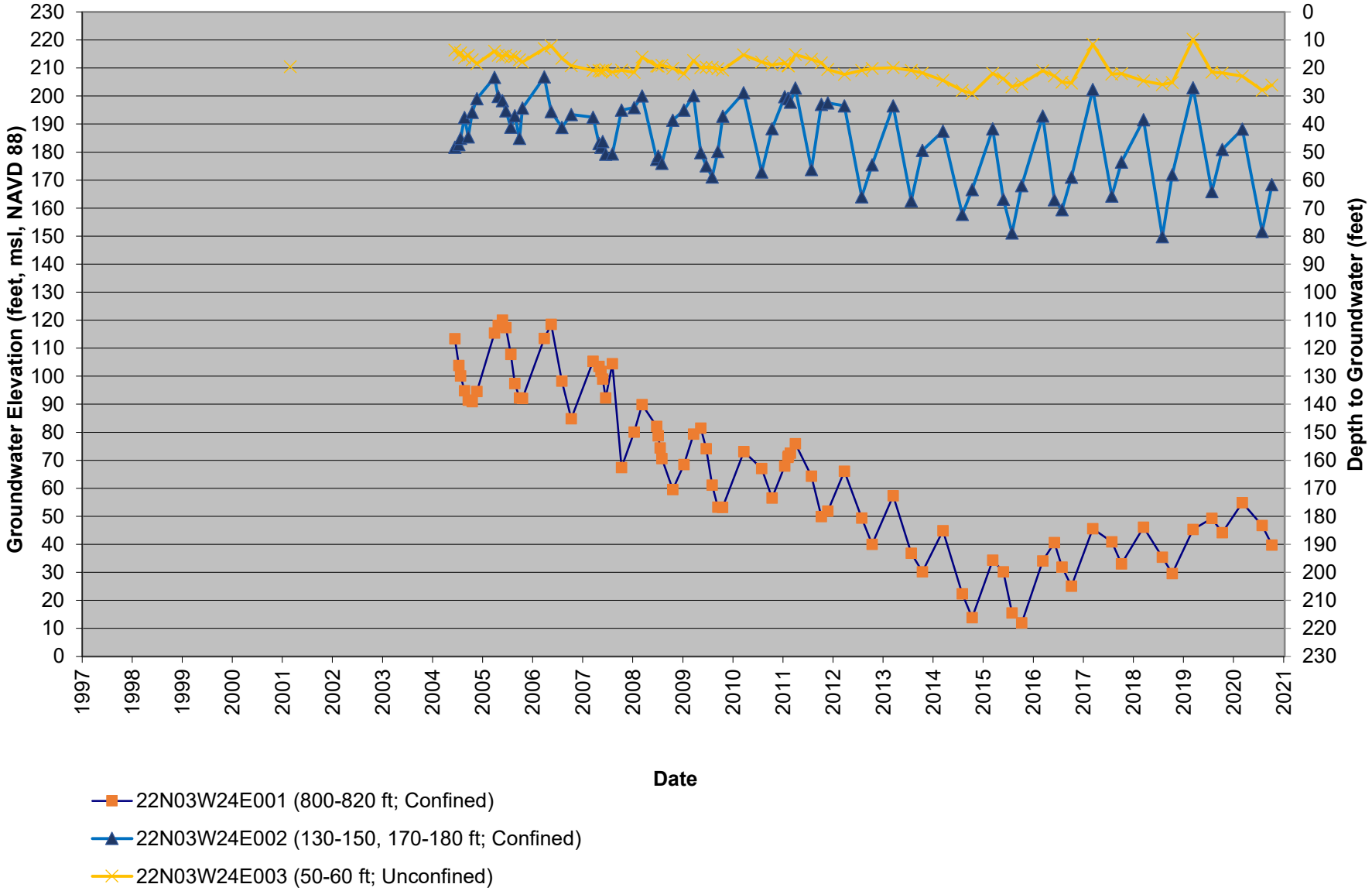
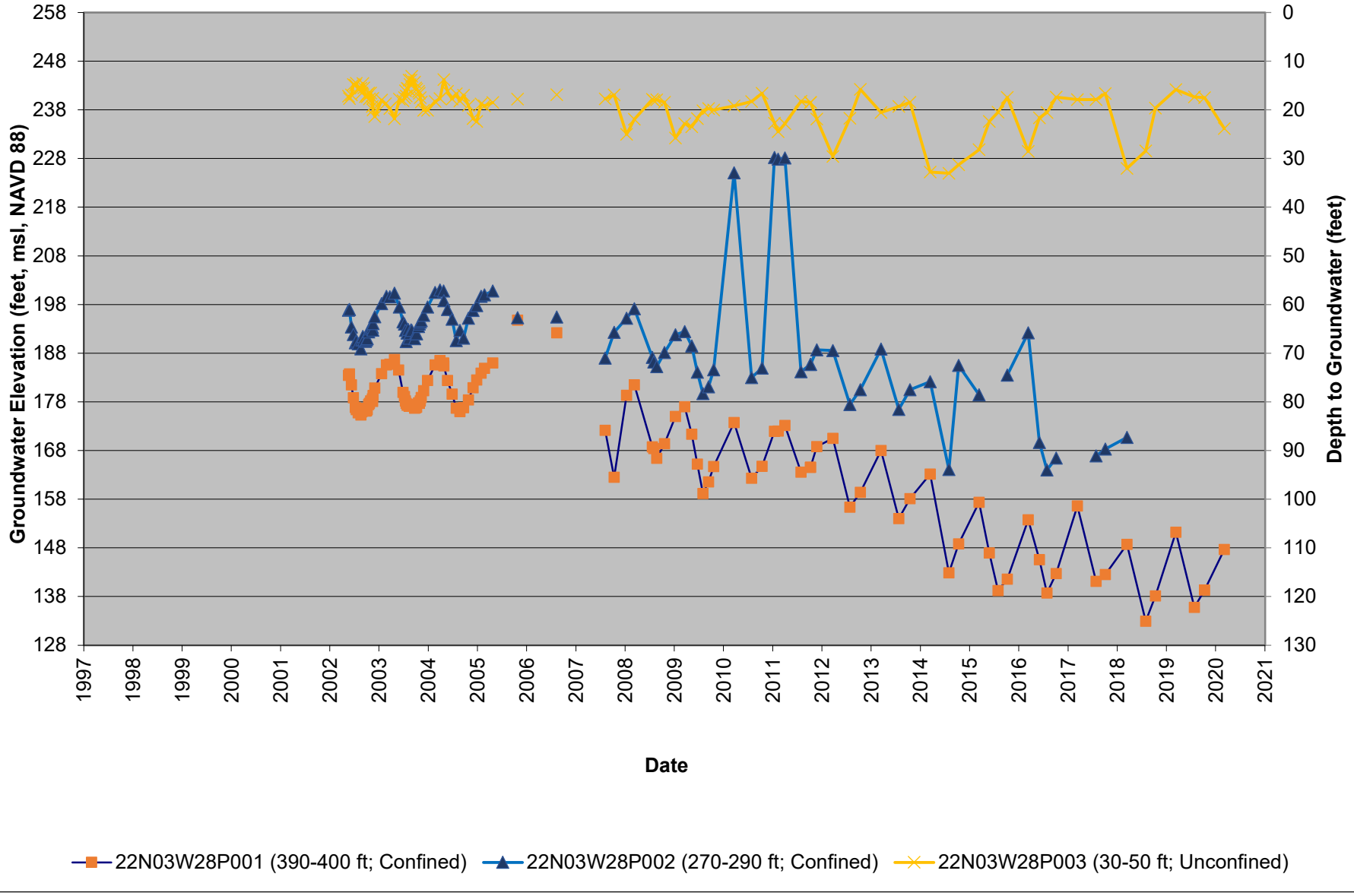


Figure 3A-51. 22N03W28P001-003M Active Observation Well Cluster
Ground Surface Elevation 258.22 feet msl, NAVD 88



Appendix 3B

Historical Groundwater Elevation Contour Maps

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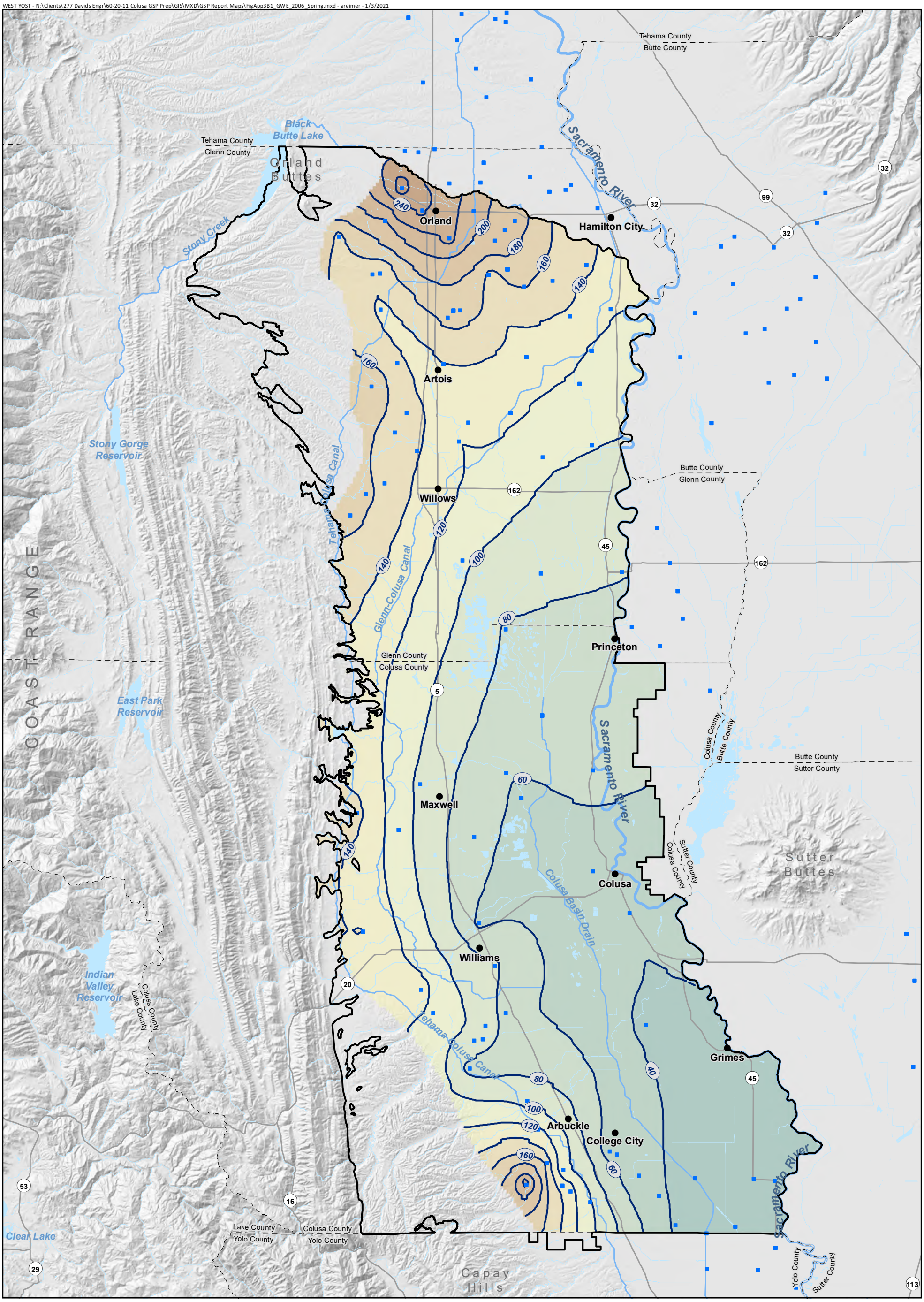


Groundwater Elevation (ft)

260 - 280	140 - 160	20 - 40
240 - 260	120 - 140	0 - 20
220 - 240	100 - 120	-20 - 0
200 - 220	80 - 100	-40 - -20
180 - 200	60 - 80	
160 - 180	40 - 60	

- Well Used for Contouring
- Groundwater Elevation Contour (20-Foot Interval)
- Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Vertical Datum: North American Vertical Datum of 1988, feet (NAVD 88).

N

0 2.5 5

Scale in Miles

Figure 3B-1

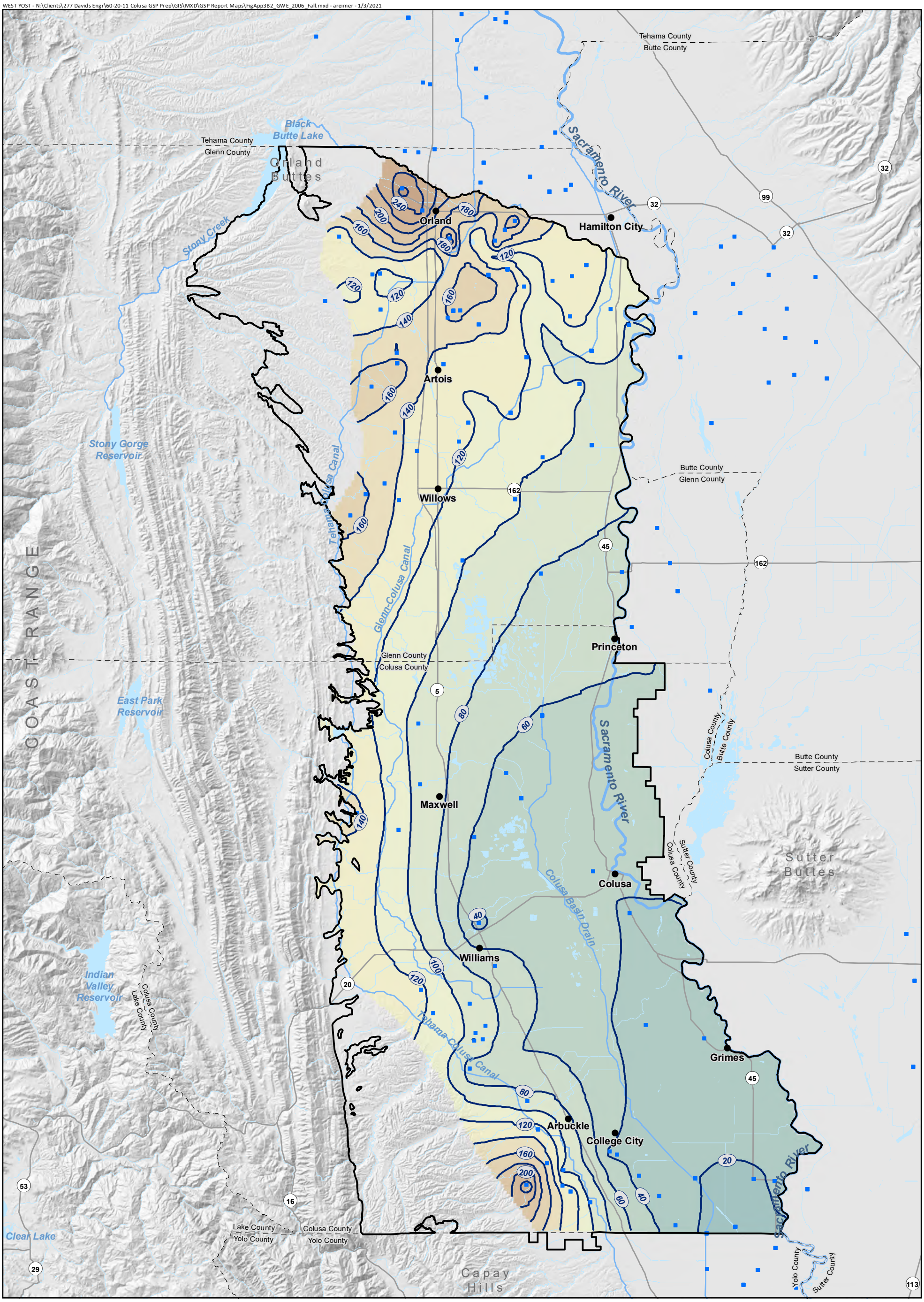
Groundwater Elevation Contours Spring 2006

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

WEST YOST - N:\Clients\277 Davids Engr\60-20-11 Colusa GSP Prep\GIS\MXD\GSP Report Maps\FigApp3B2_GWE_2006_Fall.mxd - areimer - 1/3/2021



Groundwater Elevation (ft)

- 260 - 280
- 240 - 260
- 220 - 240
- 200 - 220
- 180 - 200
- 160 - 180
- 140 - 160
- 120 - 140
- 100 - 120
- 80 - 100
- 60 - 80
- 40 - 60
- 20 - 40
- 0 - 20
- -20 - 0
- -40 - -20

- Well Used for Contouring
- Groundwater Elevation Contour (20-Foot Interval)
- Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Vertical Datum: North American Vertical Datum of 1988, feet (NAVD 88).

N

0 2.5 5

Scale in Miles

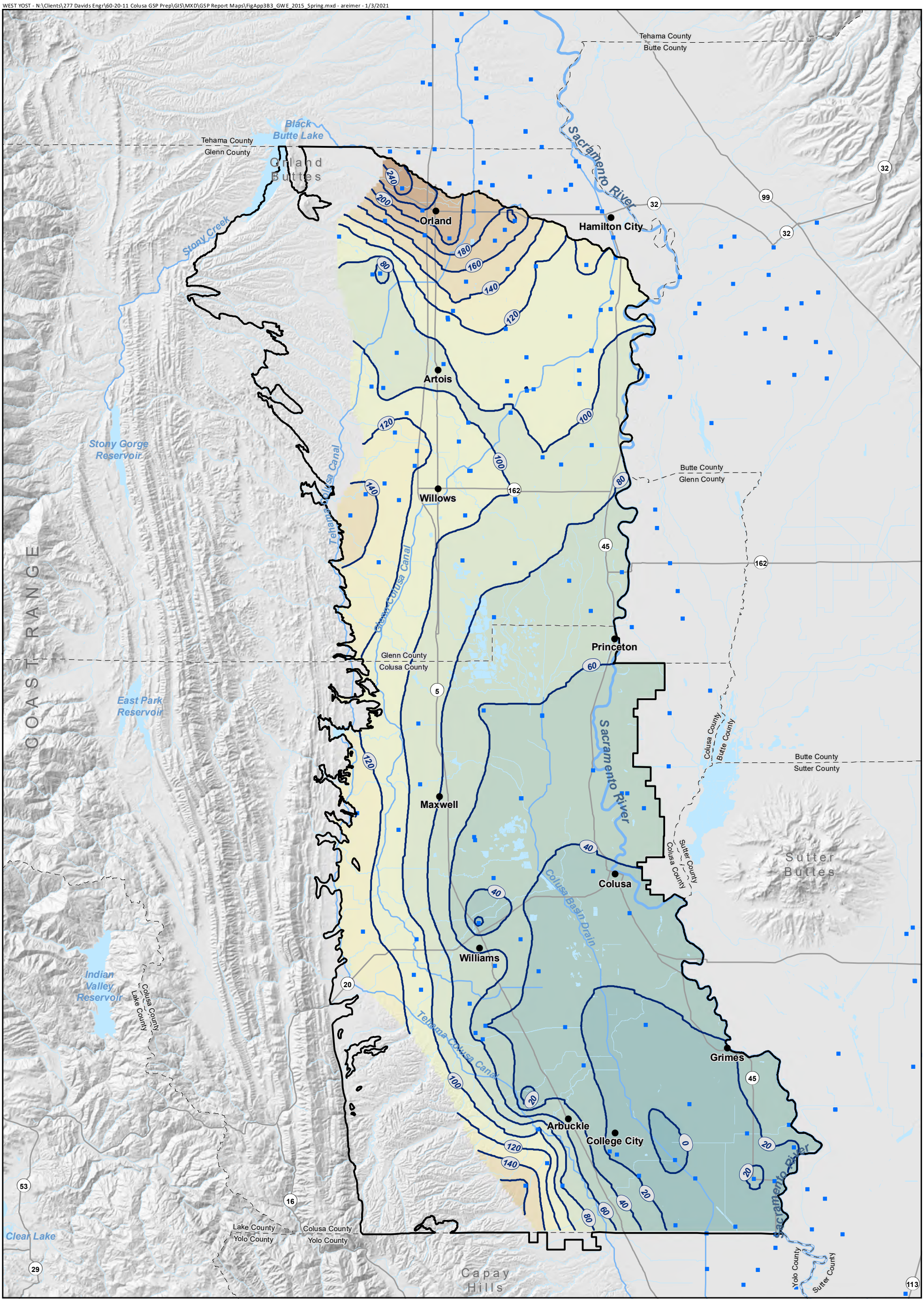
Figure 3B-2

Groundwater Elevation Contours Fall 2006

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan



Groundwater Elevation (ft)

260 - 280	140 - 160	20 - 40
240 - 260	120 - 140	0 - 20
220 - 240	100 - 120	-20 - 0
200 - 220	80 - 100	-40 - -20
180 - 200	60 - 80	
160 - 180	40 - 60	

Well Used for Contouring

Groundwater Elevation Contour (20-Foot Interval)

Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Vertical Datum: North American Vertical Datum of 1988, feet (NAVD 88).

N

0 2.5 5

Scale in Miles

Figure 3B-3

Groundwater Elevation Contours Spring 2015

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

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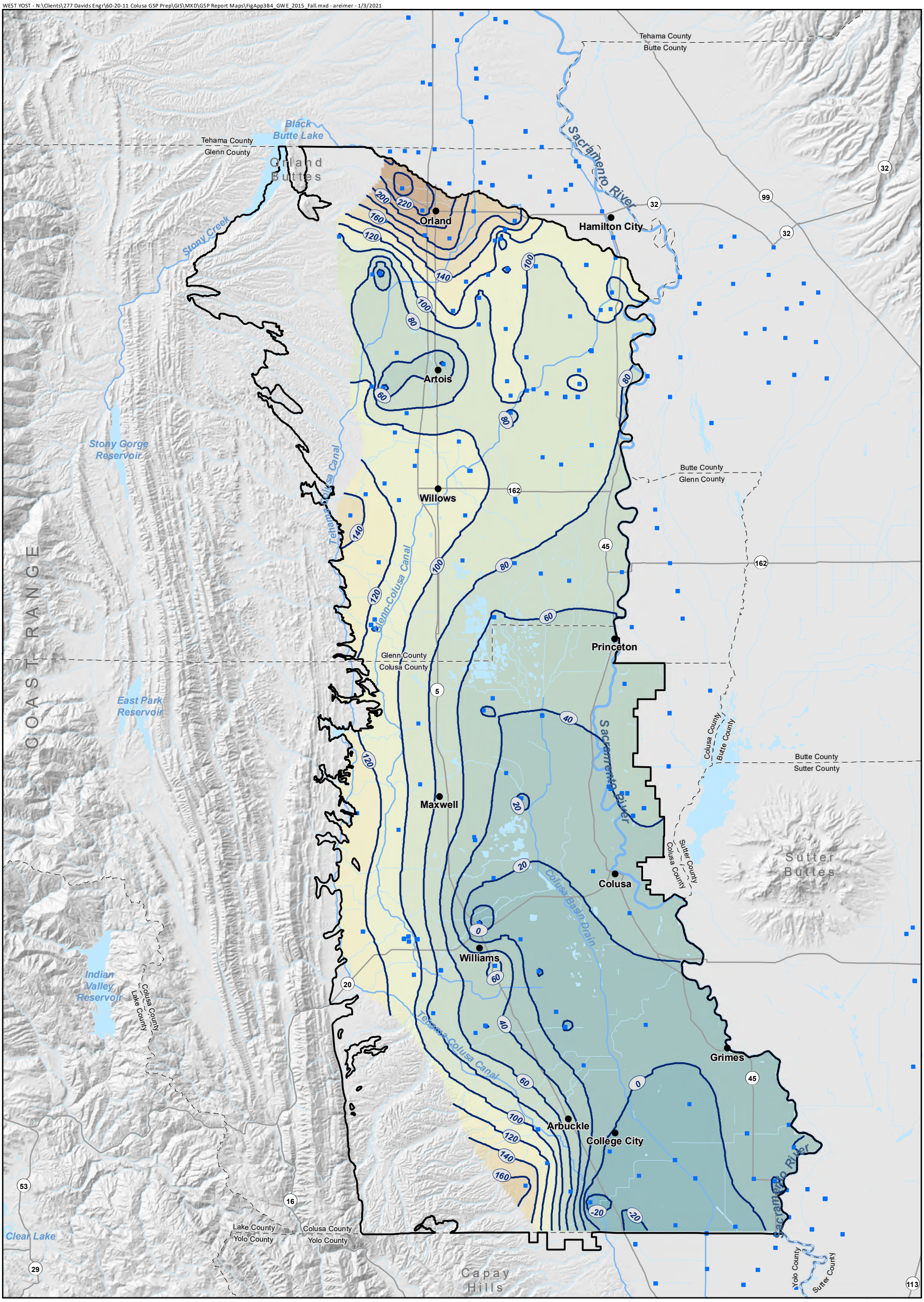

Groundwater Elevation (ft)

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Vertical Datum: North American Vertical Datum of 1988, feet (NAVD 88).

Figure 3B-4

Groundwater Elevation Contours Fall 2015

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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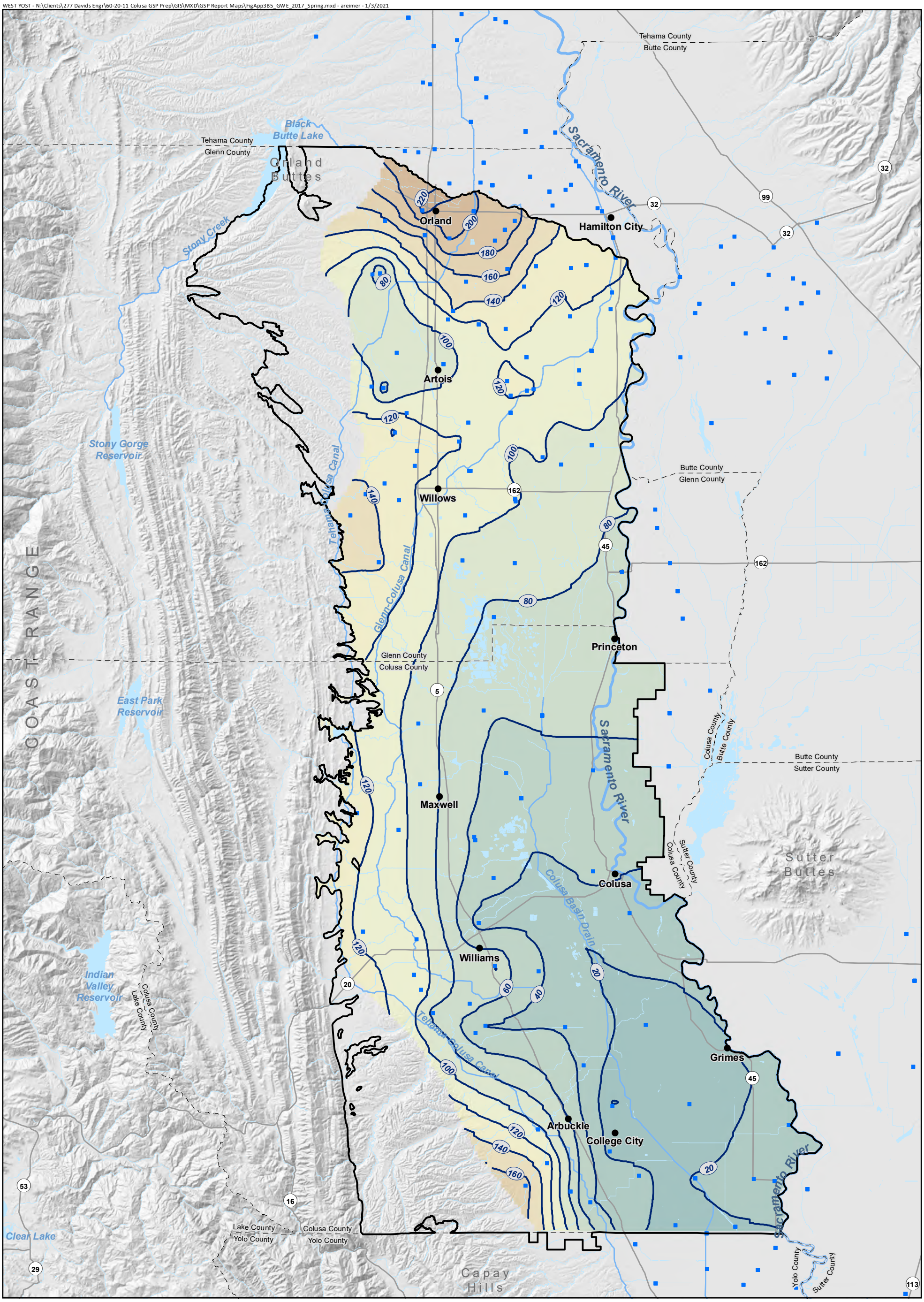


Groundwater Elevation (ft)

260 - 280	140 - 160	20 - 40
240 - 260	120 - 140	0 - 20
220 - 240	100 - 120	-20 - 0
200 - 220	80 - 100	-40 - -20
180 - 200	60 - 80	
160 - 180	40 - 60	

- Well Used for Contouring
- Groundwater Elevation Contour (20-Foot Interval)
- Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Vertical Datum: North American Vertical Datum of 1988, feet (NAVD 88).

N

0 2.5 5

Scale in Miles

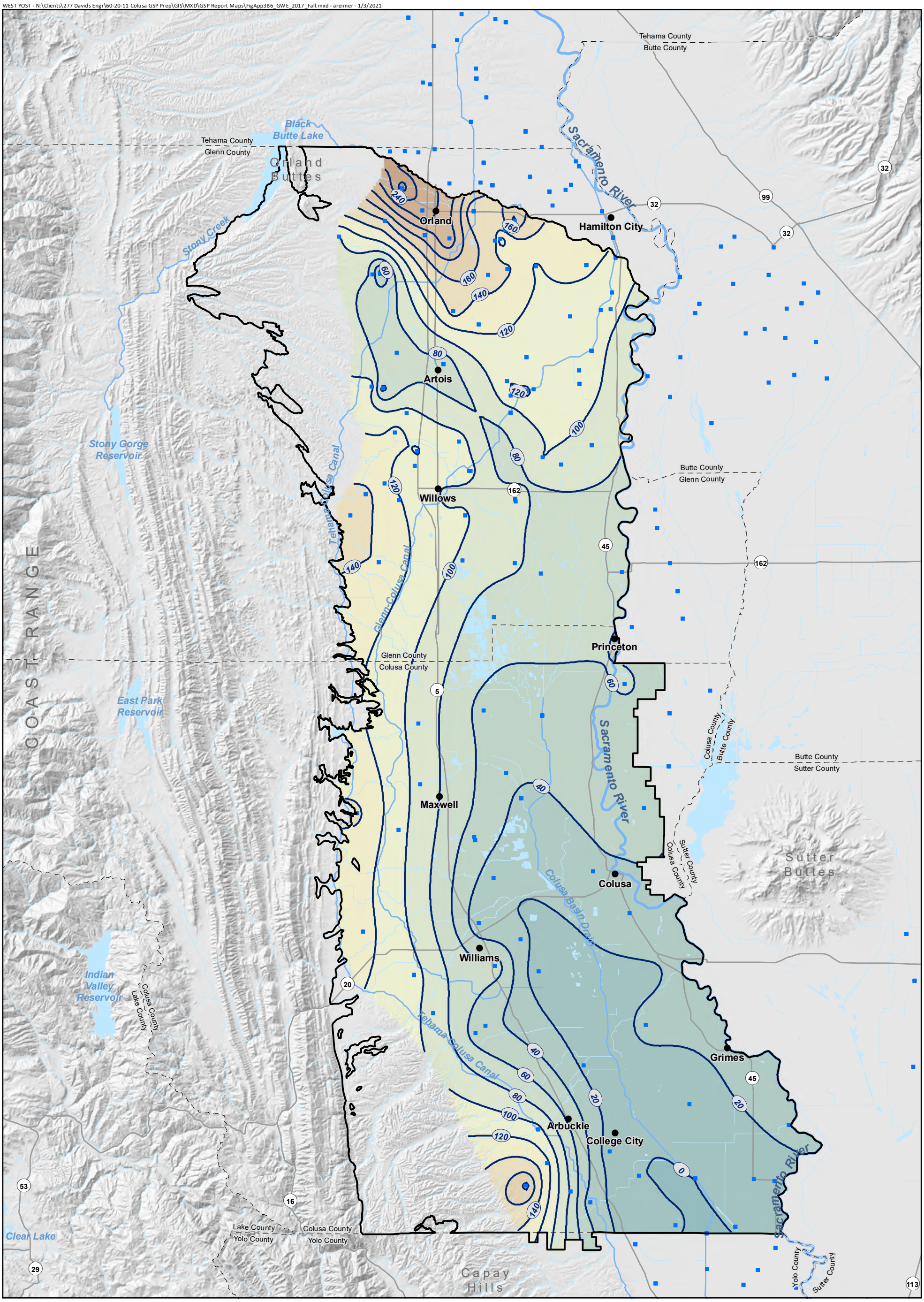
Figure 3B-5

Groundwater Elevation Contours Spring 2017

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan



Groundwater Elevation (ft)

- 260 - 280
- 240 - 260
- 220 - 240
- 200 - 220
- 180 - 200
- 160 - 180
- 140 - 160
- 120 - 140
- 100 - 120
- 80 - 100
- 60 - 80
- 40 - 60
- 20 - 40
- 0 - 20
- -20 - 0
- -40 - -20

Well Used for Contouring

Groundwater Elevation Contour (20-Foot Interval)

Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Vertical Datum: North American Vertical Datum of 1988, feet (NAVD 88).

N

0 2.5 5

Scale in Miles

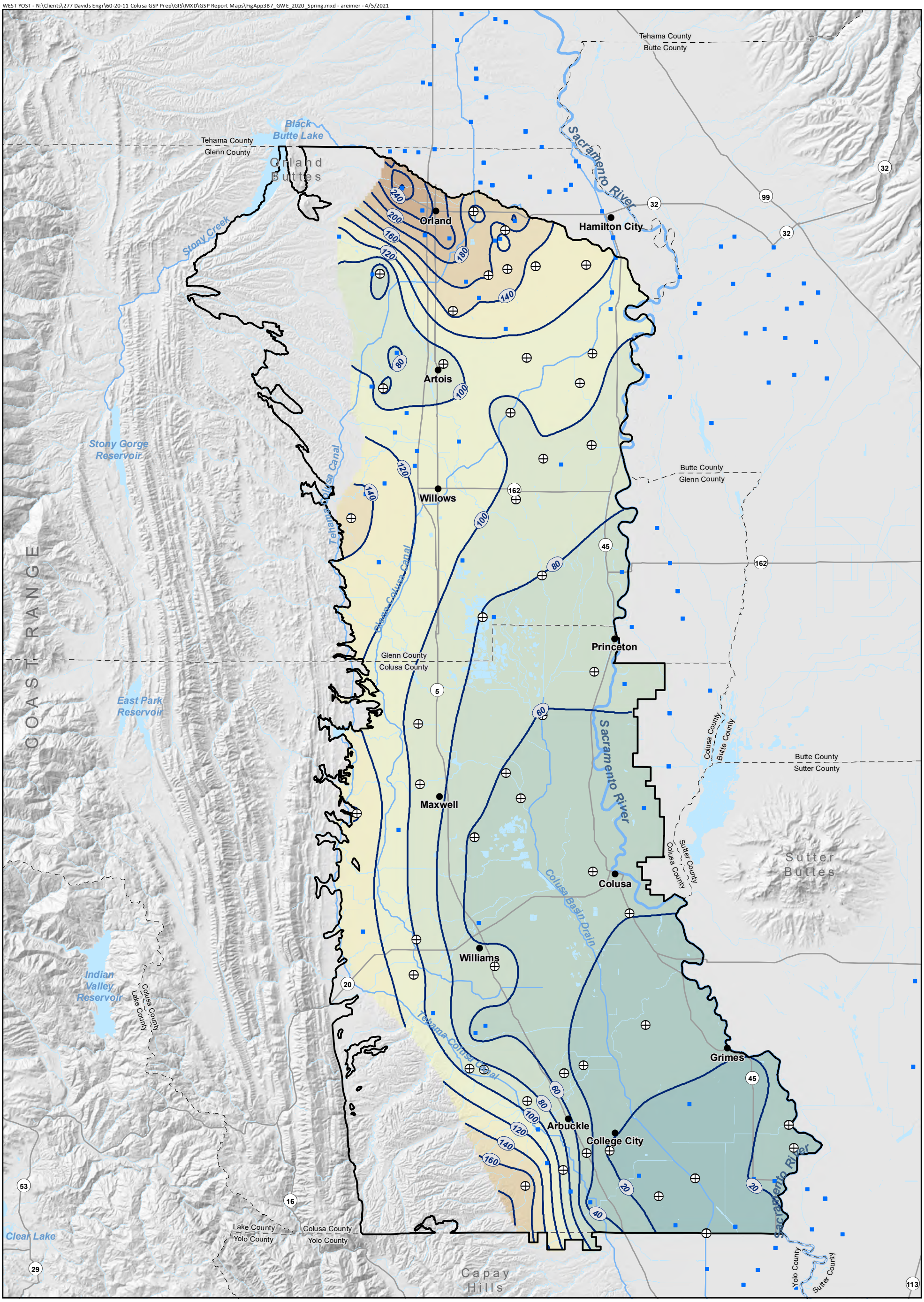
Figure 3B- 6

Groundwater Elevation Contours Fall 2017

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan



Groundwater Elevation (ft)

260 - 280	140 - 160	20 - 40
240 - 260	120 - 140	0 - 20
220 - 240	100 - 120	-20 - 0
200 - 220	80 - 100	-40 - -20
180 - 200	60 - 80	
160 - 180	40 - 60	

- Well Used for Contouring
- Monitoring Network Wells
- Groundwater Elevation Contour (20-Foot Interval)
- Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Vertical Datum: North American Vertical Datum of 1988, feet (NAVD 88).

N

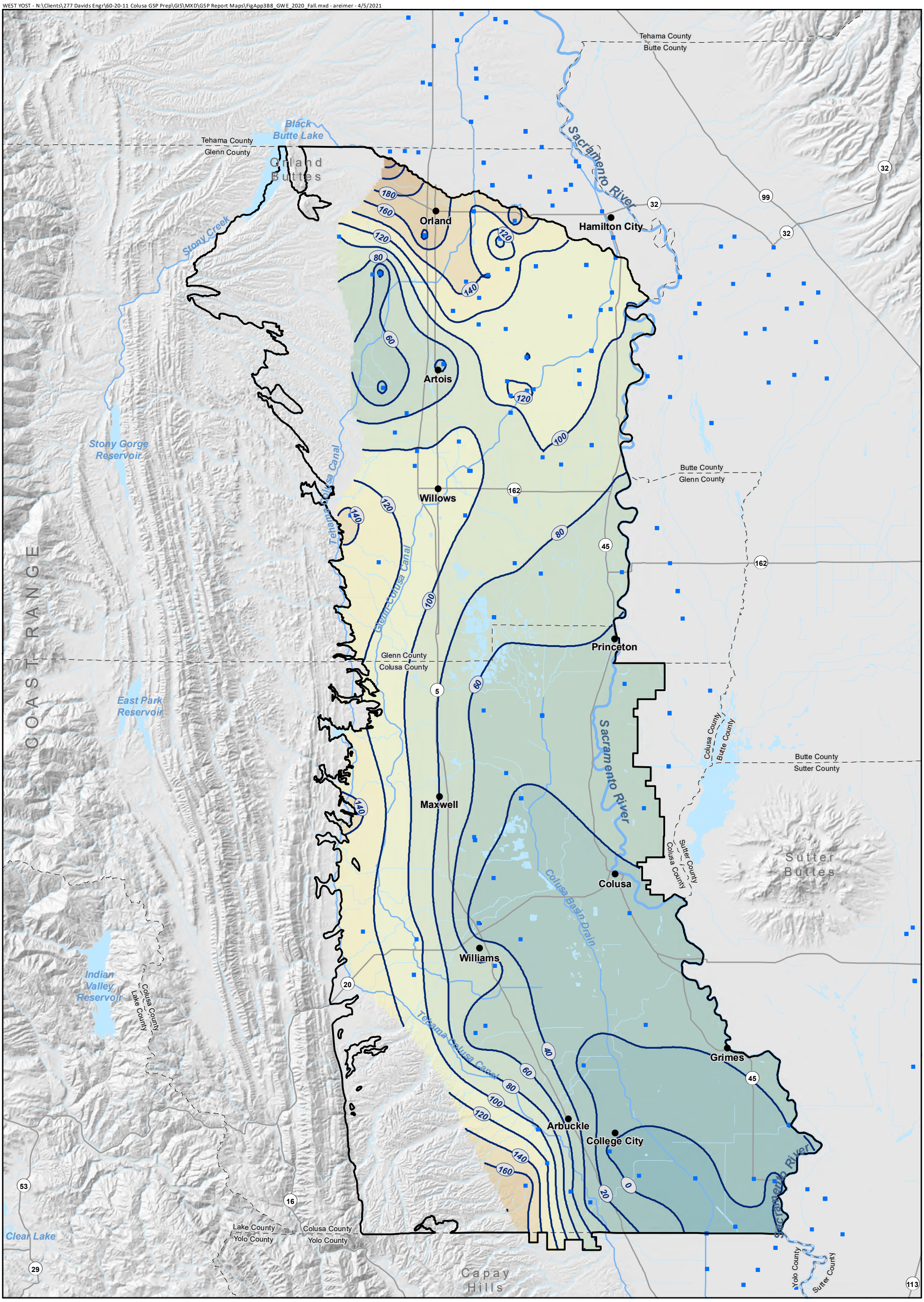
0 2.5 5

Scale in Miles

Figure 3B-7

Groundwater Elevation Contours Spring 2020

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan



Groundwater Elevation (ft)

- 260 - 280
- 240 - 260
- 220 - 240
- 200 - 220
- 180 - 200
- 160 - 180
- 140 - 160
- 120 - 140
- 100 - 120
- 80 - 100
- 60 - 80
- 40 - 60
- 20 - 40
- 0 - 20
- -20 - 0
- -40 - -20

Well Used for Contouring

Groundwater Elevation Contour (20-Foot Interval)

Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Vertical Datum: North American Vertical Datum of 1988, feet (NAVD 88).

N

0 2.5 5

Scale in Miles

Figure 3B-8

Groundwater Elevation Contours Fall 2020

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

Appendix 3C

Extensometer Measurements

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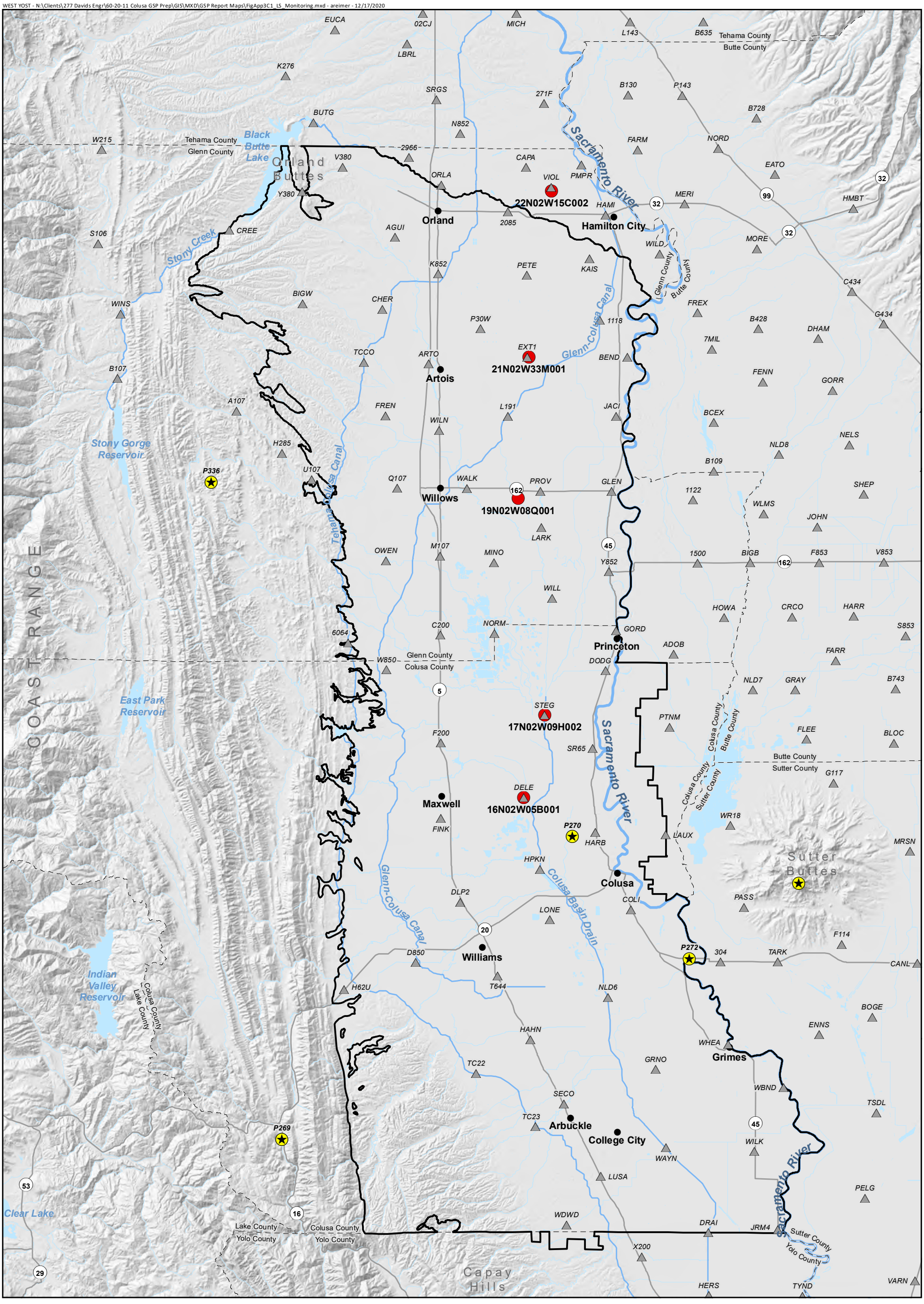

- Sacramento Valley Benchmark
- Extensometer
- Continuous GPS Station
- Colusa Subbasin

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

N

0 2.5 5

Scale in Miles

Figure 3C-1

Land Subsidence Monitoring Networks

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

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Figure 3C-2. Extensometer Data for 16N02W05B001M

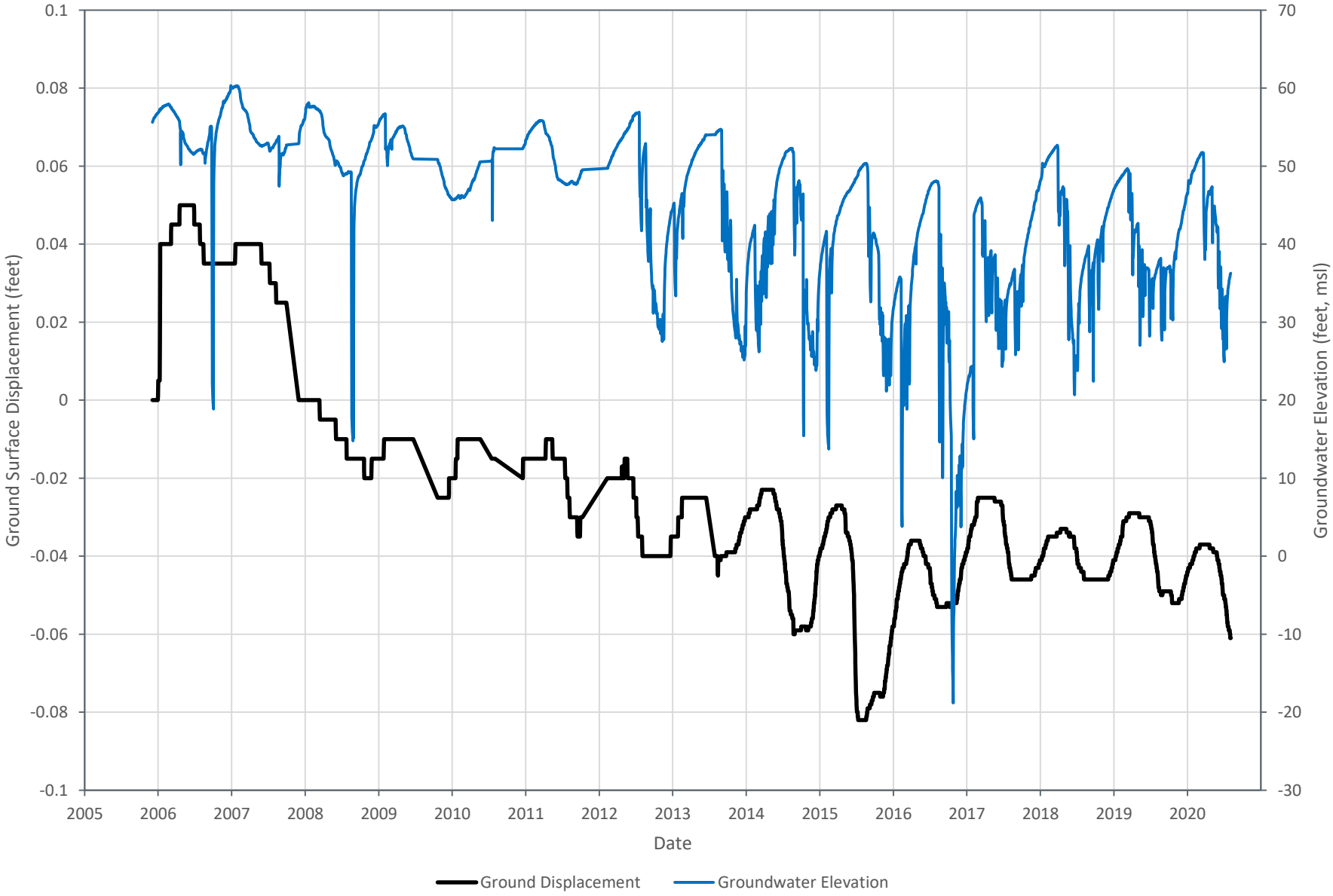


Figure 3C-3. Extensometer Data for 17N02W09H002M

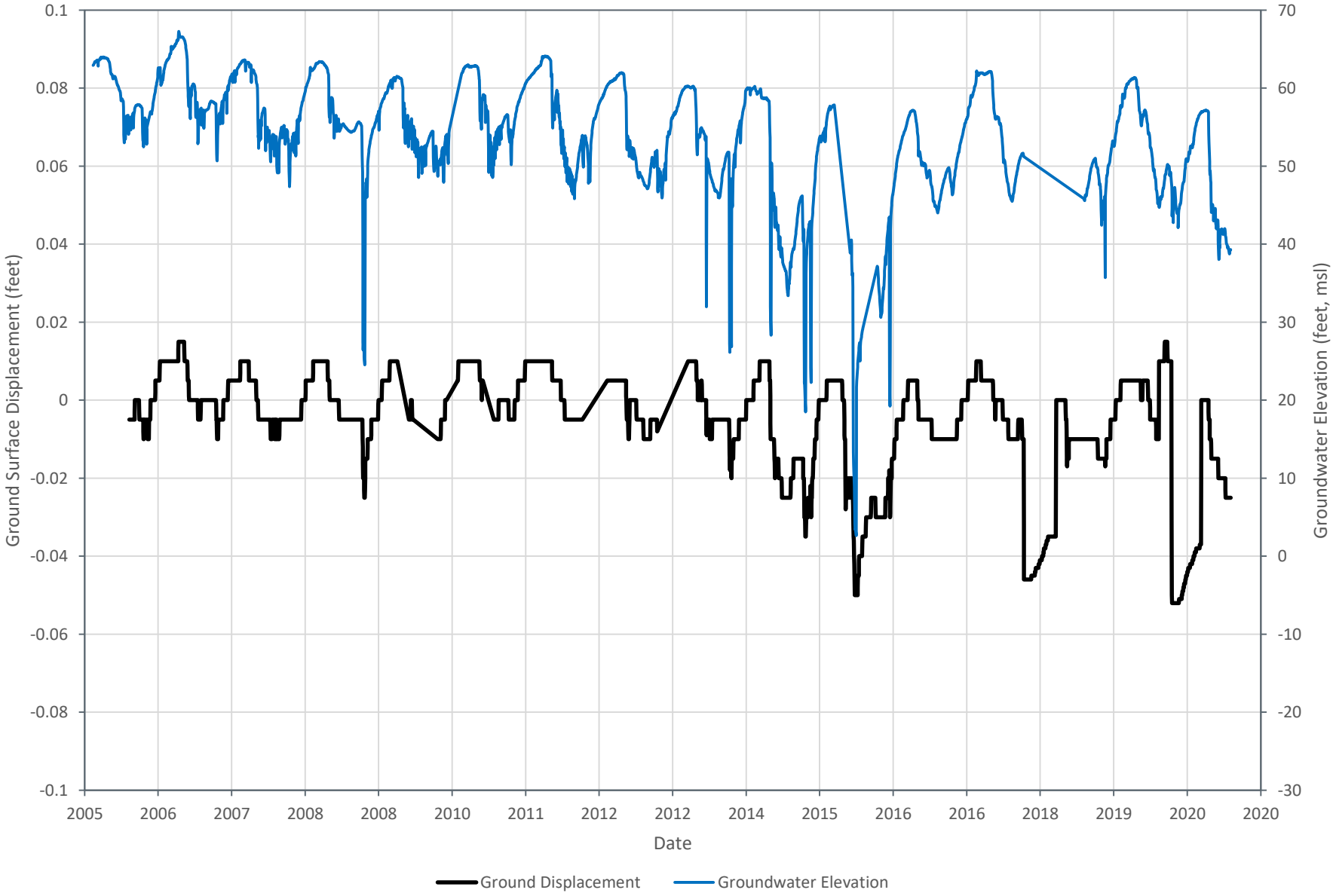


Figure 3C-4. Extensometer Data for 19N02W08Q001M

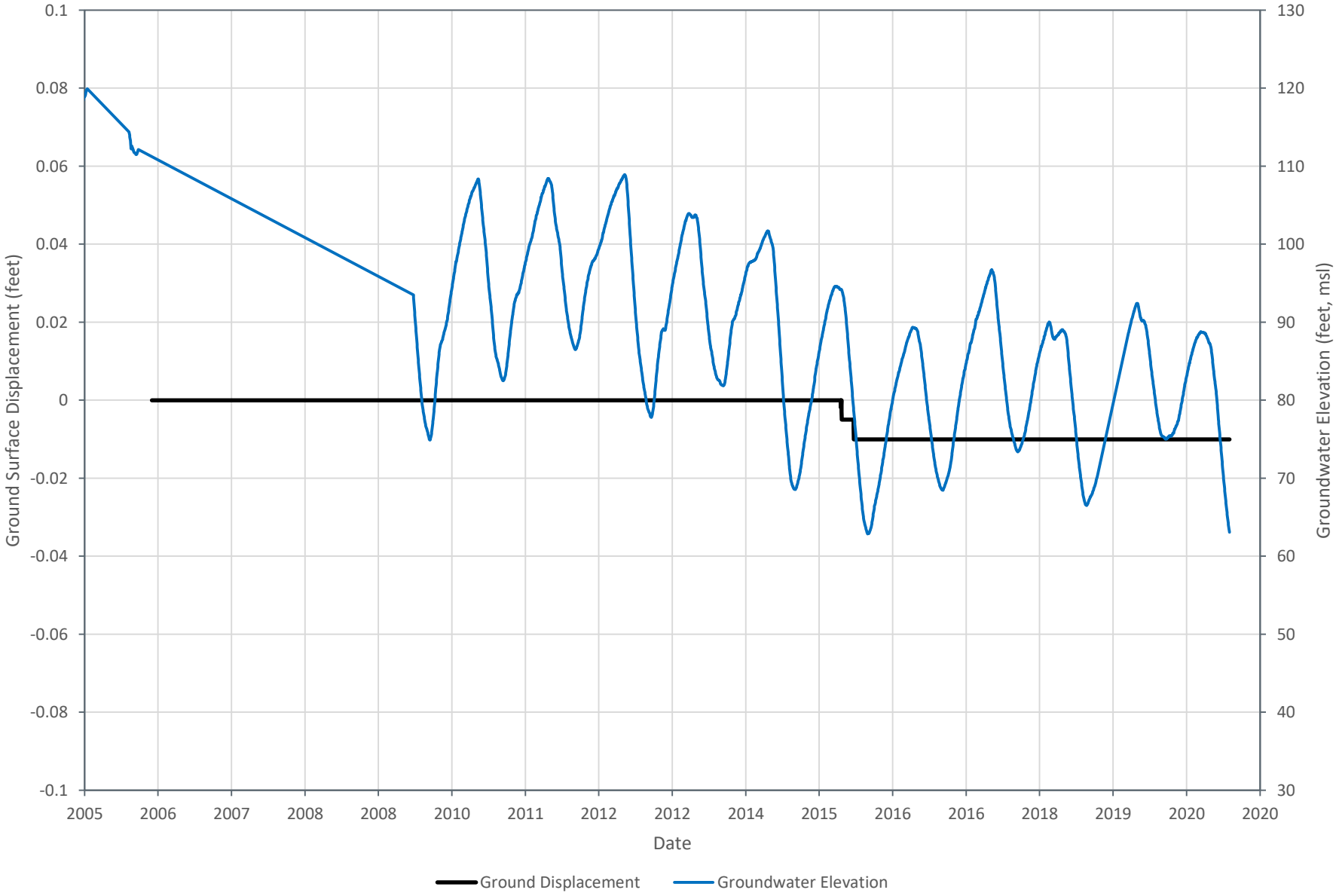


Figure 3C-5. Extensometer Data for 21N02W33M001M

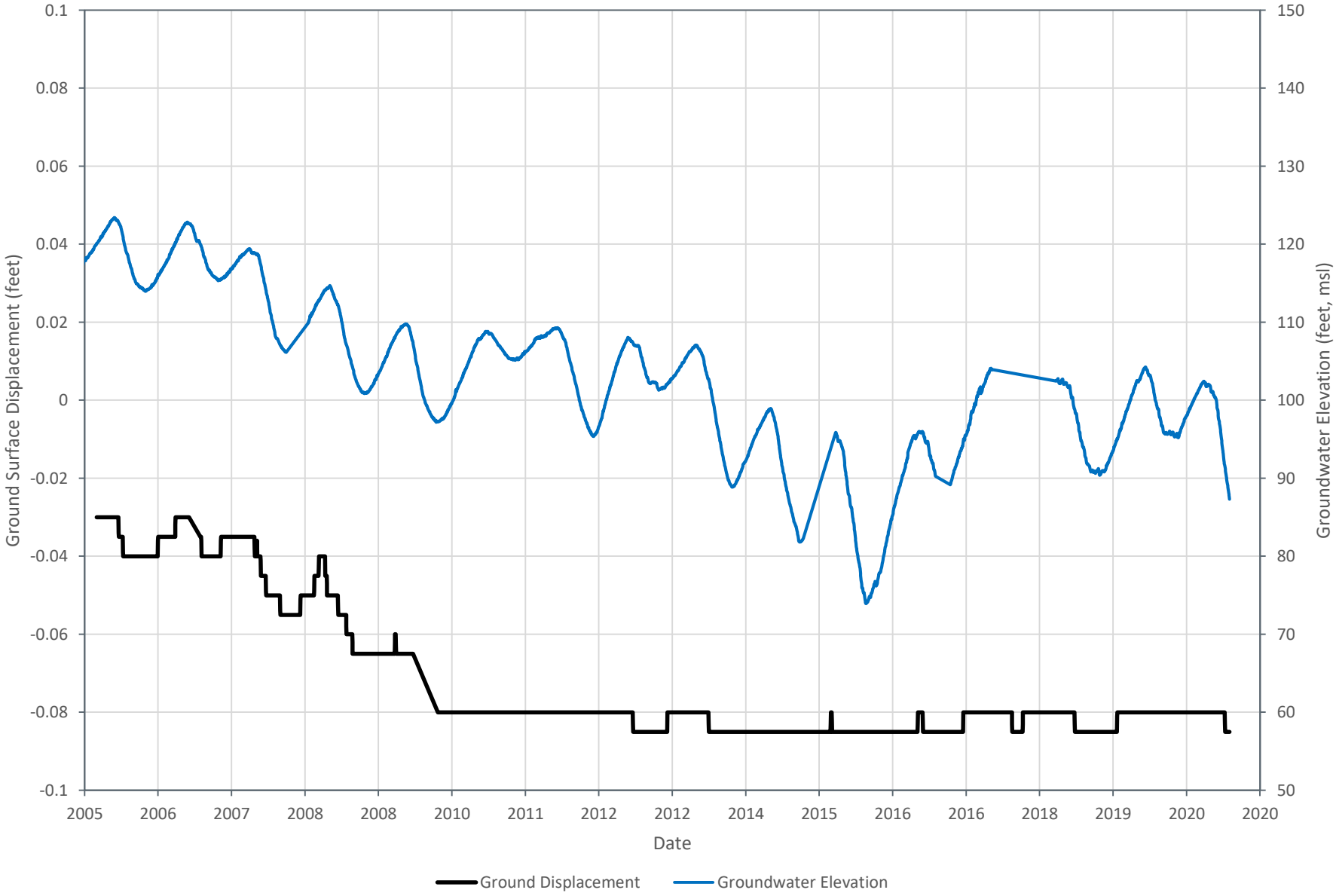
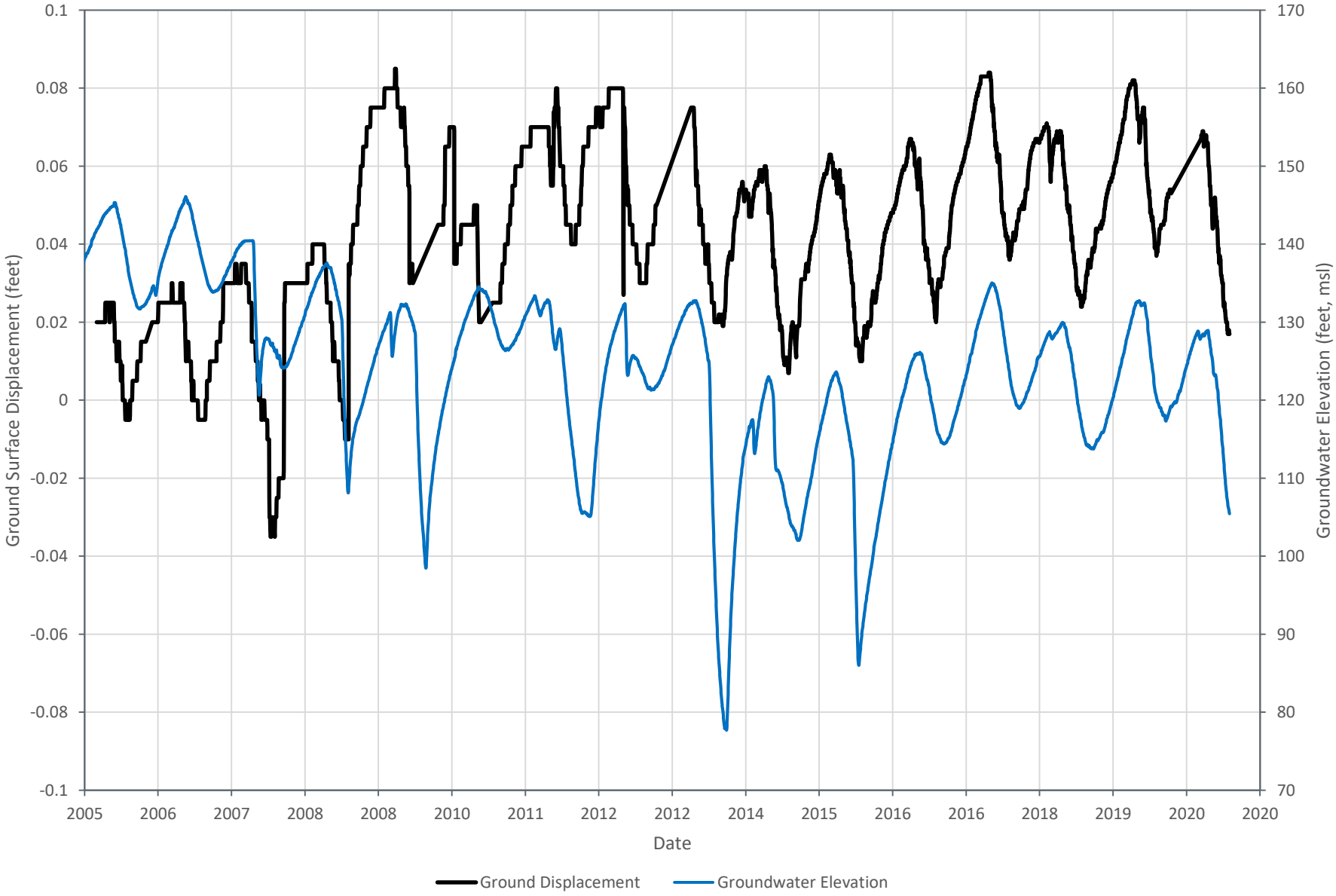


Figure 3C-6. Extensometer Data for 22N02W15C002M



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Appendix 3D

Model Development and Calibration Technical Memorandum

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TECHNICAL MEMORANDUM – C2VSimFG-Colusa Model Development and Calibration

TO: Colusa Groundwater Authority and Glenn Groundwater Authority

PREPARED BY: Sara Miller/Emily Honn (Woodard & Curran), Katherine Klug (Davids Engineering)

REVIEWED BY: Reza Namvar (Woodard & Curran), Grant Davids (Davids Engineering)

DATE: April 1, 2021

RE: C2VSimFG-Colusa Model Development and Calibration

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1. INTRODUCTION

This technical memorandum documents the development and calibration of the C2VSimFG-Colusa model, an integrated hydrologic flow model for the Colusa Subbasin (Subbasin) that is used to support development of the Subbasin Groundwater Sustainability Plan (GSP). The C2VSimFG-Colusa model was adapted from the Fine Grid California Central Valley Groundwater-Surface Water Simulation Model (C2VSimFG).

Specifically, this technical memorandum focuses on model enhancements and calibrations that were made to characterize the historical water budget in the Colusa Subbasin. Other model runs for current and projected water budget scenarios were adapted from the historical C2VSimFG-Colusa model inputs described in this technical memorandum. Those water budget inputs, assumptions, and results are described in the Colusa Subbasin GSP.

The C2VSimFG-Colusa model is based on the C2VSimFG Beta2 model released May 2019, with updates and enhancements to better represent local conditions in the Colusa Subbasin. C2VSimFG-Colusa runs the entire C2VSimFG model; however, data updates and calibration efforts are focused only on the area within and immediately surrounding the Colusa Subbasin. The Subbasin plus a five-mile buffer was chosen as the calibration area for C2VSimFG-Colusa (Figure 1).

The following sections describe specific enhancements to the C2VSimFG Beta2 inputs that were made to better reflect local water supply and water use characteristics; specific calibrations of model inputs to match available streamflow data, groundwater level data, and local water budget results; sensitivity analyses of the C2VSimFG-Colusa model; and a summary of the historical water budget results from the refined and calibrated historical model.

2. REFINEMENTS AND ENHANCEMENTS TO C2VSIMFG BETA2

The C2VSimFG-Colusa model was refined from C2VSimFG Beta2 through enhancements to specific model inputs, assumptions, and parameters related to the surface water and groundwater systems. Davids Engineering and Woodard & Curran refined and calibrated the surface and groundwater system water budgets for the portion of the model domain within and five miles surrounding the Colusa Subbasin.

The C2VSimFG-Colusa model inputs have been updated using the best available data and science, including information from publicly available data sources, past water and groundwater management planning documents, and other local water budgets computed for areas of the Colusa Subbasin. Data and information about specific water agencies was used to quantify water supply and water use within the agency's service area, to the extent permitted by the resolution of the C2VSimFG-Colusa model element grid.

Specific enhancements made to C2VSimFG Beta2 include changes to the simulation period, initial groundwater elevation, groundwater pumping, land use, evapotranspiration, soil properties, irrigation operations and efficiency, urban demand, surface water diversions, streambed elevation, and aquifer parameters. These changes are described in the sections below. Other changes made to calibrate specific root zone, stream, and aquifer characteristics are discussed further in Section 3. Unless otherwise noted, other inputs to the C2VSimFG Beta2 model were generally used directly in the C2VSimFG-Colusa model.

2.1 Historical Simulation Period

C2VSimFG Beta2 operates on a monthly time step and was initialized to simulate the period of October 1973 through September 2015, corresponding to water years (WY) 1974-2015. Time series data is provided in the C2VSimFG Beta2 input files for WY 1921-2015.

The C2VSimFG-Colusa model historical simulation period was updated to begin in October 1985 (WY 1986), simulating WY 1986-2015. The revised historical simulation period was selected based on the availability of local data for the Colusa Subbasin, and to allow sufficient time for the initial model conditions to stabilize prior to the start of the historical water budget analysis period (WY 1990-2015). Selection of the historical water budget period is described in the GSP.

2.2 Initial Groundwater Elevation

Initial groundwater elevations in C2VSimFG-Colusa were updated to reflect the new historical simulation start date in Fall 1985. Groundwater elevations for Fall 1985 for each model node and each layer were first extracted from C2VSimFG-Beta2 and then portions of the Subbasin were updated with elevations developed using the DWR's WDL database. A raster was developed using 202 observations from Fall 1985, supplemented with Fall 1984 and Fall 1986 readings. The difference between this observed data and simulated Layer 1 groundwater levels was calculated. For those areas with differences greater than 25 feet, initial groundwater heads were adjusted to reflect historical data. The groundwater level initial conditions for C2VSimFG-Colusa representing October 1985 are shown in Figure 2.

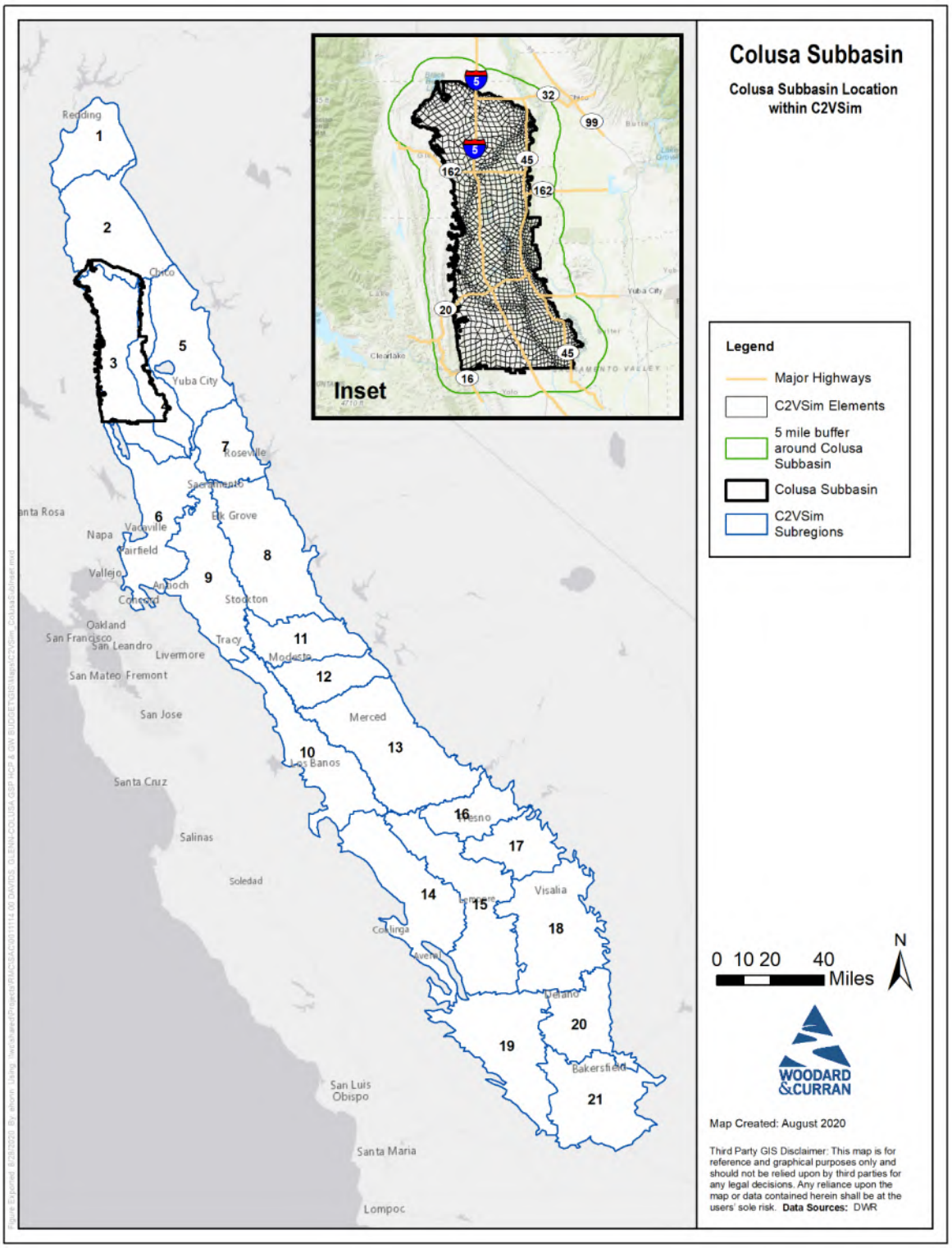

Figure 1: C2VSimFG and Location of Colusa Subbasin

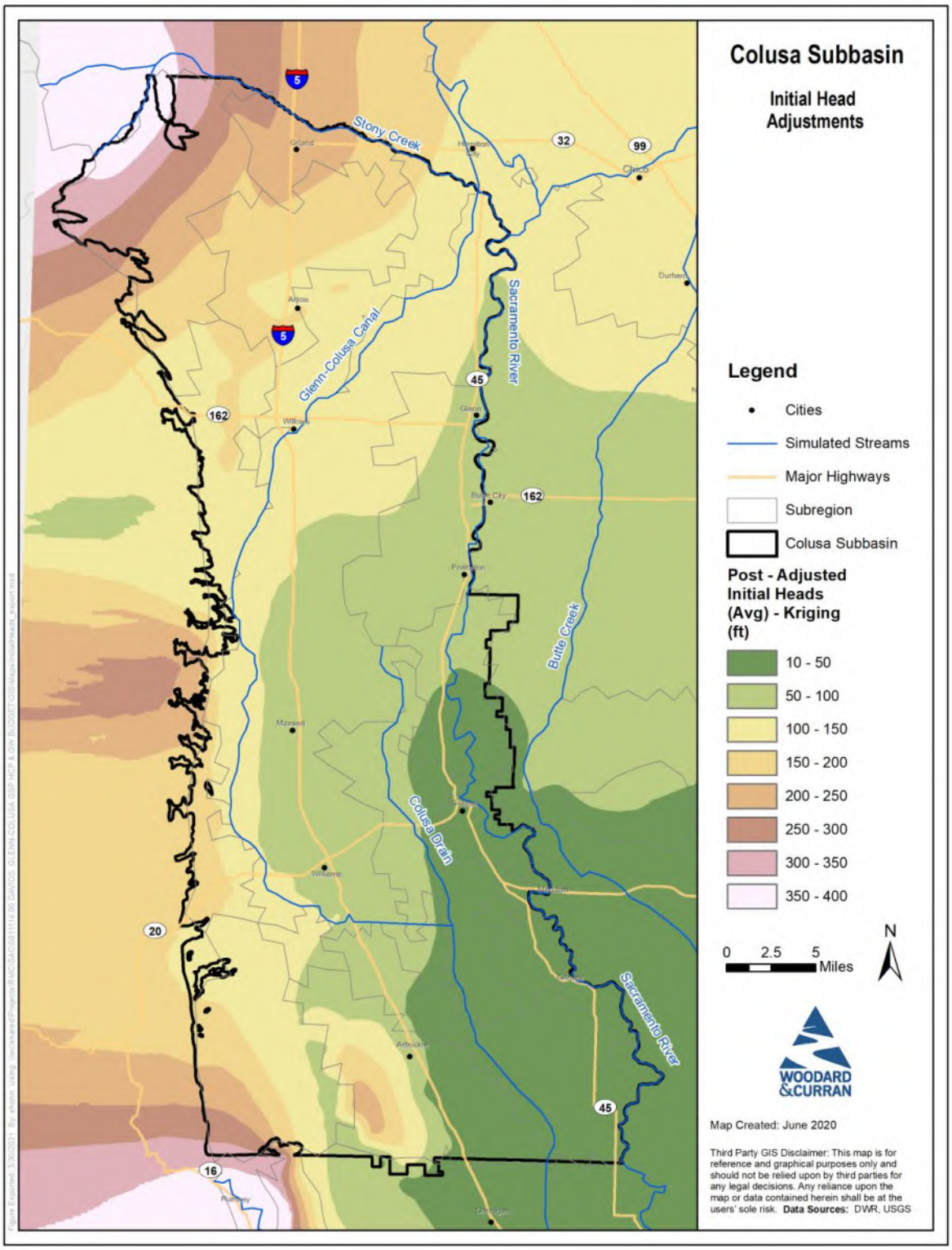

Figure 2: Initial Groundwater Elevation (Average of Layers 1-4)

2.3 Groundwater Pumping

Groundwater pumping in C2VSimFG-Colusa was refined by (1) specifying or refining groundwater pumping volumes in areas where data or other information on pumping was available, and by (2) assigning and refining virtual wells to simulate private groundwater pumping by agricultural and rural domestic well users based on demand in the model. The data sources and methods used to make these refinements are described below.

2.3.1 Specified or Refined Pumping

Groundwater pumping volumes in C2VSimFG-Colusa were specified or refined where possible based on groundwater pumping data reported by local water suppliers and based on other local information related to historical groundwater pumping.

Agricultural groundwater pumping previously enabled in C2VSimFG Beta2 for areas within the Sacramento, Delevan, and Colusa National Wildlife Refuges was turned off in C2VSimFG-Colusa, based on local information indicating that agricultural pumping does not occur within the bounds of these areas.

Urban groundwater pumping was refined for urban demand areas in the Colusa Subbasin based on pumping data reported by specific urban suppliers and public water systems (Table 2-1). Groundwater pumping by public water systems was summarized from Small Supplier Conservation Reports available through the California State Water Resources Control Board (SWRCB). Reports were available for the Cities of Colusa, Orland, and Williams and the Arbuckle and Maxwell Public Utility Districts. Groundwater pumping for use within the City of Willows was summarized from Urban Water Supplier Reports, also available through the SWRCB. . Available groundwater pumping data were combined with population data to refine the model inputs that define per capita water use. As a result, the groundwater pumping calculated by the C2VSimFG-Colusa model was refined to match pumping data in years when these data were available. Additional information about these procedures and urban inputs are described further in Section 2.7.

Table 2-1. Groundwater Pumping Data for Urban Suppliers and Public Water Systems

Supplier Name	Data Source	Reported Years (Partial or Complete)
Arbuckle Public Utility District	SWRCB Small Supplier Conservation Report (ID CA0610001)	2013, 2015, 2016
City Of Colusa	SWRCB Small Supplier Conservation Report (ID CA0610002)	2013, 2015, 2016
City Of Orland	SWRCB Small Supplier Conservation Report (ID CA1110001)	2013, 2015, 2016
City Of Williams	SWRCB Small Supplier Conservation Report (ID CA0610004)	2013, 2015, 2016
Maxwell Public Utility District	SWRCB Small Supplier Conservation Report (ID CA0610003)	2013, 2015, 2016
California Water Service Company Willows	SWRCB Urban Water Supplier Report (ID CA1110003)	2014-2019

2.3.2 Private Groundwater Pumping

Private groundwater pumping quantities on an individual well basis are largely unknown, though aggregate estimates for private pumping are often included in planning documents (e.g., AWMPs, UWMPs, groundwater management plans). Private pumping in C2VSimFG-Colusa was estimated on an element basis by assigning two virtual wells at the

centroid of each model element. One well represents private agricultural pumping and one well represents rural residential pumping. The estimated pumping at these wells was calculated within C2VSimFG-Colusa as the additional volume of water necessary to meet agricultural and urban demand within that element, after distributing any other specified groundwater pumping and surface water deliveries. Figure 3 shows the total groundwater pumping in feet in each element in WY 2015.

The well screening interval or well depth was used to assign the model layers from which each simulated well extracts water. These assignments were made separately for the agricultural and rural residential wells in each element. Rural residential wells used a statistical analysis of typical perforation intervals developed for C2VSimFG. Agricultural wells were initially mainly assigned to pump from Layer 1, C2VSimFG's unconfined layer. Data provided by DWR and extracted from well completion reports was processed by Davids Engineering for updating agricultural pumping (Characterization of Groundwater Development in Colusa County and Evaluation of Potential Future Groundwater Demands TM by Davids Engineering, 2018). These data included information on well depths of irrigation wells drilled since 1970. These wells were mapped and assigned to C2VSimFG layers based on the total well depth (Figure 4 and Figure 5). Analysis of the north-western and south-western areas of the Subbasin revealed that most agricultural wells were pumping mainly from Layers 2 and 3. As a result, pumping in the majority of elements in these areas was edited so that 30% of groundwater pumping was from Layer 2 and 70% from Layer 3.

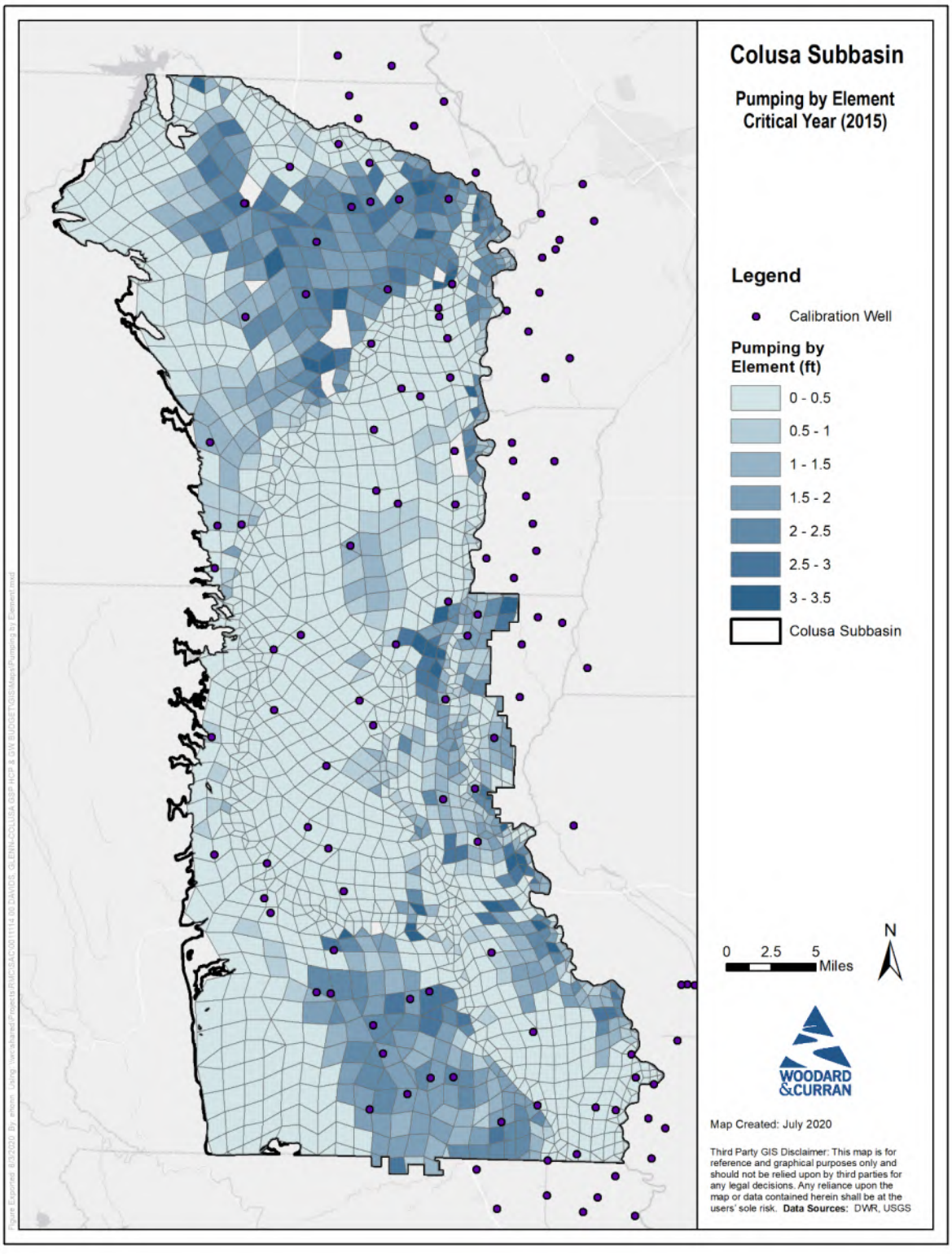

Figure 3: Element Pumping in Colusa Subbasin for WY 2015

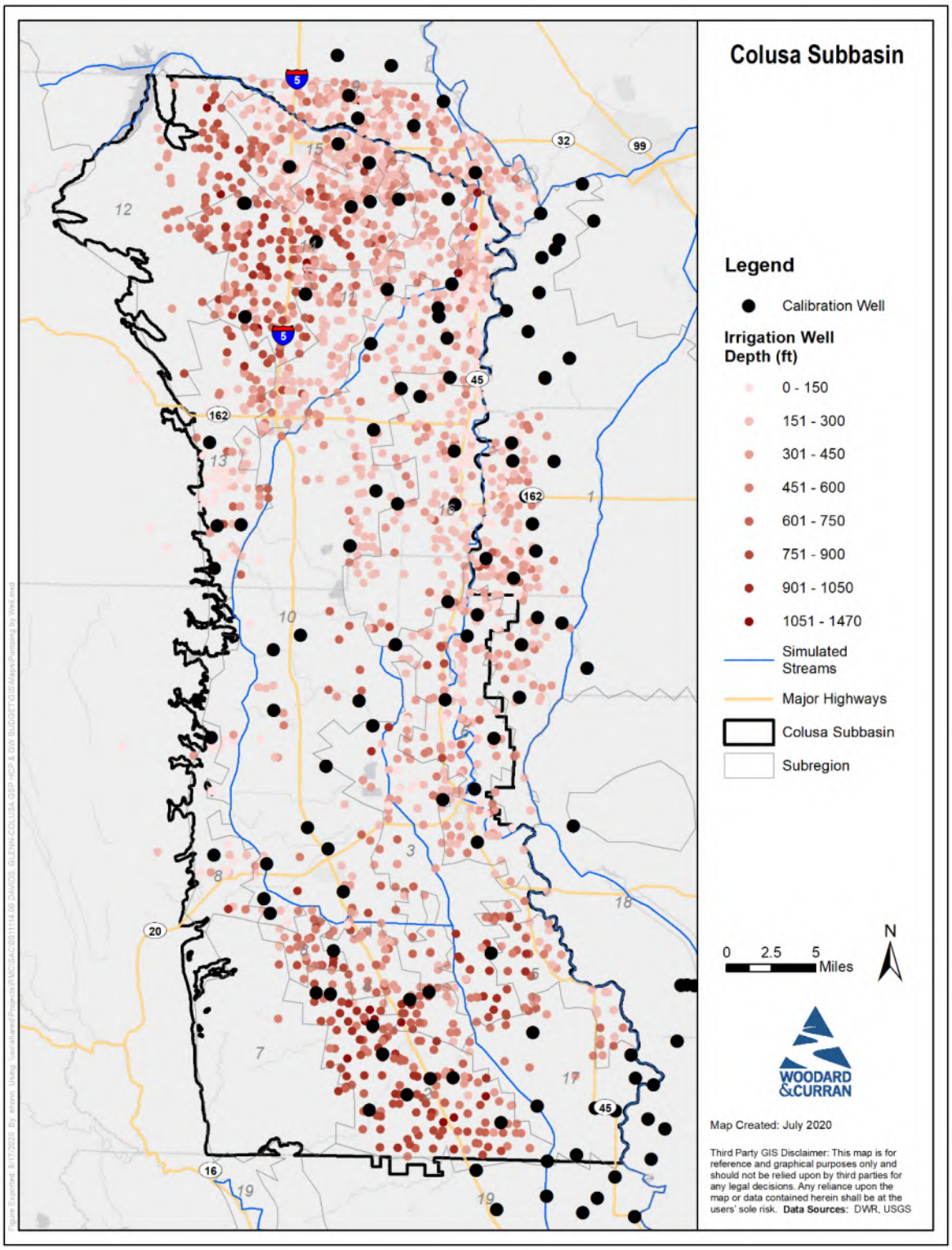

Figure 4: Irrigation Well Depths in Colusa Subbasin

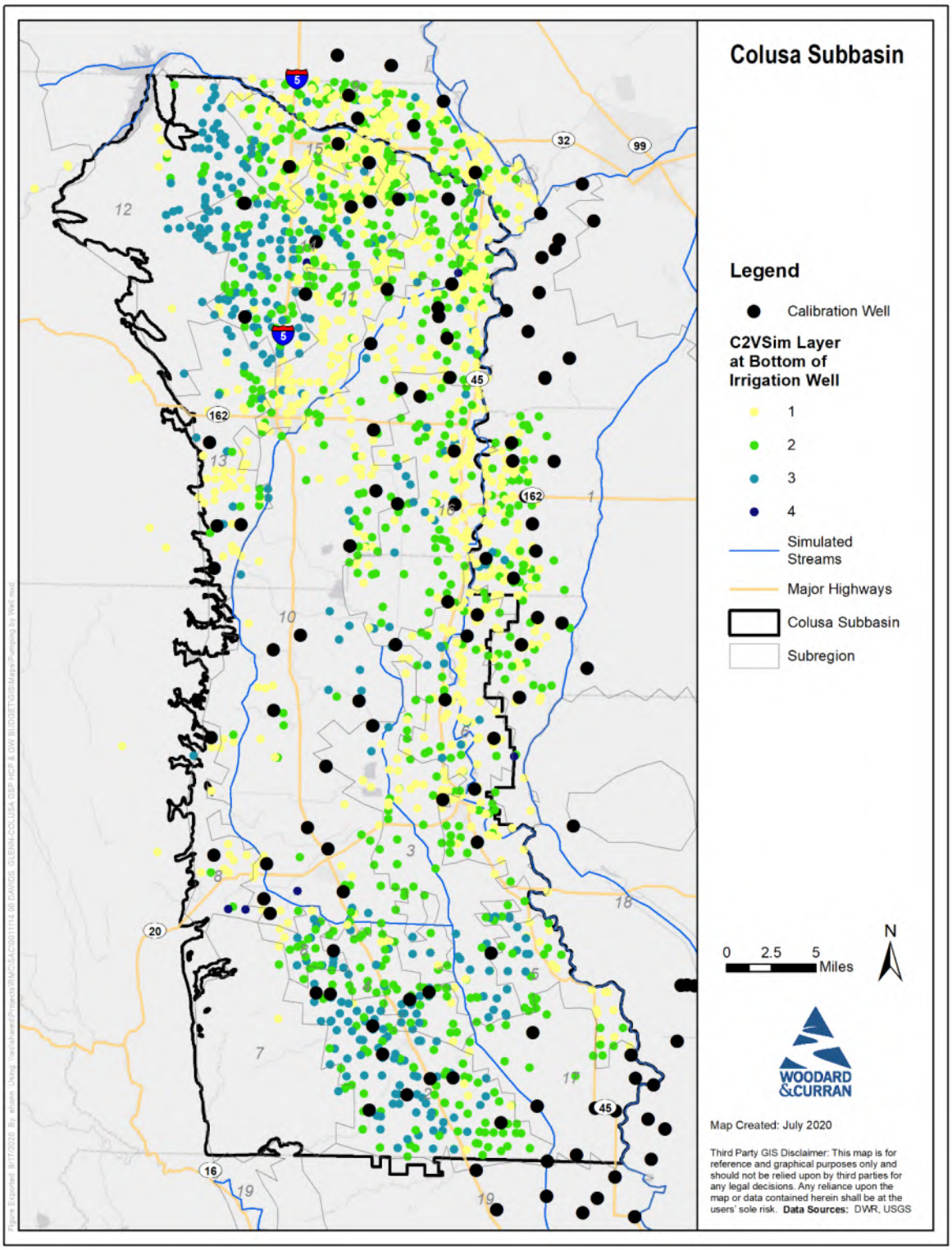

Figure 5: Irrigation Well Depths in Colusa Subbasin by Model Layer

2.4 Land Use

Annual land use in the Colusa Subbasin was estimated primarily based on spatially distributed land use information from DWR Land Use surveys in 1993, 1998, 2004, and 2009 and Land IQ[1] remote sensing-based land use identification in 2014. County Agricultural Commission land use areas were used to interpolate between years with available spatial land use information. The DWR LUEXINT Land Use Adjustment Preprocessor interpolation tool was implemented to create annual spatial cropping data sets in all years, compiling spatial land use data and creating estimates of spatial land use assignments in years when spatial data was unavailable. The spatial land use refinements were compared to the land use inputs to C2VSimFG Beta2, and were also reviewed by GSA representatives, Boards, and other local agencies to confirm the accuracy of annual patterns in crop acreage.

Land areas in the Colusa Subbasin were assigned to one of 29 land uses, and summarized under 22 land use classes. These land use classes are summarized by water use sector in Table 2-2. The area of each land use class was spatially assigned according to the percent area represented in each model element. Complete land use areas for the entire Colusa Subbasin are provided in the GSP.

Table 2-2. Land Use Classes by Water Use Sector.

Water Use Sector	C2VSimFG Land Use Class	C2VSimFG Land Use Code	Land Uses Included in Land Use Class
Agricultural (Nonponded and Ponded)	Alfalfa	AL	Alfalfa
	Almonds & Pistachios	AP	Almonds, Pistachios
	Citrus & Subtropical	CS	Citrus, Olives
	Corn	CN	Corn
	Cucurbits	CU	Melons
	Dry Beans	DB	Beans (Dry)
	Grain	GR	Grain
	Idle	ID	Idle
	Other Deciduous	OR	Misc Deciduous, Prunes
	Other Field	FL	Misc Field, Sudan, Sunflower
	Other Truck	TR	Misc Truck
	Pasture	PA	Pasture
	Rice with non-flooded decomposition	RICE_NFL	Rice with non-flooded decomposition
	Rice with no decomposition	RICE_NDC	Rice with no decomposition
	Safflower	SA	Safflower
	Tomato-Processing	TP	Tomatoes
	Vineyards	VI	Vineyards
	Walnuts	WN	Walnuts
Refuge	Seasonal refuges	REFUGE_SL	Wetlands
Native and Riparian Vegetation	Native	NV	Native
	Riparian	RV	Riparian, Water
Urban	Urban	UR	Urban, Semiagricultural

[1] Land IQ is a firm that was contracted by DWR to use remote sensing methodologies to identify crops in fields.

2.5 Evapotranspiration

Crop evapotranspiration (ET_c), or crop consumptive use, represents the volume of water that is lost to the atmosphere through both evaporation from the soil and transpiration from crop surfaces. A portion of the total water that crops and vegetation consume originates from precipitation (referred to as evapotranspiration of precipitation, or ET_{pr}) while other portions of ET_c may originate from applied water (referred to as evapotranspiration of applied water, or ET_{aw}).

C2VSimFG-Colusa computes a monthly root zone water budget, utilizing inputs of monthly ET_c together with other parameters that describe soil and land use characteristics in order to quantify all inflows and outflows through the root zone.[1] A root zone water budget is a generally accepted and widely used method to accurately and consistently track the portions of ET_c attributed to precipitation and applied water, respectively, as well as other water that is transmitted through the soil and plant surfaces (ASCE, 2016 and ASABE, 2007).

Monthly ET_c inputs for each crop and land use class in the Colusa Subbasin were adapted from the C2VSimFG Beta2 standard ET_c inputs. The C2VSimFG Beta2 inputs were first quality controlled and then adjusted to reflect local crop water use characteristics more accurately. Adjustments were determined through comparisons with local ET_c data and through discussion and consultation with selected local growers. Three main local ET_c data sources were compared to the C2VSimFG Beta2 inputs:

- METRIC Results (METRIC): Actual ET (ET_a) estimates were calculated using satellite imagery and the Mapping Evapotranspiration at High Resolution using Internalized Calibration (METRIC) (Allen, et al. 2007a) remotely-sensed surface energy balance model. METRIC ET_a estimates account for actual, observed conditions in the Colusa Subbasin that affect crop consumptive use, such as salinity, deficit irrigation, disease, fertilization, immature permanent crops, and crop canopy structure, and other factors. Studies by Bastiaanssen et al. (2005), Allen et al. (2007b, 2011), Thoreson et al. (2009), and others have found that when performed by an expert analyst, seasonal ET_a estimates by remotely-sensed surface energy balance models are expected to be within five percent of actual ET determined using other reliable methods. METRIC ET_a results are available for 2017 in the Sacramento Valley. Notably, METRIC results represent ET_a in a single, wet year (2017), rather than a multi-year average.

- Cal-SIMETAW Results (DWR): ET_c is computed in the California Simulation of Evapotranspiration of Applied Water (Cal-SIMETAW) model, and is publicly reported by the California Department of Water Resources (DWR) for 132 individual crops, 20 crop categories, and four land-use categories by county for use in the California Water Plan. Cal-SIMETAW is a daily, spatial crop water balance model that utilizes weather data, soil properties, crop coefficients, rooting depths, seepage, and other parameters to calculate ET_c and ET_{aw}. Monthly ET_c values were available from Cal-SIMETAW for 24 land use types in Glenn and Colusa Counties over the period spanning water years 2000-2015. The monthly ET_c values were averaged across both counties and all years for each land use type, and were summarized to average annual values for comparison.

- ITRC Results (Cal Poly): The Irrigation Training & Research Center (ITRC) at California Polytechnic State University, San Luis Obispo has compiled a database of typical ET_c rates for agricultural crop types across the various ETo Zones in California. These rates are publicly available online (http://itrc.org/etdata/index.html), and are offered for water budget and irrigation scheduling and design purposes. The ITRC provides typical

[1] The root zone is defined as "the upper portion of the soil where water extraction by plant roots occurs." (ASCE, 2016)

ET_c rates for various irrigation methods, two of which were considered for analyses in the Colusa Subbasin: surface irrigation systems and drip/micro irrigation systems. Across these irrigation systems, ITRC also summarizes ET_c for various relative precipitation conditions, with 1997 representing a "typical" year, 1998 representing a "wet" year, and 1999 representing a "dry" year.

ET_c values in C2VSimFG-Colusa were refined to provide for similar results among all crops represented in the model and described in the various ET_c data sources above. Sample comparisons of the average annual ET_c for major crops are shown in Figure 6.

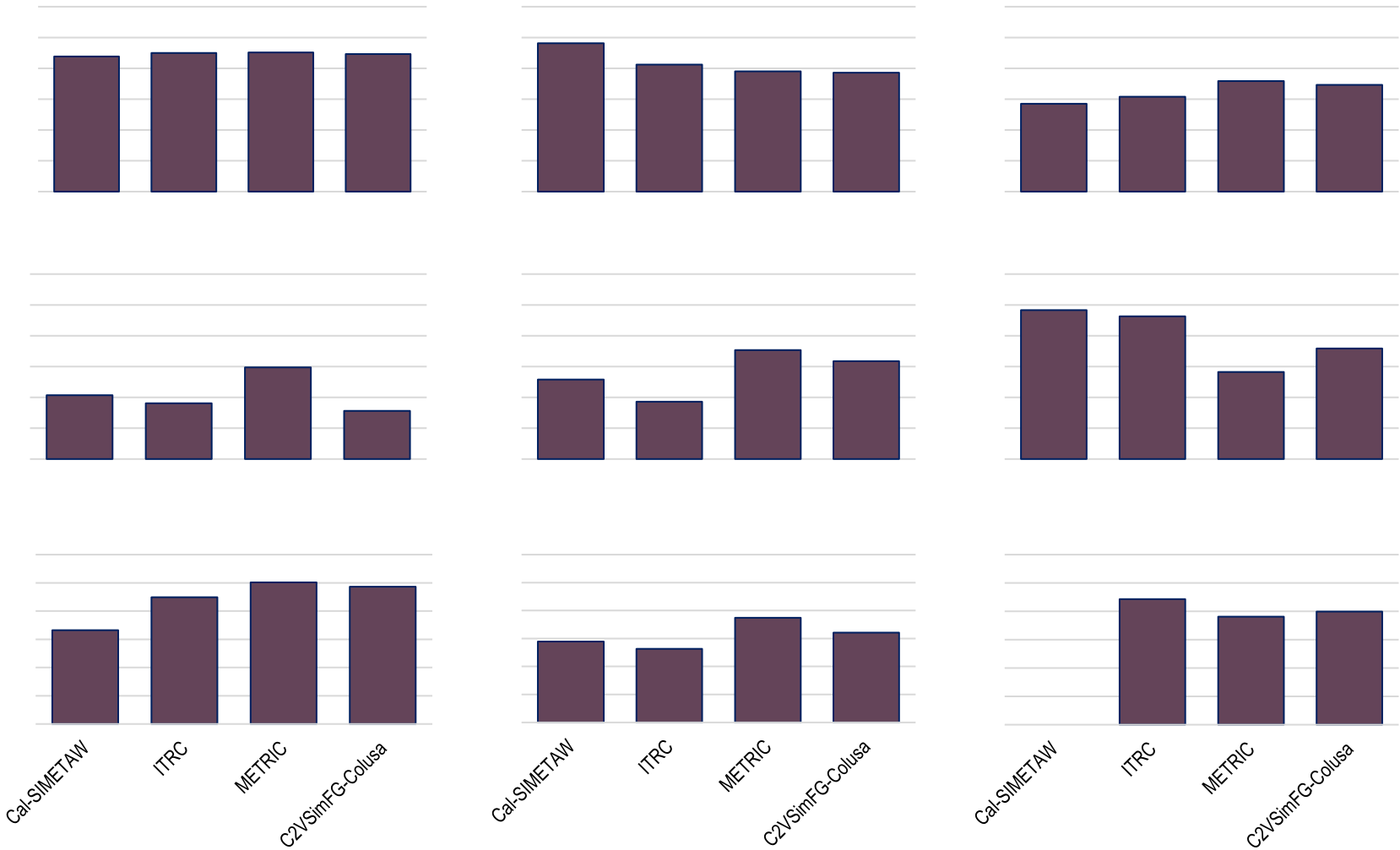

Figure 6. Average Annual* ET_c Comparison between Cal-SIMETAW, ITRC, METRIC, and C2VSimFG-Colusa for Major Irrigated Crops in the Colusa Subbasin (1990-2015 Average Annual Area Greater Than 10,000 acres).

**Average summary years vary, see text for description of years considered.*

2.6 Other Irrigation and Crop Inputs

2.6.1 Irrigation Period

The irrigation period identifies the months during which irrigation is available to a crop or land use class. A value of one designates a month during which IDC calculates applied water demand for the land use class and simulates irrigation events, as needed. A value of zero designates a non-irrigation month during which IDC does not compute applied water and does not simulate irrigation for the land use class. Different monthly designations can be defined for different land use classes, if necessary.

In C2VSimFG-Colusa, the irrigation period was defined through time series inputs corresponding to typical crop irrigation seasons in the Colusa Subbasin. The irrigation period was also refined for rice in select months in order to better match the timing of planting and application of water in the winter months, according to local agricultural practices.

2.6.2 Reuse and Return Flow

The return flow fraction determines the proportion of applied water that can leave the land use area as runoff, while the reuse fraction determines the proportion of applied water that is captured and reused for irrigation. A value of one for each indicates that all applied water can leave as runoff, but that all applied water is captured and reused for irrigation. A value of zero for each indicates that no applied water leaves the land use cell, and that no water is reused for irrigation.

In C2VSimFG-Colusa, irrigation water return flow fractions were converted to timeseries inputs for all crops, with decreasing values that reflect changes in local irrigation practices over time, leading to reductions in runoff (Figure 7). Irrigation reuse fractions were unchanged from C2VSimFG Beta2, with values of 0 set for all crops.

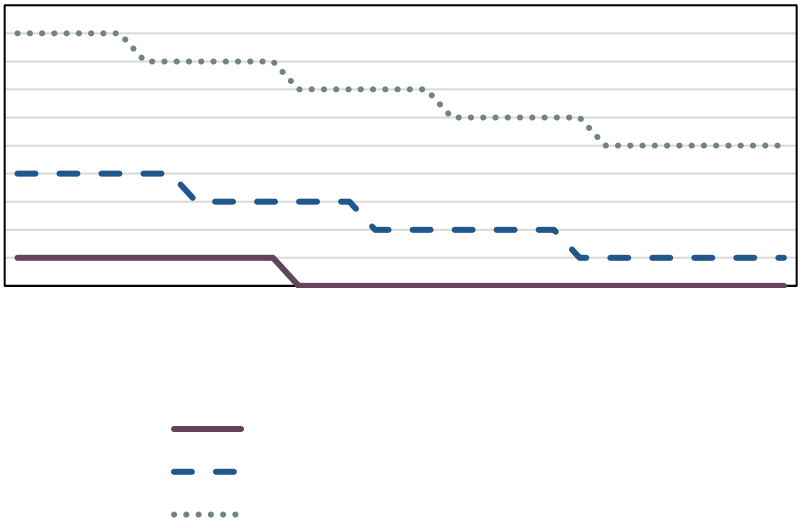

Figure 7. Return Flow Fractions in C2VSimFG-Colusa.

2.6.3 Ponded Crop Inputs

Ponding depth inputs to the model dictate the amount of water that is applied to ponded crops during irrigation. Monthly ponding depths for rice with non-flooded decomposition and rice with no decomposition were refined in C2VSimFG-Colusa to more accurately match early and late-season water application rates in the Colusa Subbasin in recent years (Table 2-3). Other ponding depths were unchanged from the standard C2VSimFG Beta2 inputs.

Table 2-3. Average Monthly Ponding Depths Updated in C2VSimFG-Colusa.

Month	Average Ponding Depth by Crop Type (ft; 1990-2015 Average)	
	Rice with Non-Flooded Decomposition	Rice with No Decomposition
1	0.15	0.00
2	0.02	0.00
3	0.00	0.00
4	0.01	0.02
5	0.34	0.35
6	0.38	0.38
7	0.35	0.35
8	0.25	0.25
9	0.01	0.03
10	0.09	0.00
11	0.32	0.00
12	0.26	0.00

2.7 Other Urban Inputs

Urban inputs to C2VSimFG-Colusa were updated from the standard inputs to C2VSimFG Beta2 to accommodate new, locally-defined urban demand areas. These new urban demand areas in the Colusa Subbasin were specified as subdivisions of larger urban demand areas in C2VSimFG Beta2, corresponding to specific urban subareas for which water supply and water use data were available. The new urban demand areas corresponded to:

- Arbuckle (Public Utility District service area)
- City of Colusa
- City of Orland
- City of Williams
- City of Willows (California Water Service Company Willows service area)
- Unincorporated urban areas in the Colusa Subbasin

Data sources used to describe these new urban demand areas include SWRCB Small Supplier Conservation Reports and Urban Water Supplier Reports, population data and estimates from the California Department of Finance, census data, and the Willows 2015 Urban Water Management Plan.

Key urban inputs that were identified or refined for these new urban demand areas are population, groundwater pumping, per capita water use, urban pervious area fractions, and urban indoor water use fractions. These inputs are described below.

2.7.1 Population

The population in each urban demand area was quantified based on population data and population estimates available from the California Department of Finance or from United States Census Bureau. Annual population estimates were available from the Department of Finance for the Cities of Colusa, Orland, Williams, and Willows, and for Colusa and Glenn Counties in 1989-2015. The population in the Community of Arbuckle was summarized from available Census Bureau data in 1990, 2000, and 2010. The population in Arbuckle in other years was estimated through linear interpolation. The population of unincorporated areas in each county was calculated as the total population in that county (adjusted to the area overlying the Subbasin), minus the population in each city or community overlying the Subbasin.

2.7.2 Groundwater Pumping

Groundwater pumping data for urban suppliers and public water systems in the Colusa Subbasin were available from the SWRCB, as described in Section 2.3.1.

2.7.3 Per Capita Water Use

Per capita water use for the new urban demand areas was estimated based on available urban population and total urban water use from water supplier data, where available. Average per capita water use and data sources for each urban demand area are identified in Table 2-4.

Per capita water use in Willows was calculated in 1995-2015 from California Department of Finance population data and water use data. Per capita water use in 1989-1994 was calculated as the 1999-2008 average, taken to approximate average conditions observed in the early 1990s.

Per capita water use in Colusa, Orland, Williams, Arbuckle, and unincorporated areas in the Colusa Subbasin was calculated from the per capita water use in Willows, adjusted upward to accommodate slight differences in typical water use in these areas.

Average per capita water use values range from 231 gallons per capita per day in Willows and Colusa, to 277 gallons per capita per day in Orland.

Table 2-4. Urban Per Capita Water Use for New Urban Demand Areas in Colusa Subbasin.

Urban Demand Area	Average Per Capita Water Use (Gallons per Capita Per Day, 1990-2015)	Source
Arbuckle	254	Adjusted from Willows per capita water use (annual adjustment factor 1.1)
City Of Colusa	231	Assumed equal to Willows per capita water use (annual adjustment factor 1.0)
City Of Orland	277	Adjusted from Willows per capita water use (annual adjustment factor 1.2)
City Of Williams	242	Adjusted from Willows per capita water use (annual adjustment factor 1.05)

Urban Demand Area	Average Per Capita Water Use (Gallons per Capita Per Day, 1990-2015)	Source
Willows	231	Department of Finance population data; gross water use data (1995-2015); estimated as 199-2008 average (1989-1994)
Unincorporated urban areas in the Colusa Subbasin	254	Adjusted from Willows per capita water use (annual adjustment factor 1.1)

2.7.4 Urban Pervious Area Fractions

The urban pervious area fraction input is used by the C2VSimFG-Colusa model to quantify evapotranspiration (ET) and runoff from urban areas. It is assumed that only pervious areas are available for ET, and that no ET occurs in impervious areas. It is also assumed that all precipitation that falls on impervious areas becomes runoff. The runoff and ET of pervious areas is defined in C2VSimFG Beta2 according to typical conditions in urban areas.

The pervious fractions in the C2VSimFG-Colusa urban demand areas were updated to monthly values ranging from 0.40 to 0.49 in cities and incorporated urban demand areas (indicating less pervious area, and more developed area), and to a value of 0.70 in unincorporated urban demand areas (indicating more pervious area, and less developed area than cities and incorporated urban areas). These values were estimated to reflect the proportion of 'built-up' and undeveloped areas within the respective urban demand areas, and are similar to the pervious fractions specified for other urban areas in C2VSimFG Beta2.

2.7.5 Indoor Use Fractions

C2VSimFG-Colusa parses the total volume of applied water in each urban demand area into the amount of water that is used indoors versus outdoors based on user-defined indoor use fractions. A monthly pattern of indoor use fractions was calculated based on the average monthly average ratio of estimated indoor to outdoor water use in each city or community in the Colusa Subbasin in 2013, compared to total groundwater pumping that year. The year 2013 was taken to be representative of a typical year. The indoor use fractions in Table 2-5 were used for all new urban demand areas.

Table 2-5. Urban Indoor Water Use Fractions for New Urban Demand Areas in Colusa Subbasin.

Month	Fraction of Total Urban Water Used Indoors
January	1.00
February	0.93
March	0.57
April	0.47
May	0.37
June	0.30
July	0.28
August	0.32
September	0.36
October	0.41
November	0.59
December	0.69

2.8 Diversions

Diversions are specified in C2VSimFG-Colusa to quantify the volume of water available for deliveries to specific land use areas in the Colusa Subbasin. The diversion specifications are also used by the model to quantify the volumes of nonrecoverable loss to the atmosphere through evaporation and recoverable loss to the GWS through seepage (infiltration of surface water).

Diversions that are used within the Colusa Subbasin are generally quantified based on outside data sources, including: delivery records reported by the United States Bureau of Reclamation (USBR), groundwater management or water planning documents developed by water agencies, and publicly available records maintained by the California State Water Resources Control Board (SWRCB) in the Electronic Water Rights Information Management System (eWRIMS). Data sources and updates to specific diversion volumes and specifications are described below.

Diversions of supply used outside the Subbasin are generally assumed to be equal to diversions data specified in C2VSimFG Beta2. Deliveries are generally calculated by C2VSimFG-Colusa as the water supply used to meet simulated crop water demands, after accounting for seepage and evaporation of the diverted supply.

Table 2-6 identifies new diversions added to C2VSimFG-Colusa, and Table 2-7 identifies diversions originally in C2VSimFG Beta2 that were changed in C2VSimFG-Colusa. Details about these added diversions and changes are described in the sections below.

Table 2-6. Diversions Added to C2VSimFG-Colusa.

Diversion ID	Description	Data Source	Average Volume in Historical Water Budget (AF per year, 1990-2015)
444	Orland Unit Water Users' Association (OUWUA) (South Canal only)	USBR delivery reports (1989-2015); estimated other years	60,011
445	Colusa County Water District (WD)	USBR delivery reports (1989-2015); estimated other years	50,967
446	Orland-Artois WD (OAWD)	USBR delivery reports (1989-2015); estimated other years	42,688
447	Glenn-Colusa ID (GCID) (Tehama-Colusa Canal)	USBR delivery reports (1989-2015); estimated zero other years (included in Div ID 458)	31,176
448	Westside WD	USBR delivery reports (1989-2015); estimated other years	30,038
449	Kanawha WD	USBR delivery reports (1989-2015); estimated other years	26,032
450	Glide WD	USBR delivery reports (1989-2015); estimated other years	11,422
451	La Grande WD	USBR delivery reports (1989-2015); estimated other years	4,307
452	Davis WD	USBR delivery reports (1989-2015); estimated other years	2,319
453	4-M WD	USBR delivery reports (1989-2015); estimated other years	1,947

Diversion ID	Description	Data Source	Average Volume in Historical Water Budget (AF per year, 1990-2015)
454	Holthouse WD	USBR delivery reports (1989-2015); estimated other years	1,059
455	Glenn Valley WD	USBR delivery reports (1989-2015); estimated other years	860
456	Cortina WD	USBR delivery reports (1989-2015); estimated other years	825
457	Myers-Marsh Mutual Water Company (MWC)	USBR delivery reports (1989-2015); estimated other years	192
458	GCID (Main Canal)	GCIDWIS and eWRIMS data when available (1989-2015); estimated other years	678,941
459	Reclamation District #108	USBR delivery reports (1989-2015); estimated other years	155,615
460	Princeton-Codora-Glenn ID	USBR delivery reports (1989-2015); estimated other years	60,285
461	Provident ID	USBR delivery reports (1989-2015); estimated other years	50,790
462	Sycamore MWC	USBR delivery reports (1989-2015); estimated other years	22,969
463	Maxwell ID	USBR delivery reports (1989-2015); estimated other years	7,796
464	Carter MWC	USBR delivery reports (1989-2015); estimated other years	1,320
465	Misc Sac River Riparian Diversions	USBR delivery reports (1989-2015); estimated other years	5,050
466	Misc Sac River Riparian Diversions	USBR delivery reports (1989-2015); estimated other years	8,205
467	Misc Sac River Riparian Diversions	USBR delivery reports (1989-2015); estimated other years	3,585
468	Andreotti, Arnold and Arthur, et al	USBR delivery reports (1989-2015); estimated other years	2,296

Table 2-7. Diversions in C2VSimFG Beta2 Revised for C2VSimFG-Colusa.

Diversion ID	Description in C2VSimFG Beta2	Revision in C2VSimFG-Colusa	Diversion ID Replacement
19	Black Butte Reservoir to South Canal for Ag (06_PA)	No longer used (replaced with specified USBR diversions)	444
31	Tehama-Colusa Canal to Kirkwood WD for Ag (04_PA2)	Revised to exclude TCC diversions in Colusa Subbasin and account only for TCC diversions outside Subbasin	445-457
32	T-C Canal Deliveries to 07N_PA: Glide WD, Holthouse WD (portion 65%) Kanawha WD, Orland-Artois WD	No longer used (replaced with specified USBR diversions)	445-457

Diversion ID	Description in C2VSimFG Beta2	Revision in C2VSimFG-Colusa	Diversion ID Replacement
33	T-C Canal Deliveries to 07S_PA: 4-M WD, Colusa County WD, Cortina WD, Davis WD, Dunnigan WD, Glenn Valley WD, Holthouse WD (portion 35%), La Grande WD, Myers-Marsh MWC, Westside WD	No longer used (replaced with specified USBR diversions)	445-457
34	T-C Canal Deliveries to 07S_PA: 4-M WD, Colusa County WD, Cortina WD, Davis WD, Dunnigan WD, Glenn Valley WD, Holthouse WD (portion 35%), La Grande WD, Myers-Marsh MWC, Westside WD	No longer used (replaced with specified USBR diversions)	445-457
36	Glenn-Colusa Canal to Glenn-Colusa ID (58%) for Ag (08N_SA2)	No longer used (replaced with specified diversions from GCIDWIS and eWRIMS data)	458
37	Glenn-Colusa Canal to Glenn-Colusa ID (42%) for Ag (08S_SA2)	No longer used (replaced with specified diversions from GCIDWIS and eWRIMS data)	458
116	Sacramento River RM 178 to Provident ID, Princeton-Cordua-Glenn ID and miscellaneous diverters for Ag (08N_SA1)	No longer used (replaced with specified USBR diversions)	460-468
117	Sacramento River RB diversions between Butte City and Wilkins Slough to Princeton-Cordora-Glenn ID, Green Valley Corporation (Formerly Cannell, F.), and Maxwell ID (5%) and miscellaneous settlement contractors for Ag (08N_SA1)	No longer used (replaced with specified USBR diversions)	460-468
118	Sacramento River RB diversions between Butte City and Wilkins Slough to Maxwell ID (95%), Odysseus Farms, Robert Ditch Irrigation Company, Colusa Irrigation Company, Mehrhof Susan M. (Formerly Swinford Tract Irrigation Company), and Sycamore Family Trust (Formerly Davis, Olive P. et al) and miscellaneous settlement contractors for Ag (08S_SA1)	No longer used (replaced with specified USBR diversions)	460-468
119	Sacramento River RM 146 miscellaneous non-CVP diversions for Ag (08S_NA1)	No longer used (replaced with specified USBR diversions)	460-468

Diversion ID	Description in C2VSimFG Beta2	Revision in C2VSimFG-Colusa	Diversion ID Replacement
122	Sacramento River RB diversions between Butte City and Wilkins Slough to miscellaneous non-CVP diverters for Ag (08S_NA2)	Revised to account only for River Garden Farms and misc. outside Colusa SB	N/A
124	Sacramento River RB diversions between Butte City and Wilkins Slough to Reclamation District 108 and miscellaneous diverters for Ag (08S_SA3)	No longer used (replaced with specified USBR diversions)	459
126	Sacramento River RB diversions between Wilkins Slough and Knights Landing to RD 108, River Garden Farms and miscellaneous CVP diverters for Ag (08S_SA3)	No longer used (replaced with specified USBR diversions)	459

2.8.1 Diversions by USBR Contractors and Diverters

New diversions were added to C2VSimFG-Colusa to specify the monthly USBR deliveries to individual CVP contractors and diverters within the Colusa Subbasin (Diversion IDs 444-468). While many diversions of CVP supplies were specified in C2VSimFG Beta2, the original model largely aggregated the diversion volumes and element groups across multiple diverters. The new diversions were specified to instead distinguish the diversion volume and distribution area for each of the major diverters.

Diversions data were initially downloaded from USBR for all diverters that receive water from the Tehama-Colusa Canal (TCC), the Sacramento River, and other CVP supplies. Monthly data were quality controlled and reviewed for consistency. Diversion locations were generally identified from eWRIMS, and were used to classify diverters as within, outside, or partly within the Colusa Subbasin.

New diversions were specified in C2VSimFG-Colusa for all diverters within or partly within the Subbasin that receive water from the TCC and other CVP supplies, and for all diverters within or partly within the Subbasin that divert more than 3,000 acre-feet (AF) from the Sacramento River each year. Smaller diverters that divert less than 3,000 AF from the Sacramento River each year were grouped in C2VSimFG-Colusa based on their location along the Sacramento River. A small number of diverters identified in the USBR data diverted from an unknown location. It was assumed that a diversion from the TCC to support “fish facilities” in an unknown location was not within the Subbasin, while thirteen smaller diversions from the Sacramento River were assumed to be located within the Subbasin. These smaller diversions range from less than 100 AF per year to 2,900 AF per year, on average, with a total average volume of approximately 17,000 AF per year.

For diverters entirely within the Colusa Subbasin, the volume of diversions from USBR was taken directly from USBR reports in years when data were available (1989-2015). For diverters partially within the Colusa Subbasin, the volume of diversions from USBR was prorated based on the relative area inside the Subbasin. Any diversions originally specified in C2VSimFG Beta2 that accounted for these same USBR deliveries were used to quantify the diversion volumes in years prior to 1989, either directly or prorated based on area (if the diverter is partly within the Colusa Subbasin). In 1989-2015, these original C2VSimFG Beta2 diversions were either set to zero volume (for diverters within the Colusa Subbasin), or revised to deliver a reduced volume prorated by area to only those the elements located outside the Subbasin.

The diversion specifications were updated for all new and revised USBR deliveries, as needed. Diversion locations were updated to the stream node closest to the point of diversion identified in eWRIMS, where available. Distribution and recharge element groups were revised to match the diverter's service area, if available, as well as all changes in how the diversions are distributed inside and outside the Colusa Subbasin, refined to exclude areas within or outside the subbasin, as needed. The recoverable and nonrecoverable loss fraction of each new USBR diversion was updated based on local water budget information, where available.

2.8.2 Other Diversions

Diversions to Glenn-Colusa Irrigation District (GCID) were updated with diversion data available from GCIDWIS (1989-2015), and with eWRIMS data to account for winter water use.

Diversions to Reclamation District 108 (RD108), Princeton-Codora-Glenn Irrigation District (PCGID), and Provident Irrigation District (PID) were specified with all available data from the Districts between water year 1989-2015. Estimates of winter water used within these Districts were also specified, assuming similarity to the winter water use observed in GCID.

The diversion element groups and recharge element groups were updated for all new diversions, reflecting the service area of each District to the extent permitted by the model element resolution.

3. MODEL CALIBRATION

3.1 Calibration Goals

The goals of model calibration are (1) to achieve a reasonable water budget for each component of the hydrologic cycle modeled (i.e., land and water use, stream flow, and groundwater) and (2) to maximize the agreement between a) simulated and observed groundwater levels at selected well locations and b) simulated and observed streamflow hydrographs at selected gaging stations. These objectives are achieved through verification of the model input data and adjustment of model parameters.

3.2 Calibration Approach

Model calibration begins after data analysis and input data file development are completed. The calibration effort can be broken down into subsets that align with packages within the Integrated Water Flow Model (IWFM) platform. IWFM is used for development of C2VSim-FG Colusa model. As an integrated groundwater model, the results of each part of the simulation are interrelated with the other parts. The model calibration can be considered a systematic process that includes the following activities:

- Calibration of water budgets to other local water budgets through adjustment of root zone parameters
- Calibration of simulated groundwater levels and stream flows to observed data
- Comparison of calibration performance with the calibration targets
- Completion of additional model refinements, as necessary

C2VSimFG-Colusa was calibrated to achieve agreement with other local water budget results, measured stream flows and groundwater elevations, and groundwater elevation contours. The major data sources used to check model results include measured groundwater levels and contours and observed streamflow data. Though the model simulation period is October 1985 through September 2015 (30 years) or water years 1986 through 2015, the model calibration focused on water years 1990 through 2015 (26 years) because land and water use data for the model area is more reliable in those years.

3.3 Water Budget Calibration

Numerous water agencies and organizations use and manage water resources in areas overlying the Colusa Subbasin. For many of these entities, developing local water budgets is an important means of tracking and reporting water supply and water use in their service area. Local water budgets have been developed and are publicly available through various water management planning documents, including Agricultural Water Management Plans (AWMPs), Urban Water Management Plans (UWMPs), USBR Water Management Plans (WMPs), and Groundwater Management Plans.

The historical C2VSimFG-Colusa water budget results were evaluated for consistency with other local water budgets in the Subbasin by reporting and comparing subarea water budgets from the C2VSimFG-Colusa model with these local water budgets. To facilitate these comparisons, the historical C2VSimFG-Colusa model was divided into 38 subareas, several of which represent the service areas of specific water agencies and organizations.

Major flow paths considered in the calibration process included surface water deliveries, groundwater pumping, evapotranspiration, and deep percolation. Sample comparisons of these four parameters are shown in Figure 8 through Figure 10 for GCID, OAWD, and OUWUA. Other flow paths reported in both the local water budgets and the C2VSimFG-Colusa water budget results were also compared, as available. Comparisons were made in subareas and years when local water budget results were available to ensure similarity between major inflows to and outflows from land surfaces. Other comparisons were also made to confirm the accuracy of diversions, and the seepage and evaporation of diversions in the subarea.

Across the entire Subbasin, a key parameter considered during the calibration process was the crop consumptive use fraction (CCUF). CCUF is a ratio of the consumptive use of applied water (also referred to as or evapotranspiration of applied water, or ET_{aw}) to the total volume of applied water. High CCUF values close to 1.0 generally indicate higher irrigation efficiency, while lower CCUF values generally indicate lower irrigation efficiency. Discussion with local water users and review of irrigation methods throughout the Colusa Subbasin over time suggest that irrigation efficiency has generally increased over time, leading to increasing CCUF values over the historical water budget period.

Root zone parameters were refined, as needed, through an iterative process to calibrate the C2VSimFG-Colusa subarea water budget results (1) for agreement with local water budget results, and (2) to provide for typical historical CCUF values and increasing CCUF values over the historical water budget period, reflecting trends toward higher irrigation efficiency in the Colusa Subbasin.

For most areas, calibrations were made by adjusting the target soil moisture (TSM) for each land use class in C2VSimFG-Colusa. The TSM specifies the irrigation target soil moisture as a fraction of field capacity, and is used by C2VSimFG-Colusa to compute irrigation depths for each land use in the model domain. When simulating an irrigation event, C2VSimFG-Colusa will apply water until the soil reaches the specified percent of field capacity. TSM fractions in the C2VSimFG-Colusa were refined through several iterations of adjustment and comparison against local water budgets (Figure 8 through Figure 10) and evaluation of local CCUF values. Average CCUF values for crops in the Colusa Subbasin range from 0.55 for rice, which is typically irrigated with higher volumes of water relative to demand, to values between 0.80 and 0.85 for almonds, pistachios, and grain crops.

TSM fractions in the calibrated model range from 0.9 to 1.0 (i.e., 90 to 100 percent of field capacity) for rice, to values generally between 0.76 and 1.00 (i.e., 76 to 100 percent of field capacity) for other nonponded crops. These values approximate soil moisture resulting from common irrigation practices in the Sacramento Valley.

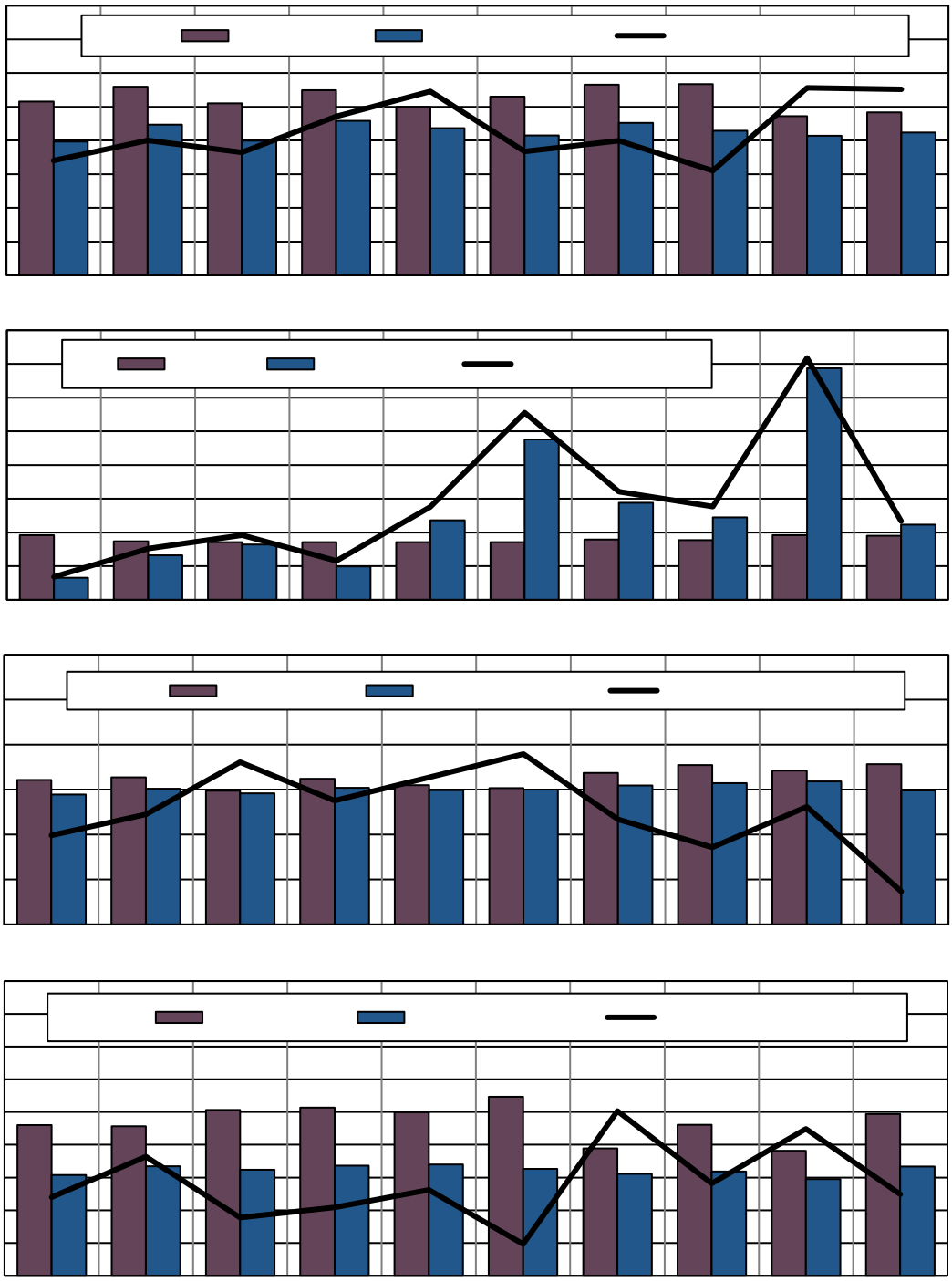

Figure 8. Comparison of Major Flow Paths from Local Water Budget and C2VSimFG-Colusa Results for the Glenn-Colusa Irrigation District.

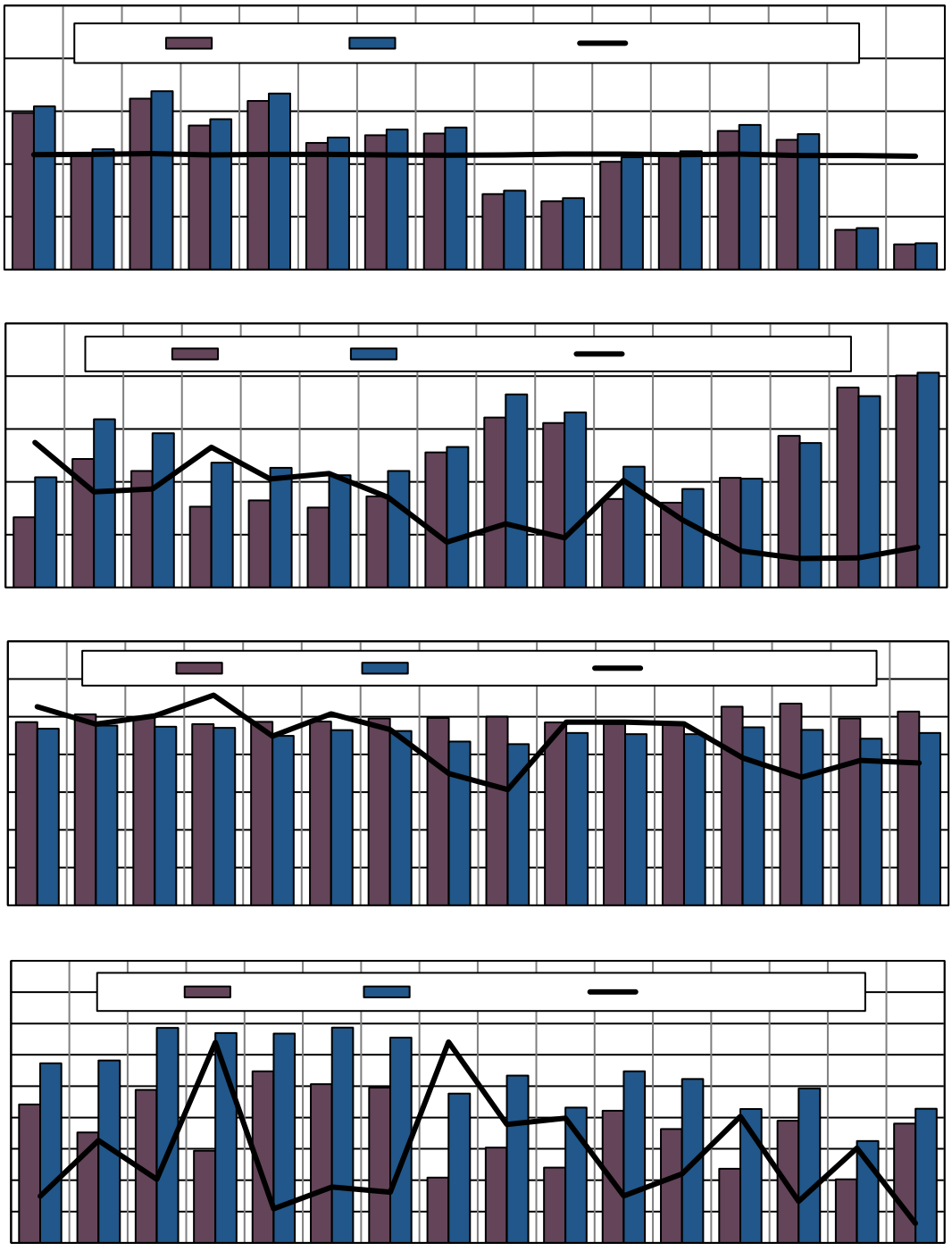

Figure 9. Comparison of Major Flow Paths from Local Water Budget and C2VSimFG-Colusa Results for the Orland-Artois Water District.

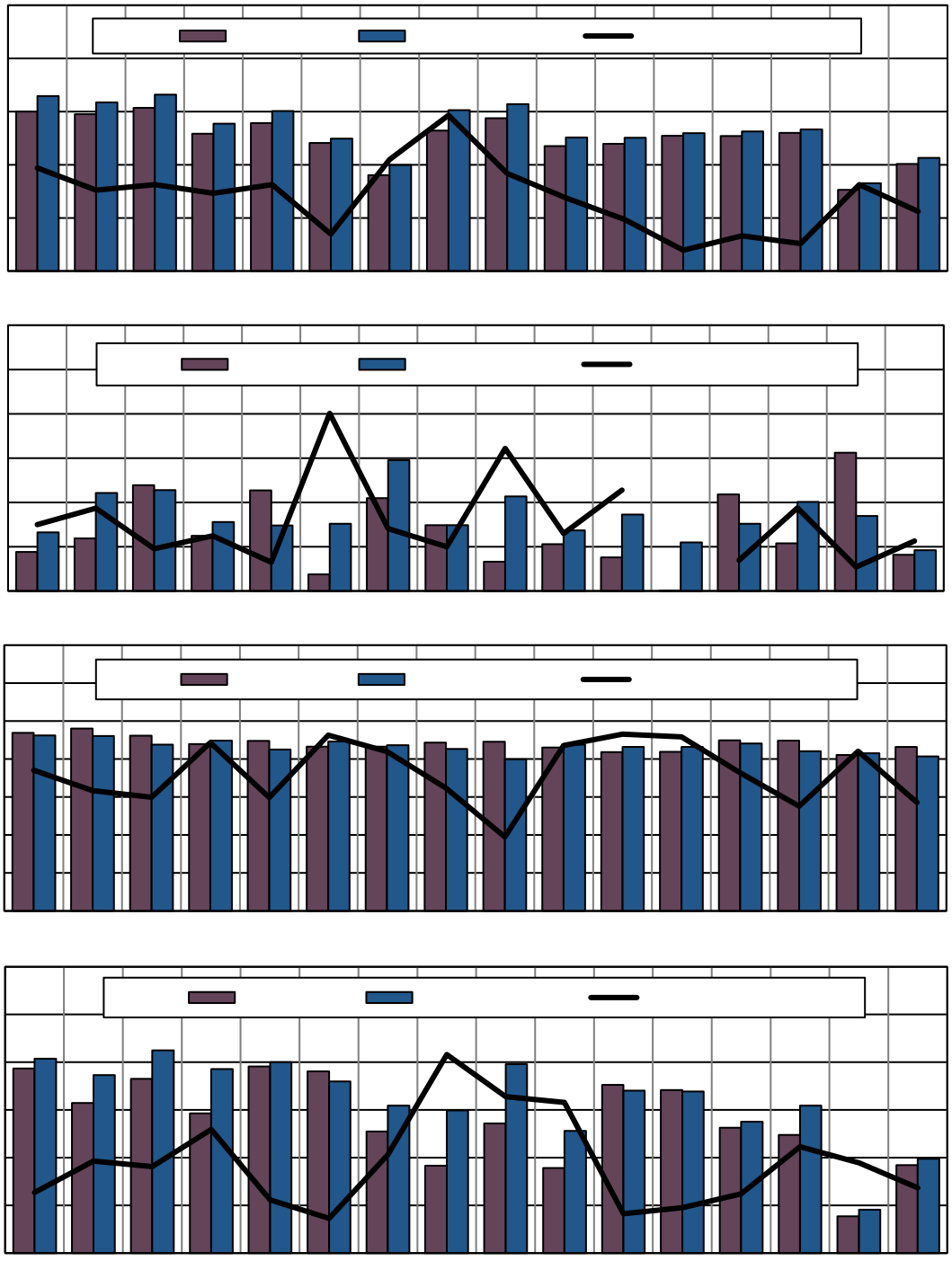

Figure 10. Comparison of Major Flow Paths from Local Water Budget and C2VSimFG-Colusa Results for the Orland Unit Water Users Association.

3.4 Streamflow Calibration

The major streams in the C2VSimFG-Colusa are Stony Creek, Sacramento River, Glenn-Colusa Canal, and Colusa Drain. Streamflow calibration is primarily performed by comparing the simulated streamflow at 6 locations with local data from 9 stream gages (Table 3-1 and Figure 11). Data for these gages came from the United States Geological Survey (USGS) and California Data Exchange Center (CDEC).

Table 3-1: Summary of C2VSimFG-Colusa Streamflow Calibration Gages

Stream	Stream Node	Agency	Gage Name	Period of Record
Stony Creek	3315	USGS	USGS 11388500: Stony Creek Near Hamilton City	January 1941 to September 1973
Sacramento River	3341	CDEC	CDEC ORD: Sacramento River at Ords Ferry	January 1984 to present
Sacramento River	3370	USGS	USGS 11389000: Sacramento River at Butte City, CA	October 1938 to June 1995
		CDEC	CDEC BTC: Sacramento River at Butte City	January 1998 to present
Sacramento River	3502	USGS	USGS 11389500: Sacramento River at Colusa, CA	April 1921 to present
		CDEC	CDEC COL: Sacramento River at Colusa	January 1984 to present
Sacramento River	3502	USGS	USGS 11390500: Sacramento River Below Wilkins Slough Near Grimes, CA	October 1938 to present
		CDEC	CDEC WLK: Sacramento River Below Wilkins Slough	January 1984 to present
Colusa Drain	3764	CDEC	CDEC CDR: Colusa Drain Near Hwy 20	November 1997 to present

Colusa Drain[1], as the major collector of excess irrigation flows or rice field runoff, was analyzed in the central portion of the Subbasin bounded by Glenn-Colusa Canal and Sacramento River. Most of the runoff in this region ends up flowing into Colusa Drain. Groundwater elevations in the vicinity of Colusa Drain are closely influenced by volume of runoff collected by Colusa Drain. It was necessary to increase shallow groundwater flow into the drain to lower the simulated groundwater levels to match the observed groundwater levels. This was achieved by adjusting the streambed conductance and elevation of Colusa Drain nodes in order to increase the capacity of flows into Colusa Drain. Simulated streamflows of Colusa Drain were compared to measured streamflows at CDEC CDR station in Colusa Drain.

Streamflow calibration included analysis of the streambed hydraulic conductivity and stream gain from or loss to the groundwater system. Simulated stream flows were compared with observed records and exceedance charts were also used to check the model performance when simulating high and low flows at each gage location. Calibration results for select stream gages (except Stony Creek due to lack of observation data) are included in Figure 12 through Figure 16.

[1] Also commonly referred to as the Colusa Basin Drain.

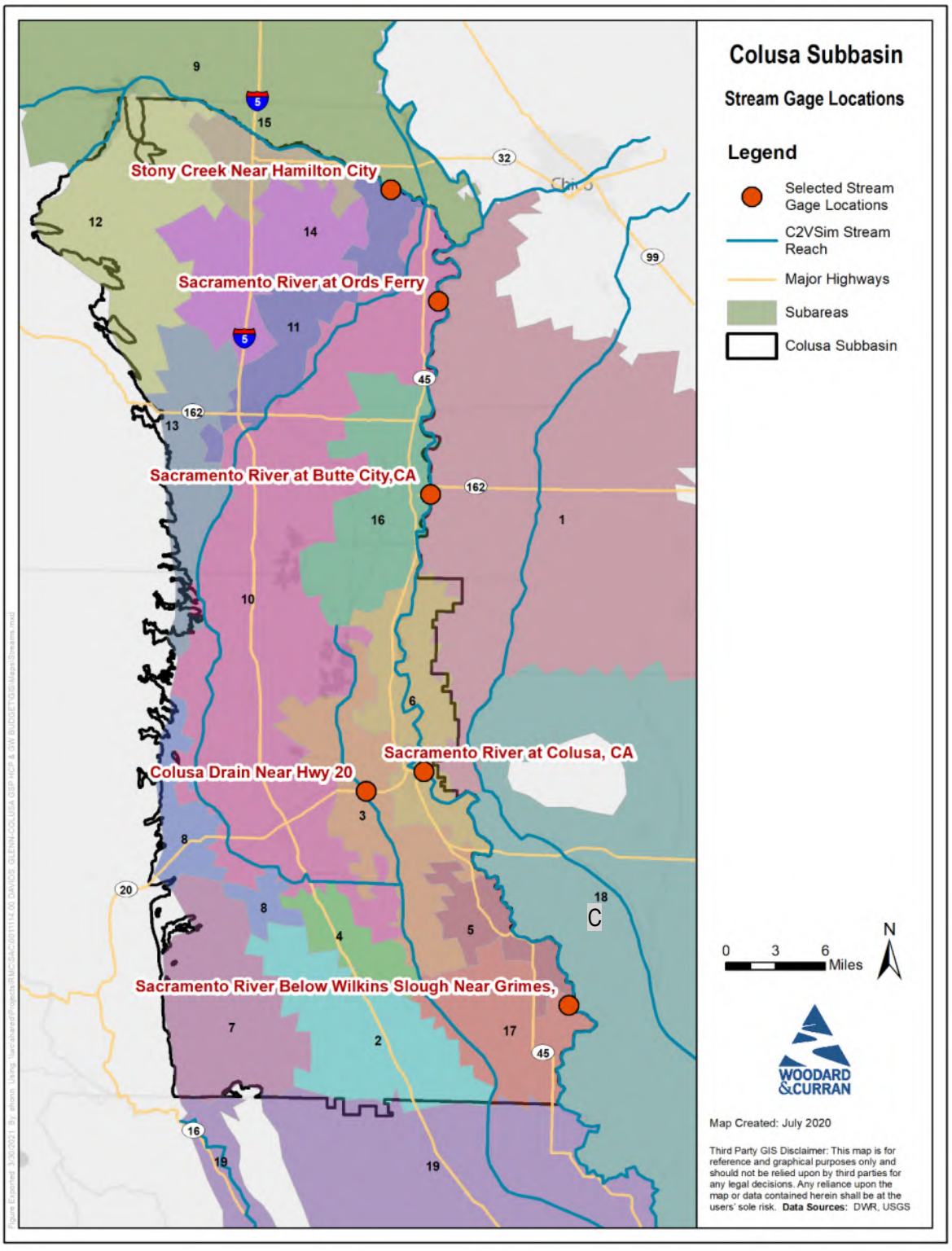

Figure 11: Calibration Stream Gage Locations

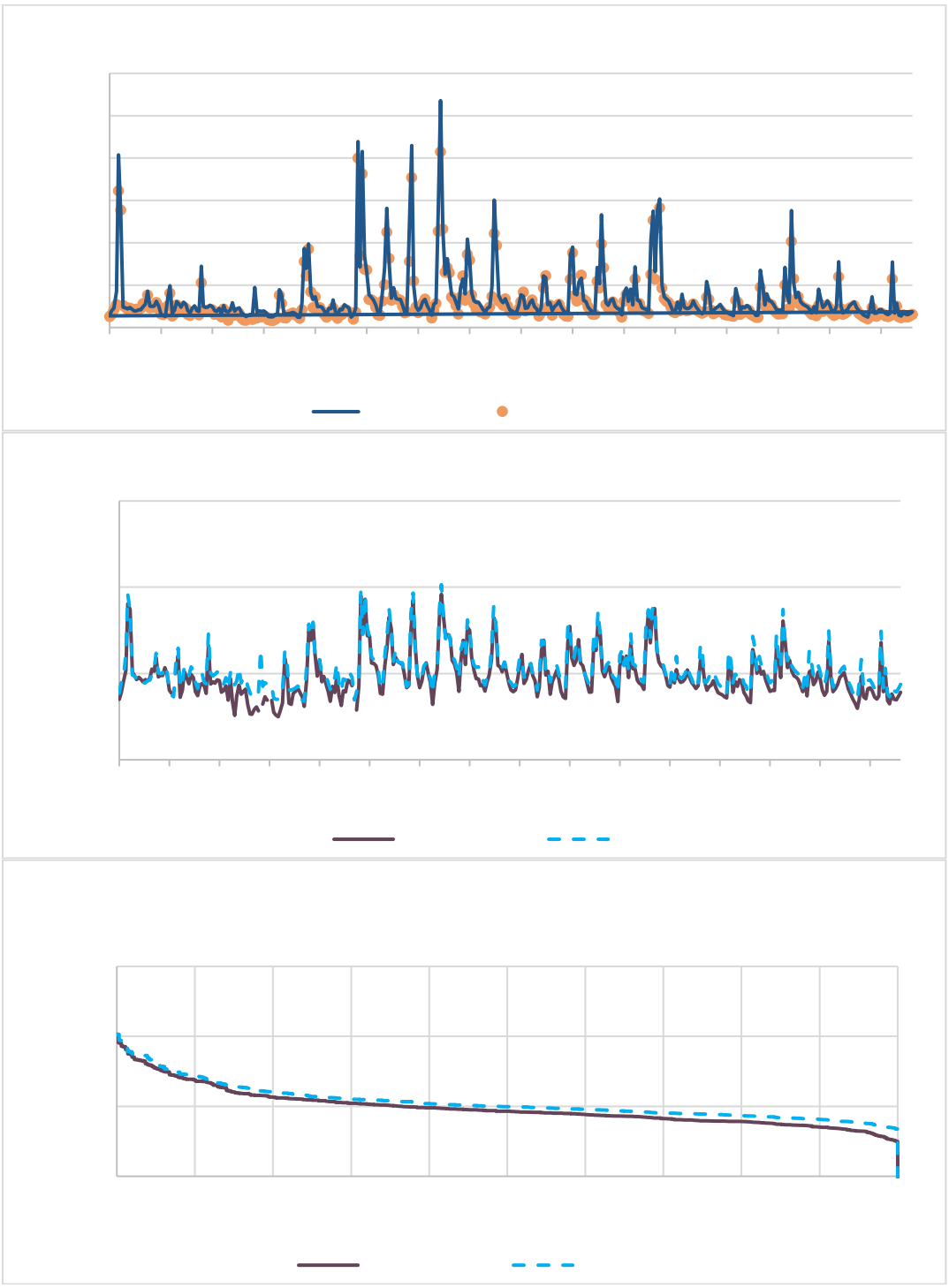

Figure 12: Streamflow Calibration for Sacramento River at Ords Ferry

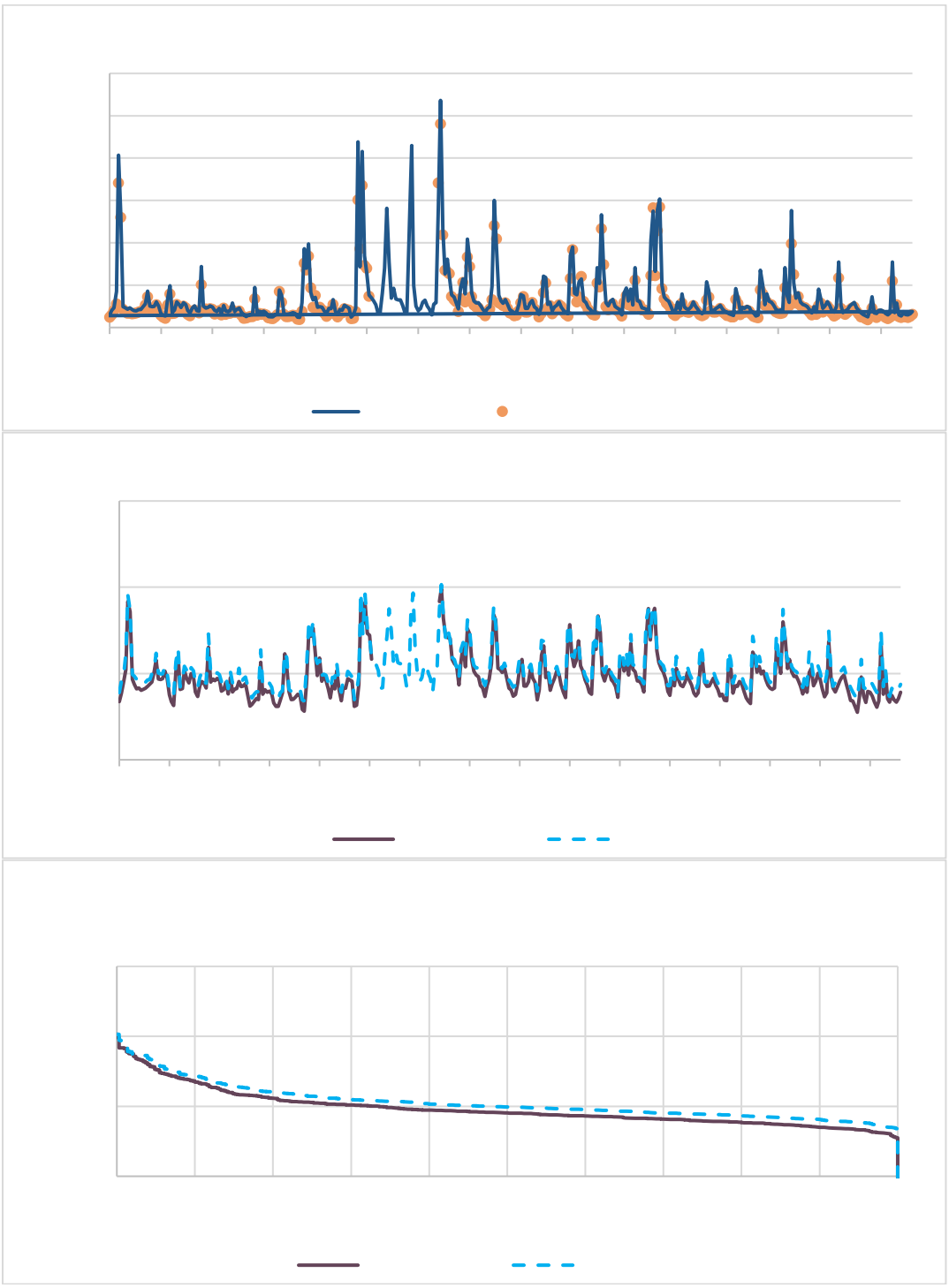

Figure 13: Streamflow Calibration for Sacramento River at Butte City

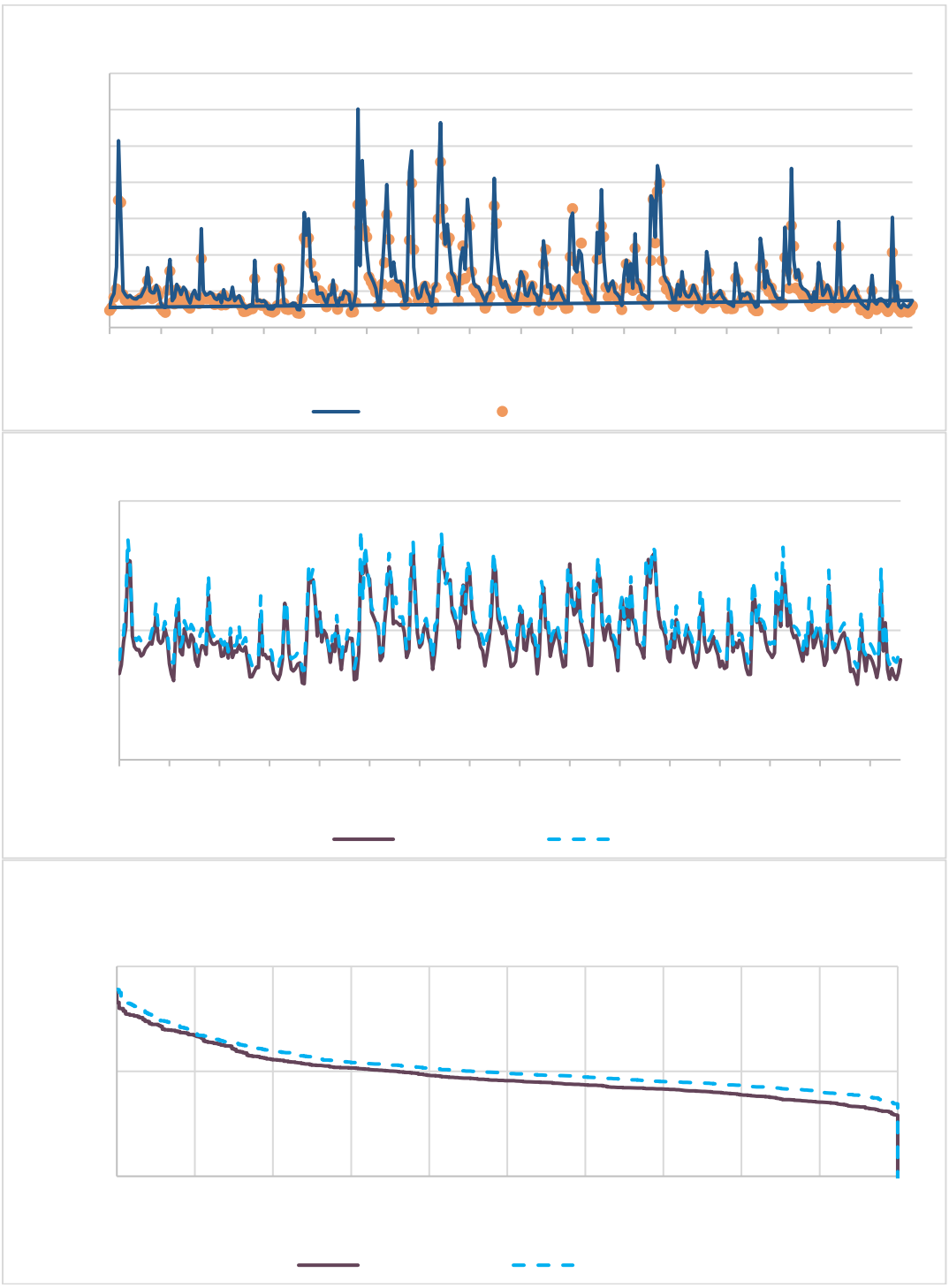

Figure 14: Streamflow Calibration for Sacramento River at Colusa

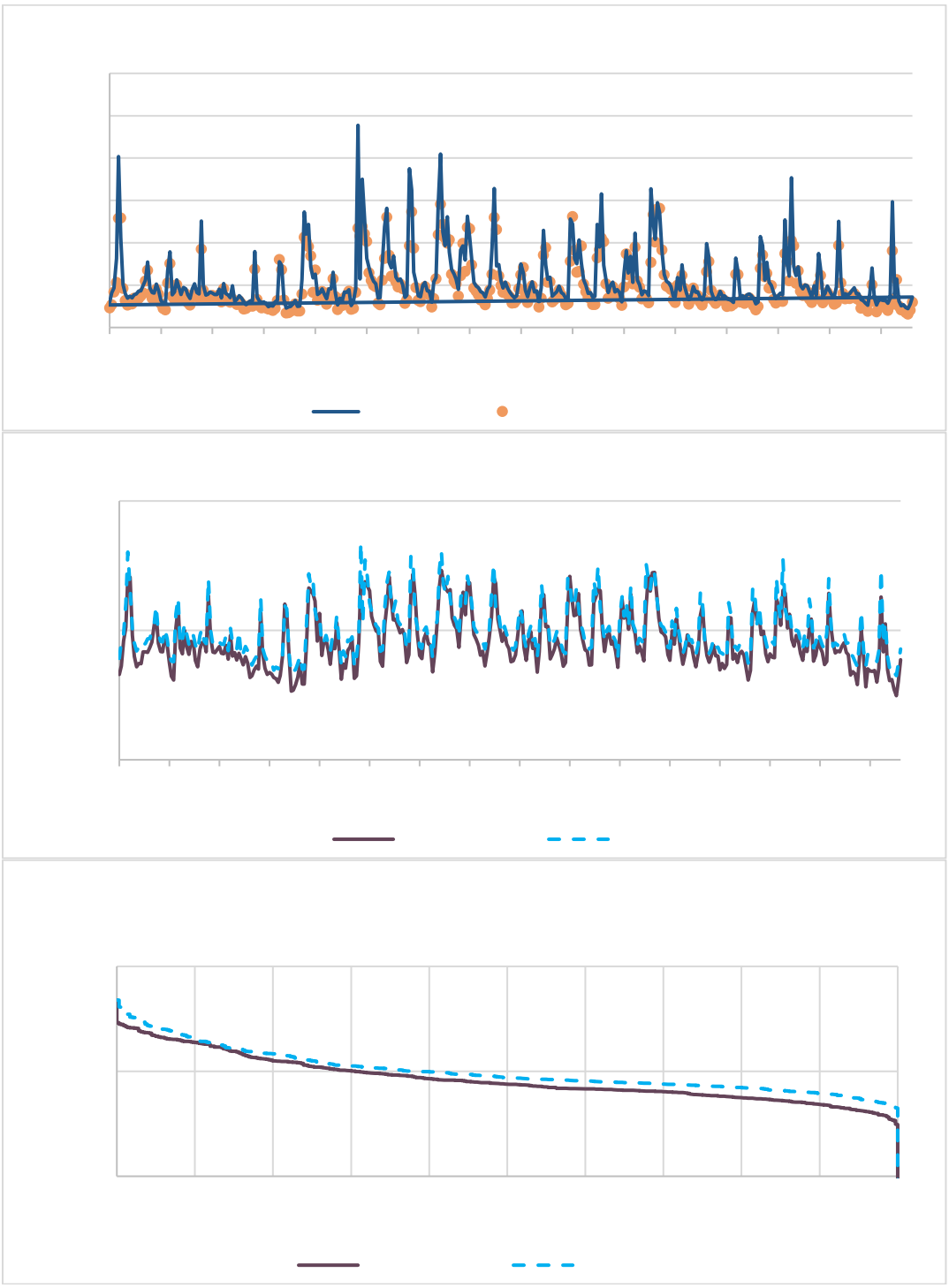

Figure 15: Streamflow Calibration for Sacramento River below Wilkins Slough

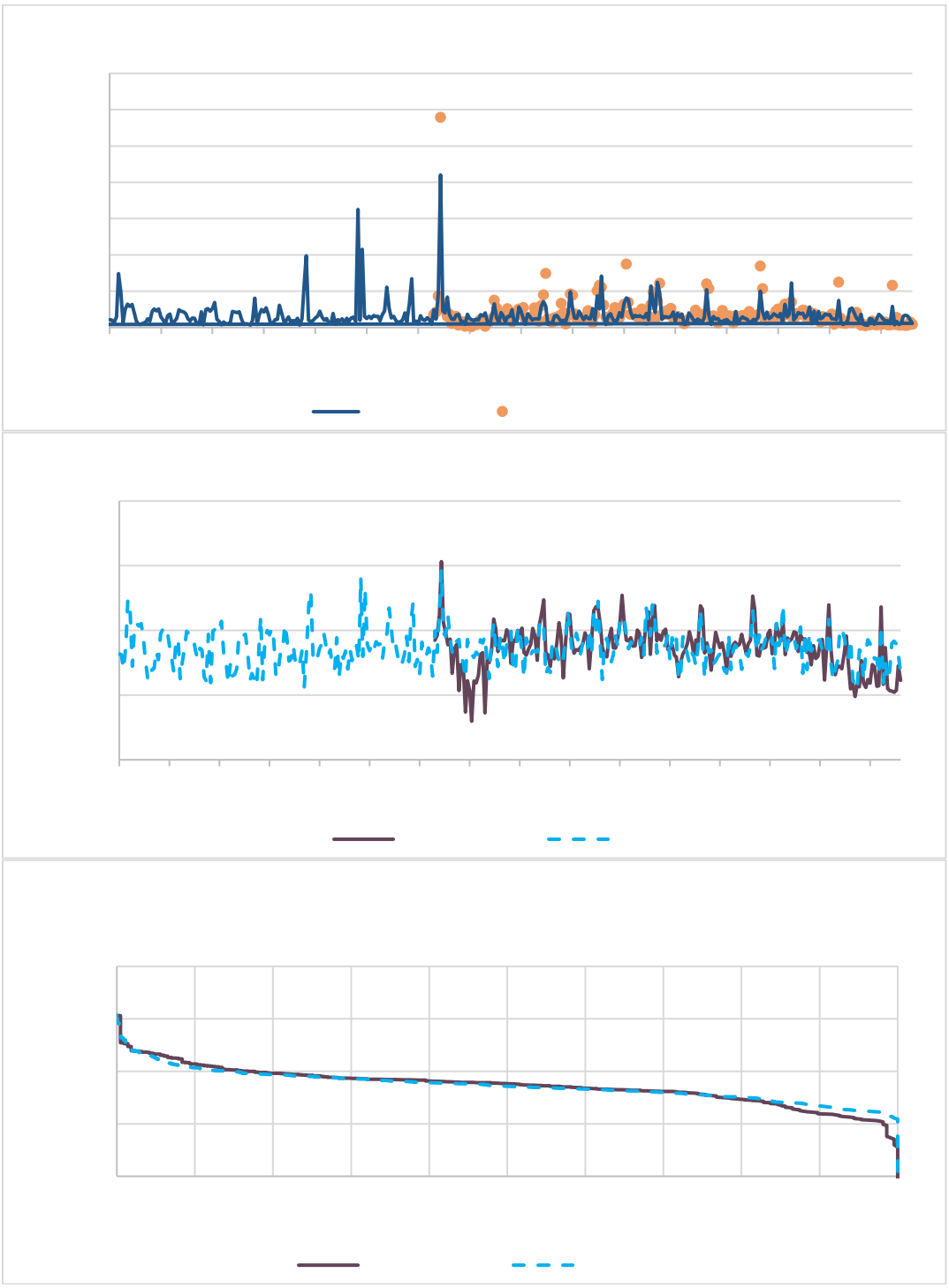

Figure 16: Streamflow Calibration for Colusa Drain near Highway 20

3.5 Groundwater Level Calibration

Like streamflow calibration, the goal of groundwater level calibration is to achieve reasonable agreement between the simulated and observed groundwater levels at the calibration wells. Within Colusa Subbasin and a five-mile buffer around the Subbasin, 740 wells were evaluated for developing groundwater observation locations to track calibration at both a regional and local scale. These wells came from DWR's California Statewide Groundwater Elevation Monitoring (CASGEM) Program and the groundwater level monitoring network for Colusa Subbasin. The calibration wells were filtered based on their period of observation records, availability of construction information (e.g., well depth and screen intervals), number of measurements between 1990 and 2015, number of spring measurements (assumed to be March, April, or May), spatial location, and active completions (for nested wells). Checks were also made on whether wells were included in Colusa Subbasin's groundwater level monitoring network, Butte Basin Groundwater Model's (BBGM) calibration wells, and C2VSimFG's calibration wells. An ultimate set of 252 wells were chosen that are representative of the long-term conditions of groundwater levels both at a local and regional scale in the area in and around the Colusa Subbasin. Calibration well locations are shown in Figure 17.

Calibration wells were assigned to a model layer based on the well top/bottom perforations or total well depth. C2VSimFG-Colusa's model layering was not altered and is described in C2VSimFG documentation. Of the 252 calibration wells, 134 were assigned to Layer 1 (unconfined aquifer), 70 to Layer 2, and 48 to Layer 3 which extends to the base of fresh water. Layer 4, which is saline water, extends down to the base of continental deposits and typically does not contain any wells.

Simulated groundwater levels were calibrated to observed levels through adjustments to model aquifer parameters including hydraulic conductivity, specific storage, and specific yield. The goal of groundwater level calibration is to achieve the maximum agreement between simulated and observed groundwater elevations at calibration wells while maintaining reasonable values for aquifer parameters. The groundwater level calibration was performed in two stages:

- The initial calibration effort was focused on the regional scale to verify hydrogeological assumptions made during model data development and confirm the accuracy of general groundwater flow directions. During this iteration, simulated groundwater elevation trends, flow directions, and groundwater gradients were compared to measured data. DWR's groundwater level contours for Fall 2015 and West Yost's draft contours for Spring 2006 and Spring 2015 were used to evaluate C2VSimFG-Colusa groundwater contours from matching time periods. Figure 18 through Figure 20 show the simulated C2VSimFG-Colusa groundwater elevation contours (developed using Layer 1 elevations at model nodes) compared to DWR contours for Fall 2015 and West Yost contours for Spring 2006 and Spring 2015. Fall 2015 also represents the end of simulation groundwater levels.
- The second stage of calibration of groundwater levels was to compare the simulated and observed groundwater levels at each calibration well. This comparison provides information on the overall model performance during the simulation period, focusing on the calibration period of water years 1990 through 2015. To minimize the effects of groundwater pumping on groundwater elevations, only spring groundwater levels (assumed to be March, April, or May) were used to calculate calibration statistics. The simulated groundwater elevations at the 252 calibration wells were compared with corresponding observed values for concurrence in long-term trends as well as spring water levels.

The results of the groundwater level calibration indicate that the C2VSimFG-Colusa reasonably simulates the long-term hydrologic responses under various hydrologic conditions in Colusa Subbasin. Calibration statistics are provided in Section 6. Figure 21 shows a selection of calibration wells with their resulting groundwater level hydrographs. Appendix A shows all calibration groundwater level hydrographs. Appendix B shows all nested well locations with their hydrographs plotted on the same plot.

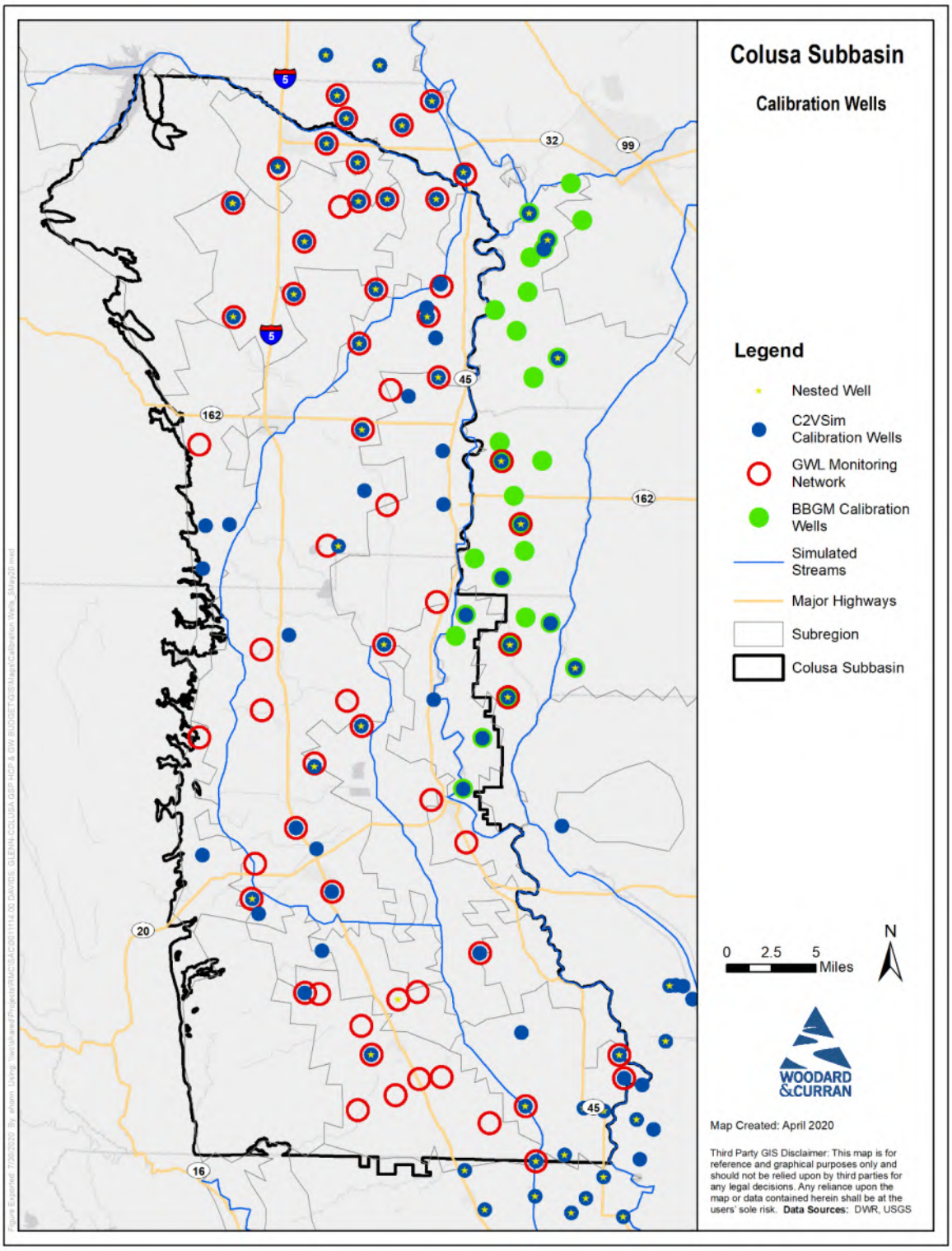

Figure 17: Groundwater Calibration Well Locations

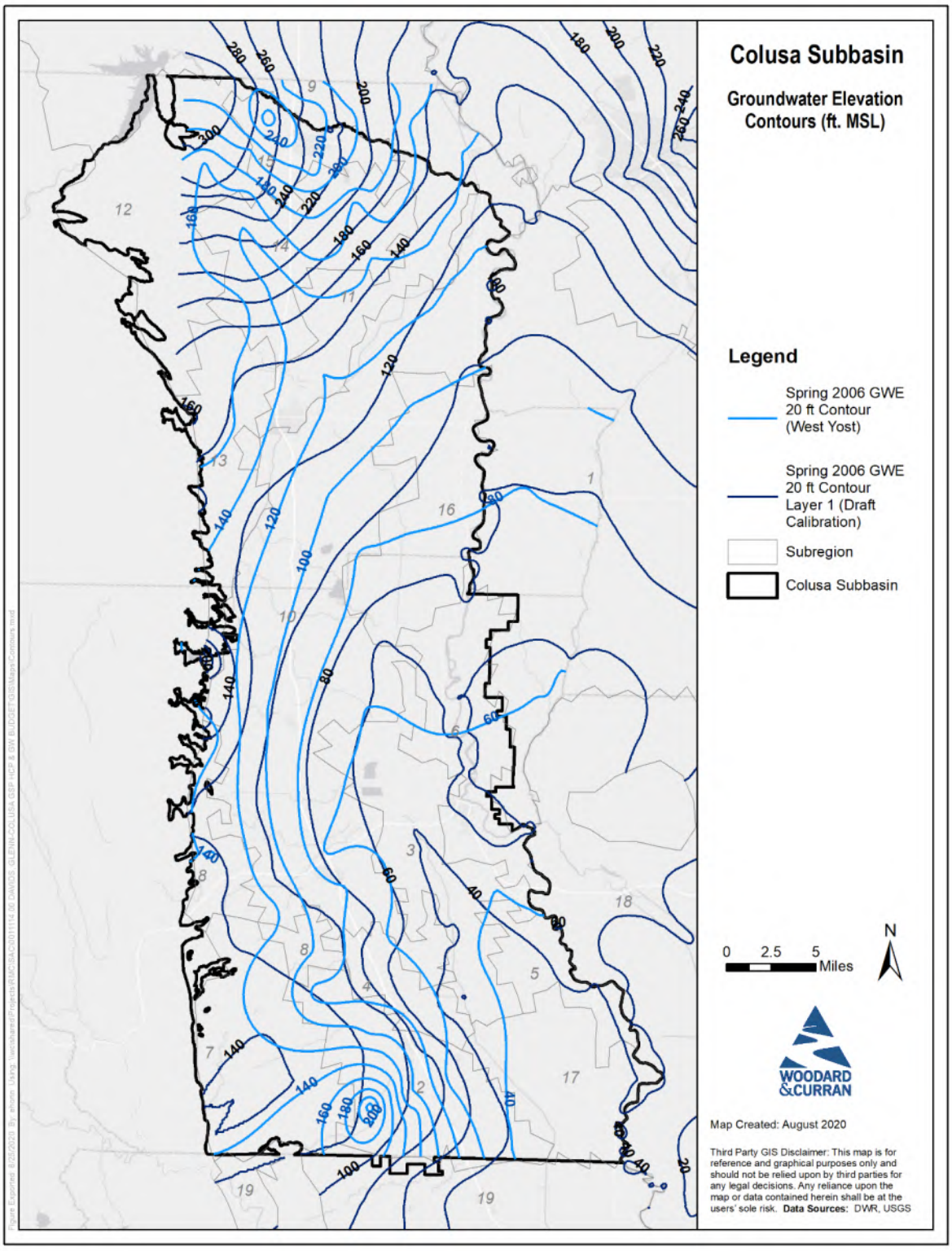

Figure 18: Spring 2006 Groundwater Elevation Contours Comparison

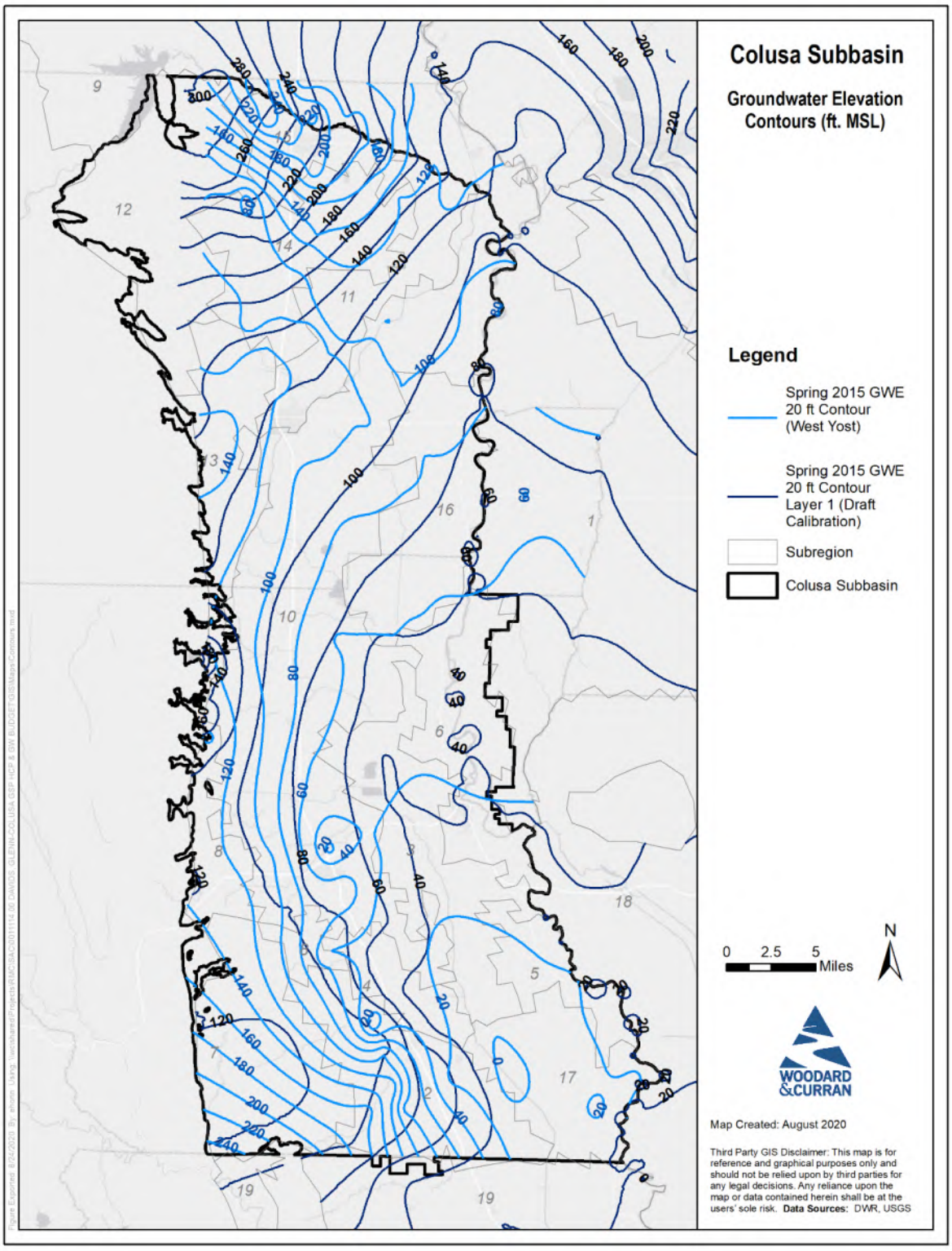

Figure 19: Spring 2015 Groundwater Elevation Contours Comparison

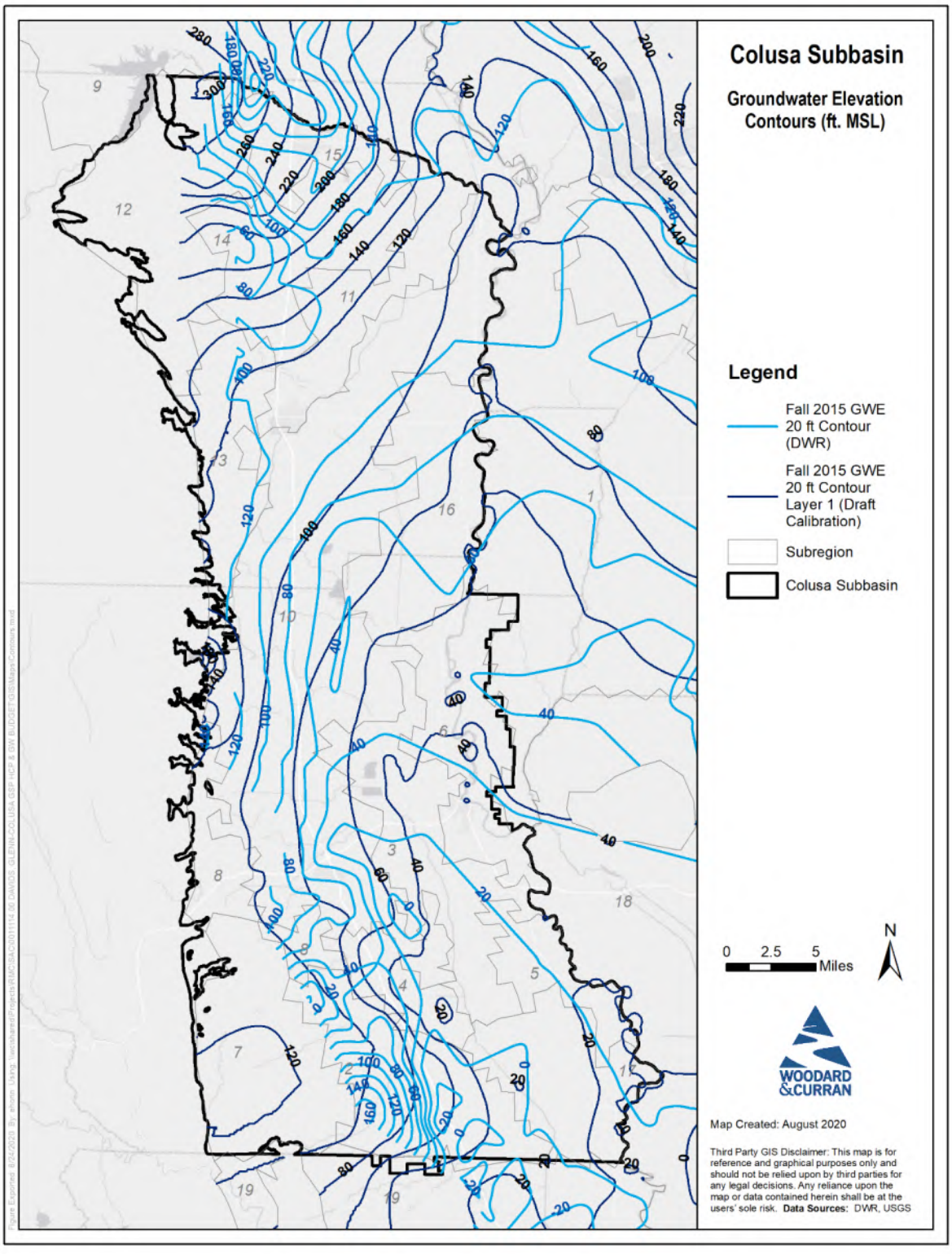

Figure 20: Fall 2015 Groundwater Elevation Contours Comparison

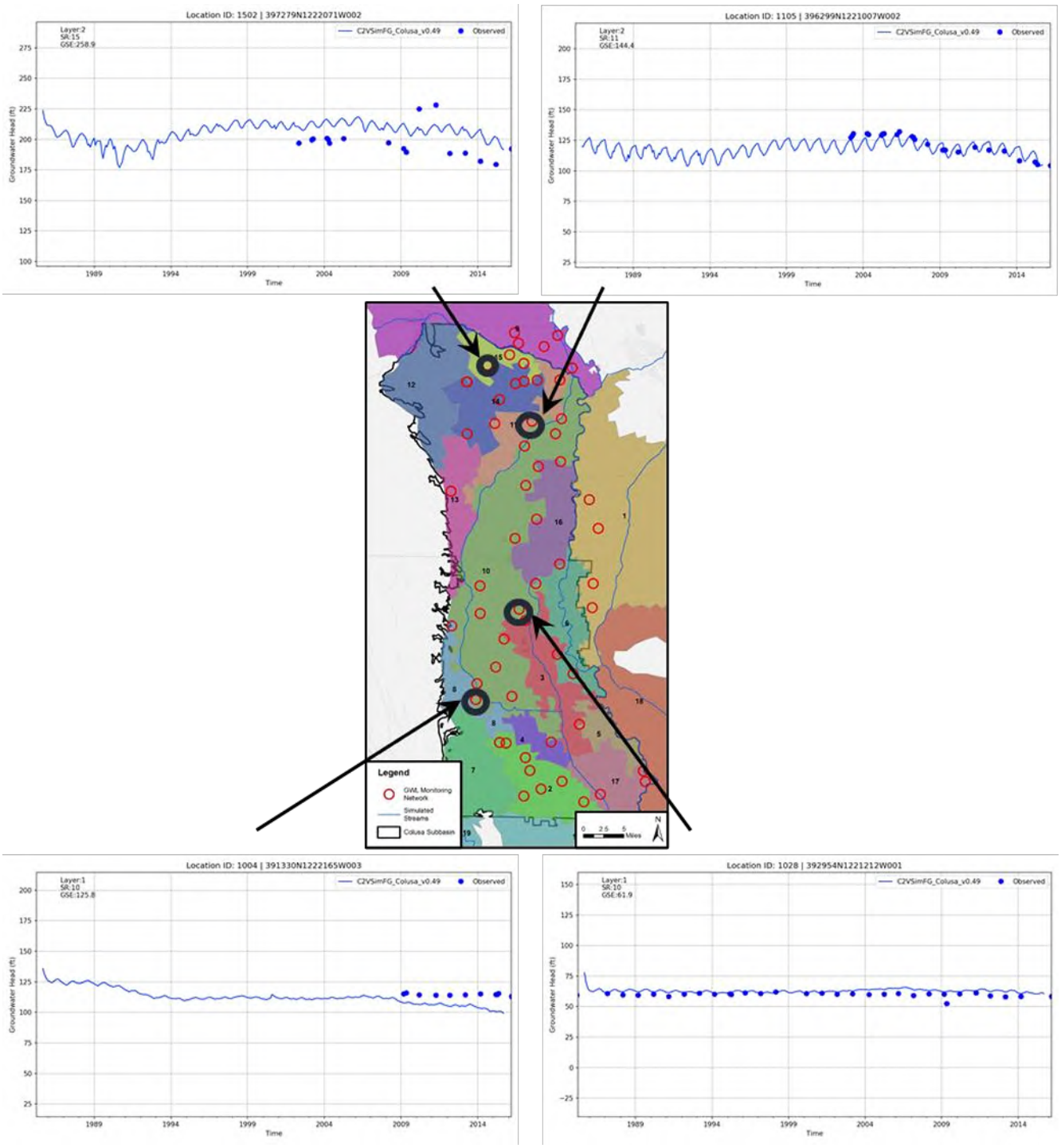

Figure 21: Selection of Groundwater Calibration Well Hydrographs

4. AQUIFER PARAMETERS AND DATA

C2VSimFG-Colusa uses a parametric grid that has been developed based on C2VSim Fine Grid (C2VSimCG) nodes and elements. The parametric grid nodes are spaced approximately 3.5 miles apart. Aquifer parameters are assigned to each parametric node and interpolated to the nearby C2VSimFG-Colusa groundwater nodes. Figure 22 shows the parametric grid nodes used to calibrate Colusa Subbasin. After regional calibration using the parametric grid, local calibration was made by changing aquifer parameters at each C2VSimFG-Colusa model node.

The initial aquifer parameters were from C2VSimFG Beta2 model. Through analysis of subregion water budgets and groundwater level hydrographs at the calibration wells, aquifer parameters were adjusted either model-wide or by node in particular areas. The parameters resulting from the calibration process are listed in Table 4-1.

Table 4-1: Range of Calibrated Aquifer Parameter Values

Layer	Horizontal Hydraulic Conductivity (ft/day)	Specific Storage (1/ft)	Specific Yield (-)	Aquifer Vertical Hydraulic Conductivity (ft/day)
1	1 - 218	1.00E-05 – 1.00E-04	0.06 - 0.11	0.02 – 0.69
2	2 - 215	1.00E-05 – 1.00E-04	0.06 - 0.11	0.02 – 0.67
3	2 - 127	9.00E-6 - 1.00E-04	0.06 - 0.11	0.02 – 0.48
4	5 - 49	1.00E-05 – 1.00E-04	0.06 - 0.11	0.14 – 1.05

The horizontal hydraulic conductivity in the C2VSimFG-Colusa varies across the horizontal direction and across model layers. The fully calibrated values for model layers 1 through 4 range from 1 ft/day to 218 ft/day, and the spatial distribution is represented in Figure 23 through Figure 26.

The aquifer vertical hydraulic conductivity facilitates the separation between the unconfined and confined aquifers within the C2VSimFG-Colusa and controls the flow of groundwater between the materials making up the different modeled aquifer layers. Analysis of the groundwater levels in each layer for calibration wells (i.e., nested calibration wells spanning multiple layers) determined that greater separation between layers was needed in some areas and resulted in a range of 0.02 ft/day to 1.05 ft/day across the model layers.

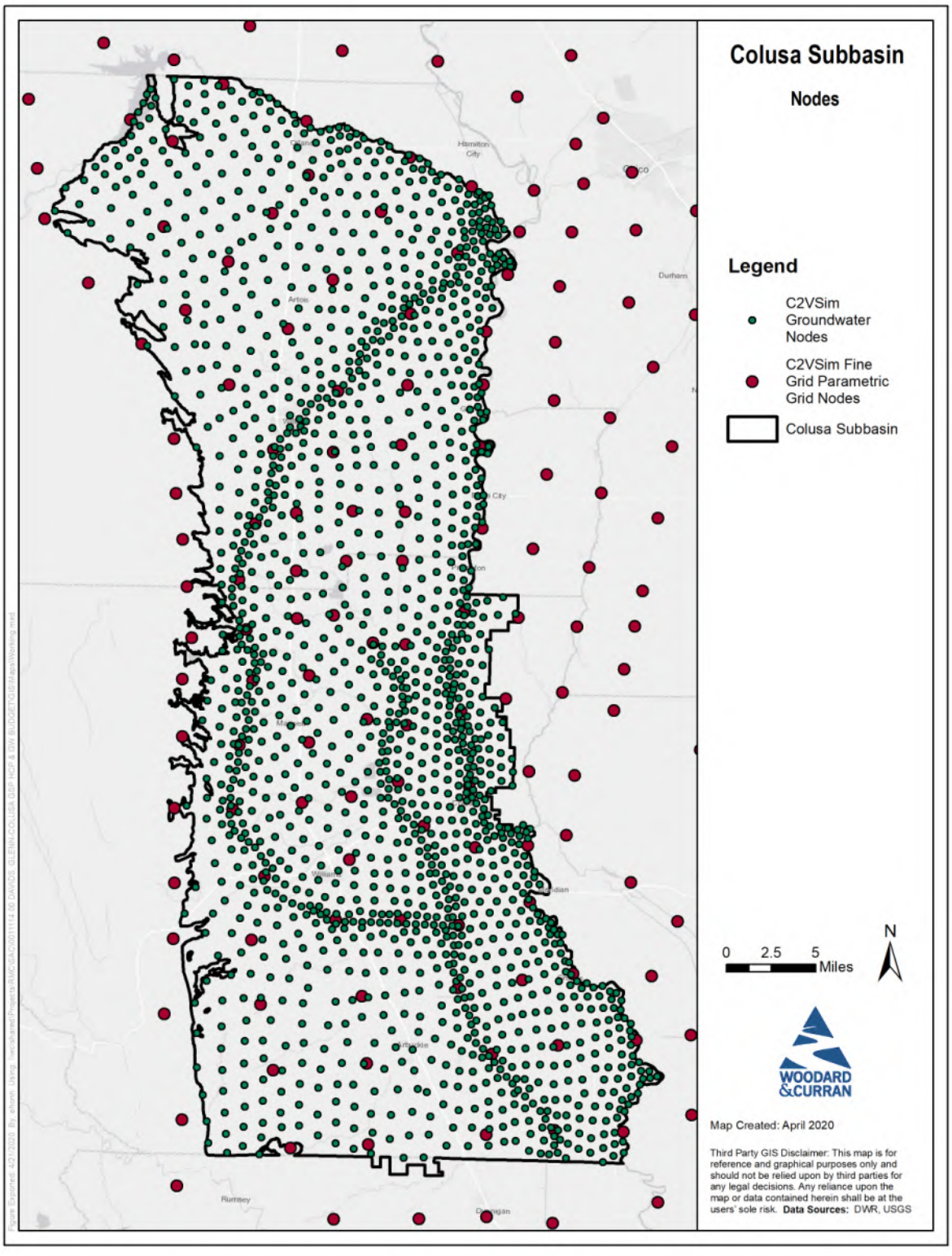

Figure 22: Parametric Grid Nodes within Colusa Subbasin and Five-Mile Buffer Area

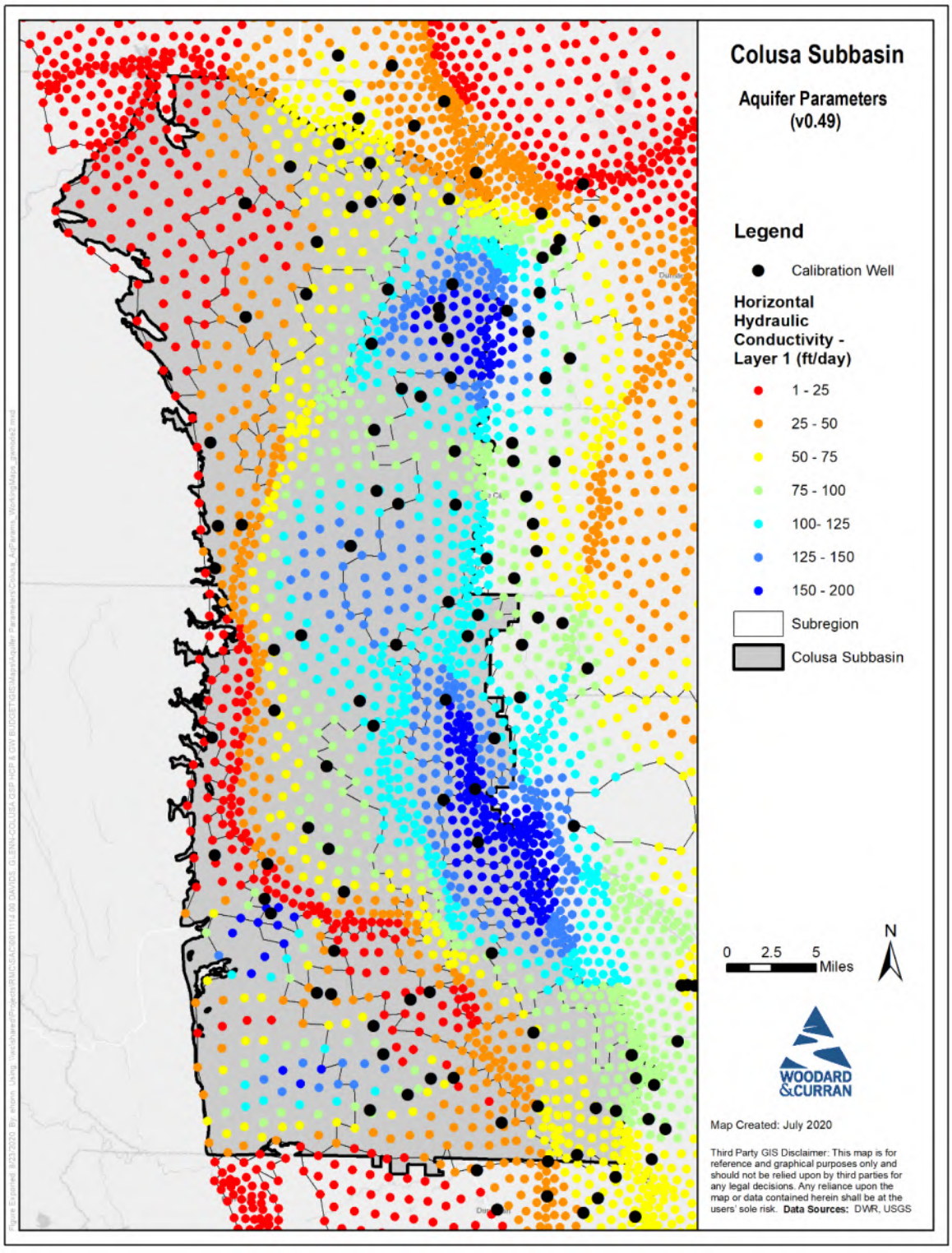

Figure 23: Calibrated Layer 1 Horizontal Hydraulic Conductivity (ft/day)

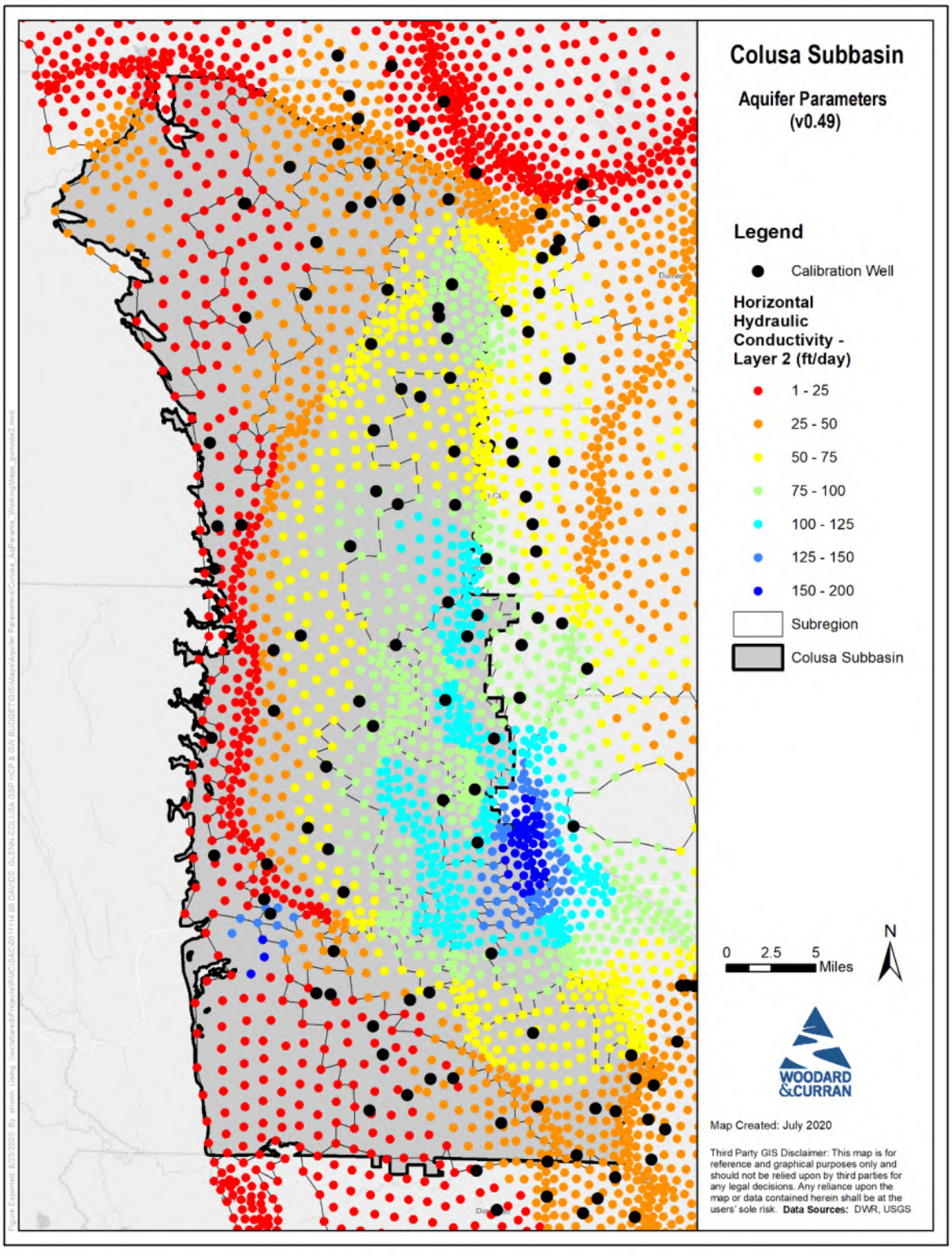

Figure 24: Calibrated Layer 2 Horizontal Hydraulic Conductivity (ft/day)

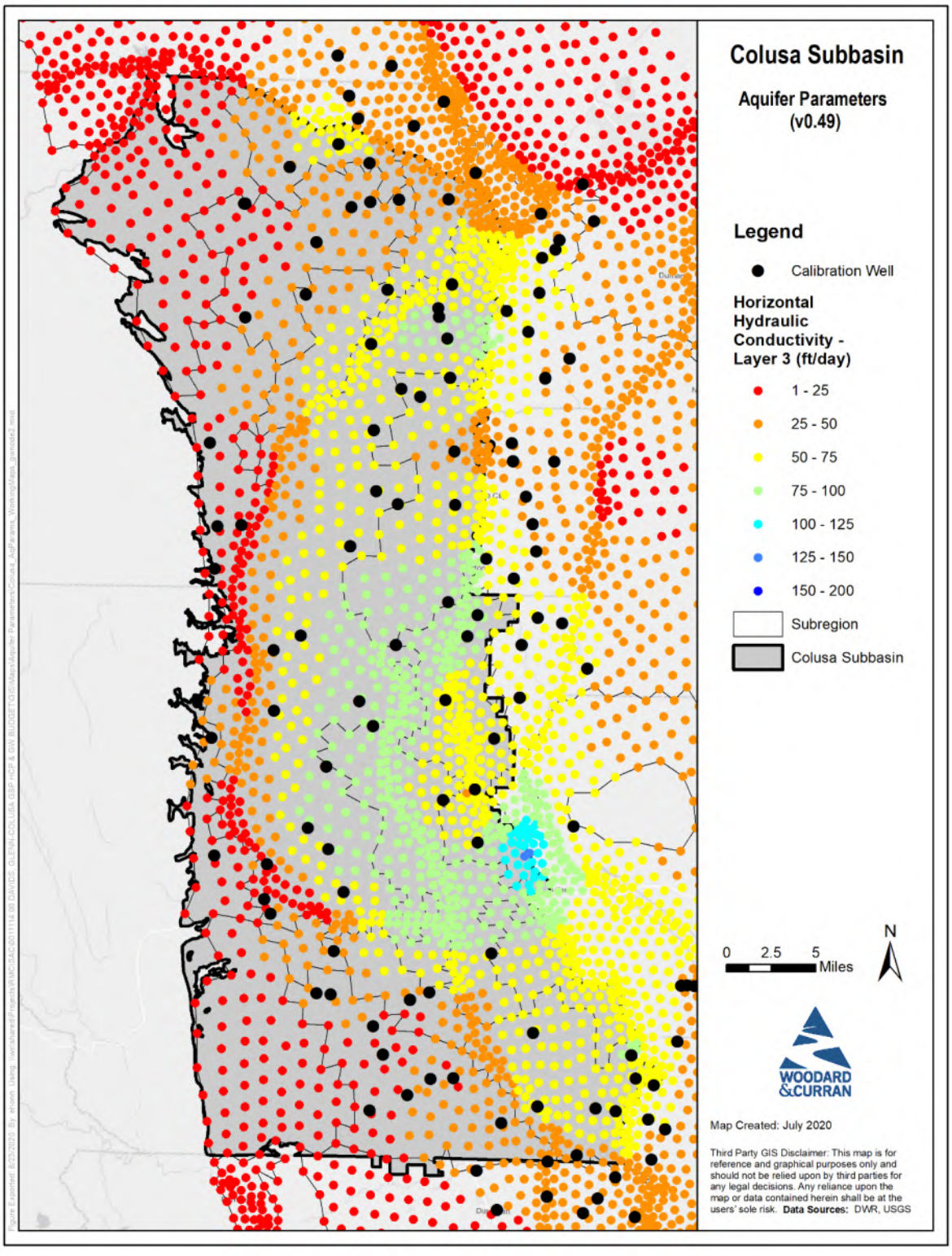

Figure 25: Calibrated Layer 3 Horizontal Hydraulic Conductivity (ft/day)

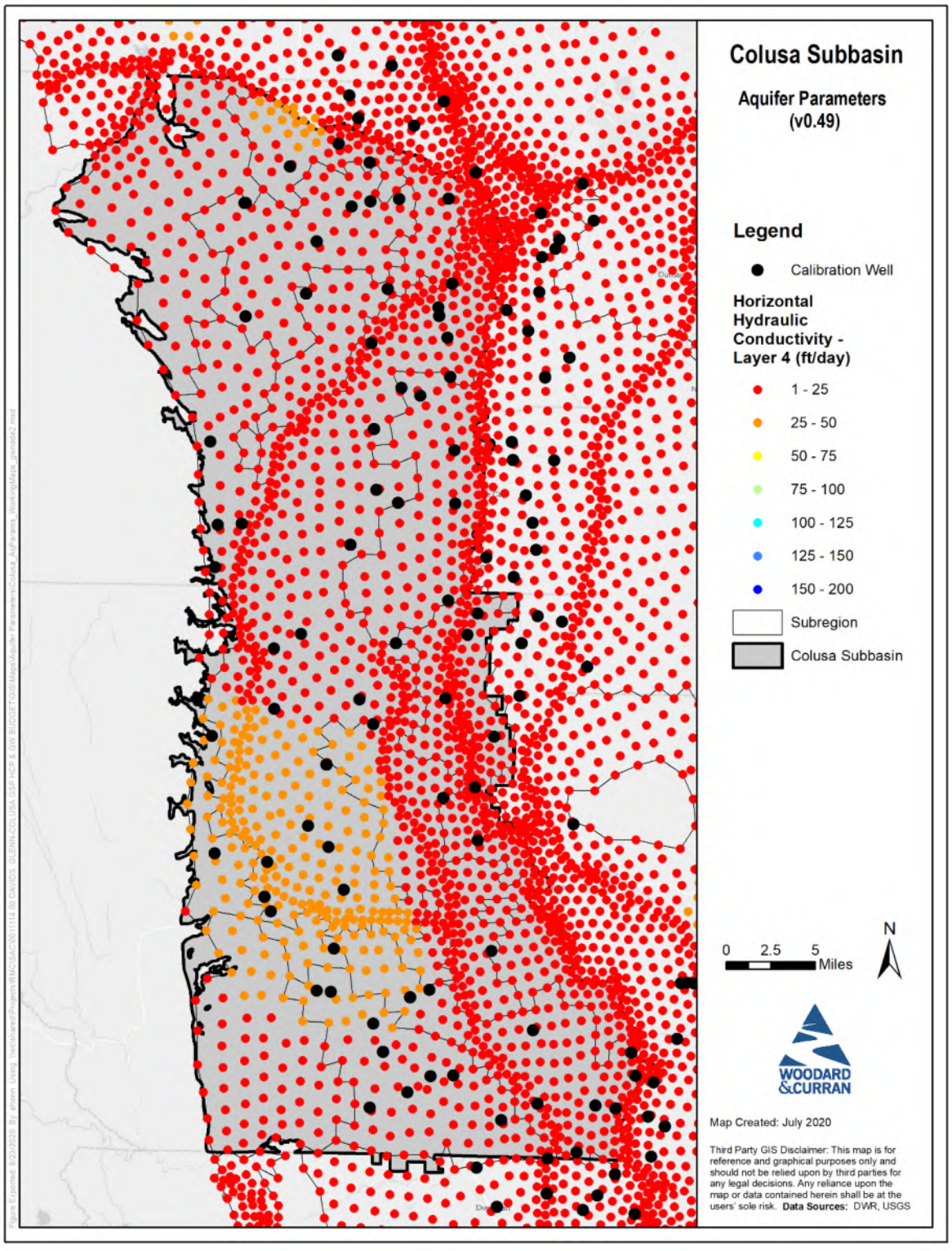

Figure 26: Calibrated Layer 4 Horizontal Hydraulic Conductivity (ft/day)

5. CALIBRATION TARGETS AND STATISTICS

The C2VSim-Colusa simulated groundwater levels were evaluated to meet the American Standard Testing Method (ASTM) standards. The "Standard Guide for Calibrating a Groundwater Flow Model Application" (ASTM D5981) states that "the acceptable residual should be a small fraction of the head difference between the highest and lowest heads across the site." The residual is defined as the simulated head minus the observed head. An analysis of all observed groundwater levels within the model area indicated the presence of 250+ feet of groundwater level changes in Colusa basin. Assuming 10 percent as the small fraction, the acceptable residual level would be about 25 feet. Calibration goals for the groundwater level residuals were set such that no more than 10 percent of the observed groundwater levels would exceed the acceptable residual level of 25 feet.

- 69% of observed groundwater levels are within +/- 10 feet of its respective simulated values
- 81% of observed groundwater levels are within +/- 15 feet of its respective simulated values
- 92% of observed groundwater levels are within +/- 25 feet of its respective simulated values

The residual histogram for the monitoring wells selected to be part of the calibration dataset for C2VSimFG-Colusa is shown in Figure 27. Additionally, a scatter plot of simulated versus observed values is shown in Figure 28.

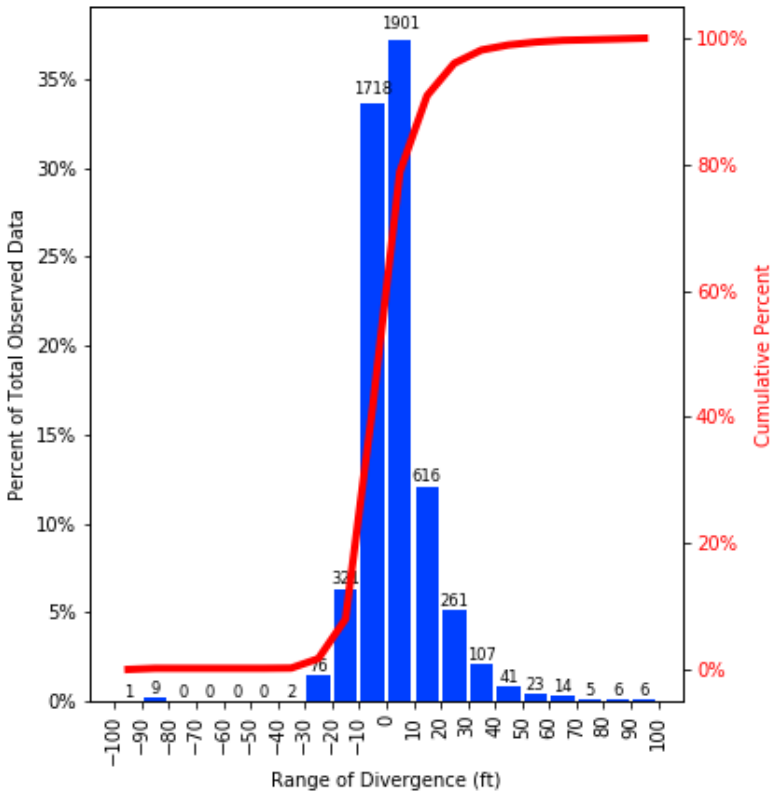

Figure 27: Residual Histogram of C2VSimFG-Colusa

Note: Observed water levels only for Spring (March-May) WY 1986-2015

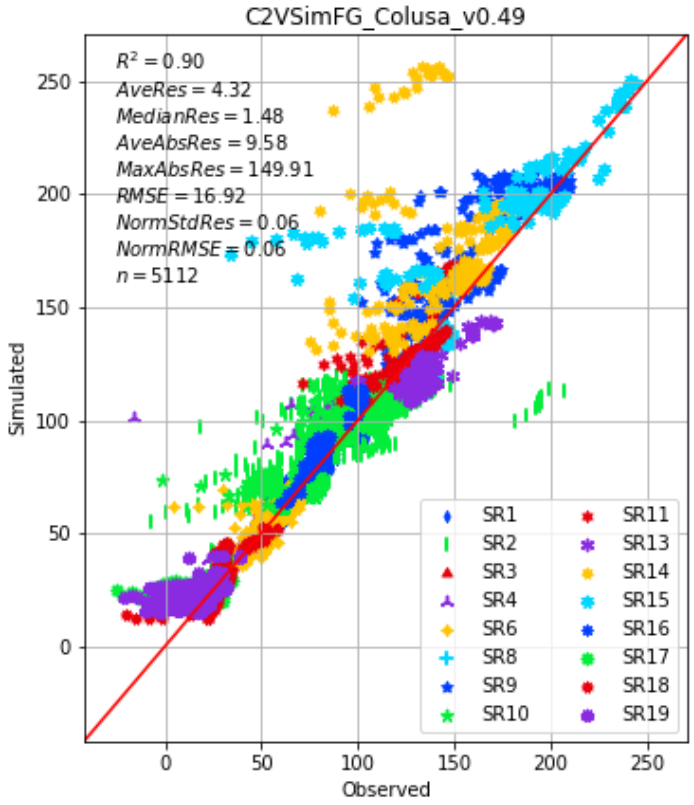

Figure 28: Scatter Plot of C2VSimFG-Colusa

Note: Statistics calculated using only observed water levels for Spring (March-May) WY 1986-2015

6. SENSITIVITY ANALYSIS

Sensitivity analysis is an important step in the model development process. It is defined as "the study of distribution of dependent variables (e.g., groundwater elevations in a groundwater model) in response to changes in the distribution of independent variables, initial conditions, boundary conditions, and physical parameters" (AWWA, 2001). In general, a sensitivity analysis of an integrated groundwater and surface water model is performed for the following purposes:

- To test the robustness and stability of the model by establishing tolerance within which the model parameters can vary without significantly changing the model results;
- To understand the impact of inaccuracies in input data on model results (e.g., how model results can change because of a 10% error in the estimation of agricultural pumping); and
- To develop an understanding of the relative sensitivity of the components of the hydrologic cycle and data, so that an effective data collection and monitoring plan can be developed.

A sensitivity analysis was performed using the C2VSimFG-Colusa to assess the sensitivity of model results to specific model parameters. Adjustments of aquifer parameters, and analyses of the resulting calibration well residuals, was performed across all calibration wells for various model runs. Analysis performed on parameters indicated that the model was fairly sensitive to horizontal hydraulic conductivity, specific yield, and less sensitive to the other parameters (Figure 29).

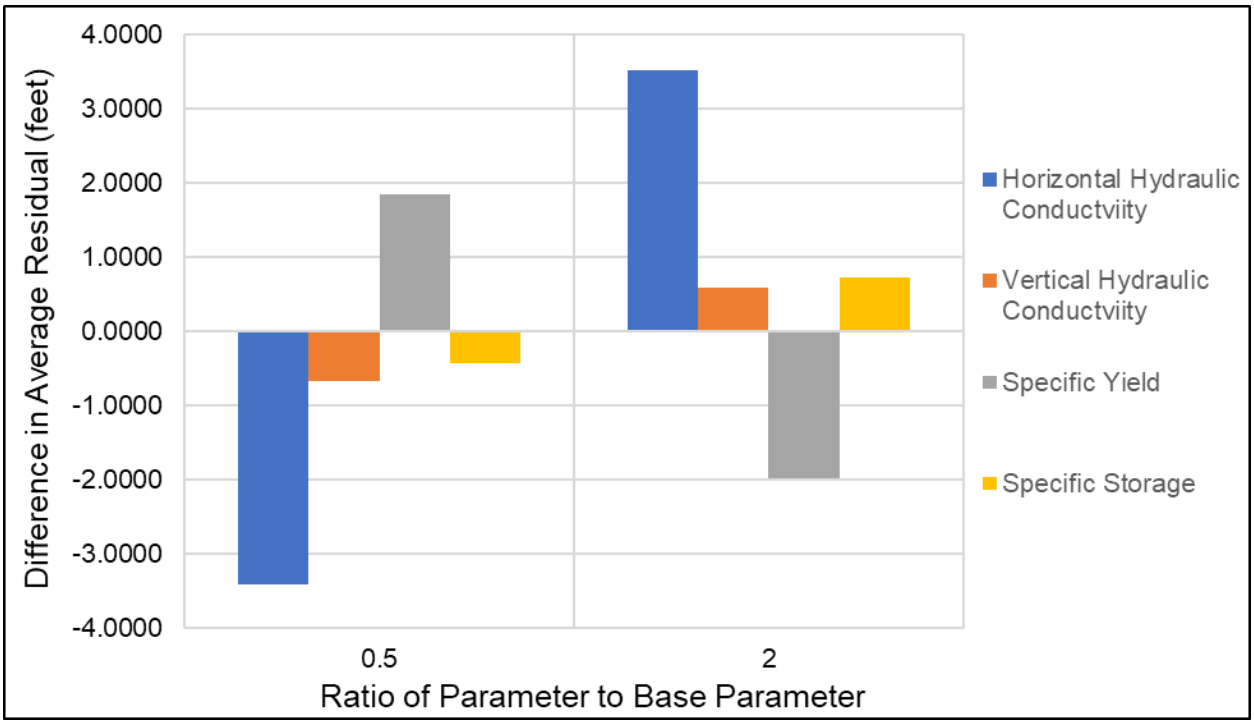

Figure 29: Difference in Calibration Well Residuals due to Changes in Aquifer Parameters

7. HISTORICAL WATER BUDGET RESULTS

Following all refinements, enhancements, and calibration procedures described in this technical memorandum, the C2VSimFG-Colusa model was used to quantify the historical water budget for the Colusa Subbasin. The historical water budget provides a foundation for understanding how the Subbasin has behaved historically, as well as insight into historical groundwater conditions (e.g. observed water levels) and insight into the sustainability of past groundwater management. In accordance with the GSP Regulations, the historical water budget covers a period of at least ten years (26-year period from 1990 to 2015).

A summary of the historical water budget results are presented below for the Subbasin land and surface water system (SWS), and for the Subbasin groundwater system (GWS). Additional information and discussion of the historical water budget is provided in the GSP, including an evaluation of the availability and reliability of historical surface water supplies per the GSP regulations. It is anticipated that the water budgets will be refined and updated over time as part of GSP implementation in the basin.

7.1 Historical Water Budget: Land and Surface Water System

Average annual inflows and outflows to and from the Colusa Subbasin land and surface water system were estimated to be nearly 13.83 million acre-feet (MAF) per year. Average annual values are shown in Figure 30 and Table 7-1.

Primary inflows to the land and SWS include surface water inflows (11,747 TAF/yr), precipitation (1,210 TAF/yr), groundwater pumping (502 TAF/yr), and stream gains from groundwater (i.e., stream accretions) (366 TAF/yr). Surface water inflows predominantly enter the Colusa Subbasin along the Sacramento River, where the river is wholly contained within the subbasin, flowing into the Subbasin south of the town of Princeton and out near of the City of Colusa. Additional surface water inflows occur through diversions from outside the Subbasin to land within the Subbasin (1,168 TAF/yr), and through overland runoff of precipitation from upslope small watersheds to the Subbasin (78 TAF/yr).

Primary outflows from the land and SWS include surface water outflows (11,302 TAF/yr), evapotranspiration (1,740 TAF/yr), deep percolation from land surfaces and small watersheds (441 TAF/yr), and seepage from streams, canals, and drains (345 TAF/yr). Surface water outflows include outflows along the Sacramento River, outflows to Sutter Bypass at Colusa Weir, drainage from the Colusa Basin Drain, overland runoff of precipitation and applied water to downslope lands, and other outflows to boundary streams. Evapotranspiration is primarily from agricultural lands, but also from managed wetlands, canal evaporation, native vegetation, and urban and industrial lands.

The average annual change in SWS storage is negligible compared to other inflows and outflows due to similar soil moisture content in the root zone, on average, across water years.

Figure 31 and Table 7-2 summarize the applied water computed by the C2VSimFG-Colusa model for the historical water budget period, according to the data sources and refinements describe in this technical memorandum. The total applied water includes surface water deliveries and groundwater pumping applied to all water use sectors in the Colusa Subbasin (agricultural, managed wetlands, and urban and industrial lands). Total surface water deliveries are computed based on the refined diversions data described above, averaging just over 1,260 TAF/yr (approximately 72 percent of the total applied water). Total groundwater pumping averages just over 500 TAF/yr (approximately 28 percent of the total applied water).

Figure 32 and Table 7-3 summarize the total groundwater recharge from the surface water system in the Colusa Subbasin. More than half of all groundwater recharge comes from deep percolation of applied water and precipitation on land surfaces, averaging 439 TAF/yr over the 1990-2015 historical water budget period (56 percent of total groundwater recharge). Other major contributors to groundwater recharge are stream seepage, and canal seepage. Stream seepage averaged 206 TAF/yr in 1990-2015 (26 percent of total groundwater recharge), while canal seepage averaged 139 TAF/yr over the same period (18 percent of total groundwater recharge). Percolation of runoff from small watersheds has contributed another 2 TAF/yr (less than one percent of total groundwater recharge).

Additional details describing the historical land and surface water system water budget are provided in the Colusa Subbasin GSP Appendix A.

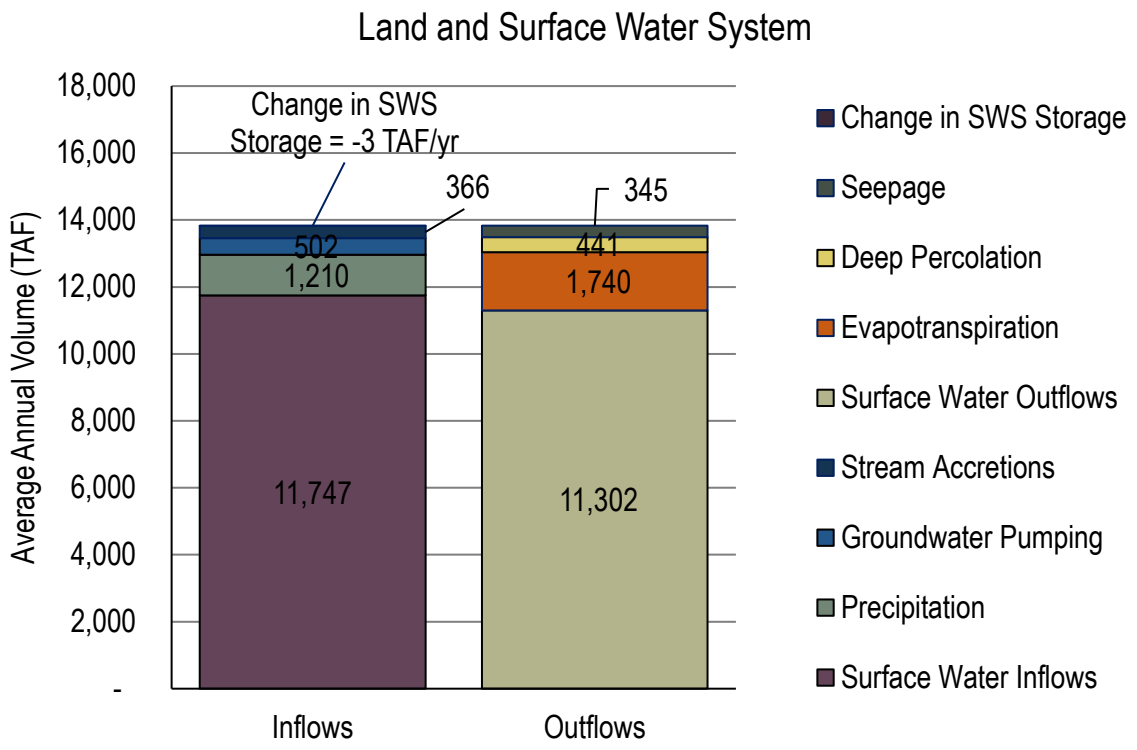

Figure 30: Historical Water Budget: Land and Surface Water System Summary.

Table 7-1. Historical Water Budget: Land and Surface Water System Summary.

Land and Surface Water System Flow Direction	Water Budget Component	Average Volume (TAF per year, 1990-2015)[1]
Inflows	Surface Water Inflows	11,747
	Precipitation	1,210
	Groundwater Pumping	502
	Stream Accretions	366
Total Inflows		***13,825***
Outflows	Surface Water Outflows	11,302
	Evapotranspiration	1,740
	Deep Percolation[2]	441
	Seepage[3]	345
Total Outflows		***13,828***
Change in SWS Storage (Inflows – Outflows)		***-3***

[1] Volumes rounded to 1,000 AF.

[2] Deep percolation includes deep percolation of applied water, deep percolation of precipitation, and small watershed percolation.

[3] Seepage includes stream, canal, and drain seepage to groundwater.

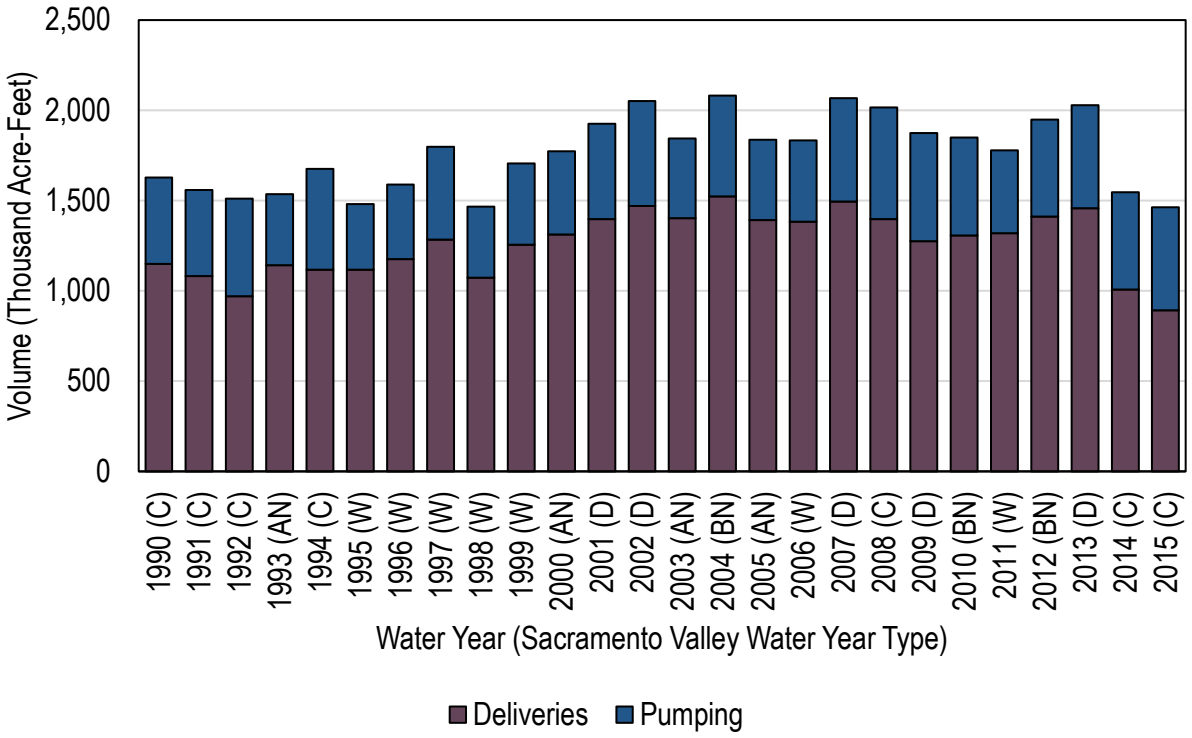

Figure 31. Historical Water Budget: Applied Water in All Water Use Sectors.

Table 7-2. Historical Water Budget: Average Annual Applied Water in All Water Use Sectors (TAF/yr, rounded).

Year Type	Number of Years	Surface Water Deliveries	Groundwater Pumping	Total Applied Water
W	7	1,230	435	1,664
AN	4	1,313	435	1,748
BN	3	1,414	546	1,960
D	5	1,419	570	1,990
C	7	1,088	540	1,628
Annual Average (1990-2015)	26	1,262	502	1,764

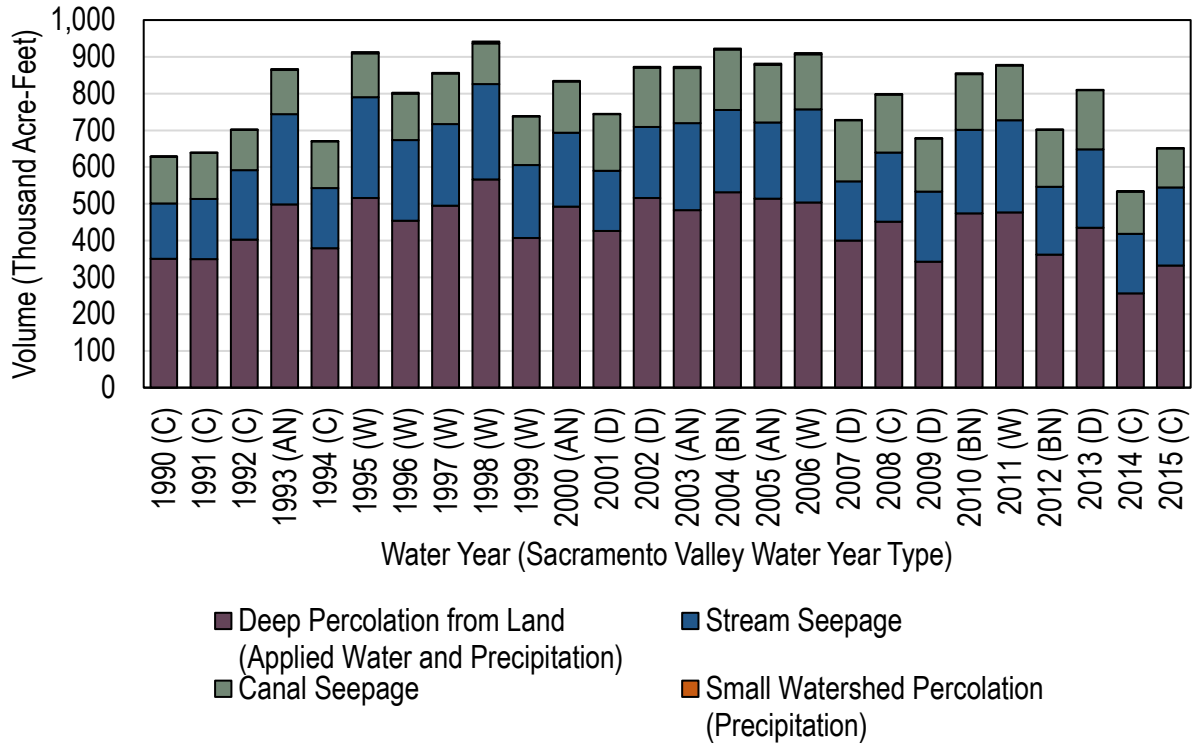

Figure 32. Historical Water Budget: Groundwater Recharge from the Land and Surface Water System.

Table 7-3. Historical Water Budget: Average Annual Groundwater Recharge from the Land and Surface Water System (TAF/yr, rounded).

Year Type	Number of Years	Deep Percolation		Seepage		Total Groundwater Recharge
		Deep Percolation from Land (From Applied Water and Precipitation)	Small Watershed Percolation (From Precipitation)	Stream Seepage	Canal and Drain Seepage	
W	7	489	3	239	132	863
AN	4	497	3	222	142	864
BN	3	456	2	212	157	827
D	5	424	1	184	158	767
C	7	360	1	175	124	661
Annual Average (1990-2015)	26	439	2	206	139	786

7.2 Historical Water Budget: Groundwater System

Average annual inflows and outflows to and from the Colusa Subbasin groundwater system are shown in Figure 33 and Table 7-4.

Primary inflows to the GWS include deep percolation from land surfaces and small watersheds (441 TAF/yr), seepage from streams, canals, and drains (345 TAF/yr), and subsurface inflows from adjacent subbasins (200 TAF/yr).

Primary outflows from the GWS include groundwater pumping (502 TAF/yr), stream gains from groundwater (i.e., stream accretions) (366 TAF/yr), and subsurface outflows to adjacent subbasins (146 TAF/yr). On average, subsurface outflows of groundwater from the Colusa Subbasin exceed subsurface gains of groundwater to the Colusa Subbasin.

The average annual change in storage is -28 TAF/yr over the 1990-2015 historical water budget period. This indicates that on average more groundwater leaves the Colusa Subbasin than enters, resulting in an average net reduction in groundwater stored in the Subbasin. The majority of groundwater inflows and outflows are exchanged directly with the land and SWS overlying the Colusa Subbasin GWS. Figure 34 summarizes the annual change in storage and the cumulative change in storage in the Colusa Subbasin GWS over the historical water budget period.

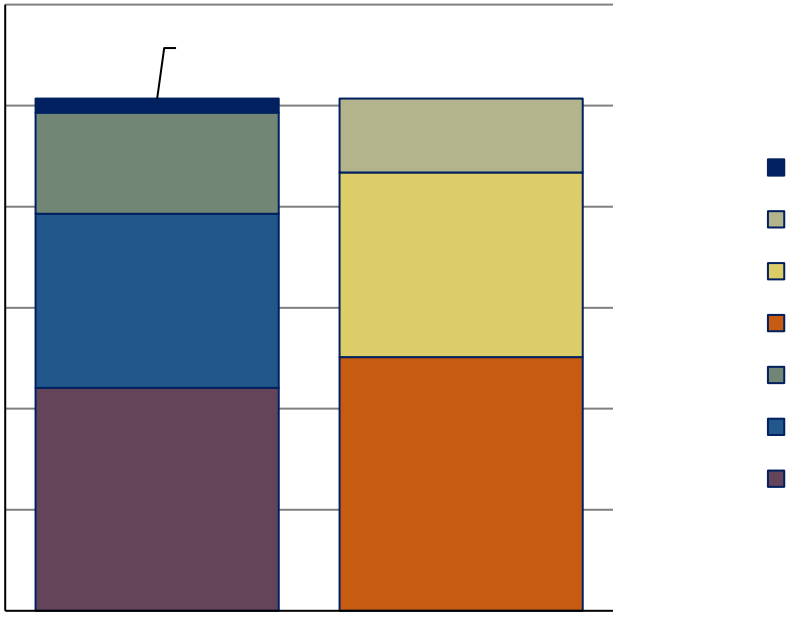

Figure 33. Historical Water Budget: Groundwater System Summary.

Table 7-4. Historical Water Budget: Groundwater System Summary.

Groundwater System Flow Direction	Water Budget Component	Average Volume (TAF per year, 1990-2015)[1]
Inflows	Deep Percolation[2]	441
	Seepage[3]	345
	Subsurface Inflows	200
Total Inflows		***986***
Outflows	Groundwater Pumping	502
	Stream Accretions	366
	Subsurface Outflows	146
Total Outflows		***1,014***
Change in Storage (Inflows – Outflows)		***-28***

[1] Volumes rounded to 1,000 AF.
[2] Deep percolation includes deep percolation of applied water, deep percolation of precipitation, and small watershed percolation.
[3] Seepage includes stream, canal, and drain seepage to groundwater.

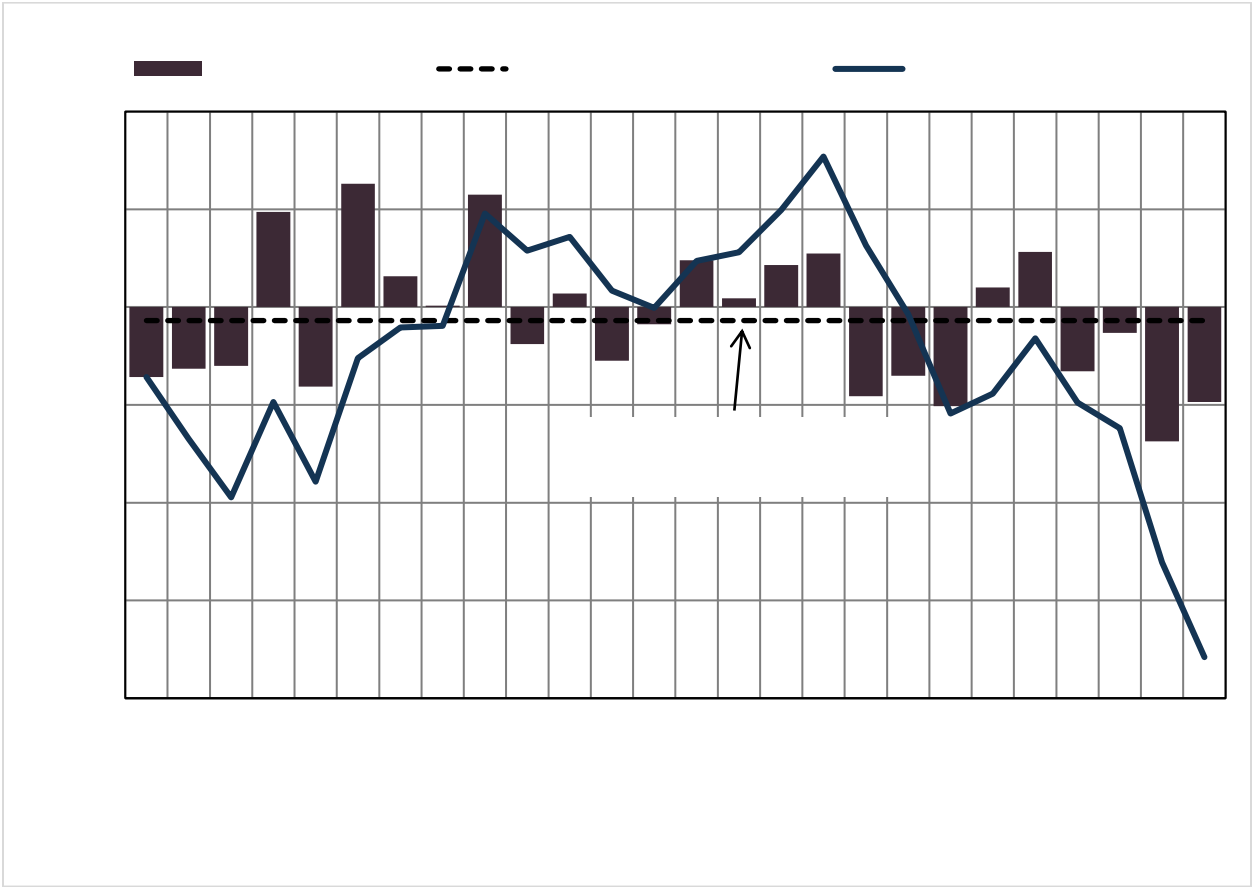

Figure 34. Historical Water Budget: Groundwater System Change in Storage.

8. SUMMARY AND FUTURE REFINEMENTS

The C2VSimFG-Colusa model is a well-calibrated regional integrated surface water and groundwater model that can be used effectively to analyze surface and groundwater conditions of the Colusa Subbasin. This model could be used adequately for evaluation of effectiveness and impacts of groundwater sustainability projects and management actions that are being developed as part of Groundwater Sustainability Plan (GSP) of the Colusa Basin.

C2VSimFG-Colusa model was developed based on DWR's C2VSimFG model for the entire Central Valley of California for a simulation period ending in 2015. The simulation period and model grid resolution and layers thicknesses of C2VSimFG were not changed in development of C2VSimFG-Colusa model. However, many local features and data such as land use and surface water delivery were updated for C2VSimFG-Colusa model. During development and calibration of C2VSimFG-Colusa model, several potential refinements were identified to may be included in future refinements to the model. These refinements may include:

- **Extension of time series data past WY 2015**. With the calibrated model, extending time series data (e.g., precipitation, land use, stream inflows, evapotranspiration, surface water diversions, urban demand, groundwater pumping) allows for use of more recent data and improved accuracy of the model for predicting near-term and future conditions in the Colusa groundwater subbasin.

- **Model layering**. Model layer thicknesses may be adjusted locally, primarily in the southwest and northwest areas of the model, to better represent local geologic conditions and potential faults in these areas.

- **Distribution of groundwater pumping between layers**. Model layer thicknesses may be refined such that distribution of groundwater pumping between model layers better matches groundwater extraction from different depth and layers of the aquifer.

- **Small watersheds**. The water coming from the foothills is simulated using small watersheds representing small streams and groundwater flowing into the western side of the Colusa Subbasin. These streams, mostly ephemeral, may need explicit representation and simulation in the model to better control recharge and flows from the foothills as some observed groundwater levels near the foothills show signs of recharge from nearby small streams.

- **Interbasin flows**. C2VSimFG-Colusa model is well calibrated along the eastern boundary of the basin and the five mile zone on the eastern side of this boundary. Quantification of Sacramento River recharge along the eastern boundary of the basin and subsurface groundwater underflow across this boundary into and out of Colusa, Butte and Vina basins will be useful in building consensus for management of groundwater by these neighboring basins.

- **Model Grid Resolution**. The observed groundwater level data show high spatial gradients in the northwestern and southwestern areas of the model. Model grid may be refined in these areas the simulate these local high groundwater gradients.

Appendix 3E

Historical Land and Surface Water System and Groundwater System Water Budget Tables

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Table 3E-1. Historical Land and Surface Water System Water Budget, 1990 to 2015

Component	Water Year														
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Inflows															
Surface Water Inflows	7,165,843	6,480,396	6,638,674	13,269,887	7,403,760	21,507,109	14,925,862	15,746,226	23,329,324	13,920,996	14,179,083	8,831,837	10,162,491	13,742,120	14,325,951
Sacramento River Diversions	948,727	906,494	778,191	944,228	909,497	928,149	956,283	1,056,121	869,476	1,026,817	1,087,640	1,187,367	1,273,544	1,227,916	1,339,952
Stony Creek Diversions	89,430	89,720	94,900	75,480	104,470	80,060	102,250	107,340	67,870	100,940	106,440	109,350	113,110	89,230	108,420
Sacramento River Inflows	6,127,101	5,479,158	5,751,094	12,047,054	6,388,496	20,129,890	13,753,954	14,504,523	21,939,530	12,771,626	12,960,893	7,523,186	8,735,913	12,366,220	12,739,067
Other Inflows from Boundary Streams	586	5,024	14,489	203,124	1,296	369,010	113,374	78,242	452,448	21,614	24,110	11,934	39,923	58,754	138,512
Precipitation	698,765	900,162	1,120,879	1,786,232	903,912	2,276,873	1,491,532	1,355,938	2,393,636	902,086	1,163,312	988,061	1,084,757	1,355,424	1,220,093
Groundwater Pumping	477,946	476,926	539,945	393,531	557,477	362,526	412,959	514,321	392,869	450,073	461,713	528,115	581,766	440,968	558,363
Agricultural	443,714	441,621	505,894	361,336	526,586	331,856	378,951	476,909	357,502	410,484	418,967	484,785	539,579	398,241	515,509
Urban and Industrial	10,509	10,735	10,937	11,089	11,176	10,857	11,110	11,990	10,746	11,298	11,669	11,865	12,472	11,929	12,595
Managed Wetlands	23,724	24,570	23,114	21,107	19,715	19,813	22,899	25,422	24,620	28,291	31,078	31,465	29,716	30,798	30,259
Stream Gains from Groundwater	361,161	354,935	347,708	343,103	355,723	359,645	379,803	395,484	361,854	411,989	387,686	371,536	369,766	372,060	380,934
Total Inflow	**8,703,715**	**8,212,418**	**8,647,205**	**15,792,752**	**9,220,871**	**24,506,153**	**17,210,156**	**18,011,969**	**26,477,683**	**15,685,145**	**16,191,795**	**10,719,549**	**12,198,781**	**15,910,572**	**16,485,341**
Outflows															
Evapotranspiration	1,527,370	1,388,793	1,583,422	1,728,551	1,719,160	1,757,267	1,820,537	1,785,625	1,786,811	1,706,457	1,750,242	1,784,406	1,846,841	1,823,814	1,827,447
Agricultural	1,253,469	1,133,017	1,292,701	1,400,523	1,443,352	1,392,355	1,478,506	1,476,205	1,403,955	1,393,683	1,418,631	1,475,575	1,545,150	1,471,263	1,518,646
Urban and Industrial	16,796	16,488	17,738	17,449	16,812	19,873	18,514	18,719	21,316	19,827	21,212	19,741	17,686	21,793	17,932
Managed Wetlands	62,674	61,572	66,424	64,007	65,743	66,237	69,608	72,079	66,671	69,072	72,037	73,192	72,105	71,719	71,716
Native Vegetation	162,752	149,345	179,713	205,457	162,898	223,475	207,845	178,466	243,316	181,080	196,357	179,776	172,362	214,889	176,787
Canal Evaporation	31,679	28,372	26,847	41,115	30,355	55,328	46,064	40,157	51,554	42,796	42,006	36,122	39,538	44,151	42,366
Deep Percolation	350,785	350,448	403,716	501,067	379,765	519,628	457,292	497,153	571,681	408,780	494,897	427,772	517,682	486,386	534,833
Precipitation	134,061	130,465	170,086	260,064	150,969	278,224	218,722	200,022	310,164	159,467	188,007	145,891	170,567	192,840	179,280
Applied Surface Water	170,639	170,325	165,857	190,658	160,535	190,348	188,144	210,973	196,951	192,463	237,227	207,134	246,916	224,756	248,871
Applied Groundwater	46,085	49,658	67,774	50,346	68,260	51,056	50,426	86,158	64,566	56,851	69,663	74,746	100,199	68,791	106,682
Seepage	278,205	288,475	298,944	365,713	291,164	393,464	345,235	359,579	369,690	330,459	339,951	317,544	354,901	386,403	387,772
Streams	150,491	163,726	188,655	245,683	163,591	274,236	219,097	221,979	258,661	198,235	200,565	163,569	193,730	236,497	223,251
Canals and Drains	127,714	124,750	110,289	120,030	127,573	119,228	126,137	137,599	111,029	132,223	139,386	153,975	161,171	149,907	164,522
Surface Water Outflows	6,593,251	6,192,374	6,360,123	13,179,569	6,832,019	21,825,252	14,593,753	15,376,079	23,732,489	13,263,299	13,607,533	8,183,129	9,490,644	13,204,231	13,758,653
Precipitation Runoff	10,514	35,646	44,364	96,399	22,224	157,681	74,871	63,816	162,238	21,185	43,209	31,299	42,307	60,220	64,944
Operational Flows															
Applied Surface Water Return Flows	84,636	78,432	89,516	96,491	95,355	88,803	87,315	99,220	85,955	77,708	63,117	109,639	115,427	115,703	112,832
Applied Groundwater Return Flows	15,570	15,201	25,324	17,518	24,286	15,303	16,350	26,167	18,634	16,121	15,465	24,543	29,002	21,496	27,342
Sacramento River	6,028,803	5,410,632	5,640,834	10,820,783	6,284,591	14,951,836	11,958,688	11,592,836	16,314,482	11,973,231	10,756,896	7,325,174	8,293,239	11,435,929	11,115,273
Colusa Basin Drain	386,120	581,381	487,448	1,073,186	338,719	1,607,475	782,840	768,777	1,710,498	462,043	616,529	540,685	638,769	760,664	917,570
Colusa Weir to Sutter Bypass	0	0	30,620	1,064,648	0	4,993,091	1,626,437	2,760,115	5,415,790	642,359	2,039,886	63,710	299,549	767,629	1,461,327
Other Outflows to Boundary Streams[1]	67,608	71,081	42,017	10,544	66,844	11,064	47,252	65,147	24,890	70,652	72,431	88,079	72,350	42,590	59,365
Total Outflow	**8,749,612**	**8,220,091**	**8,646,205**	**15,774,900**	**9,222,107**	**24,495,611**	**17,216,816**	**18,018,436**	**26,460,672**	**15,708,995**	**16,192,624**	**10,712,851**	**12,210,068**	**15,900,835**	**16,508,705**
Change in Storage (Inflow - Outflow)	**-45,896**	**-7,673**	**1,000**	**17,853**	**-1,236**	**10,542**	**-6,660**	**-6,467**	**17,012**	**-23,850**	**-829**	**6,698**	**-11,287**	**9,737**	**-23,364**

Table 3E-1. Historical Land and Surface Water System Water Budget, 1990 to 2015, continued

Component	Water Year										
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Inflows											
Surface Water Inflows	11,282,360	21,203,001	8,618,376	8,726,414	7,941,916	9,989,848	14,098,828	8,895,178	9,405,821	6,371,986	7,246,109
Sacramento River Diversions	1,248,729	1,222,261	1,324,904	1,223,655	1,106,723	1,146,353	1,165,323	1,252,911	1,296,136	850,042	702,073
Stony Creek Diversions	81,370	91,470	108,640	105,890	85,070	80,810	82,290	89,780	92,690	61,890	80,960
Sacramento River Inflows	9,829,151	19,666,083	7,182,835	7,386,917	6,749,337	8,705,010	12,773,588	7,550,495	8,010,692	5,459,493	6,459,857
Other Inflows from Boundary Streams	123,110	223,188	1,997	9,952	786	57,675	77,627	1,991	6,302	562	3,218
Precipitation	1,483,465	1,642,203	645,613	969,805	783,935	1,322,534	1,465,349	955,291	977,763	637,076	944,535
Groundwater Pumping	444,103	450,016	570,999	618,395	599,386	541,689	458,941	536,599	571,120	539,253	570,709
Agricultural	403,994	408,824	527,573	575,392	557,980	501,889	425,013	497,334	530,508	493,760	526,047
Urban and Industrial	12,536	12,443	13,018	12,667	11,935	10,244	9,359	9,992	10,812	9,145	7,590
Managed Wetlands	27,573	28,748	30,409	30,335	29,471	29,556	24,568	29,273	29,799	36,349	37,073
Stream Gains from Groundwater	386,026	383,206	390,025	368,814	338,378	329,322	357,795	358,015	349,361	336,765	352,745
Total Inflow	**13,595,954**	**23,678,426**	**10,225,013**	**10,683,427**	**9,663,615**	**12,183,393**	**16,380,912**	**10,745,083**	**11,304,065**	**7,885,081**	**9,114,097**
Outflows											
Evapotranspiration	1,870,571	1,878,738	1,750,765	1,780,707	1,825,272	1,838,050	1,814,196	1,821,305	1,803,856	1,513,007	1,500,657
Agricultural	1,489,390	1,493,575	1,492,126	1,516,539	1,547,275	1,507,320	1,453,183	1,521,011	1,536,256	1,276,516	1,249,376
Urban and Industrial	26,912	25,524	20,704	18,998	24,498	28,127	31,556	28,852	24,394	26,655	25,312
Managed Wetlands	69,637	69,417	71,594	70,516	71,421	65,833	67,160	68,069	68,878	70,190	69,616
Native Vegetation	241,160	232,476	127,254	140,010	146,082	197,695	211,958	162,235	135,865	112,849	130,948
Canal Evaporation	43,474	57,747	39,086	34,644	35,997	39,076	50,339	41,139	38,463	26,796	25,406
Deep Percolation	517,541	508,252	401,504	453,314	343,083	476,647	479,125	362,434	436,345	257,294	333,010
Precipitation	228,652	228,717	97,824	128,709	101,788	178,340	206,544	125,171	134,224	75,275	121,738
Applied Surface Water	206,796	200,859	218,858	222,677	169,184	198,939	191,397	166,391	217,662	140,443	156,844
Applied Groundwater	82,093	78,676	84,821	101,927	72,111	99,368	81,184	70,872	84,460	41,576	54,427
Seepage	364,172	402,427	326,985	345,389	335,742	378,617	399,343	339,860	374,027	276,350	318,924
Streams	207,009	253,379	160,723	187,991	190,554	227,109	250,219	184,695	212,971	161,670	212,321
Canals and Drains	157,163	149,048	166,261	157,398	145,188	151,508	149,124	155,165	161,055	114,680	106,603
Surface Water Outflows	10,834,750	20,888,786	7,748,339	8,113,030	7,150,369	9,490,116	13,691,869	8,227,428	8,690,801	5,846,430	6,973,708
Precipitation Runoff	57,353	86,926	14,660	47,435	25,853	58,030	73,104	32,650	37,344	14,289	42,567
Operational Flows											
Applied Surface Water Return Flows	122,940	102,929	107,309	99,013	87,828	96,549	114,461	108,089	115,325	72,033	68,864
Applied Groundwater Return Flows	26,265	21,551	25,164	26,776	22,546	26,676	25,146	22,744	25,248	14,661	15,233
Sacramento River	9,475,296	16,130,331	7,061,947	7,235,060	6,592,032	8,439,756	11,807,110	7,439,600	7,806,198	5,385,429	6,371,539
Colusa Basin Drain	851,470	1,148,448	428,152	601,460	332,745	704,199	829,571	557,333	576,354	295,562	440,304
Colusa Weir to Sutter Bypass	227,880	3,357,104	13,940	29,370	30,870	124,790	810,079	0	78,420	0	0
Other Outflows to Boundary Streams[1]	73,548	41,497	97,167	73,916	58,495	40,117	32,400	67,011	51,912	64,456	35,202
Total Outflow	**13,587,035**	**23,678,202**	**10,227,592**	**10,692,440**	**9,654,467**	**12,183,430**	**16,384,534**	**10,751,028**	**11,305,029**	**7,893,081**	**9,126,299**
Change in Storage (Inflow - Outflow)	**8,920**	**224**	**-2,580**	**-9,013**	**9,149**	**-37**	**-3,622**	**-5,945**	**-964**	**-7,999**	**-12,202**

Table 3E-2. Historical Groundwater System Water Budget, 1990 to 2015

Component	Water Year														
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Inflows															
Subsurface Water Inflows	201,406	200,087	199,599	198,729	206,109	199,167	192,310	200,117	188,933	191,711	193,979	194,506	198,449	192,506	199,804
Deep Percolation	350,785	350,448	403,716	501,067	379,765	519,628	457,292	497,153	571,681	408,780	494,897	427,772	517,682	486,386	534,833
Precipitation	134,061	130,465	170,086	260,064	150,969	278,224	218,722	200,022	310,164	159,467	188,007	145,891	170,567	192,840	179,280
Applied Surface Water	170,639	170,325	165,857	190,658	160,535	190,348	188,144	210,973	196,951	192,463	237,227	207,134	246,916	224,756	248,871
Applied Groundwater	46,085	49,658	67,774	50,346	68,260	51,056	50,426	86,158	64,566	56,851	69,663	74,746	100,199	68,791	106,682
Seepage	278,205	288,475	298,944	365,713	291,164	393,464	345,235	359,579	369,690	330,459	339,951	317,544	354,901	386,403	387,772
Streams	150,491	163,726	188,655	245,683	163,591	274,236	219,097	221,979	258,661	198,235	200,565	163,569	193,730	236,497	223,251
Canals and Drains	127,714	124,750	110,289	120,030	127,573	119,228	126,137	137,599	111,029	132,223	139,386	153,975	161,171	149,907	164,522
Total Inflow	**830,396**	**839,010**	**902,259**	**1,065,509**	**877,037**	**1,112,258**	**994,836**	**1,056,849**	**1,130,304**	**930,950**	**1,028,828**	**939,822**	**1,071,033**	**1,065,296**	**1,122,409**
Outflows															
Subsurface Water Outflows	134,554	132,989	134,397	133,887	126,746	137,942	139,170	143,789	145,751	144,457	151,840	149,682	154,730	156,308	165,200
Groundwater Pumping	477,946	476,926	539,945	393,531	557,477	362,526	412,959	514,321	392,869	450,073	461,713	528,115	581,766	440,968	558,363
Agricultural	443,714	441,621	505,894	361,336	526,586	331,856	378,951	476,909	357,502	410,484	418,967	484,785	539,579	398,241	515,509
Urban and Industrial	10,509	10,735	10,937	11,089	11,176	10,857	11,110	11,990	10,746	11,298	11,669	11,865	12,472	11,929	12,595
Managed Wetlands	23,724	24,570	23,114	21,107	19,715	19,813	22,899	25,422	24,620	28,291	31,078	31,465	29,716	30,798	30,259
Stream Gains from Groundwater	361,161	354,935	347,708	343,103	355,723	359,645	379,803	395,484	361,854	411,989	387,686	371,536	369,766	372,060	380,934
Total Outflow	**973,662**	**964,849**	**1,022,049**	**870,521**	**1,039,945**	**860,114**	**931,933**	**1,053,594**	**900,474**	**1,006,520**	**1,001,240**	**1,049,333**	**1,106,262**	**969,336**	**1,104,496**
Change in Storage (Inflow - Outflow)	**-143,265**	**-125,839**	**-119,790**	**194,988**	**-162,908**	**252,145**	**62,903**	**3,255**	**229,830**	**-75,570**	**27,588**	**-109,511**	**-35,229**	**95,961**	**17,913**

Table 3E-2. Historical Groundwater System Water Budget, 1990 to 2015, continued

Component	Water Year										
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Inflows											
Subsurface Water Inflows	194,420	196,864	204,638	205,946	207,844	207,110	201,677	203,767	206,758	206,595	212,601
Deep Percolation	517,541	508,252	401,504	453,314	343,083	476,647	479,125	362,434	436,345	257,294	333,010
Precipitation	228,652	228,717	97,824	128,709	101,788	178,340	206,544	125,171	134,224	75,275	121,738
Applied Surface Water	206,796	200,859	218,858	222,677	169,184	198,939	191,397	166,391	217,662	140,443	156,844
Applied Groundwater	82,093	78,676	84,821	101,927	72,111	99,368	81,184	70,872	84,460	41,576	54,427
Seepage	364,172	402,427	326,985	345,389	335,742	378,617	399,343	339,860	374,027	276,350	318,924
Streams	207,009	253,379	160,723	187,991	190,554	227,109	250,219	184,695	212,971	161,670	212,321
Canals and Drains	157,163	149,048	166,261	157,398	145,188	151,508	149,124	155,165	161,055	114,680	106,603
Total Inflow	**1,076,133**	**1,107,542**	**933,127**	**1,004,649**	**886,668**	**1,062,374**	**1,080,146**	**906,061**	**1,017,130**	**740,239**	**864,534**
Outflows											
Subsurface Water Outflows	159,987	164,844	154,252	158,165	151,491	150,938	150,444	142,515	149,252	138,604	134,908
Groundwater Pumping	444,103	450,016	570,999	618,395	599,386	541,689	458,941	536,599	571,120	539,253	570,709
Agricultural	403,994	408,824	527,573	575,392	557,980	501,889	425,013	497,334	530,508	493,760	526,047
Urban and Industrial	12,536	12,443	13,018	12,667	11,935	10,244	9,359	9,992	10,812	9,145	7,590
Managed Wetlands	27,573	28,748	30,409	30,335	29,471	29,556	24,568	29,273	29,799	36,349	37,073
Stream Gains from Groundwater	386,026	383,206	390,025	368,814	338,378	329,322	357,795	358,015	349,361	336,765	352,745
Total Outflow	**990,116**	**998,065**	**1,115,276**	**1,145,374**	**1,089,255**	**1,021,949**	**967,180**	**1,037,129**	**1,069,733**	**1,014,623**	**1,058,362**
Change in Storage (Inflow - Outflow)	**86,017**	**109,477**	**-182,149**	**-140,725**	**-202,586**	**40,425**	**112,966**	**-131,068**	**-52,603**	**-274,384**	**-193,827**

Appendix 3F

Colusa Subbasin Subarea Water Budgets

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Specialists in Agricultural Water Management
Serving Stewards of Western Water since 1993

Technical Memorandum

To: Colusa Groundwater Authority, Glenn Groundwater Authority

From: Davids Engineering

Date: August 2021

Subject: **Colusa Subbasin Subarea Water Budgets**

Overview

Water budgets have been developed for the Colusa Subbasin using the C2VSimFG-Colusa model, an integrated hydrologic flow model for the Colusa Subbasin (Subbasin) that is used to support development of the Subbasin Groundwater Sustainability Plan (GSP). The C2VSimFG-Colusa model is an element adapted from DWR's Fine Grid California Central Valley Groundwater – Surface Water Simulation Model (C2VSimFG). The development and calibration of the C2VSimFG-Colusa model is documented in Appendix 3D of the GSP.

This technical memorandum (TM) presents water budget results from the C2VSimFG-Colusa model for 32 distinct subareas defined within the Colusa Subbasin. Each subarea approximately represents a region of the Subbasin that shares a common water supplier (e.g., irrigation or water district), a common governing agency (e.g., county or city), and a common primary water supply source (e.g., areas with access to surface water or areas with access to only groundwater, i.e., "groundwater" areas).

Subareas were delineated within the C2VSimFG-Colusa model element grid to support development of model inputs and to support quality control and calibration of model outputs. Data and information corresponding to specific subareas were used to quantify water supply and water use within the subarea, to the extent permitted by the resolution of the model element grid. Specific data and information used to create model inputs are summarized in Appendix 3D of the GSP.

Local refinements were generally made to the following model inputs and attributes:

- Land use areas and characteristics for:
  - Non-ponded agriculture (17 crop types, including idle)
  - Ponded crops and managed wetlands
  - Native vegetation
  - Urban/Rural residential
- Water use characteristics, including:
  - Evapotranspiration (ET)
  - Irrigation efficiency
  - Return flows and reuse
  - Irrigation timing (all crops) and pond depths (rice and wetlands)
  - Population and per capita water use

- Surface Water Diversions, including:
    - Surface water diversion volumes (applied to corresponding subareas)
    - Seepage (recoverable loss)
    - Evaporation (non-recoverable loss)
- Aquifer and stream parameters

The following sections briefly describe the water budget components evaluated and reported in this TM, the unique subareas defined within the Colusa Subbasin, and the historical water budget results summarized from the C2VSimFG-Colusa model outputs for these subareas.

Water Budget Components

The general structure of the Colusa Subbasin water budget is shown in Figure 1. The structure contains two interacting systems: the surface water system and the groundwater system. The water budget results for these two systems may be reported separately to describe conditions at/near the land surface or in the underlying aquifer, or the results may be combined to describe the overall Subbasin water budget. The surface water budget comprises all inflows and outflows of water at the land surface within the spatial extent of the Subbasin, and all exchanges of water to and from the underlying groundwater system. The groundwater budget comprises these same exchanges with the surface water system in addition to subsurface inflows and outflows across the Subbasin boundary.

The C2VSimFG-Colusa model computes the complete surface water and groundwater budgets for each element within the model grid. Water budget results reported in Chapter 3 of the GSP are summarized for all elements that approximately represent the entire Colusa Subbasin. Water budget results reported in this TM are summarized for all subsets of elements that represent the water budget subareas described in the following section.

This section describes the water budget components that are reported in the surface water budgets and groundwater budgets for each subarea. Land uses simulated in the C2VSimFG-Colusa model are also described because of their significant effect on both the surface water and groundwater systems. Additional information about specific data sources and model inputs for land use and all water budget components are provided in Appendix 3D of the GSP.

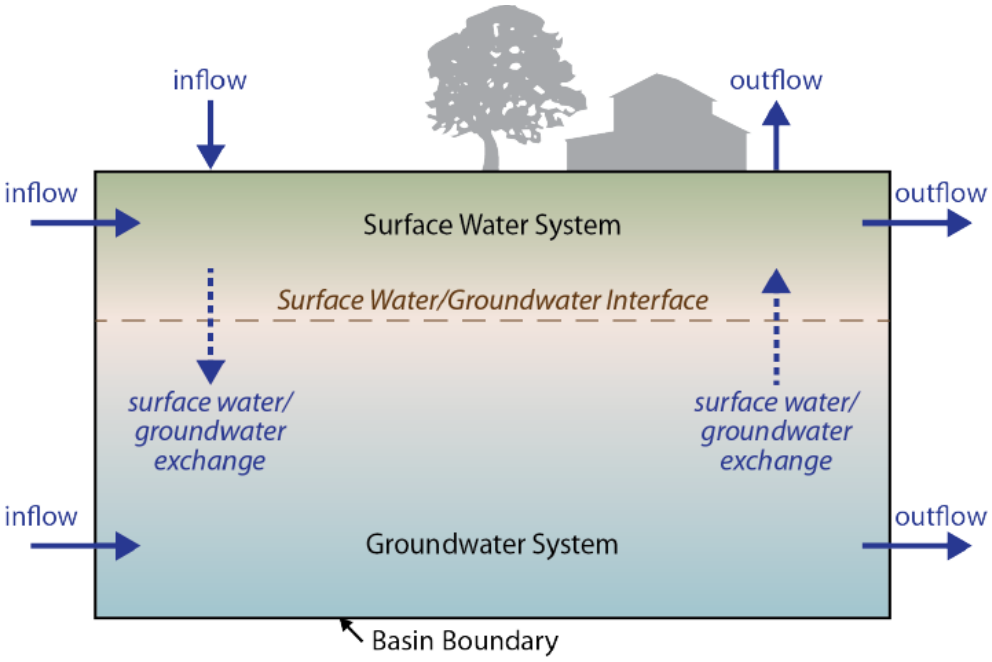

Figure 1. Generalized Water Budget Structure (Source: DWR).

Land Use

Table 1 identifies the general land use types and land use classes simulated in the C2VSimFG-Colusa model. Four general land use types are simulated: non-ponded agriculture, ponded crops and managed wetlands, native vegetation, and urban/rural residential. Land use characteristics are provided as inputs to the C2VSimFG-Colusa model and are used to simulate many of the water budget components that relate to land use, from crop irrigation demand and pumping requirements to percolation through the root zone and runoff from the land surface. Land use areas are also used to compute the volume of all water budget components in each model element. Water budget components are initially calculated on a unitized depth basis and are then converted to a volume by multiplying the unitized depth across the area represented by that land use class in the element.

Non-ponded agriculture land uses include 17 distinct land use classes, of which 16 represent specific crop types and one represents idle land. The model evaluates the water budget for each of these land use classes separately, considering differences in crop consumptive use (i.e., ET), rooting depth, irrigation practices, and other factors that affect how much water is applied to and used by the crop.

Ponded crops and managed wetlands in the model include all rice crops and managed wetlands – land uses that are periodically flooded and ponded. Like non-ponded crop land use classes, the model also evaluates the water budget for each of these land use classes separately.

Native vegetation includes native and riparian land use classes. Native land use represents undeveloped and uncultivated areas, while riparian land use represents undeveloped areas along waterways. Like crop land use classes, the model evaluates the water budget for each of these land use classes separately.

Urban/rural residential land is represented by a single “urban” land use class that includes all urban, rural residential, industrial, and semi-agricultural lands (e.g. dairies and farmsteads) as well as roads. Model inputs and results are specified for the combined urban land use class.

Table 1. Land Use Classes in the Colusa Subbasin.

General Land Use Type	Land Use Class
Non-Ponded Agriculture	Includes 16 crop types and idle land. The water budget for each is evaluated individually within the model based on differences in consumptive use, rooting depth, irrigation practices, etc.
Ponded Crops and Managed Wetlands	Rice and Managed Wetlands
Native Vegetation	Native and Riparian
Urban/Rural Residential	Urban land use class includes urban, rural residential, industrial, and semi-agricultural lands (e.g. dairies and farmsteads) as well as roads.

Surface Water Budget

Table 2 describes the surface water budget components reported from the C2VSimFG-Colusa model results, as well as the corresponding section of the GSP regulations that requires reporting of that component. Each of these components is reported in the surface water budget for each subarea.

Table 2. Surface Water Budget Components

Surface Water Budget Component[1]	Category	Description	GSP Regulation Section[2]
Surface Water (SW) Diversions	Inflow	Diversions of surface water supply for irrigation in the subregion.	§354.18(b)(1)
Groundwater (GW) Pumping	Inflow	Groundwater pumping to meet water demands not met by surface water. Simulated for all land uses except native vegetation.	§354.18(b)(3)
Precipitation	Inflow	Direct precipitation on the land surface.	Implied
Evapotranspiration	Outflow	Consumptive use of applied water and precipitation through the processes of evaporation and transpiration. Includes evaporation from canals and drains.	§354.18(b)(3)
Percolation *(from Land Surface)*	Outflow	Percolation (i.e., vertical movement) of applied water and precipitation below the root zone to the groundwater system. Does not include percolation from upslope small watersheds.	§354.18(b)(2)
Seepage *(from Canals and Drains)*	Outflow	Seepage (i.e., vertical movement) to the groundwater system from canals and drains. Does not include seepage from rivers and streams.	§354.18(b)(2)

Surface Water Budget Component[1]	Category	Description	GSP Regulation Section[2]
Return Flow	Inflow	Surface outflow from irrigation tailwater and drainage of rice and wetlands ponds.	§354.18(b)(1)
Runoff	Outflow	Surface outflow from precipitation.	§354.18(b)(1)
Change in Storage	Storage	Change in root zone soil moisture storage. Does not represent change in groundwater storage.	§354.18(a)
Net Recharge[3]	Recharge	Seepage + Percolation - Groundwater Pumping.	N/A

[1] Inflows to and outflows from the rivers and streams system in the Colusa Subbasin (i.e., stream gains and seepage from rivers and streams) are excluded from the subarea surface water budget summary.

[2] California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2 Groundwater Sustainability Plans, Article 5 Plan Contents.

[3] Net vertical movement of water from the land surface to the groundwater system (excluding rivers and streams).

Groundwater Budget

Table 3 describes the groundwater budget components reported from the C2VSimFG-Colusa model results, as well as the corresponding section of the GSP regulations that requires reporting of that component. Each of these components is reported in the groundwater budget for each subarea.

Table 3. Groundwater Budget Components.

Groundwater Budget Component	Category	Description	GSP Regulation Section[1]
Percolation *(from Land Surface and Small Watersheds)*	Inflow	Percolation (i.e., vertical movement) of applied water, precipitation, and drainage from upslope small watersheds below the root zone to the groundwater system.	§354.18(b)(2)
Seepage *(Seepage from rivers, streams, canals, and drains)*	Inflow	Seepage (i.e., vertical movement) to the groundwater system from rivers, streams, canals, and drains.	§354.18(b)(2)
Subsurface Inflows (net)	Inflow	Net subsurface groundwater inflow from adjacent groundwater basins or from the Coast Range foothills on the west side of the Subbasin.	§354.18(b)(2)
Groundwater (GW) Pumping	Outflow	Groundwater pumping to meet water demands not met by surface water. Simulated for all land uses except native vegetation.	§354.18(b)(3)
Stream Gains	Outflow	Groundwater flowing into rivers and streams, resulting in gaining streamflows (e.g. accretions).	§354.18(b)(2)
Change in Storage	Storage	Change in groundwater storage throughout the year; does not represent change in root zone soil moisture.	§354.18(b)(4)
Cumulative Change in Storage	Storage	Change in groundwater storage accumulated annually.	§354.18(b)(4)

[1] California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2 Groundwater Sustainability Plans, Article 5 Plan Contents

Water Budget Subareas

Water budget subareas in the Colusa Subbasin are listed in Table 4 and shown in Figure 2. As described previously, these subareas were delineated within the C2VSimFG-Colusa model element grid to support development of model refinements, and to support quality control and calibration of model outputs. Historical summaries of land use, surface water budgets, and groundwater budgets for each of these subareas are reported below.

Table 4. Water Budget Subareas.

Subarea Number	Subarea Name	County	Description[1]	Acres
1	4MWD	Colusa	4M W.D., Colusa County	2,070
2	CCWD	Colusa	Colusa County W.D., Colusa County	49,335
3	CDMWC	Colusa	Colusa Drain M.W.C, Colusa County	30,943
4	ColGWE	Colusa	Colusa Groundwater East	42,360
5	ColGWM	Colusa	Colusa Groundwater Middle	5,194
6	ColGWS	Colusa	Colusa Groundwater South	16,036
7	ColGWSE	Colusa	Colusa Groundwater Southeast	17,722
8	ColGWSW	Colusa	Colusa Groundwater Southwest	51,123
9	GCID[2]	Colusa	Glenn-Colusa I.D., Colusa County	105,199
10	GCID[2]	Glenn	Glenn-Colusa I.D., Glenn County	73,285
11	Glide	Glenn	Glide W.D., Glenn County	10,397
12	GlnGWE	Glenn	Glenn Groundwater East	13,373
13	GlnGWM	Glenn	Glenn Groundwater Middle	9,761
14	GlnGWN	Glenn	Glenn Groundwater North	24,738
15	GlnGWNW	Glenn	Glenn Groundwater Northwest	61,707
16	GlnGWS	Glenn	Glenn Groundwater South	3,529
17	GVWD	Colusa	Glenn Valley W.D., Colusa County	893
18	Holthouse	Colusa	Holthouse W.D., Colusa County	1,428
19	Kanawha	Glenn	Kanawha W.D., Glenn County	16,896
20	LaGrande	Colusa	LaGrande W.D., Colusa County	1,267
21	Maxwell	Colusa	Maxwell W.D., Colusa County	7,028
22	OAWD	Glenn	Orland Artois W.D., Glenn County	46,967
23	OUWUA_S	Glenn	Orland Unit W.U.A., Glenn County	18,815
24	PCGID[2]	Colusa	Princeton-Codora-Glenn I.D., Colusa County	6,275
25	PCGID[2]	Glenn	Princeton-Codora-Glenn I.D., Glenn County	7,765
26	PID[2]	Colusa	Provident I.D., Colusa County	8,876
27	PID[2]	Glenn	Provident I.D., Glenn County	17,744
28	RD108	Colusa	Reclamation District 108, Colusa County	34,208
29	Roberts	Colusa	Roberts Ditch Irrigation Company	2,794
30	Sycamore	Colusa	Sycamore M.W.C.	7,742
31	Westside	Colusa	Westside W.D.	17,803
32	Willows	Glenn	City of Willows	1,234
			Total[3]	**714,507**

[1] Abbreviations: I.D.: Irrigation District
M.W.C: Mutual Water Company
W.D.: Water District
W.U.A.: Water Users Association

[2] Substantial portions of the GCID, PCGID, and PID service areas are located within Colusa and Glenn County. Separate subareas have been evaluated for the portions of each district in each county. The subarea boundaries shown in Figure 2 indicate the boundary line between the Colusa and Glenn County subareas; however, the subarea labels describe only the name of each district.

[3] Total acreage across all subareas differs from the total acreage of the Colusa Subbasin primarily because of slight differences between subarea and subbasin boundaries, particularly along the western edge of the Colusa Subbasin.

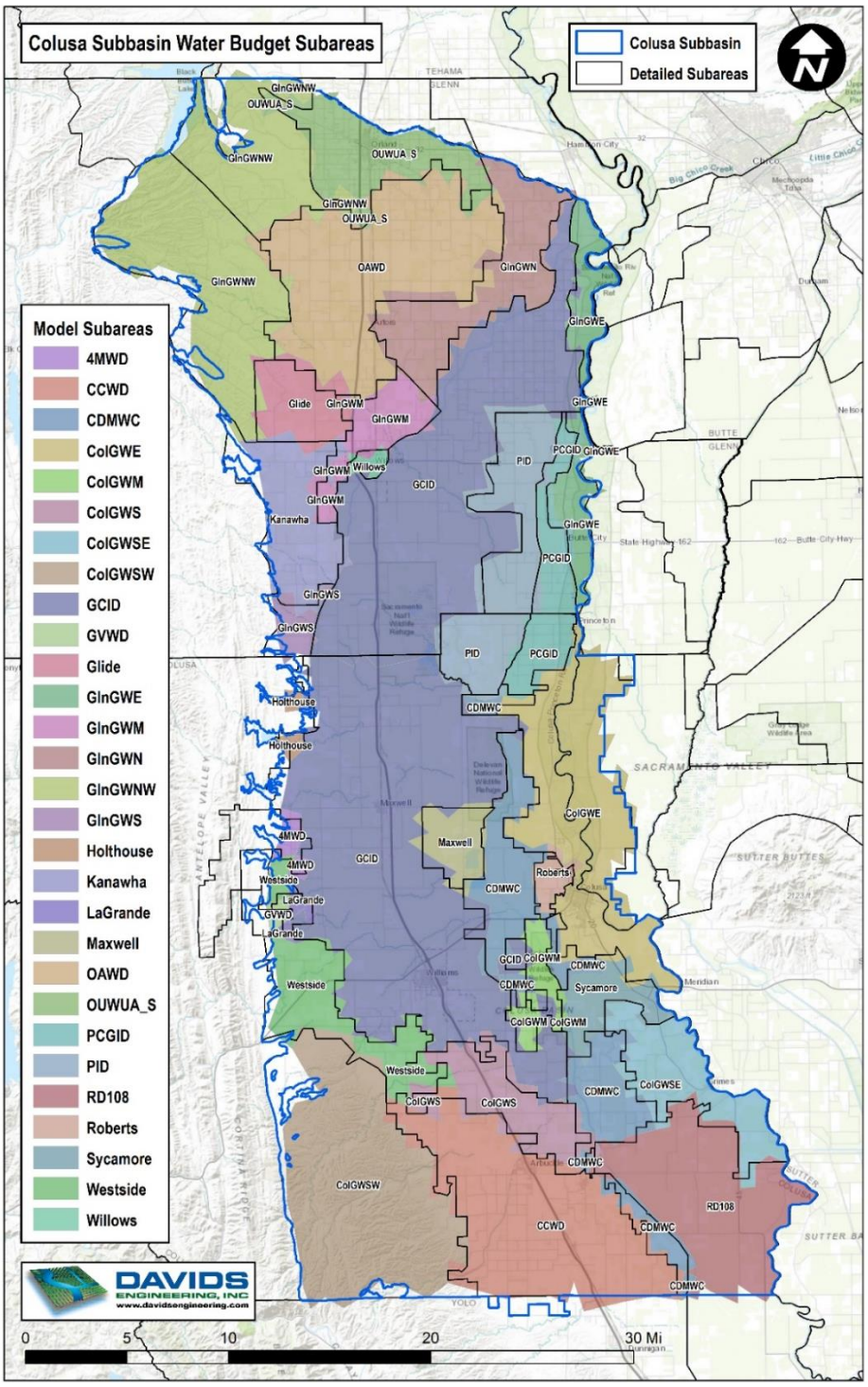

Figure 2. Water Budget Subareas.[1]

[1] Substantial portions of the GCID, PCGID, and PID service areas are located within Colusa and Glenn County. Separate subareas have been evaluated for the portions of each district in each county. The subarea boundaries shown in Figure 2 indicate the boundary line between the Colusa and Glenn County subareas; however, the subarea labels describe only the name of each district.

Uncertainties and Limitations

All estimates of water budget components are subject to uncertainty. These uncertainties arise from potential inaccuracies of input data, errors in assumptions, limitations of model processes used to simulate the physical world, and other factors. The basin-wide and subarea water budgets developed for the Colusa Subbasin for planning purposes to support GSP development have been assembled using the best available science and data. Uncertainties in the water budget are described with the subbasin water budget results in Chapter 3 of the Colusa Subbasin GSP.

Summary of Historical Water Budgets

This section summarizes the historical water budget results across all subareas in the Colusa Subbasin. Results presented in this section are generally extracted from the C2VSimFG-Colusa model outputs and summarized as average annual values over the historical water budget period (water years 1990-2015). Annual results for all water years during the 1990-2015 period are presented for each subarea in the final section of this TM.

Land Use Summary

Table 5 provides a summary of the total acreage simulated in each subarea and the average percent of the total area represented by each of the four general land use types over the 1990-2015 period. The total acreage of each subarea ranges from less than 1,000 acres (GVWD) to more than 100,000 acres (GCID subarea in Colusa County).

Across all subareas, non-ponded agriculture represents approximately 41 percent of the total area simulated in the C2VSimFG-Colusa model during the 1990-2015 period, while ponded-crops and managed wetlands represent approximately 30 percent of the total area. Across most subareas, non-ponded agriculture represents at least 20 percent of the total area. Ponded crops and managed wetlands represent a wider range of areas, from less than 5 percent in several water districts and subregions largely comprised of urban areas or undeveloped native vegetation, to more than 70 percent of the total area in Maxwell W.D., PID, and the PCGID subarea in Colusa County.

Native vegetation represents approximately 24 percent of the total acreage across all subareas. Urban/rural residential areas represent less than 10 percent of the total acreage in most subareas except those representing cities, such as Willows, or regions with higher urban or residential populations.

Table 5. Total Area and Average Percent of Total Area by General Land Use Type for all Subareas, 1990-2015.

Subarea Name	Total Area (acres)	Average Percent Total Area by General Land Use Type, 1990-2015 (percent)			
		Non-Ponded Agriculture	Ponded Crops and Managed Wetlands	Native Vegetation	Urban/Rural Residential
4MWD	2,070	82%	4%	12%	2%
CCWD	49,335	77%	5%	14%	4%
CDMWC	30,943	30%	60%	8%	2%
ColGWE	42,360	49%	27%	18%	6%
ColGWM	5,194	20%	61%	17%	2%
ColGWS	16,036	84%	5%	7%	4%
ColGWSE	17,722	75%	14%	8%	3%
ColGWSW	51,123	3%	0%	97%	0%
GCID - Colusa	105,199	24%	64%	8%	4%
GCID - Glenn	73,285	24%	56%	10%	10%
Glide	10,397	49%	16%	30%	5%
GlnGWE	13,373	57%	6%	32%	5%
GlnGWM	9,761	76%	3%	7%	14%
GlnGWN	24,738	87%	2%	5%	6%
GlnGWNW	61,707	18%	0%	80%	2%
GlnGWS	3,529	25%	2%	68%	5%
GVWD	893	51%	32%	15%	2%
Holthouse	1,428	34%	3%	62%	1%
Kanawha	16,896	77%	8%	10%	5%
LaGrande	1,267	39%	54%	5%	2%
Maxwell	7,028	6%	87%	5%	2%
OAWD	46,967	72%	4%	15%	9%
OUWUA_S	18,815	58%	0%	21%	21%
PCGID - Colusa	6,275	17%	74%	6%	3%
PCGID - Glenn	7,765	40%	41%	9%	10%
PID – Colusa	8,876	3%	88%	8%	1%
PID – Glenn	17,744	9%	74%	10%	7%
RD108	34,208	45%	48%	6%	1%
Roberts	2,794	60%	20%	9%	11%
Sycamore	7,742	23%	66%	8%	3%
Westside	17,803	77%	8%	12%	3%
Willows	1,234	10%	0%	3%	87%
Total	**714,507**	**41%**	**30%**	**24%**	**5%**

Surface Water Budget Summary

This section summarizes average results of key components in the subarea surface water budgets. Average results are summarized from the C2VSimFG-Colusa model outputs over the 1990-2015 period. The complete annual surface water budget results for each subarea over the entire 1990-2015 period are summarized in the final section of this TM.

Total Inflows

Table 6 summarizes the average annual total inflows to the surface water budget for all subareas. Total inflows include surface water (SW) diversions into the subarea, groundwater (GW) pumping, and total precipitation that falls within the subarea. Across all subareas, average total inflows are estimated to be more than 3.11 million acre-feet (maf), or approximately 4.4 acre-feet per acre (af/ac). On average, approximately 45 percent of this total (1.42 maf) is comprised of SW diversions, approximately 16 percent (0.50 maf) is comprised of GW pumping, and the remaining 38 percent (1.20 maf) is precipitation.

In individual subareas, average total inflow volumes range from less than 10 thousand acre-feet (taf) in smaller water districts and subareas to more than 600,000 acre-feet in the GCID subarea in Colusa County, the largest of all subareas. Adjusted for area, average total inflows are typically between 2 and 6 af/ac, with typically higher values in subareas with greater access to SW diversions. In both the Colusa and Glenn County subareas of PCGID, average total inflows exceed 9 af/ac, of which approximately 80 percent is supplied by SW diversions.

The portion of total inflows supplied by GW pumping varies among subareas, but is generally higher in "groundwater" subareas outside the service areas of surface water suppliers. In these "groundwater" subareas, SW diversions are generally unavailable or limited to individual water rights users.

The portion of total inflows supplied by precipitation is approximately 30 percent or more in most subareas. While only a portion of the total precipitation is consumed within each subarea, precipitation is the primary water supply for much of the native vegetation in the Colusa Subbasin, and also supplies valuable soil moisture to support winter crops and other crops in the early spring months.

Table 6. Average Annual Total Inflows to the Surface Water Budget for all Subareas, 1990-2015.

Subarea Name	Average Annual Total Inflows, 1990-2015		Percent Average Total Inflows by Water Source, 1990-2015		
	(acre-feet, rounded)	(acre-feet/acre)	SW Diversions	GW Pumping	Precipitation
4MWD	6,000	2.9	32%	17%	51%
CCWD	187,400	3.8	27%	32%	41%
CDMWC	139,900	4.5	37%	28%	35%
ColGWE	151,700	3.6	11%	44%	45%
ColGWM	27,300	5.3	49%	21%	30%
ColGWS	57,400	3.6	1%	56%	43%
ColGWSE	55,800	3.1	4%	46%	50%
ColGWSW	87,700	1.7	0%	3%	97%
GCID - Colusa	618,200	5.9	72%	1%	27%
GCID - Glenn	455,800	6.2	69%	2%	29%
Glide	33,800	3.3	34%	15%	51%
GlnGWE	50,500	3.8	0%	47%	53%
GlnGWM	37,200	3.8	0%	54%	46%
GlnGWN	105,900	4.3	0%	55%	45%
GlnGWNW	132,200	2.1	0%	18%	82%
GlnGWS	7,500	2.1	0%	23%	77%
GVWD	2,900	3.2	0%	54%	46%
Holthouse	3,300	2.3	28%	4%	68%
Kanawha	58,200	3.4	45%	8%	47%
LaGrande	6,600	5.2	65%	7%	28%
Maxwell	43,600	6.2	65%	9%	26%
OAWD	188,200	4.0	23%	32%	45%
OUWUA_S	97,800	5.2	60%	4%	36%
PCGID - Colusa	58,600	9.3	81%	1%	18%
PCGID - Glenn	71,600	9.2	78%	2%	20%
PID – Colusa	49,000	5.5	50%	19%	31%
PID – Glenn	104,400	5.9	52%	17%	31%
RD108	161,600	4.7	64%	3%	33%
Roberts	9,300	3.3	19%	34%	47%
Sycamore	39,300	5.1	62%	8%	30%
Westside	61,300	3.4	53%	5%	42%
Willows	3,400	2.8	0%	36%	64%
Total	**3,113,400**	**4.4**	**45%**	**16%**	**38%**

Net Recharge

Table 7 summarizes the simulated average net recharge from the surface water system for each subarea over the 1990-2015 period. Net recharge from the subarea water budgets is defined as the sum of groundwater recharge from the surface water system caused by water use and water management within the subarea (percolation from the land surface plus seepage from canals and drains) minus the sum of groundwater extraction from the groundwater system within the subarea (GW pumping).

Net recharge is a useful metric for understanding and analyzing the combined effects of land surface processes on the underlying groundwater system. When calculated from the historical water budget, average net recharge represents the average additional recharge that exceeds pumping (when positive) or the average additional groundwater pumping in excess of recharge (when negative) that occurs in the surface water system based on historical cropping, land use practices, and average hydrologic conditions.

Notably, the calculation of net recharge does not consider the net seepage or stream gains exchanged between the groundwater system and rivers and streams on the land surface. Stream seepage and stream gains also impact the groundwater budget (see Table 3); however, stream seepage and stream gains are driven by many factors that are not all directly related to or caused by water use and water management within a given subarea. The calculation of net recharge is also not meant to connote change in groundwater storage because it does not include subsurface inflows and outflows. Change in groundwater storage is reported in the groundwater budget results in the following section.

Over all subareas, the total average annual net recharge is approximately 76.8 taf per year, indicating that across all subareas the simulated groundwater recharge exceeds the simulated groundwater extraction, on average, during the 1990-2015 period. On a per-acre basis, the average annual net recharge across all subareas is approximately 0.11 af/ac. Within individual subareas, average net recharge ranges from more than 1.0 af/ac (indicating that recharge exceeds pumping) within subareas that have access to substantial surface water supplies, to less than -1.0 af/ac (indicating that pumping exceeds recharge) within many of the “groundwater” subareas located outside the service areas of surface water suppliers. In-lieu groundwater recharge projects that provide surface water supplies to irrigated lands in “groundwater” subareas would help to offset some of these localized shortages, and would help to increase net recharge subbasin-wide if additional surface water could be imported into the Colusa Subbasin.

Percolation across all subareas contributes approximately 438 taf per year to the groundwater system, and seepage from canals and drains contributes approximately 139 taf per year. During the 1990-2015 period, nearly 85 taf of seepage was contributed each year by the GCID distribution system, including the district’s 65-mile Main Canal and nearly 1,000 miles of other canals, laterals, and drains. Groundwater pumping across all subareas totals nearly 500 taf per year, on average, with higher volumes generally in “groundwater” subareas without access to significant volumes of surface water.

Table 7. Average Annual Net Recharge for all Subareas, 1990-2015.

Subarea Name	Average Annual Net Recharge (a+b-c), 1990-2015		Average Volume, 1990-2015 (acre-feet, rounded)		
	(acre-feet, rounded)	(acre-feet/ acre)	Percolation[1] (a)	Seepage[2] (b)	GW Pumping (c)
4MWD	300	0.14	1,300	0	1,000
CCWD	-10,430	-0.21	48,820	0	59,250
CDMWC	-25,870	-0.84	9,480	4,440	39,790
ColGWE	-54,400	-1.28	10,880	1,870	67,150
ColGWM	-630	-0.12	2,850	2,340	5,820
ColGWS	-19,430	-1.21	12,880	0	32,310
ColGWSE	-22,010	-1.24	3,520	240	25,770
ColGWSW	19,150	0.37	21,890	0	2,740
GCID - Colusa	105,730	1.01	63,780	49,200	7,250
GCID - Glenn	79,530	1.09	51,650	35,470	7,590
Glide	-950	-0.09	4,170	0	5,120
GlnGWE	-15,890	-1.19	8,080	0	23,970
GlnGWM	-11,250	-1.15	8,840	0	20,090
GlnGWN	-35,120	-1.42	23,220	0	58,340
GlnGWNW	-4,480	-0.07	18,910	0	23,390
GlnGWS	-660	-0.19	1,050	0	1,710
GVWD	-1,240	-1.39	330	0	1,570
Holthouse	410	0.29	550	0	140
Kanawha	3,740	0.22	8,340	0	4,600
LaGrande	340	0.27	820	0	480
Maxwell	-230	-0.03	1,070	2,720	4,020
OAWD	-6,870	-0.15	52,700	0	59,570
OUWUA_S	35,600	1.89	30,370	9,150	3,920
PCGID - Colusa	16,200	2.58	3,670	12,990	460
PCGID - Glenn	27,400	3.53	11,490	17,020	1,110
PID – Colusa	-3,470	-0.39	4,140	1,560	9,170
PID – Glenn	-8,840	-0.50	9,000	30	17,870
RD108	4,720	0.14	9,100	280	4,660
Roberts	-2,460	-0.88	610	110	3,180
Sycamore	-380	-0.05	1,240	1,560	3,180
Westside	9,320	0.52	12,670	0	3,350
Willows	-1,020	-0.83	190	0	1,210
Total	**76,810**	**0.11**	**437,610**	**138,980**	**499,780**

[1] Percolation from the land surface within the subarea. Does not include simulated percolation from upslope small watersheds originating from outside the subarea.

[2] Seepage from canals and drains within the subarea. Does not include seepage from rivers and streams.

Groundwater Budget Summary

Table 8 summarizes the average simulated change in storage and cumulative change in storage from the subarea groundwater budgets. These results are summarized from the C2VSimFG-Colusa model outputs over the 1990-2015 period. The complete annual groundwater budget results for each subarea over the entire 1990-2015 period are summarized in the final section of this TM.

Across all subareas, the average simulated change in storage in the groundwater system is approximately -27.5 taf per year over the 1990-2015 period, or approximately -0.04 af/ac, indicating a net decrease in groundwater storage across all subareas. This change in storage equates to a change in groundwater storage of less than 0.5 inches over the aggregate area of all subareas. The cumulative change in groundwater storage across all subareas over the 1990-2015 period is approximately -717 taf per year, or approximately -1.0 af/ac in total.

In individual subareas, the average change in groundwater storage varies between approximately 1 taf and -6 taf per year, and between approximately 0.01 af/ac (less than 0.2 inches) to approximately -0.12 af/ac -1.3 inches) per year.

It is noted that change in groundwater storage is strongly affected by modeled estimates of subsurface groundwater flows. Subsurface groundwater flows are in turn strongly affected by the model calibration and the variable quality and timing of available groundwater level data that may be used to create and calibrate model inputs. Inaccuracies or inadequacies in the historical model calibration have the potential to strongly bias subsurface lateral flow calculations. Likewise, groundwater level data represent only discrete snapshots of groundwater levels, and may not adequately represent all spatial and temporal changes in groundwater flows. Thus, the change in storage and cumulative change in storage calculations for all subareas, especially small subareas, are reported only for general and relative understanding of the groundwater budget simulation results for regions within the Colusa Subbasin. Firm conclusions cannot be drawn from individual subarea groundwater budget results.

Table 8. Average Change in Storage and Cumulative Change in Storage for all Subareas, 1990-2015.

Subarea Name	Average Change in Storage, 1990-2015		Cumulative Change in Storage, 1990-2015	
	(acre-feet)	(acre-feet/ acre)	(acre-feet)	(acre-feet/ acre)
4MWD	-100	-0.05	-2,900	-1.41
CCWD	-6,100	-0.12	-158,100	-3.21
CDMWC	-700	-0.02	-18,500	-0.60
ColGWE	-400	-0.01	-11,600	-0.27
ColGWM	-100	-0.02	-3,100	-0.60
ColGWS	-1,200	-0.07	-31,000	-1.93
ColGWSE	-300	-0.02	-7,600	-0.43
ColGWSW	-5,500	-0.11	-142,500	-2.79
GCID - Colusa	-3,600	-0.03	-92,400	-0.88
GCID - Glenn	-1,600	-0.02	-40,500	-0.55
Glide	-200	-0.02	-5,200	-0.50
GlnGWE	-300	-0.02	-6,900	-0.52
GlnGWM	-200	-0.02	-5,700	-0.59
GlnGWN	-1,200	-0.05	-32,200	-1.30
GlnGWNW	900	0.01	23,200	0.38
GlnGWS	0	-0.01	-500	-0.14
GVWD	0	-0.05	-1,100	-1.22
Holthouse	0	-0.03	-1,100	-0.75
Kanawha	-400	-0.03	-11,500	-0.68
LaGrande	-100	-0.06	-1,900	-1.53
Maxwell	-100	-0.01	-2,300	-0.33
OAWD	-2,900	-0.06	-74,600	-1.59
OUWUA_S	-200	-0.01	-4,300	-0.23
PCGID - Colusa	-100	-0.01	-1,900	-0.30
PCGID - Glenn	-100	-0.01	-2,900	-0.37
PID – Colusa	-100	-0.01	-1,600	-0.18
PID – Glenn	-100	-0.01	-3,900	-0.22
RD108	-1,200	-0.03	-30,400	-0.89
Roberts	0	-0.01	-900	-0.31
Sycamore	-100	-0.02	-3,500	-0.46
Westside	-1,500	-0.09	-39,500	-2.22
Willows	0	-0.01	-400	-0.33
Total	**-27,500**	**-0.04**	**-717,300**	**-1.00**

Historical Water Budgets by Subarea

Historical water budgets for each subarea are presented on the following pages. Information for each subarea is listed in numerical order based on the subarea number listed in Table 4.

For all subareas, annual values are provided for the 1990-2015 historical water budget period in both tabular and graphical form, summarizing the following information:

- **Land use**: Annual acreage and average acreage, presented for each general land use type listed in Table 1 (ponded crops and managed wetlands separated into rice and managed wetlands)
- **Surface Water Budget**: Annual volumes and average annual volumes (in acre-feet) for all components listed in Table 2, summarized by water year type according to the Sacramento Valley Water Year Index[2]
- **Groundwater Budget**: Annual volumes and average annual volumes (in acre-feet) for all components listed in Table 3, summarized by water year type according to the Sacramento Valley Water Year Index

Inflows to the surface water budget and groundwater budgets are presented as positive values in each figure, while outflows are presented as negative values. Net recharge (in the surface water budget) and cumulative change in groundwater storage (in the groundwater budget) are presented as line graphs.

In general, surface water diversions and groundwater pumping represent the greatest combined inflows to the surface water budget, with greater surface water diversions generally in subareas representing the service areas of surface water suppliers and greater groundwater pumping in "groundwater" subareas outside those service areas. The greatest outflows from the surface water budget are generally evapotranspiration and percolation in some subareas. Higher volumes of runoff occur in wet years when greater precipitation occurs, and higher volumes of seepage occur within surface water supplier service areas.

Inflows and outflows to and from the groundwater system vary significantly between subareas. In many of the primarily agricultural subareas, percolation of irrigation water is a major inflow and groundwater pumping is a major outflow from the groundwater system. In subareas adjacent to gaining reaches of the Colusa Basin Drain and the Sacramento River, stream gains also represent a major outflow from the groundwater budget and inflow to the surface water budget. In adjoining subareas with significantly different water supplies and demands, such as surface water supplier service areas adjacent to "groundwater" areas, net subsurface inflows between those subareas also represent a major water budget component. Generally, greater subsurface inflows enter "groundwater" areas, and greater subsurface outflows (negative net subsurface inflows) leave surface water supplier service areas or other subareas where significant seepage occurs. However, as described previously, the change in storage and cumulative change in storage calculations for all subareas, especially small subareas, are reported only for general and relative understanding of the groundwater budget simulation results for regions within the Colusa Subbasin. Firm conclusions cannot be drawn from the individual subarea groundwater budget results.

Specific water budget results vary between subareas, as shown in the results that follow.

[2] The Sacramento Valley Water Year Index classifies water years as wet, above normal, below normal, dry, or critical based on Sacramento River unimpaired flows. Additional details describing the Sacramento Valley Water Year Index are available from the California Data Exchange Center.

Appendix 3G

Evaluation of Depletions of Interconnected Surface Water in the Colusa Subbasin

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Specialists in Agricultural Water Management
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Technical Memorandum

To: Colusa Groundwater Authority and Glenn Groundwater Authority

From: Davids Engineering

Date: July 12, 2021

Subject: **Evaluation of Depletions of Interconnected Surface Water in the Colusa Subbasin**

Introduction

The Groundwater Sustainability Plan (GSP) emergency regulations (emergency regulations), described in 23 CCR §354.28[1], stipulate that Groundwater Sustainability Agencies (GSAs) shall establish minimum thresholds that quantify groundwater conditions for each applicable sustainability indicator that, if exceeded, may cause undesirable results. One of the applicable sustainability indicators in the Colusa Subbasin (Subbasin) is "Depletions of Interconnected Surface Water," referred to in this memorandum as streamflow depletion. The emergency regulations require that the minimum threshold for streamflow depletion be determined based on "the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results" (23 CCR §354.28(c)(6)). The regulations also allow that groundwater levels can be used as a proxy for setting minimum thresholds for streamflow depletion, provided that adequate evidence is given to demonstrate that groundwater levels are a reasonable proxy for those minimum thresholds (§354.28(d)).

Direct quantification of streamflow depletion is a challenge in the Colusa Subbasin because of the substantial distance between streamflow measurement sites and the Subbasin boundaries, and also because the volume of streamflow depletion is small relative to the total volume of streamflow, resulting in measurement accuracy issues. Given these challenges, the two GSAs in the Colusa Subbasin (the Colusa Groundwater Authority GSA and the Glenn Groundwater Authority GSA) elected to use near-stream groundwater levels as a proxy for setting streamflow depletion minimum thresholds. Chapter 4 of the Colusa Subbasin GSP, *Monitoring Networks,* shows the location of representative monitoring wells in the interconnected surface water representative monitoring network. Groundwater levels in the vicinity of a stream or river are considered to be a reasonable proxy for monitoring depletions of surface water (EDF, 2018).

[1] California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2 Groundwater Sustainability Plans, Article 5, Section 354.28 Minimum Thresholds.

This memorandum presents and discusses results of the C2VSimFG-Colusa model (model) used to evaluate stream-aquifer interactions in the Colusa Subbasin. This memorandum provides a foundation to support the Colusa Subbasin GSP development with respect to streamflow depletion. The results reflect the simulated groundwater elevations and stream water surface elevations that, together with streambed and aquifer properties, determine the simulated streamflow accretions and depletions over time. This memorandum does not directly address quantitative minimum thresholds for streamflow depletion. Minimum thresholds for streamflow depletion are identified and discussed in the Colusa Subbasin GSP.

The Colusa Subbasin underlies approximately 724,000 acres in California and experiences significant variability in groundwater conditions in certain areas. Due to the large size and variability in conditions, the groundwater model is not currently well calibrated. This leads to greater uncertainty in simulated groundwater levels and streamflow depletions in some areas. Potential future refinements to the C2VSimFG-Colusa Model are noted at the end of this TM and are described in Appendix 3D of the GSP. However, at the time of GSP development the model is considered to provide the best available information on groundwater conditions in the Subbasin, and the accuracy of this information is generally sufficient to support GSP preparation, including description of streamflow depletion and related groundwater levels. For simplicity, hereinafter stream accretions are referred to as “gains” and depletions as “losses.”

Analytic Approach

Modeling Approach

Streamflow depletion in the Colusa Subbasin was evaluated using the C2VSimFG-Colusa model (model), an integrated hydrologic flow model for the Colusa Subbasin. Development and refinement of this model to support GSP development is described in Appendix 3D. The model was adapted from the Fine Grid California Central Valley Groundwater-Surface Water Simulation Model (C2VSimFG).

The model simulates inflows and outflows between the Subbasin surface water system and groundwater system in a grid of land elements, stream nodes, and groundwater nodes that span and surround the Colusa Subbasin. The model calculates a water budget for each element and node on a monthly timestep for different historical, current, and future scenarios described in the GSP. Results of these element and node-level water budgets are aggregated to quantify the historical, current, and future water budgets for the entire Colusa Subbasin, as required in the GSP regulations.

Stream gains (flows from groundwater into the stream) and stream losses (flows from the stream to groundwater) are quantified as components of the element and node-level water budgets along streams explicitly simulated in the Subbasin. Groundwater levels are also quantified within this model. Additional information about how the model operates, its inputs, and assumptions are provided in the model documentation and Appendix 3D.

Modeled Streams and Stream Reaches

There are four surface waterways that are explicitly represented in the model and that can be directly simulated to evaluate streamflow depletion in the Colusa Subbasin under different model scenarios:

1) The Sacramento River, which borders the Colusa Subbasin along most of its eastern boundary and runs through a portion of the Subbasin where the subbasin boundary lies east of the river,
2) Stony Creek, which borders the northern edge of the Subbasin,
3) The Colusa Basin Drain (Colusa Drain), which originates within, flows southward through, and exits the Subbasin at the Colusa-Yolo Subbasin boundary, and
4) The Glenn-Colusa Irrigation District Main Canal (GCID Canal), which originates at its point of diversion from the Sacramento River north of Hamilton City in the Corning Subbasin.

This analysis addresses all of the waterways listed above except the GCID Canal. The GCID Canal is excluded because it lies mostly within the subbasin, is fed by regulated surface water supplies, and does not have sensitive habitat along it.[2] In contrast, the Sacramento River, Stony Creek, and the Colusa Drain support riparian habitat and are also connected to the larger Sacramento River system with its many downstream users.

Water budget calculations are made for each model element for each monthly timestep, including the elements that adjoin the four streams named above[3]. The stream-adjoining elements were assigned to stream reaches for analysis, with each stream separated into two reaches as follows:

- Sacramento River
    - Glenn (Glenn County reach)—the portion of the Sacramento River adjoining the subbasin north of the Glenn-Colusa County line
    - Colusa (Colusa County reach)—the portion of the Sacramento River adjoining the subbasin south of the Glenn-Colusa County line. (Note that a portion of this reach runs through the subbasin rather than bounding it.)
- Stony Creek
    - Upper Stony Creek—the portion of the creek that is less likely to be connected to groundwater (based on separate analysis[4])
    - Lower Stony Creek—the portion of the creek that is more likely to be connected to groundwater
- Colusa Drain
    - Colusa Drain Above GCID Canal Confluence—the portion of the drain upstream of the Glenn Colusa Canal end-spill into the drain
    - Colusa Drain Below GCID Canal Confluence —the portion of the drain downstream of the Glenn Colusa Canal end-spill into the drain

[2] An analysis of groundwater dependent ecosystems in the Colusa Subbasin is described in Section 3.2.8 of the GSP.

[3] Additional information on the C2VSimFG-Colusa model is provided in Appendix 3D.

[4] An analysis of groundwater levels relative to the Stony Creek streambed is described in Section 3.2 of the GSP.

These reaches and their associated model elements are illustrated in ***Figure 1***. Note that for streams that bound the Colusa Subbasin, only the model elements along the Colusa Subbasin side of the stream were selected for analysis. In contrast, for streams or reaches flowing within the subbasin, elements on both sides of the stream were selected for analysis.

Model Scenarios

Stream gains and losses were extracted from the model results for the elements selected along each reach (***Figure 1***) and summed to get an aggregate gain or loss for each monthly timestep. This analysis was done for three model scenarios:

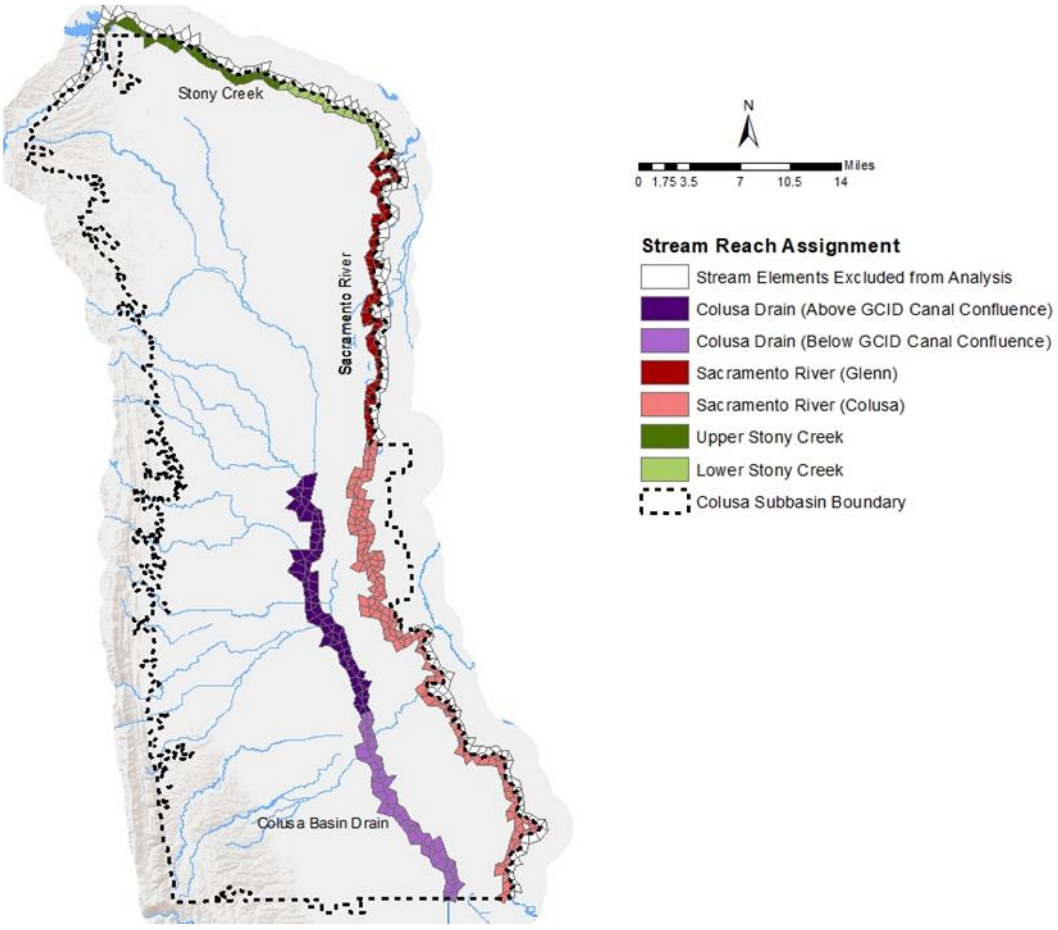

Figure 1. Modeled Streams and Stream Reaches Evaluated for Stream-Aquifer Interactions

- Scenario 1—Projected Future Conditions without Climate Change and without Projects. This is the baseline projection of future conditions over the 50-year period from 2016 through 2065, assuming no climate change and no groundwater recharge or other types of projects are implemented.

- Scenario 2—Projected Future Conditions with 2070 Climate Change and without Projects. This is the same as the Scenario 1 baseline, except that precipitation, evapotranspiration, and surface water supplies were adjusted in the model inputs to reflect the estimated effects of climate change based on the 2070 Central Tendency climate change datasets provided by DWR to support GSP development.[5] The main effect of these adjustments is an estimated increase in future crop water requirements, which result in the need for increased groundwater pumping. It is further assumed that a no groundwater recharge or other types of projects are implemented. Thus, differences in model results between this scenario and Scenario 1 are due entirely to the effects of climate change.
- Scenario 3—Projected Future Conditions with 2070 Climate Change and with Projects. This is the same as the Scenario 2 except that it is assumed that three recharge projects are in operation for the full duration of the 50-year simulation. Thus, differences in model results between this scenario and Scenario 2 are due entirely to the effects of the projects.

Hereinafter, for convenience, these model scenarios are referred to as Scenarios 1, 2, and 3, respectively.

The analysis period and assumptions about hydrology, land use, and water supplies associated with each of the three model scenarios are summarized in. Projected future water supplies and land use are expected to vary depending on Shasta watershed hydrologic conditions, which are monitored and reported by the Bureau of Reclamation (Reclamation). Water supplies and flows through the Colusa Subbasin may be reduced in hydrologic years designated by Reclamation as "Shasta Critical"[6], such as 2015, resulting in reduced cropped acreage in those years. In "Shasta Non-Critical" years, water supplies and land use are expected to be similar to current conditions in recent non-drought years, such as 2013. Additional information on Scenarios 1 and 2 is provided in Chapter 3, Section 3.3, of the Colusa Subbasin GSP. The projects modeled in Scenario 3 are described in the next section.

[5] Climatological, hydrological, and water operations datasets, change factors, and the DWR Climate Change Resource Guide are available at: https://data.cnra.ca.gov/dataset/sgma-climate-change-resources.

[6] In general, "Shasta Critical" conditions are declared when the forecast inflow to Lake Shasta for a particular water year is equal to or less than 3.2 million acre-feet. Conversely, Shasta Non-Critical conditions are declared when the forecast inflow to Lake Shasta for a particular water year exceeds 3.2 million acre-feet. Between 1966-2015, five years were "Shasta Critical," or approximately 1 in 10 years.

Table 1. Summary of Water Budget Assumptions Used for Future Conditions without Projects, Future Conditions with 2070 Climate Change without Projects, and Future Conditions with 2070 Climate Change with Projects

Model Scenario	Analysis Period[1]	Hydrology	Land Use	Water Supplies
Scenario 1: Projected Future Conditions, without Climate Change and without Projects (Baseline)	2016-2065	Historical (1966-2015)	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively, for water diversions; 2006-2015 average for urban demands
Scenario 2: Projected Future Conditions, with 2070 Climate Change and without Projects (Baseline)	2016-2065	Historical (1966-2015), adjusted based on 2070 Central Tendency climate change datasets	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Same as Current (see above), adjusted for 2070 Central Tendency climate change
Scenario 3: Projected Future Conditions with 2070 Climate Change with Projects	2016-2065	Historical (1966-2015), adjusted based on 2070 Central Tendency climate change datasets	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Same as Current (see above), adjusted for 2070 Central Tendency climate change

[1] Results over analysis period are summarized by water year (October 1 through September 30)

Groundwater Recharge Projects Modeled in Scenario 3

There are five recharge projects described in the Colusa Subbasin GSP that are on track for implementation. Three of those projects were selected for simulation in the model Scenario 3 because they are substantial recharge projects that could have large effects on groundwater conditions relative to other projects and management actions. The three modeled projects are described below.

Colusa County Water District In-Lieu Groundwater Recharge

Colusa County Water District (CCWD) has a total service area of approximately 46,000 acres, of which 39,875 acres are currently irrigable with existing District infrastructure. This area is predominantly planted to permanent crops. CCWD delivers surface water to approximately 35,000 acres, with the remaining acres being idle or irrigated with privately pumped groundwater. CCWD has a Central Valley Project (CVP) water supply contract that provides a maximum of 62,200 acre-feet (af) annually. CCWD also holds a CVP contract water supply for 5,666 af that was part of a Colusa County subcontract assigned to CCWD in 2006. Both contracts are subject to curtailments determined by Reclamation each year based on Shasta watershed hydrologic conditions.

Additionally, CCWD typically transfers in CVP water supplies purchased from others to augment water available under its CVP contract. Historical transfers have been primarily from Westside Water District and, more recently, from Reclamation District 108 (RD108) under a five-year pilot transfer agreement that ends in 2022. Despite the availability of surface water, some CCWD growers choose to pump

groundwater because it is less expensive than surface water and because groundwater requires less screening and filtering compared to surface water.

Under the CCWD In-Lieu Groundwater recharge project, CCWD will acquire additional surface water and incentives will be put in place to make the cost of surface water the same or less than the cost of pumping groundwater, thereby incentivizing growers who would otherwise use groundwater to use surface water. The additional surface water is expected to be acquired under long-term water transfer agreements with other CVP contractors, including Sacramento River Settlement Contractors (settlement contractors), and potentially other sources. The plan is to acquire and deliver 30,000 acre-feet per year (AF/yr) except in Shasta Critical years (approximately one in 10 years[7]) when groundwater stored through in-lieu recharge in prior years would be used. For modeling, it was assumed that 30,000 AF/yr will be delivered to irrigated agricultural land in model elements that approximately represent the CCWD service area during Shasta Non-Critical years in the 2016-2065 analysis period. Based on the model results, the average additional surface water use, and thus the average in-lieu groundwater recharge benefit, over the 2016-2065 analysis period is estimated to be approximately 27,000 AF/yr.

Orland-Artois Water District Land Annexation and Groundwater Recharge

Orland-Artois WD (OAWD) has an existing service area of about 29,000 acres and delivers water to district landowners through 110 miles of pipelines and 300 metered deliveries. Surface water delivered by OAWD is available under a CVP water supply contract with Reclamation and through short- and long-term transfer agreements with other CVP water contractors and settlement contractors. OAWD's water supply contract provides a maximum of 53,000 AF/yr, subject to curtailments determined by Reclamation each year based on Shasta watershed hydrologic conditions. Historically, water transfers have been from Maxwell Irrigation District, Princeton-Codora-Glenn Irrigation District, and others.

OAWD is working with a group of neighboring non-district landowners to annex approximately 12,000 acres of groundwater-dependent agriculture into the district. Additional surface water for the annexed lands would be secured through multi-year purchase or transfer agreements with willing sellers, conveyed through the existing Tehama-Colusa (TC) Canal[8], and distributed to the annexed lands through new distribution facilities. Potential transferors include CVP water supply contractors and settlement contractors. The plan is to acquire and deliver 25,000 AF/yr of surface water to the annexed lands except in Shasta Critical years (approximately one in 10 years) when groundwater banked through in-lieu recharge in prior years would be used. For modeling, it was assumed that 25,000 AF/yr will be added to OAWD available supplies and delivered to irrigated agricultural land in model elements that represent existing OAWD lands and the 12,000 acres that OAWD plans to annex. The additional 25,000 AF/yr is available in only in Shasta Non-Critical years in the 2016-2065 analysis period. Based on the model results, the average additional surface water use, and thus the average in-lieu groundwater recharge benefit, over the 2016-2065 analysis period is estimated to be approximately 22,500 AF/yr.

[7] Over the 50-year period from 1966-2015, five years were classified as "Shasta Critical."

[8] The Tehama-Colusa Canal has a maximum capacity of approximately 2,530 cubic feet per second at the canal inlet (Stene, 1994), and a capacity of approximately 1,700 cubic feet per second at the southern end of the canal. Considering historical canal operations, it is likely that conveyance capacity is available to facilitate such a program, subject to certain conditions (see Appendix A).

Colusa Subbasin Multi-Benefit Groundwater Recharge

The Colusa Groundwater Authority and The Nature Conservancy (TNC) collaborated on a multi-benefit pilot project from 2018 through 2020 to demonstrate direct groundwater recharge and creation of habitat for migrating shorebirds. The pilot project concluded that multi-benefit recharge is feasible and does generate the intended recharge and habitat benefits, serving as an example of how a Colusa Subbasin-wide program could work. For purposes of modeling, the following assumptions and approach were used. Lands with the following characteristics were assumed to enroll in the program:

- Location
    - Within a surface water supplier service area
    - Within 6 miles of the Sacramento River (to have maximum mitigating effects on streamflow depletion, which would not necessarily be a factor in a subbasin-wide program)
- Desirable recharge characteristics (Soil Agricultural Groundwater Banking Index [SAGBI] of moderately good or better
- Minimum size 25 acres

A total of 4,122 acres in 46 model elements satisfy the above criteria. For this analysis, it was assumed, as a maximum "bookend" scenario, that all lands that satisfy the above criteria would be flooded for 30 days (during the month of September) each year, except in Shasta Critical years due to likely water shortages in those years.

Based on the model results, the average additional groundwater recharge (i.e., deep percolation) attributable to the Colusa Subbasin multi-benefit groundwater recharge project is estimated to be approximately 5,200 AF/yr over the 2016-2065 analysis period (including Shasta Critical years when no flooding was done), or 1.25 acre-feet per acre (AF/ac) of additional groundwater recharge.

Results

The results of the streamflow depletion analysis developed using the model outputs are summarized below. The summary is focused primarily on simulated streamflow "net gains," calculated as simulated stream gains minus simulated stream losses from elements along the modeled stream reaches (***Figure 1***). Results are presented in both annual and monthly summaries for the modeled stream reaches to help characterize the quantity and timing of streamflow depletion (23 CCR §354.16(f)). Tables and figures summarizing these results are presented at the end of this TM.

Simulated average annual gains, losses, and net gains are presented for each of the two reaches defined for each stream and for the two reaches combined. Simulated annual gains, losses, and streamflow net gains, and simulated average monthly gains are presented only for the two reaches combined. As described above, there is significant uncertainty in simulated groundwater levels and streamflow depletions in some areas of the Subbasin resulting from issues with calibration of the groundwater model. However, at the time of GSP development the model is considered to provide the best available information on groundwater conditions in the Subbasin, and the accuracy of this information is generally sufficient to support GSP preparation, including description of streamflow depletion and related groundwater levels. Potential future refinements to the C2VSimFG-Colusa Model are noted at the end of this TM.

In the following discussion, simulated gain and loss water volumes are expressed in terms of thousand acre-feet per year (TAF/yr) rounded to the nearest tenth TAF/yr, while in the supporting tables, the volumes are presented in AF/yr. Annual and average annual volumes are summarized by water year (October 1 – September 30).

Sacramento River

Simulated Average Annual Gains and Losses by Reach

Simulated average annual stream gains, losses, net gains, and net gain as a percentage of average reach flow are presented in **Table 2** for the previously defined Glenn and Colusa reaches of the Sacramento River, and for the two reaches combined.

Glenn Reach

For the Glenn reach under Scenario 1, simulated average gains are 72.4 TAF/yr and losses are 25.3 TAF/yr, resulting in a simulated net gain of 47.1 TAF/yr. The simulated net gain is 0.4 percent of the simulated average reach flow of approximately 11.2 million acre-feet per year (MAF/yr). Under Scenario 2, simulated average gains along the Glenn reach are 66.2 TAF/yr and losses are 28.8 TAF/yr resulting in a simulated net gain of 37.4 TAF/yr, or 0.3 percent of the simulated average reach flow of 11.3 MAF/yr. The decreased gains and increased losses relative to Scenario 1 generally result from the increased groundwater pumping needed to meet simulated irrigation demands. Irrigation demands are expected to increase because crop evapotranspiration rates are expected to generally increase with climate change. The slightly increased simulated average reach stream flow between Scenarios 1 and 2 is due to increased precipitation and runoff estimated to occur due to climate change.

Under the "with projects" Scenario 3, the Glenn reach gains increase slightly relative to Scenario 2, but do not recover to Scenario 1 levels. Similarly, the Glenn reach losses are reduced relative to Scenario 2 but are not reduced to the levels of Scenario 1. As shown in **Table 2**, these relative differences are very small and expected to be within the uncertainty of the model results. Analysis of near-stream groundwater levels in relation to stream stages is needed to better understand whether these relative differences are significant.

Colusa Reach

In contrast with the Glenn reach, simulated losses exceed gains in the Colusa reach of the Sacramento River, resulting in a simulated net loss under all three scenarios (**Table 2**). Under Scenario 1, simulated average gains are 148.1 TAF/yr and losses are 161.4 TAF/yr, resulting in a simulated net loss (negative net gain) of 13.2 TAF/yr. The simulated net gain is 0.1 percent of the simulated average reach flow of approximately 10.9 MAF/yr. Under Scenario 2, simulated average Colusa reach gains are 142.6 TAF/yr and losses 171.4 TAF/yr resulting in a simulated net loss of 28.8 TAF/yr, or 0.3 percent of the simulated average reach flow of 11.0 MAF/yr. Differences between Scenarios 1 and 2 are generally related to the same factors discussed above for the Glenn reach.

Under the "with projects" Scenario 3, Colusa reach gains increase slightly relative to Scenario 2, but do not recover to Scenario 1 levels. Similarly, Colusa reach losses are reduced relative to Scenario 2 but are not reduced to the levels of Scenario 1. Similar to the Glenn reach, analysis of near-stream groundwater

levels in relation to stream stages along the Colusa reach is needed to better understand whether these relative differences are significant.

Glenn and Colusa Reaches Combined

The combined effect of simulated groundwater conditions in the Colusa Subbasin on Sacramento River simulated streamflow is modest stream gains ranging between 8.7 TAF/yr and 33.9 TAF/yr, depending on the scenario. These simulated gains correspond to a range of 0.1 to 0.3 percent of the average annual reach flow. The year-to-year variation is much greater than the variation between scenarios.

Simulated Annual Gains and Losses for Combined Reaches

Simulated annual gains, losses, and net gains for the entire portion of the Sacramento River adjoining or running through the Colusa Subbasin are listed in **Table 3** for each of the three scenarios, with water year type indicated based on the Sacramento Valley Water Year Index.[9] Over the 50-year projected future simulation period, simulated stream gains in Scenario 1 range between 167.4 TAF/yr (2016, a below normal year) and 266.8 TAF/yr (2034, a wet year). Simulated stream losses range between 110.0 TAF/yr (2026, a critical year) to 260.3 TAF/yr (2023, an above normal year). Simulated annual net gain varies over a wide range of volumes, from a low of -87.6 TAF/yr (2016, a below normal year), indicating net loss, to a high of 123.1 TAF/yr (2026, a critical year). It is noted that the lowest simulated annual net gain occurs in the year with the lowest simulated stream gains (2016) while the highest simulated annual net gain occurs in the year with the lowest simulated stream losses (2026). General patterns of stream gain and loss are similar across all scenarios.

Simulated average annual gains, losses, and net gains by year type are also presented in **Table 3**. The lowest simulated average net gain occurs in below normal year types and the highest simulated average net gain occurs in dry year types. There does not appear to be a clear correlation between year type and simulated average annual net gain, possibly due to potential lagged responses of groundwater levels to varying hydrology, and the occurrence of different year type sequences over time. There are likely many other physical and operational factors influencing Sacramento River gains and losses that are beyond the scope of this analysis.

Simulated annual net gain is graphed in **Figure 2**, illustrating a highly variable pattern across years and the relatively small differences among the model scenarios. As expected based on the time dependency of groundwater flow from recharge areas to discharge areas, there is a general, lagged correlation between simulated annual net gain and sequences of generally wet or dry year types. For example, the high simulated net gains in 2025-2026 (corresponding to historical hydrology in 1974-1975) follow a series of mostly wet years that occurred from 1968-1974. Similarly, the relatively high simulated net gains in 2048-2051 (corresponding to 1997-2000 historical hydrology) occur following a wet sequence from 1994-1999. Downward spikes in simulated annual net gains appear to be related to dry sequences in some cases but not others. For example, the downward spike in 2027 maps to 1976 historical

[9] The Sacramento Valley Water Year Index is calculated as specified in the 1995 California State Water Resources Control Board Water Quality Control Plan, and is used to determine the Sacramento Valley water year type as implemented in SWRCB D-1641. Additional information is available at: https://cdec.water.ca.gov/reportapp/javareports?name=WSIHIST.
The methodology for assigning Sacramento Valley Water Year Indices to projected water years is described in the GSP.

hydrology, with that year being the second of two back-to-back critical years. Likewise, the sharp declines in 2064 and 2065 map to 2013 and 2014, also back-to-back critical years. Other downward spikes are harder to interpret.

Simulated Average Monthly Net Gains for Combined Reaches

Simulated average monthly net gains for the entire portion of the Sacramento River adjoining or running through the Colusa Subbasin are summarized in **Table 4** and **Figure 3** for each of the three scenarios. As noted previously, the C2VSimFG-Colusa model is not currently well calibrated in some areas, causing greater uncertainty in these precise volumes. However, at the time of GSP development the C2VSimFG-Colusa model is considered to provide the best available data on groundwater conditions in the Subbasin. These results are thus provided mainly as a relative summary of the average temporal exchanges between surface water and groundwater, though the actual volumes and timing may vary.

Over the 50-year projected future simulation period, simulated average monthly net gains vary from net negative values in the winter months to net positive values in the spring, summer, and fall. Similar trends are observed across all three scenarios. These results suggest that, on average, surface water in the Sacramento River recharges the groundwater system through seepage in the winter months, and the groundwater system discharges water, on average, to the river at other times of year. Simulated net gains are estimated to decline under the effects of climate change alone (Scenario 2 minus Scenario 1), but are estimated to increase from those levels following implementation of the simulated projects (Scenario 3 minus Scenario 2). Simulated changes in net gains are greatest in December and January when seepage (negative net gain) is expected to increase under the effects of climate change. Simulated net gains are also expected to decrease in mid-summer under the effects of climate change, though projects and management actions are expected to increase net gains most during the summer months. Further analysis of near-stream groundwater levels in relation to stream stages is needed to better understand whether these simulated relative differences are significant to verify the characteristics of stream-aquifer interactions.

Stony Creek

Simulated Average Annual Gains and Losses by Reach

Simulated average annual stream gains, losses, net gains, and net gain as a percentage of average reach flow are presented in **Table 5** for the previously defined reaches along Upper Stony Creek and Lower Stony Creek, and for the two reaches combined.

Upper Reach

Simulated losses exceed gains in Upper Stony Creek, resulting in a simulated net loss (a negative net gain) under all three scenarios. For the upper reach under Scenario 1, simulated average gains are 4.2 TAF/yr and losses are 12.2 TAF/yr, resulting in a simulated net loss of -8.0 TAF/yr, indicating a net loss. The simulated net gain is -4.8 percent of the simulated average reach flow, totaling approximately 166.2 TAF/yr. Under Scenario 2, simulated average upper reach gains are 3.1 TAF/yr and losses are 14.5 TAF/yr, resulting in a simulated net loss of 11.4 TAF/yr, or 6.9 percent of the simulated average reach flow of 164 TAF/yr. The decreased gains and increased losses relative to Scenario 1 generally result from the increased groundwater pumping needed to meet higher evapotranspiration rates and irrigation

demands resulting from climate change. Between Scenarios 1 and 2, simulated average reach flows decrease slightly, potentially as a result of the decreased gains and increased losses.

Under the "with projects" Scenario 3, the upper reach gains increase slightly relative to Scenario 2, but do not recover to Scenario 1 levels. Similarly, upper reach losses are reduced relative to Scenario 2 but are not reduced to the levels of Scenario 1. As discussed for the Sacramento River, analysis of near-stream groundwater levels in relation to stream stages is needed to better understand whether these relative differences are significant to verify the characteristics of stream-aquifer interactions.

Lower Reach

Like the upper reach, simulated losses exceed gains in Lower Stony Creek, resulting in a simulated net loss (a negative net gain) under all three scenarios. Under Scenario 1, simulated average gains are 0.7 TAF/yr and average losses are 9.9 TAF/yr, resulting in a simulated net gain of -9.3 TAF/yr. The simulated net gain is -2.9 percent of the simulated average reach flow of approximately 319.4 TAF/yr. Under Scenario 2, average lower reach gains slightly decrease to 0.4 TAF/yr and losses increase to 11.7 TAF/yr, resulting in a simulated net loss of 11.2 TAF/yr, or 3.6 percent of the simulated average reach flow of 313.6 TAF/yr. Differences between Scenarios 1 and 2 are generally related to the same factors discussed above for the upper reach.

Under the "with projects" Scenario 3, lower reach gains increase slightly relative to Scenario 2, but do not recover to Scenario 1 levels. Similarly, lower reach losses are reduced relative to Scenario 2 but are not reduced to the levels of Scenario 1. Similar to the upper reach, analysis of near-stream groundwater levels in relation to stream stages is needed to better understand whether these relative differences are significant.

Upper and Lower Reaches Combined

The combined effect of simulated groundwater conditions in the Colusa Subbasin on Stony Creek simulated streamflow is net losses ranging between 17.2 TAF/yr and 22.6 TAF/yr, depending on the scenario. These losses represent a range of 7.1 to 9.5 percent of the average annual reach flow. The year-to-year variation is much greater than the variation between scenarios.

Simulated Annual Gains and Losses for Combined Reaches

Simulated annual gains, losses, and net gains for the entire portion of Stony Creek adjoining or running through the Colusa Subbasin are listed in **Table 6**, with water year type indicated based on the Sacramento Valley Water Year Index. Over the 50-year projected future simulation period for Scenario 1, simulated stream gains range between approximately 0 TAF/yr (2026 and 2040, both critical years, and 2039, a below-normal year) and 11.4 TAF/yr (2033, a wet year). Simulated stream losses range between 3.3 TAF/yr (in 2026) and 51.1 TAF/yr (in 2027), occurring in two sequential critical years. Overall, Stony Creek has a simulated net loss (negative net gain) in all years, ranging from a loss of 50.6 TAF/yr (2027, a critical year) to a loss of 2.6 TAF/yr (2034, a wet year). General patterns of stream gain and loss are similar across all scenarios.

Simulated average annual gains, losses, and net gains by year type are also presented in **Table 6**. The greatest volume of simulated net loss generally occurs in critical years. Lesser volumes of simulated net loss generally occur in progressively wetter water year types, with the exception of below normal years. However, patterns vary due to the lagged responses of groundwater levels to varying hydrology, and the

occurrence of different year type sequences over time. Other factors may also contribute to Stony Creek losses that are beyond the scope of this analysis.

Simulated annual net gain is graphed in **Figure 4**, illustrating a variable pattern of net loss across all years, and a relatively small differences among the model scenarios. The simulated volume of net loss is generally greatest (i.e., more negative net gain) in Scenario 2, when affected only by climate change, and is generally least in Scenario 1, when unaffected by climate change. Like the Sacramento River, there is a general, lagged correlation between simulated annual net loss and sequences of generally wet or dry year types. For example, the relatively higher (i.e., less negative) net gains in 2025-2026 are simulated based on historical hydrology in 1974-1975, which followed a series of mostly wet years that occurred from 1968 through 1974. In 2027, the significant decline in net gain (significant increase in net loss) corresponds to 1976 historical hydrology, the second of two sequential critical years.

Simulated Average Monthly Net Gains for Combined Reaches

Simulated average monthly net gains for the entire portion of Stony Creek adjoining the Colusa Subbasin are summarized in **Table 7** and **Figure 5** for each of the three scenarios. As noted previously, the C2VSimFG-Colusa model is not currently well calibrated in some areas, causing greater uncertainty in these precise volumes. However, at the time of GSP development the C2VSimFG-Colusa model is considered to provide the best available data on groundwater conditions in the Subbasin. These results are thus provided mainly as a relative summary of the average temporal exchanges between surface water and groundwater, though the actual volumes and timing may vary.

Over the 50-year projected future simulation period, simulated average monthly net gains are negative in all months, indicating net loss (seepage) from the streams to groundwater, with fluctuations between seasons. Seepage is comparatively highest in the winter, and comparatively lowest in spring and mid-fall. Similar trends are observed across all three scenarios. Simulated net gains are estimated to decline further under the effects of climate change alone (Scenario 2 minus Scenario 1), but are estimated to increase from those levels following implementation of the simulated projects (Scenario 3 minus Scenario 2). Further analysis of near-stream groundwater levels in relation to stream stages is needed to better understand whether these simulated relative differences are significant to verify the characteristics of stream-aquifer interactions.

Colusa Drain

Simulated Average Annual Gains and Losses by Reach

Simulated average annual stream gains, losses, net gains, and net gain as a percentage of average reach flow are presented in **Table 8** for the previously defined reaches along Colusa Drain above and below the GCID Canal confluence, and for the two reaches combined.

Colusa Drain Above GCID Canal Confluence

Under all scenarios, the upper reach of the Colusa Drain above the GCID Canal confluence is a significantly gaining reach. In Scenario 1, simulated average gains are 104.9 TAF/yr and losses are only 1 TAF/yr, resulting in a simulated net gain of 103.9 TAF/yr, or 28.5 percent of the simulated average reach flow. In Scenario 2, simulated average gains along Colusa Drain above the GCID Canal confluence

are 95.1 TAF/yr and losses are 1.4 TAF/yr, for a simulated net gain of 93.6 TAF/yr, or 25.4 percent of the simulated average reach flow. While simulated net gains slightly decrease under the effects of climate change, the net gain remains a significant fraction of the reach flow.

Under the "with projects" Scenario 3, simulated net gains along the Colusa Drain above the GCID Canal confluence increase slightly relative to Scenario 2, but do not recover to Scenario 1 levels. Like the Sacramento River and Stony Creek, analysis of near-stream groundwater levels in relation to stream stages is needed to better understand whether these relative differences are significant.

Colusa Drain Below GCID Canal Confluence

In contrast with the upper reach of Colusa Drain, Colusa Drain below the GCID Canal is only a slightly gaining reach in Scenarios 1 and 3, and is a slightly losing reach under the effects of climate change in Scenario 2. In Scenario 1, simulated average gains are 13.5 TAF/yr and average losses are 8.9 TAF/yr, resulting in a simulated net gain of 4.6 TAF/yr. This simulated net gain is just 0.6 percent of the simulated average reach flow of approximately 749 TAF/yr. In Scenario 2, simulated average reach gains decrease to 10.6 TAF/yr and simulated average losses increase to 13.1 TAF/yr, resulting in a net loss of 2.5 TAF/yr, or 0.3 percent of the simulated average reach flow. Differences between Scenarios 1 and 2 are expected to be generally related to the same factors discussed above for the other reaches.

Under the "with projects" Scenario 3, average reach gains increase to 14.2 TAF/yr, above the levels observed in Scenarios 1 and 2. However, losses are reduced relative to Scenario 2 but are not reduced to the levels of Scenario 1, resulting in a slight decrease in net gains relative to Scenario 1, totaling just 4.4 TAF/yr.

Upper and Lower Reaches Combined

Altogether, the Colusa Drain is a significantly gaining stream, with simulated net gains ranging between 91.1 and 108.5 TAF/yr, depending on the scenario. These simulated gains correspond to a range of 16.1 to 19.5 percent of the simulated average annual flow.

Simulated Annual Gains and Losses for Combined Reaches

Simulated annual gains, losses, and net gains for the entire portion of the Colusa Drain running through the Colusa Subbasin are listed in **Table 9**, with water year type indicated based on the Sacramento Valley Water Year Index. Over the 50-year projected future simulation period for Scenario 1, simulated net gains range from 80.8 TAF/yr (2042, a critical year) to 138.3 TAF/yr (2049, a wet year). In general, patterns of stream gain and loss are similar across all scenarios, with the highest gain in Scenario 1 (except 2026) and the lowest gain in Scenario 2.

Simulated average annual gains, losses, and net gains by year type are also presented in **Table 9**. On average, the greatest simulated net gains occur in wet years. Across other water year types, simulated average net gains are generally similar within each scenario, ranging within 2 to 5 TAF/yr. Like the Sacramento River and Stony Creek, patterns of net gain vary due to the lagged responses of groundwater levels to varying hydrology, and the occurrence of different year type sequences over time. Other factors may also contribute to net gains in the Colusa Drain that are beyond the scope of this analysis.

Annual net gain is graphed in **Figure 6**, illustrating a variable pattern of net gain across all years. The year-to-year variation exceeds the variation between scenarios. Simulated net gains are generally greatest in

Scenario 1, when unaffected by climate change, and are generally least in Scenario 2, when affected by climate change and without the benefits of projects. The difference in simulated net gains between these scenarios is generally 10 to 20 TAF/yr. Like the Sacramento River and Stony Creek, there is a general, lagged correlation between annual net loss and sequences of generally wet or dry year types.

Simulated Average Monthly Net Gains for Combined Reaches

Simulated average monthly net gains for the entire portion of Colusa Drain running through the Colusa Subbasin are summarized in **Table 10** and **Figure 7** for each of the three scenarios. As noted previously, the C2VSimFG-Colusa model is not currently well calibrated in some areas, causing greater uncertainty in these precise volumes. However, at the time of GSP development the C2VSimFG-Colusa model is considered to provide the best available data on groundwater conditions in the Subbasin. These results are thus provided mainly as a relative summary of the average temporal exchanges between surface water and groundwater, though the actual volumes and timing may vary.

Over the 50-year projected future simulation period, simulated average monthly net gains are positive in all months, but fluctuate from month to month. Net gains are comparatively lower in the winter and in May and October, and peak in mid spring, late summer, and in November. These seasonal patterns are believed to be related to rainfall runoff from westside streams and rice water management practices including winter flooding of fields for rice straw decomposition. Similar trends are observed across all three scenarios. Simulated net gains are estimated to decline under the effects of climate change alone (Scenario 2 minus Scenario 1), but are estimated to increase from those levels nearly back to the pre-climate change estimates following implementation of the simulated projects (Scenario 3 minus Scenario 2). Further analysis of near-stream groundwater levels in relation to stream stages is needed to better understand whether these simulated relative differences are significant to verify the characteristics of stream-aquifer interactions.

Provisional Observations and Conclusions

The results of this analysis are uncertain, resulting primarily from the C2VSimFG-Colusa model not being well calibrated at this time. The GSAs further recognize that there are data gaps in current understanding of stream-aquifer interactions in the Colusa Subbasin. Therefore, firm conclusions cannot be made regarding the nature and patterns of stream-aquifer interaction in relation to groundwater management activities in the Colusa Subbasin. The following provisional observations and conclusions are made for each of the three streams analyzed, pending refinement of the model and additional data collection and analysis, particularly data describing near-stream, shallow groundwater levels and groundwater gradients. To close data gaps and improve future understanding of streamflow depletion in the Colusa Subbasin, the GSAs have proposed GSP implementation studies to update and enhance the C2VSimFG-Colusa model, expand near-stream, shallow groundwater monitoring, and complete other activities to address data gaps. These proposed studies are described in GSP Chapter 7, Plan Implementation. Future refinements to the C2VSimFG-Colusa model are further described below. Finally, because gains and losses in the Sacramento River and Stony Creek are likely affected by groundwater management in adjoining and upstream subbasins, the GSAs in the Colusa Subbasin will seek opportunities to improve understanding of stream accretion and depletion in these water bodies through interbasin coordination.

Sacramento River

The Sacramento River is a very modestly gaining stream as related to groundwater conditions in the Colusa Subbasin, with simulated net gains representing just 0.1 percent to 0.3 percent of the relatively large flows in the river. It is noted that these simulated net gains are less than the typical ±2.5% accuracy of annual volume measurements when calculated from current meter-based stage-discharge functions (Clemmens and Wahlin, 2006). Consequently, these simulated net gains are not considered to be significantly different than the uncertainty of average annual streamflows along these reaches, and cannot be measured directly from stream gage measurements with certainty. It does not appear that patterns of simulated gain and loss are strongly affected by increases in groundwater pumping needed to satisfy increased irrigation requirements resulting from potential future climate change, or by recharge projects that could be implemented in the Subbasin. Therefore, it is concluded, on a provisional basis, that the effects of groundwater management in the Colusa Subbasin do not have significant and unreasonable effects on beneficial uses and users of Sacramento River water. However, recognizing that there are data gaps in current understanding and monitoring of streamflow depletion in the Colusa Subbasin, these analyses and provisional conclusions will be revisited and revised, as needed, in future updates to the Colusa Subbasin GSP when more information is known.

Stony Creek

Overall, based on best available data and analysis, Stony Creek is regarded as a losing stream as related to groundwater conditions in the Colusa Subbasin, losing a simulated average net volume of 17.2 to 22.6 TAF/yr over the projected future scenarios. Simulated losses represent between 4.8 and 6.9 percent of simulated average flows in the upper reach, and between 2.9 and 3.6 percent of simulated average flows in the lower reach. The simulated volume of net loss is generally greater in critical water years and lower in wetter water years. Under the potential future effects of climate change, patterns of simulated net loss do not appear to be significantly or consistently affected by increased demand for groundwater pumping, as evidenced by the similarity in patterns and volumes of simulated net loss across all scenarios. Therefore, it is concluded, on a provisional basis, that the effects of groundwater management in the Colusa Subbasin do not have significant and unreasonable effects on beneficial uses and users of Stony Creek water. Recognizing that there are data gaps in current understanding and monitoring of streamflow depletion in the Colusa Subbasin, these analyses and provisional conclusions will be revisited and revised, as needed, in future updates to the Colusa Subbasin GSP when more information is known.

Colusa Drain

Overall, Colusa Drain is considered to be a significantly gaining stream as related to groundwater conditions in the Colusa Subbasin, with simulated net gains between 91.1 and 108.5 TAF/yr over the projected future scenarios. These simulated net gains represent a significant fraction of the total average streamflow, between 16.1 and 19.5 percent overall. On average, simulated net gains are greatest in wet water years, and generally similar in other water year types. The pattern of simulated annual net gains varies over time, but is generally similar between scenarios and does not appear to be significantly or consistently affected by increased demand for groundwater pumping in drier water years. Therefore, it is concluded, on a provisional basis, that the effects of groundwater management in the Colusa Subbasin do not have significant and unreasonable effects on beneficial uses and users of Colusa Drain water. Recognizing that there are data gaps in current understanding and monitoring of

streamflow depletion in the Colusa Subbasin, these analyses and provisional conclusions will be revisited and revised, as needed, in future updates to the Colusa Subbasin GSP when more information is known.

Future Refinements to the C2VSimFG-Colusa Model

As described previously, the C2VSimFG-Colusa model is expected to require future refinements to improve its calibration. Due to the large area and variability in conditions across the Colusa Subbasin, there is significant uncertainty in simulated groundwater levels and resulting streamflow depletions in some areas.

During development and initial calibration of C2VSimFG-Colusa model, several potential future refinements to the model were identified. These refinements are described in Appendix 3D of the GSP, and may include:

- Refine the model grid resolution in areas where observed groundwater level data show high spatial gradients, to better simulate these local high groundwater gradients.
- Use more recent data (e.g. 2016-2021) to improve the accuracy of the model for predicting near-term and future conditions in the Colusa Subbasin.
- Adjust model layer thicknesses to better represent local geologic conditions and potential faults in these areas.
- Adjust model layer thicknesses to distribute groundwater pumping and better match groundwater extraction from different depth and layers of the aquifer.
- Explicitly model small, ephemeral streams flowing into the western side of the Colusa Subbasin to better represent recharge.
- Improve calibration and representation of interbasin flows, including Sacramento River recharge along the eastern boundary of the Colusa Subbasin and subsurface groundwater flows into and out of Colusa, Butte and Vina Subbasins.

Table 2. Simulated Sacramento River Stream-Aquifer Interaction: Average Annual Summary (Water Years 2016-2065, AF/yr)

Sacramento River					
	Glenn County Reach				
Model Scenario	**Average Reach Flow**	**Stream Gains**	**Stream Losses**	**Net Gains**	**Net Stream Gains as a Percent of Average Reach Flow**
Scenario 1	11,175,100	72,400	25,300	47,100	0.42%
Scenario 2	11,328,100	66,200	28,800	37,400	0.33%
Scenario 3	11,290,900	69,400	27,400	41,900	0.37%
Difference: Scenario 2 minus Scenario 1	153,000	-6,200	3,500	-9,700	-0.09%
Difference: Scenario 3 minus Scenario 2	-37,200	3,100	-1,400	4,500	0.04%
	Colusa County Reach				
Model Scenario	**Average Reach Flow**	**Stream Gains**	**Stream Losses**	**Net Gains**	**Net Stream Gains as a Percent of Average Reach Flow**
Scenario 1	10,876,800	148,100	161,400	-13,200	-0.12%
Scenario 2	11,012,200	142,600	171,400	-28,800	-0.26%
Scenario 3	10,984,900	145,600	167,800	-22,200	-0.20%
Difference: Scenario 2 minus Scenario 1	135,400	-5,500	10,000	-15,600	-0.14%
Difference: Scenario 3 minus Scenario 2	-27,300	3,000	-3,600	6,600	0.06%
	All Reaches				
Model Scenario	**Average Reach Flow**	**Stream Gains**	**Stream Losses**	**Net Gains**	**Net Stream Gains as a Percent of Average Reach Flow**
Scenario 1	11,025,900	220,500	186,600	33,900	0.31%
Scenario 2	11,170,100	208,900	200,200	8,700	0.08%
Scenario 3	11,137,900	215,000	195,300	19,700	0.18%
Difference: Scenario 2 minus Scenario 1	144,200	-11,700	13,600	-25,200	-0.23%
Difference: Scenario 3 minus Scenario 2	-32,200	6,200	-4,900	11,100	0.10%

Table 3. Simulated Sacramento River Stream-Aquifer Interaction: Annual Summary of All Reaches (Water Years 2016-2065, AF/yr).

Sacramento Valley Water Year Type	Water Year	Scenario 1			Scenario 2			Scenario 3		
		Stream Gains	Stream Losses	Net Gains	Stream Gains	Stream Losses	Net Gains	Stream Gains	Stream Losses	Net Gains
BN	2016	167,400	255,000	-87,600	163,700	259,800	-96,200	164,500	258,800	-94,300
W	2017	208,900	183,500	25,300	202,700	191,300	11,500	204,700	189,500	15,200
BN	2018	200,900	213,700	-12,800	193,600	222,900	-29,300	196,100	220,600	-24,500
W	2019	245,000	213,700	31,300	236,300	225,800	10,500	239,900	223,300	16,600
W	2020	194,500	230,300	-35,800	187,600	245,100	-57,500	191,000	241,400	-50,400
W	2021	226,800	162,900	63,900	215,900	176,500	39,500	220,400	173,100	47,300
BN	2022	201,600	206,800	-5,200	191,000	219,100	-28,100	195,500	215,000	-19,500
AN	2023	205,200	260,300	-55,100	193,700	274,200	-80,500	198,500	269,400	-70,900
W	2024	212,900	195,300	17,600	201,400	208,400	-6,900	206,700	203,900	2,700
W	2025	233,000	157,600	75,400	223,300	171,100	52,100	229,300	167,000	62,300
C	2026	233,100	110,100	123,100	215,000	124,000	91,100	219,800	120,700	99,200
C	2027	193,800	208,500	-14,700	181,300	217,700	-36,500	184,900	214,200	-29,200
AN	2028	219,200	171,500	47,600	208,200	189,900	18,300	212,900	186,200	26,800
BN	2029	232,700	203,500	29,100	219,800	215,900	3,900	225,200	211,900	13,200
AN	2030	217,300	168,100	49,100	204,500	185,300	19,200	209,800	181,100	28,700
D	2031	203,000	241,600	-38,600	189,300	256,700	-67,400	194,500	251,700	-57,300
W	2032	202,100	258,300	-56,200	189,300	272,700	-83,400	194,900	267,400	-72,500
W	2033	255,900	188,700	67,100	243,200	204,600	38,600	249,800	199,800	49,900
W	2034	266,800	164,000	102,800	251,100	176,600	74,500	258,300	172,200	86,100
D	2035	247,100	208,500	38,600	230,700	220,000	10,700	237,300	215,100	22,200
W	2036	225,000	165,400	59,500	212,500	182,100	30,400	219,600	176,900	42,700
D	2037	208,200	149,900	58,300	194,700	164,500	30,200	201,500	158,800	42,700
C	2038	216,000	159,500	56,500	204,800	180,400	24,400	211,500	174,500	37,000
D	2039	219,400	151,800	67,600	204,500	169,900	34,500	211,600	164,700	46,900
C	2040	218,600	122,000	96,600	206,700	132,900	73,800	214,000	127,300	86,800
C	2041	214,600	151,200	63,400	203,100	167,800	35,200	209,100	163,200	45,900
C	2042	200,100	213,000	-12,900	187,000	227,500	-40,600	193,000	221,800	-28,700
AN	2043	229,800	158,500	71,300	218,100	176,900	41,200	224,600	171,700	52,900
C	2044	194,700	250,700	-56,000	194,000	254,800	-60,800	200,100	249,100	-49,000
W	2045	235,000	199,600	35,400	230,500	213,400	17,100	237,700	207,800	29,800
W	2046	256,800	203,000	53,800	249,000	213,700	35,300	256,600	208,600	48,000
W	2047	196,000	248,400	-52,400	185,100	262,000	-76,900	191,300	255,900	-64,500
W	2048	246,000	189,400	56,500	235,000	200,100	34,900	242,800	194,800	48,000
W	2049	239,600	179,500	60,100	226,300	191,000	35,300	233,800	185,600	48,100
AN	2050	232,800	152,100	80,700	219,500	167,200	52,300	227,100	161,400	65,600
D	2051	222,300	155,100	67,200	209,700	169,500	40,300	217,200	163,800	53,400
D	2052	213,900	198,500	15,400	201,800	212,000	-10,200	209,000	205,900	3,100
AN	2053	220,800	205,100	15,700	208,500	218,800	-10,300	215,900	212,500	3,400
BN	2054	233,100	188,100	45,000	220,700	204,600	16,200	228,600	198,900	29,700
AN	2055	212,300	236,000	-23,700	199,700	247,800	-48,200	206,900	241,400	-34,500
W	2056	251,900	160,800	91,100	238,000	175,900	62,100	246,200	170,500	75,700
D	2057	231,400	132,900	98,600	218,900	148,100	70,800	226,800	142,600	84,300
C	2058	216,900	145,400	71,600	205,400	163,700	41,700	213,300	157,600	55,700
D	2059	204,200	166,200	38,000	191,700	181,500	10,100	199,000	174,800	24,200
BN	2060	204,200	217,800	-13,600	190,500	232,600	-42,000	197,600	225,600	-27,900
W	2061	251,800	156,100	95,700	240,500	170,900	69,600	248,800	165,300	83,500
BN	2062	228,900	149,300	79,600	214,700	159,600	55,100	222,700	153,700	69,000
D	2063	247,700	130,300	117,400	230,400	140,900	89,400	238,700	135,300	103,400
C	2064	215,100	145,100	70,000	199,800	156,800	43,000	206,400	151,600	54,900
C	2065	173,100	249,500	-76,400	160,700	265,200	-104,500	165,200	259,300	-94,100
Minimum		167,400	110,100	-87,600	160,700	124,000	-104,500	164,500	120,700	-94,300
Maximum		266,800	260,300	123,100	251,100	274,200	91,100	258,300	269,400	103,400
Average	W	232,200	191,600	40,700	221,600	204,800	16,900	227,700	200,200	27,600
	AN	219,600	193,100	26,500	207,400	208,600	-1,100	213,700	203,400	10,300
	BN	209,800	204,900	4,900	199,200	216,400	-17,200	204,300	212,100	-7,700
	D	221,900	170,500	51,400	208,000	184,800	23,200	215,100	179,200	35,900
	C	207,600	175,500	32,100	195,800	189,100	6,700	201,800	183,900	17,800
	All Years	220,500	186,600	33,900	208,900	200,200	8,700	215,000	195,300	19,700

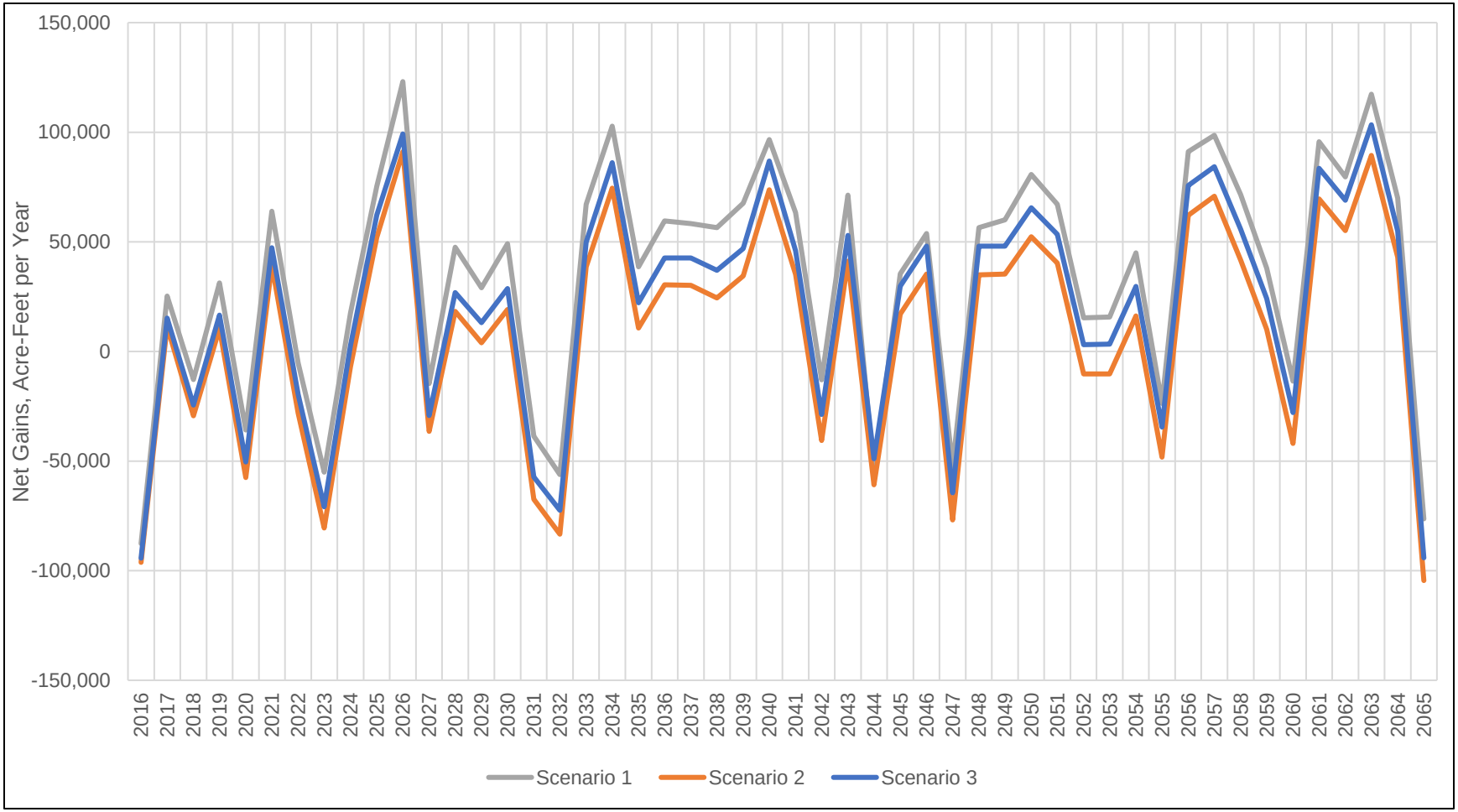

Figure 2. Simulated Sacramento River Stream-Aquifer Interaction: Annual Net Gain of All Reaches (Water Years 2016-2065, AF/yr).

Table 4. Simulated Sacramento River Stream-Aquifer Interaction: Average Monthly Net Gains (Water Years 2016-2065, AF/month)

Month	Scenario 1	Scenario 2	Scenario 3	Difference: Scenario 2 minus Scenario 1	Difference: Scenario 3 minus Scenario 2
1	-16,900	-21,000	-20,200	-4,100	800
2	-8,400	-10,300	-9,500	-1,900	800
3	-3,500	-4,900	-4,100	-1,400	800
4	20,100	20,300	21,500	200	1,200
5	13,300	12,100	13,000	-1,200	900
6	14,200	11,900	12,900	-2,300	1,000
7	5,300	2,600	3,700	-2,700	1,100
8	5,400	2,700	3,700	-2,700	1,000
9	8,700	6,100	7,400	-2,600	1,300
10	17,400	15,500	16,400	-1,900	900
11	-2,100	-3,200	-2,500	-1,100	700
12	-19,500	-23,300	-22,500	-3,800	800
Average Annual Volume[1]	34,000	8,500	19,800	-25,500	11,300

[1] Average annual volumes in this table are summed from rounded average monthly volumes and may differ from average annual volumes shown in other summary tables due to rounding.

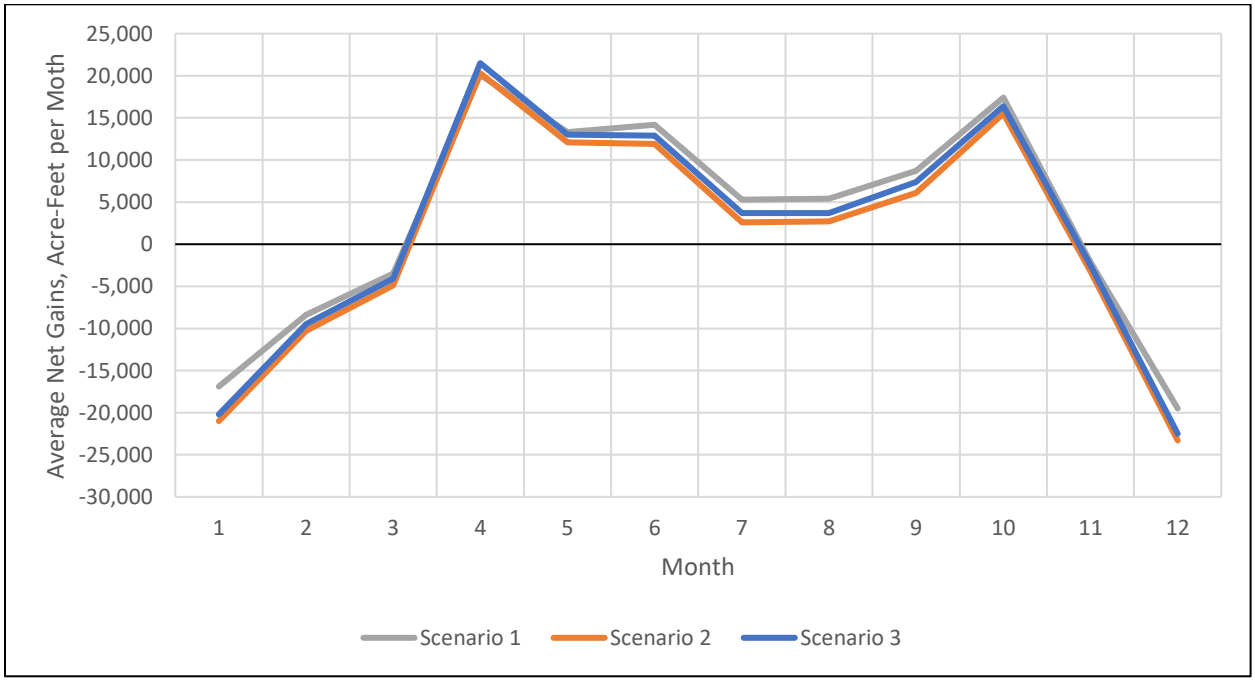

Figure 3. Simulated Sacramento River Stream-Aquifer Interaction: Average Monthly Summary (Water Years 2016-2065, AF/month)

Table 5. Simulated Stony Creek Stream-Aquifer Interaction: Average Annual Summary (Water Years 2016-2065, AF/yr)

Stony Creek					
	Upper Stony Creek				
Model Scenario	**Average Reach Flow**	**Stream Gains**	**Stream Losses**	**Net Gains**	**Net Stream Gains as a Percent of Average Reach Flow**
Scenario 1	166,200	4,200	12,200	-8,000	-4.80%
Scenario 2	164,000	3,100	14,500	-11,400	-6.93%
Scenario 3	165,400	3,600	13,500	-9,800	-5.94%
Difference: Scenario 2 minus Scenario 1	-2,200	-1,200	2,200	-3,400	-2.12%
Difference: Scenario 3 minus Scenario 2	1,400	500	-1,000	1,500	0.98%
	Lower Stony Creek				
Model Scenario	**Average Reach Flow**	**Stream Gains**	**Stream Losses**	**Net Gains**	**Net Stream Gains as a Percent of Average Reach Flow**
Scenario 1	319,400	700	9,900	-9,300	-2.90%
Scenario 2	313,600	400	11,700	-11,200	-3.59%
Scenario 3	317,200	600	10,800	-10,300	-3.23%
Difference: Scenario 2 minus Scenario 1	-5,900	-200	1,800	-2,000	-0.69%
Difference: Scenario 3 minus Scenario 2	3,600	100	-900	1,000	0.35%
	All Reaches				
Model Scenario	**Average Reach Flow**	**Stream Gains**	**Stream Losses**	**Net Gains**	**Net Stream Gains as a Percent of Average Reach Flow**
Scenario 1	242,800	4,900	22,200	-17,200	-7.10%
Scenario 2	238,800	3,500	26,100	-22,600	-9.47%
Scenario 3	241,300	4,200	24,300	-20,100	-8.32%
Difference: Scenario 2 minus Scenario 1	-4,000	-1,400	4,000	-5,400	-2.37%
Difference: Scenario 3 minus Scenario 2	2,500	700	-1,800	2,500	1.14%

Table 6. Simulated Stony Creek Stream-Aquifer Interaction: Annual Summary of All Reaches (Water Years 2016-2065, AF/yr).

Sacramento Valley Water Year Type	Water Year	Scenario 1			Scenario			Scenario		
		Stream Gains	Stream Losses	Net Gains	Stream Gains	Stream Losses	Net Gains	Stream Gains	Stream Losses	Net Gains
BN	2016	2,400	37,900	-35,400	2,200	38,800	-36,600	2,200	38,700	-36,500
W	2017	4,700	19,400	-14,700	4,000	20,100	-16,100	4,100	19,900	-15,800
BN	2018	3,200	30,300	-27,100	2,500	33,100	-30,600	2,600	32,300	-29,600
W	2019	6,100	16,200	-10,100	4,700	17,200	-12,500	5,200	16,800	-11,600
W	2020	4,600	24,700	-20,100	3,300	27,700	-24,300	3,700	26,500	-22,700
W	2021	4,400	16,100	-11,600	3,100	18,200	-15,100	3,600	17,400	-13,800
BN	2022	2,900	31,500	-28,600	1,800	35,100	-33,300	2,200	33,600	-31,400
AN	2023	6,800	22,500	-15,700	4,900	26,600	-21,700	5,600	24,900	-19,300
W	2024	6,700	20,500	-13,700	5,200	23,800	-18,600	6,000	21,900	-15,900
W	2025	3,300	9,900	-6,700	2,300	11,300	-9,000	2,900	10,600	-7,700
C	2026	0	3,300	-3,300	0	3,100	-3,100	0	3,100	-3,100
C	2027	600	51,100	-50,600	300	58,700	-58,500	300	56,000	-55,600
AN	2028	2,500	23,900	-21,500	1,300	28,300	-27,000	1,600	26,800	-25,200
BN	2029	3,100	30,000	-26,900	1,700	34,900	-33,200	2,100	33,200	-31,100
AN	2030	4,700	18,000	-13,300	2,700	20,700	-18,000	3,400	19,600	-16,200
D	2031	3,000	29,900	-27,000	1,700	35,700	-33,900	2,200	33,400	-31,200
W	2032	5,800	24,700	-18,900	4,100	31,400	-27,300	4,800	28,700	-23,900
W	2033	11,400	16,200	-4,800	8,900	19,900	-11,000	10,200	18,300	-8,100
W	2034	6,300	8,900	-2,600	4,000	10,100	-6,100	5,000	9,500	-4,600
D	2035	2,100	23,100	-21,000	1,100	27,200	-26,100	1,500	25,600	-24,100
W	2036	2,000	12,000	-10,000	700	14,200	-13,500	1,200	13,200	-12,000
D	2037	400	19,900	-19,500	200	23,100	-23,000	300	21,600	-21,300
C	2038	100	10,400	-10,300	0	11,700	-11,600	0	11,600	-11,600
D	2039	0	13,300	-13,300	0	14,300	-14,300	0	14,200	-14,200
C	2040	0	15,400	-15,400	0	16,000	-16,000	0	15,800	-15,800
C	2041	600	42,800	-42,200	200	49,600	-49,400	400	46,300	-46,000
C	2042	2,200	38,800	-36,600	1,100	48,200	-47,100	1,500	43,900	-42,400
AN	2043	5,900	26,400	-20,500	3,700	33,100	-29,400	4,500	30,500	-25,900
C	2044	4,900	29,200	-24,200	3,400	34,300	-30,800	4,300	31,600	-27,300
W	2045	7,000	22,400	-15,400	5,500	27,100	-21,700	6,500	24,400	-17,900
W	2046	8,300	21,500	-13,300	6,400	26,000	-19,600	7,500	23,500	-16,000
W	2047	6,800	22,600	-15,800	4,800	27,700	-22,900	5,800	25,000	-19,200
W	2048	11,400	15,200	-3,900	9,700	19,800	-10,100	11,200	17,500	-6,300
W	2049	8,000	19,300	-11,300	5,800	24,500	-18,700	6,900	21,900	-14,900
AN	2050	7,400	20,500	-13,100	5,300	25,700	-20,400	6,400	23,200	-16,800
D	2051	7,100	23,200	-16,100	5,400	28,000	-22,600	6,400	25,300	-18,900
D	2052	6,500	23,100	-16,600	4,600	28,600	-24,000	5,600	25,800	-20,200
AN	2053	8,000	20,200	-12,200	6,000	24,900	-18,900	7,200	22,400	-15,200
BN	2054	7,500	20,300	-12,800	5,400	25,000	-19,600	6,600	22,400	-15,900
AN	2055	10,300	17,400	-7,100	7,400	22,200	-14,800	8,700	19,600	-10,900
W	2056	10,500	15,500	-4,900	8,000	19,700	-11,700	9,400	17,500	-8,100
D	2057	5,600	23,900	-18,300	3,900	28,600	-24,700	4,800	26,000	-21,200
C	2058	7,000	18,600	-11,600	4,900	19,700	-14,800	6,100	19,200	-13,100
D	2059	4,900	27,800	-22,900	3,300	34,400	-31,100	4,100	30,900	-26,800
BN	2060	7,400	22,700	-15,300	5,800	27,500	-21,700	7,000	24,600	-17,600
W	2061	8,500	17,300	-8,800	6,600	21,800	-15,200	7,900	19,300	-11,400
BN	2062	7,600	19,600	-11,900	5,400	23,300	-17,800	6,500	21,600	-15,100
D	2063	2,900	9,300	-6,400	1,600	10,700	-9,100	2,200	10,000	-7,800
C	2064	1,300	24,300	-23,000	500	28,900	-28,400	800	26,500	-25,700
C	2065	2,100	37,500	-35,300	1,100	46,700	-45,700	1,400	42,800	-41,400
Minimum		0	3,300	-50,600	0	3,100	-58,500	0	3,100	-55,600
Maximum		11,400	51,100	-2,600	9,700	58,700	-3,100	11,200	56,000	-3,100
Average	W	6,800	17,800	-11,000	5,100	21,200	-16,100	6,000	19,500	-13,500
	AN	6,500	21,300	-14,800	4,500	25,900	-21,500	5,300	23,900	-18,500
	BN	4,900	27,400	-22,600	3,500	31,100	-27,500	4,200	29,500	-25,300
	D	3,600	21,500	-17,900	2,400	25,600	-23,200	3,000	23,600	-20,600
	C	1,900	27,100	-25,300	1,200	31,700	-30,500	1,500	29,700	-28,200
	All Years	4,900	22,200	-17,200	3,500	26,100	-22,600	4,200	24,300	-20,100

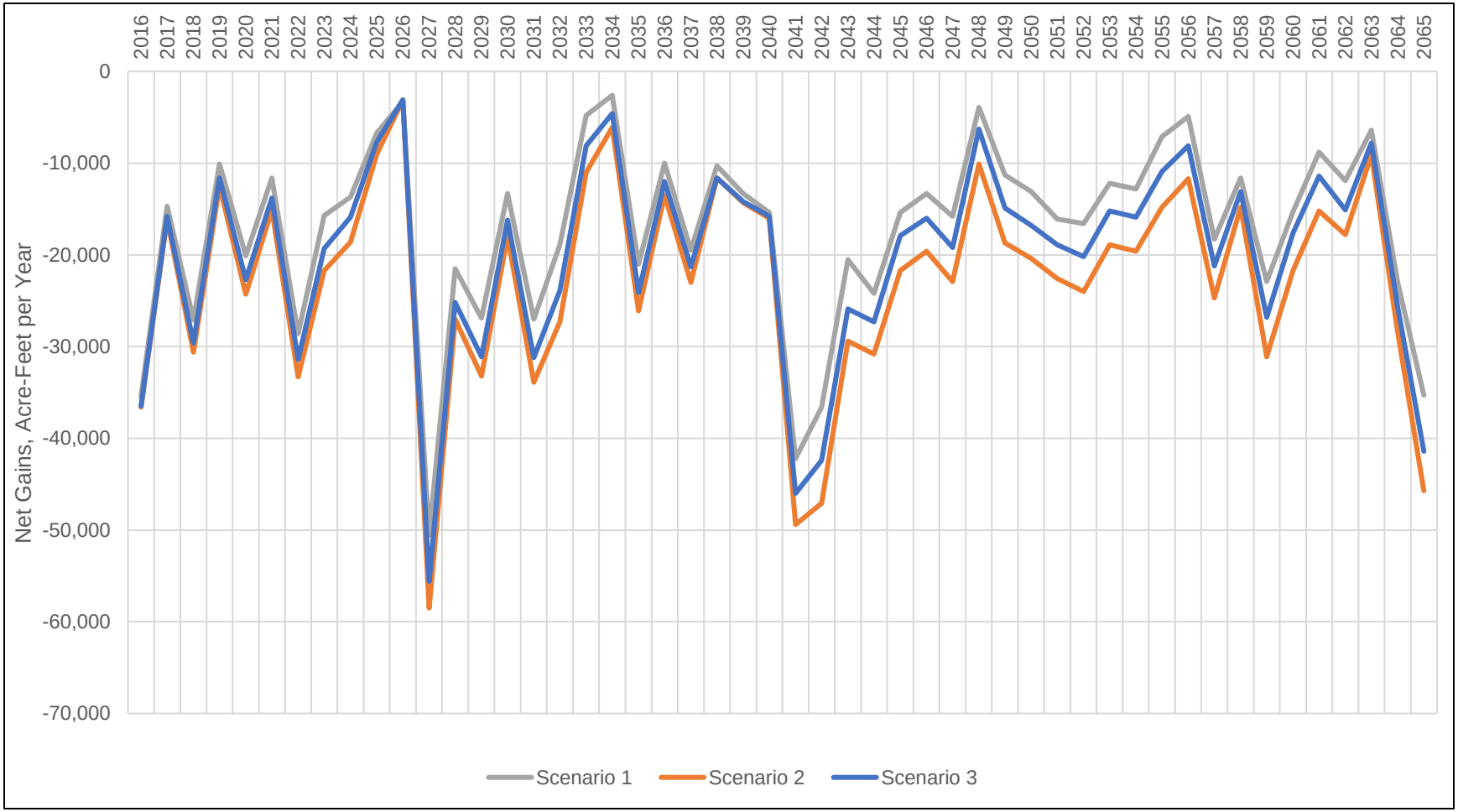

Figure 4. Simulated Stony Creek Stream-Aquifer Interaction: Annual Net Gain of All Reaches (Water Years 2016-2065, AF/yr).

Table 7. Simulated Stony Creek Stream-Aquifer Interaction: Average Monthly Summary (Water Years 2016-2065, AF/month)

Month	Scenario 1	Scenario 2	Scenario 3	Difference: Scenario 2 minus Scenario 1	Difference: Scenario 3 minus Scenario 2
1	-2,200	-3,000	-2,600	-800	400
2	-1,400	-1,900	-1,600	-500	300
3	-900	-1,400	-1,100	-500	300
4	-800	-1,100	-900	-300	200
5	-1,100	-1,600	-1,400	-500	200
6	-1,000	-1,500	-1,300	-500	200
7	-1,400	-1,800	-1,600	-400	200
8	-1,600	-2,100	-1,900	-500	200
9	-1,800	-2,200	-2,000	-400	200
10	-1,000	-1,200	-1,100	-200	100
11	-1,800	-2,100	-2,000	-300	100
12	-2,100	-2,700	-2,400	-600	300
Average Annual Volume[1]	-17,100	-22,600	-19,900	-5,500	2,700

[1] Average annual volumes in this table are summed from rounded average monthly volumes and may differ from average annual volumes shown in other summary tables due to rounding.

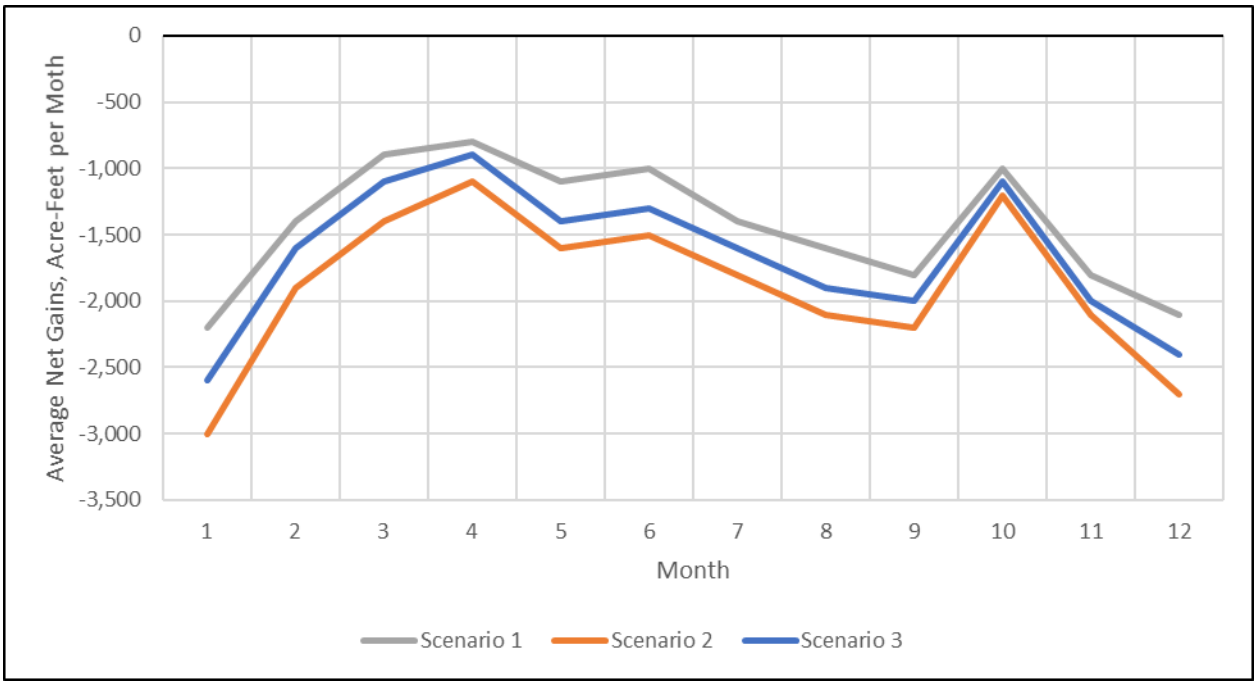

Figure 5. Simulated Stony Creek Stream-Aquifer Interaction: Average Monthly Summary (Water Years 2016-2065, AF/month)

Table 8. Simulated Colusa Drain Stream-Aquifer Interaction: Average Annual Summary (Water Years 2016-2065, AF/yr)

Colusa Drain					
	Above GCID Canal Confluence				
Model Scenario	**Average Reach Flow**	**Stream Gains**	**Stream Losses**	**Net Gains**	**Net Stream Gains as a Percent of Average Reach Flow**
Scenario 1	364,900	104,900	1,000	103,900	28.48%
Scenario 2	368,300	95,100	1,400	93,600	25.43%
Scenario 3	370,800	99,200	1,200	98,100	26.45%
Difference: Scenario 2 minus Scenario 1	3,400	-9,800	400	-10,300	-3.06%
Difference: Scenario 3 minus Scenario 2	2,500	4,200	-300	4,400	1.03%
	Below GCID Canal Confluence				
Model Scenario	**Average Reach Flow**	**Stream Gains**	**Stream Losses**	**Net Gains**	**Net Stream Gains as a Percent of Average Reach Flow**
Scenario 1	749,000	13,500	8,900	4,600	0.61%
Scenario 2	760,700	10,600	13,100	-2,500	-0.34%
Scenario 3	769,800	14,200	9,800	4,400	0.58%
Difference: Scenario 2 minus Scenario 1	11,700	-2,900	4,200	-7,100	-0.95%
Difference: Scenario 3 minus Scenario 2	9,100	3,600	-3,400	7,000	0.91%
	All Reaches				
Model Scenario	**Average Reach Flow**	**Stream Gains**	**Stream Losses**	**Net Gains**	**Net Stream Gains as a Percent of Average Reach Flow**
Scenario 1	556,900	118,400	9,900	108,500	19.48%
Scenario 2	564,500	105,600	14,600	91,100	16.14%
Scenario 3	570,300	113,400	10,900	102,500	17.98%
Difference: Scenario 2 minus Scenario 1	7,600	-12,800	4,600	-17,400	-3.35%
Difference: Scenario 3 minus Scenario 2	5,800	7,800	-3,600	11,400	1.84%

Table 9. Simulated Colusa Drain Stream-Aquifer Interaction: Annual Summary of All Reaches (Water Years 2016-2065, AF/yr).

Sacramento Valley Water Year Type	Water Year	Scenario 1			Scenario 2			Scenario 3		
		Stream Gains	Stream Losses	Net Gains	Stream Gains	Stream Losses	Net Gains	Stream Gains	Stream Losses	Net Gains
BN	2016	101,100	13,000	88,100	98,400	14,700	83,700	98,200	14,800	83,400
W	2017	107,900	16,700	91,200	101,900	19,000	82,900	102,800	18,200	84,500
BN	2018	110,200	10,800	99,400	102,500	13,800	88,700	104,600	12,500	92,100
W	2019	115,200	10,000	105,200	107,200	13,700	93,500	110,300	11,900	98,400
W	2020	118,400	10,300	108,100	109,000	14,600	94,400	113,100	12,400	100,700
W	2021	118,400	9,800	108,700	108,200	13,300	94,900	112,900	10,900	102,000
BN	2022	113,800	9,300	104,400	103,300	13,900	89,400	108,400	11,100	97,300
AN	2023	124,200	11,500	112,600	112,500	15,800	96,700	117,900	12,700	105,200
W	2024	132,200	8,300	123,900	119,800	12,700	107,100	125,800	9,600	116,300
W	2025	122,800	8,600	114,200	112,100	11,500	100,500	118,900	8,600	110,300
C	2026	104,900	9,400	95,500	112,200	6,000	106,200	120,300	3,800	116,500
C	2027	121,300	6,300	115,000	108,500	8,800	99,600	114,800	6,300	108,500
AN	2028	101,100	12,500	88,600	86,800	18,800	68,000	90,900	15,400	75,400
BN	2029	108,800	9,900	99,000	93,100	14,900	78,200	98,500	12,100	86,400
AN	2030	108,000	10,500	97,500	92,400	15,500	76,900	98,100	12,200	85,900
D	2031	120,600	10,200	110,400	105,000	16,300	88,600	111,600	12,900	98,700
W	2032	133,600	8,000	125,600	116,100	12,200	103,900	123,400	8,700	114,700
W	2033	144,200	6,100	138,100	127,300	9,100	118,100	135,600	6,500	129,100
W	2034	134,800	5,300	129,500	118,700	9,100	109,700	127,200	6,300	120,900
D	2035	120,700	8,400	112,300	104,900	14,100	90,800	113,200	10,400	102,900
W	2036	115,000	9,100	105,900	100,500	14,600	85,900	108,600	10,500	98,100
D	2037	110,000	8,600	101,400	95,100	13,300	81,800	103,700	9,500	94,200
C	2038	107,200	12,100	95,100	92,200	18,800	73,400	100,300	13,900	86,400
D	2039	97,600	15,200	82,400	82,700	24,100	58,500	90,900	18,700	72,200
C	2040	99,700	11,500	88,200	86,600	16,300	70,300	95,400	11,900	83,600
C	2041	107,700	12,600	95,100	94,400	18,100	76,300	103,300	13,700	89,600
C	2042	95,200	14,400	80,800	82,100	22,000	60,100	88,800	16,700	72,100
AN	2043	102,100	15,700	86,400	88,100	22,200	66,000	95,500	17,500	78,000
C	2044	137,100	6,300	130,900	116,000	14,600	101,400	123,800	10,600	113,200
W	2045	129,700	14,400	115,200	125,400	17,500	107,900	134,500	14,000	120,500
W	2046	123,400	7,600	115,800	115,400	11,400	103,900	124,700	7,700	117,000
W	2047	132,900	8,500	124,400	121,900	12,300	109,600	131,600	8,400	123,100
W	2048	142,700	9,600	133,100	130,900	13,300	117,600	140,900	9,800	131,100
W	2049	142,000	3,800	138,300	127,900	6,400	121,500	139,000	3,900	135,100
AN	2050	120,400	6,900	113,500	107,100	11,800	95,400	117,000	7,700	109,300
D	2051	116,100	8,600	107,500	101,900	14,100	87,800	111,700	9,700	102,100
D	2052	121,700	9,000	112,800	108,300	14,300	94,000	117,900	9,500	108,300
AN	2053	127,000	9,500	117,500	112,300	14,200	98,100	122,500	9,800	112,700
BN	2054	122,400	9,000	113,400	109,000	14,000	95,000	119,000	9,600	109,400
AN	2055	133,700	9,800	123,900	118,100	13,700	104,400	128,600	9,500	119,100
W	2056	133,400	6,800	126,600	118,300	10,700	107,600	129,100	7,000	122,100
D	2057	121,300	6,200	115,200	107,200	11,300	95,900	118,000	7,400	110,500
C	2058	107,700	12,200	95,600	93,500	18,400	75,100	103,500	13,300	90,200
D	2059	102,500	13,900	88,600	88,000	20,500	67,500	97,700	15,100	82,600
BN	2060	115,200	13,900	101,200	99,600	19,700	79,900	109,200	14,200	95,000
W	2061	122,800	10,600	112,100	108,200	15,100	93,100	118,400	10,400	108,000
BN	2062	119,300	8,600	110,700	104,800	12,900	92,000	115,200	8,400	106,900
D	2063	108,400	10,400	98,000	93,700	16,800	76,900	103,600	11,400	92,200
C	2064	114,100	7,400	106,700	97,800	12,700	85,200	108,400	7,800	100,500
C	2065	131,000	8,900	122,100	115,500	14,600	101,000	124,800	10,300	114,500
Minimum		95,200	3,800	80,800	82,100	6,000	58,500	88,800	3,800	72,100
Maximum		144,200	16,700	138,300	130,900	24,100	121,500	140,900	18,700	135,100
Average	W	127,600	9,000	118,600	115,800	12,700	103,100	123,300	9,700	113,600
	AN	116,600	10,900	105,700	102,500	16,000	86,500	110,100	12,100	98,000
	BN	113,000	10,600	102,300	101,500	14,800	86,700	107,600	11,800	95,800
	D	113,200	10,100	103,200	98,500	16,100	82,400	107,600	11,600	96,000
	C	112,600	10,100	102,500	99,900	15,000	84,900	108,300	10,800	97,500
	All Years	118,400	9,900	108,500	105,600	14,600	91,100	113,400	10,900	102,500

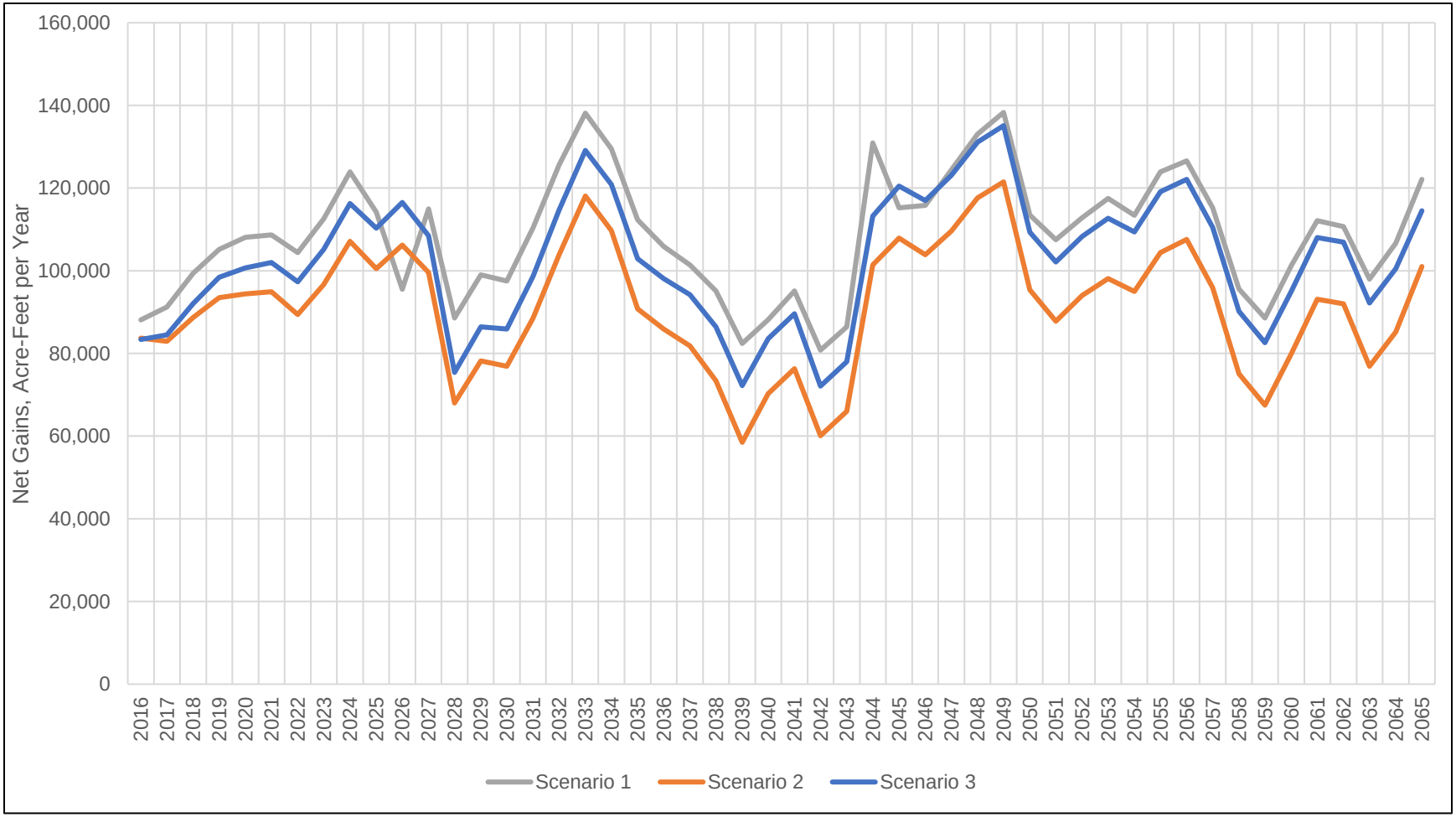

Figure 6. Simulated Colusa Drain Stream-Aquifer Interaction: Annual Net Gain of All Reaches (Water Years 2016-2065, AF/yr).

Table 10. Simulated Colusa Drain Stream-Aquifer Interaction: Average Monthly Summary (Water Years 2016-2065, AF/month)

Month	Scenario 1	Scenario 2	Scenario 3	Difference: Scenario 2 minus Scenario 1	Difference: Scenario 3 minus Scenario 2
1	7,700	5,600	6,600	-2,100	1,000
2	9,000	7,500	8,500	-1,500	1,000
3	9,700	8,700	9,700	-1,000	1,000
4	10,200	9,700	10,700	-500	1,000
5	6,200	5,400	6,400	-800	1,000
6	8,000	7,000	8,000	-1,000	1,000
7	9,700	8,200	9,100	-1,500	900
8	10,900	9,900	10,700	-1,000	800
9	11,400	8,700	9,400	-2,700	700
10	5,500	4,100	5,200	-1,400	1,100
11	11,400	9,800	10,800	-1,600	1,000
12	8,800	6,500	7,500	-2,300	1,000
Average Annual Volume[1]	108,500	91,100	102,600	-17,400	11,500

[1] Average annual volumes in this table are summed from rounded average monthly volumes and may differ from average annual volumes shown in other summary tables due to rounding.

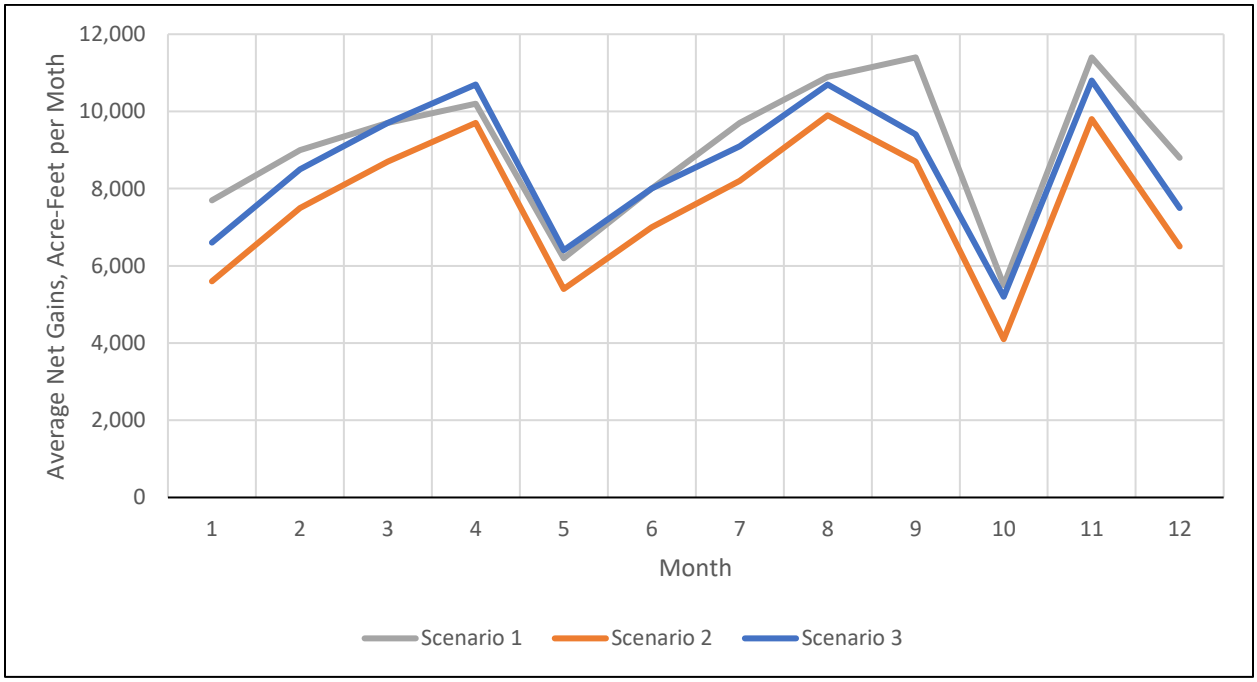

Figure 7. Simulated Colusa Drain Stream-Aquifer Interaction: Average Monthly Summary (Water Years 2016-2065, AF/month)

References

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Stene, E.A. 1994. Sacramento River Diversion, Central Valley Project. United States Bureau of Reclamation.

Appendix A. Personal Communication with J. Sutton Regarding the Tehama-Colusa Canal Capacity.

From: Jeffrey P. Sutton (Tehama-Colusa Canal Authority)

Sent: Tuesday, August 10, 2021 4:55 PM

To: Grant Davids (Davids Engineering, Inc.)

Cc: Katherine Klug (Davids Engineering, Inc.)

Subject: **RE: TCC Capacity**

Caveated with the following first blush comments (reserve the right to add to this list), I respond:

1. TCCA will not be responsible for providing the subject water rights or water supply that is diverted for this purpose.
2. TCCA will not be responsible for any permits, mitigation, or other regulatory responsibilities associated with such a program.
3. CCWD and OAWD will be responsible for any and all charges, contracting, Warren Act or other fees and/or costs associated with such a program.
4. TCCA will be paid appropriate conveyance charges pursuant to the rates in the TCCA JPA Agreement that CCWD and OAWD currently pay or other rates as agreed.

I respond to your question as follows: Currently, it is my opinion that under most (in fact all that I currently think of) scenarios experienced, there would be plenty of pumping/diversion capacity (currently maxed out at 2000 cfs) and conveyance capacity in the TC Canal (2500 cfs at the top of the canal, 2100 cfs at Funks Reservoir, 1700 cfs at the south end of the canal) to facilitate such a program. However, historical operations are not always a good predictor of future conditions. In a typical year, we typically divert/convey a maximum amount of water of around 1300-1500 cfs. I would also add that I have not yet discussed particulars details of such a program (because I have not been provided such details until this time) with my Board of Directors. Bill Vanderwaal and Emil Cavagnolo did generally outline the recharge concept being explored at my last meeting, which the Board was generally supportive of - notwithstanding the need to hear the details. However, I anticipate that this water would have to somewhat take a second tier position in the atypical case of a conflict over the available diversion/conveyance capacity.

I hope this is helpful Grant, sorry for the long caveated answer. But I don't want to give the misimpression of complete acquiescence or create a reliance on a simple statement of "sure we have capacity" until all of the details are more fully vetted and the necessary terms have been contemplated. I will leave it to your discretion on how you wish to articulate capacity availability in the Colusa GSP based on the foregoing.

Jeffrey P. Sutton
General Manager
Tehama-Colusa Canal Authority

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Appendix 4A

Well Completion Reports for Groundwater Monitoring Network Wells

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State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

SHEET 1 of 6
HOLE NO. LCB-4
ELEV. 25 (topo) FEET
DEPTH 1020 FEET

PROJECT Lower Colusa Basin Conjunctive Use
DATE DRILLED 6/24-6/25/97
FEATURE Exploratory Boring
ATTITUDE Vertical
LOCATION 12N/01E-06D*
LOGGED BY F. Nasirian
CONTR. Eaton Drilling Co. DRILL RIG Ingersoll-Rand TH-400
DEPTH TO WATER Not Determined

* Near the south east corner of the intersection of County Line Road and the Colusa Basin Drain

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
0.0	CL	Holocene/Pleistocene Sediments 0.0-1020'			Drilled mostly with clear water, at times bentonite was added.
	GC	0.0-10.0' Clay (CL): Brown, medium plasticity, moist. 10.0-20.0' Clayey Gravel (GC): Brown, about 5-10% clay, fine to medium, gravel wet.			
20.0	SP	20.0-40.0' Sand (SP): Gray, less than 5% fines, fine to coarse grained sand.			The drill rods were 2-1/2" in diameter with a 4" collar at both ends.
40.0	CL	40.0-70.0' Clay (CL): Brown, about 5-10% fine gravel, about 5-10% sand, moist			The collars would not allow any cuttings larger than 1/2 -3/4" size to come to the surface.
60.0					Soils and geologic contacts were determined from logging the drill cuttings recovered from the shaker.
	CH	70.0-245.0' Clay (CH): Bluish-brown, high plasticity, moist.			
80.0					
100.0					
120.0					
140.0		140.0-160.0' Clay with about 10-15% fine to coarse grained sand.			
160.0					

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DRILL HOLE LOG

SHEET 2 OF 6

HOLE NO. LCB-4

PROJECT & FEATURE Lower Colusa Basin Conjunctive Use

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
160.0		Holocene/Pleistocene Sediments 0.0-1020.0' (cont'd)			
	CH				
180.0					
		190.0-205.0' Bluish-gray, high plasticity.			
200.0		205.0-230.0' Bluish-green, high plasticity.			
220.0					
	CH				
		230.-240.0' About 10-15% sand and fine gravel.			
240.0					
	GP	245.0-280.0' Gravel (GP): Gray, less than 5% fines, about 10-15% fine to coarse grained sand, mostly fine gravel.			
260.0					
280.0					
	g(CL)	280.0-320.0' Gravely Clay g(CL): Grayish-brown, 15-20% sand, 20-25% fine to medium gravel.			
300.0		300.0-310.0' Reddish brown			
320.0					
	SP	320.0-330.0' Sand (SP): Gray, fine to medium grained sand, about 5-10% fines.			
		330.0-355.0' Gravel (GP): Gray, about 5-10% sand, fine to coarse grained gravel.			
340.0	GP/ GW				
		355.0-360.0' Sand (SP): Gray, fine to medium grained.			
360.0	SP				

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DRILL HOLE LOG

SHEET 3 OF 6

HOLE NO. LCB-4

PROJECT & FEATURE Lower Colusa Basin Conjunctive Use

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
360.0		Holocene/Pleistocene Sediments 0.0-1020.0' (cont'd)			
	CH	360.0-395.0' Clay (CH): Reddish-brown, high plasticity.			
380.0					Added bentonite to the mud.
400.0	GP	395.0-515.0' Poorly Graded Gravel (GP): Gray, about 10-15% fine to coarse sand grained, up to ½" in diameter.			
420.0					
440.0	GP				
460.0	GC	460.0-480.0' Clayey Gravel (GC): About 10-15% clay.			
480.0	GP	480.0-515.0' Mostly fine gravel.			
500.0	GP				
520.0	ML	515.0-530.0' Silt with about 5-10% fine gravel.			
	GC	530.0-720.0' Clayey Gravel (GC): Gray, about 15-25% fines, mostly fine gravel.			
540.0					
560.0					

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DRILL HOLE LOG

HOLE NO. LCB-4

PROJECT & FEATURE Lower Colusa Basin Conjunctive Use

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
560.0		Holocene/Pleistocene Sediments 0.0-1020.0' (cont'd)			
580.0	GC				
600.0		600.0-620.0' Mostly fine to coarse grained sand.			
620.0	GC				
640.0					
660.0	GC/ CL	650.0-680.0' About 40-50% sand and gravel.			
680.0					
700.0	GC	700.0-720.0' About 10-15% fines, gravel up to 3/4" in diameter.			
720.0		720.0-1,000.0' Sandy Clay s(CL): Gray about 15-25% fine to medium grain sand, less than 5% fine gravel.			
740.0	s(CL)				
760.0					

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DRILL HOLE LOG

SHEET 5 OF 6

HOLE NO. LCB-4

PROJECT & FEATURE Lower Colusa Basin Conjunctive Use

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
760.0		Holocene/Pleistocene Sediments 0.0-1020.0' (cont'd)			
	s(CL)				
780.0		780.0-800.0' Mostly lean clay less than 5% sand.			
	CL				
800.0					
		810.0-820.0' About 25-30% sand, fine to medium grained.			
820.0					
	s(CL)				
840.0					
860.0		860.0-900.0' About 35-40% sand mostly fine to medium grained.			
880.0					
900.0	s(CL)	900.0-940.0' About 30-40% sand, mostly fine to medium grained.			
920.0					
940.0		940.0-960.0' Mostly clay with almost no sand.			
	CL				
960.0					

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DRILL HOLE LOG

SHEET 6 OF 6

HOLE NO. LCB-4

PROJECT & FEATURE Lower Colusa Basin Conjunctive Use

DEPTH (ELEV.)	LOG	FIELD CLASSIFICATION AND DESCRIPTION	SAMPLE NO.	MODE	REMARKS
960.0		Holocene/Pleistocene Sediments 0.0-1020.0' (cont'd)			
980.0	s(CL)	980.0-1020.0' Mostly clay with some sandy clay chips.			
1000.0					
1020.0		Hole bottomed @ 1020.0'			
1040.0					

DWR 885 (2) (Rev. 9-84)

Company:
EATON DRILLING COMPANY
Well #:
WR RECLAMATION LCB-4

Date: 06-25-1997

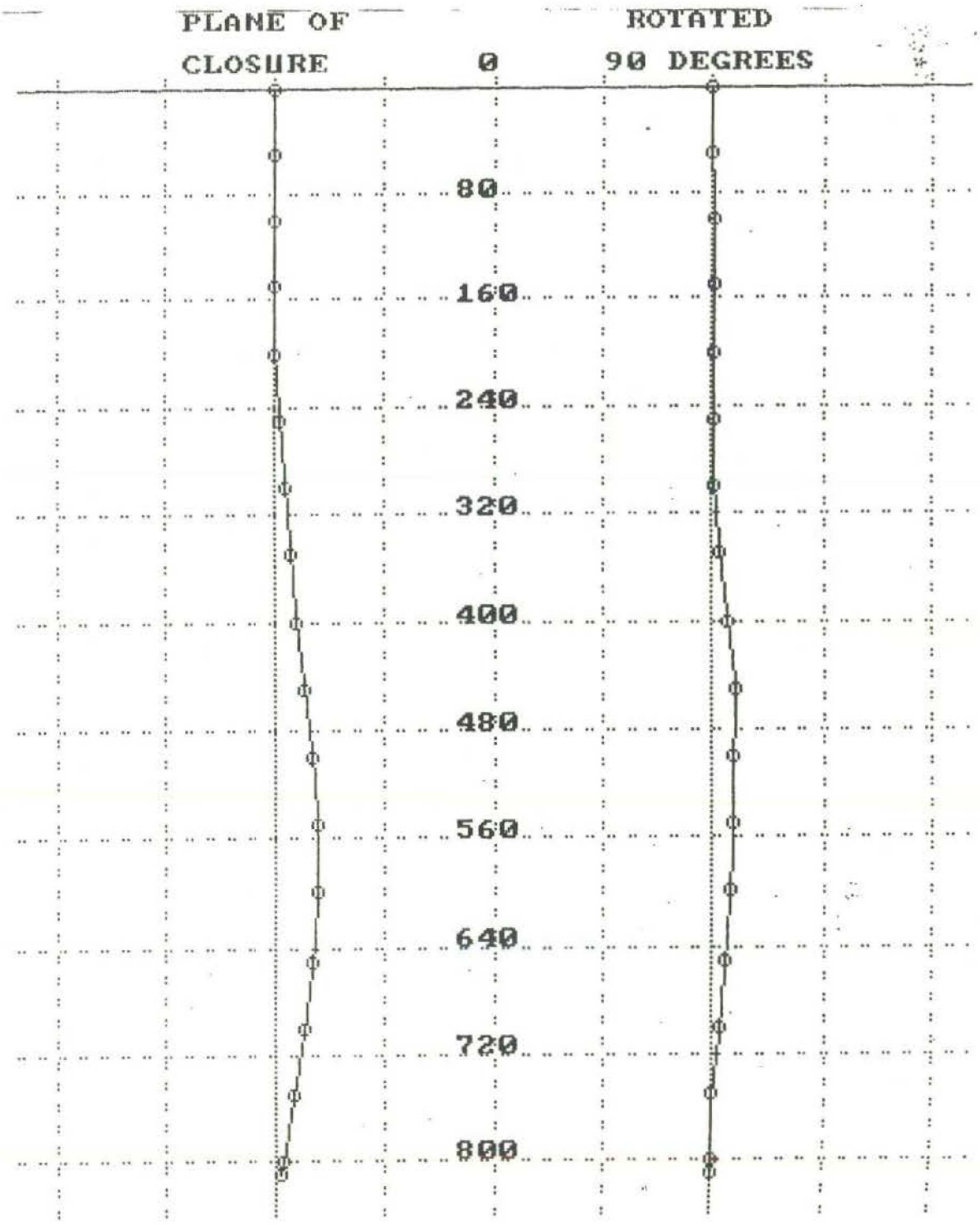
VERTICAL SECTION

Vert Scale = 80 Ft/Div
Horz Scale = 8 Ft/Div

CLOSURE

Distance: 0.55 FEET
Bearing: 255.7 DEGREES
T.V.D.: 809.95 FEET

Calc. Method:
Balanced Tangential



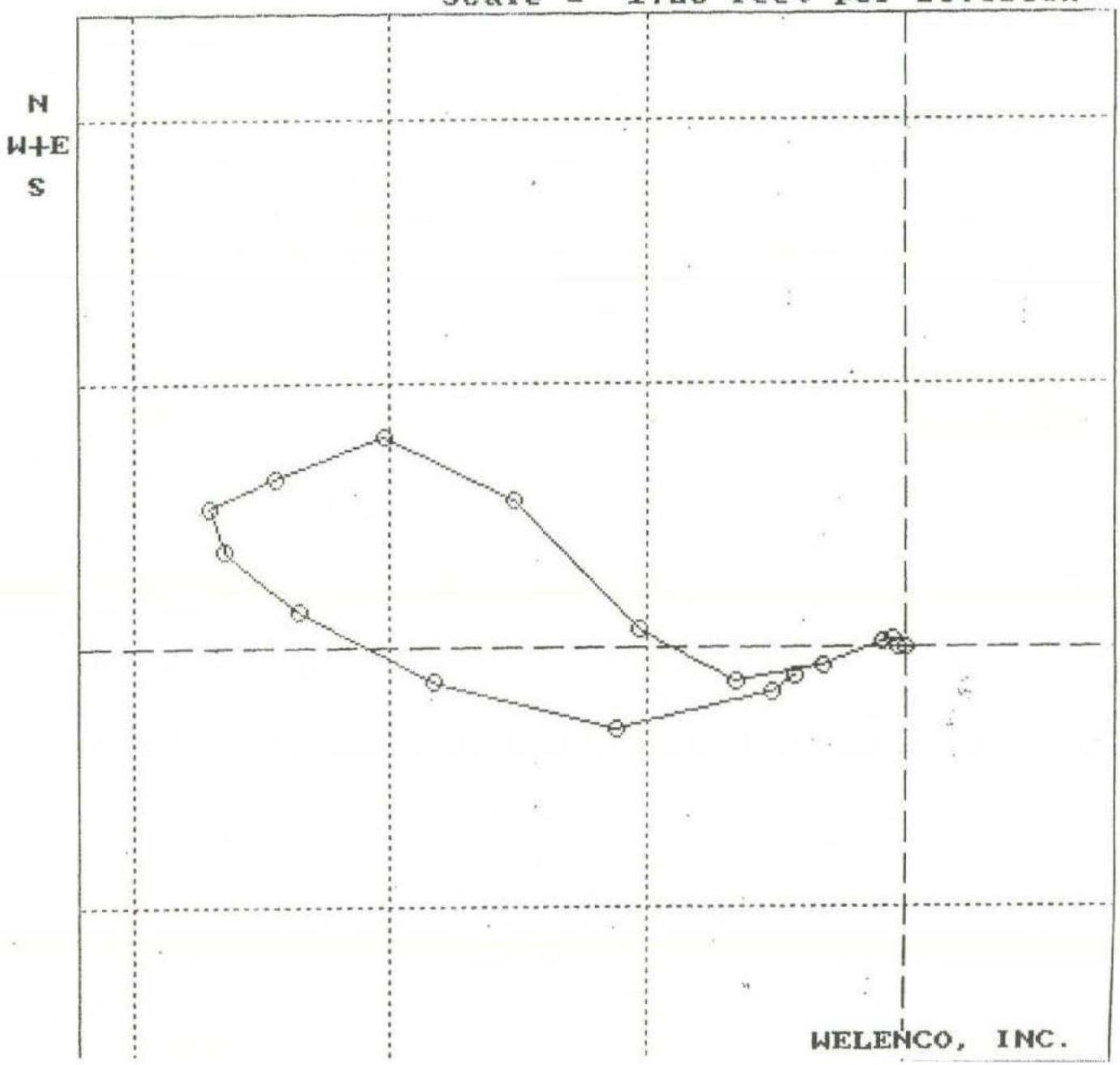
Company: EATON DRILLING COMPANY

Well #: DWR RECLAMATION LCB-4

Date: 06-25-1997

PLAN VIEW

Scale = 1.25 Feet per Division



CLOSURE

Distance: 0.55 FEET

Bearing: 255.7 DEGREES

T.V.D.: 809.95 FEET

Calc. Method
Balanced Tangential

>>>> Welenco, Inc.>>>>

DIRECTIONAL SURVEY

Date: 06-25-1997

Company : EATON DRILLING COMPANY
Well No : DWR RECLAMATION LCB-4
Field : DUNNIGAN
State : CALIFORNIA County: YOLO
Witnessed By: SMITH Rec. By: ROBERTI
Location : COLUSA BASIN DRAIN & COUNTY LINE RD.
Remarks :

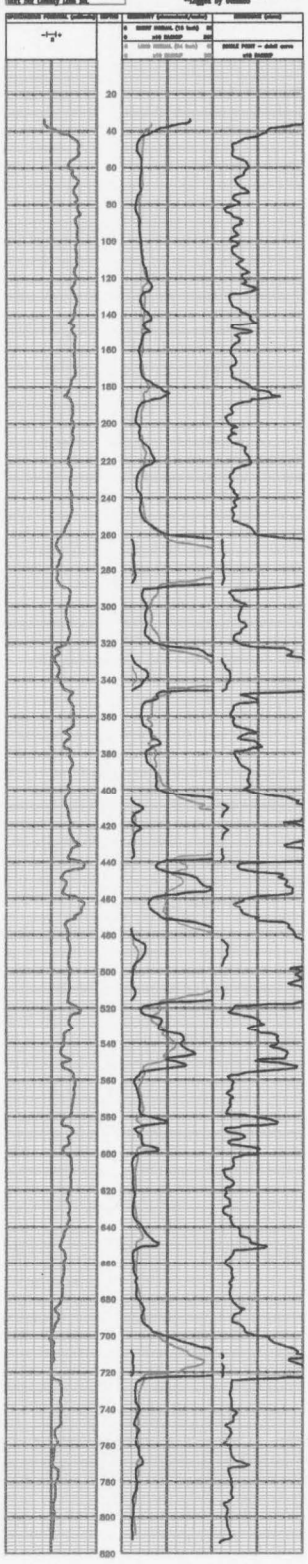
OTHER SERVICES: ELOG

Measured Depth, Feet	Inclination, Degrees	Direction, Degrees True	Course Deviation, Feet	True Vertical Depth, Feet	Closure Distance, Feet	Closure Bearing, Degrees True
0	0.0	0	0.00	0.00	0.00	0.0
50	0.0	210	0.00	50.00	0.00	32.0
100	0.1	268	0.04	100.00	0.04	268.0
150	0.1	30	0.09	150.00	0.07	298.0
200	0.2	236	0.13	200.00	0.12	281.6
250	0.5	254	0.31	250.00	0.41	257.9
300	0.5	267	0.44	300.00	0.84	259.2
350	0.8	316	0.57	349.99	1.29	273.7
400	1.2	315	0.87	399.99	2.02	290.4
450	0.6	253	0.79	449.98	2.71	291.6
500	0.7	246	0.57	499.98	3.15	284.7
550	0.1	257	0.35	549.97	3.43	281.1
600	0.5	148	0.26	599.97	3.33	278.1
650	0.6	113	0.48	649.97	2.95	273.5
700	1.1	121	0.74	699.96	2.29	265.8
750	1.1	86	0.96	749.95	1.45	254.7
800	0.7	64	0.79	799.95	0.68	251.6
810	0.9	48	0.14	809.95	0.55	255.7

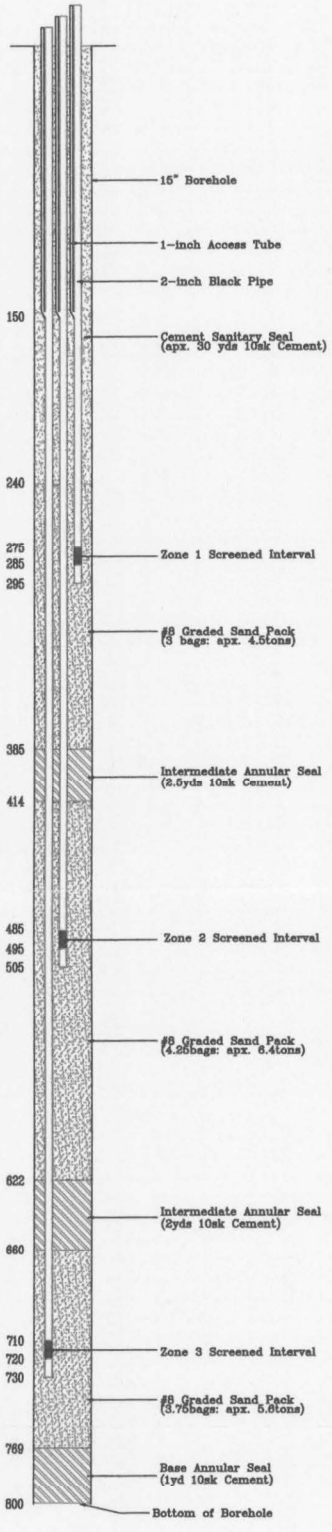
Equip.: L-16 Office: BFL Job No.: 28403

Calculation Method: Balanced Tangential

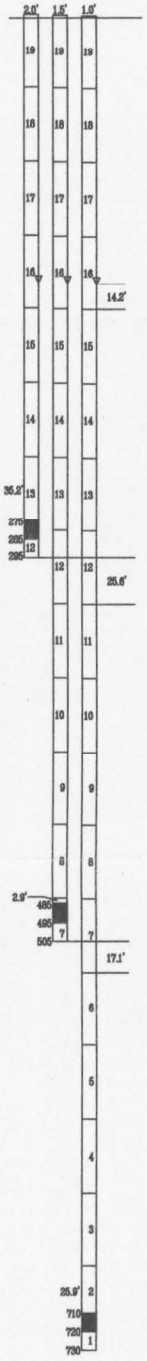
EATON DRILLING CO., INC.



AS BUILT Well Profile
LCB-4 (6853 Mon)



LCB-4
6853PIPE



welenco

LCB-4 ELECTRIC LOG

Filing No. 6933	Company EATON DRILLING COMPANY
	Well LCB-4
	Field DUNNIGAN
	County YOLO State CALIFORNIA
Job No. 20693	Location: Sec Twp Rge
	County LINE ROAD Other Serv. SUSANVILLE BASIN BRIN WNO
	Permanent Datum: G.L. Elev.: K.B.
	Log Measured From G.L. 0 Ft Above Perm. Datum D.F.
	Drilling Measured From G.L. G.L.

Date	08-25-1997
Run No.	ONE
Depth - Driller	1085'
Depth - Logger	813'
Btm. Log Interval	322'
Top Log Interval	NONE at
Casing-Driller	at
Casing-Logger	at
Bit Size	8 3/4"
Type Fluid in Hole	BENTONITE
Dens. / Visc.	N/A / N/A
pH / Fluid Loss	N/A / N/A ml
Source of Sample	ml
Rm at Meas. Temp.	19.0 at 75 F
Rmf at Meas. Temp.	at F
Rmc at Meas. Temp.	at F
Source: Rmf / Rmc	
Rm at BHT	at F
Rmf at BHT	at F
Rmc at BHT	at F
Time Since Circ.	1 HOUR
Max. Rec. Temp.	N/A F
Equip. Location	5-16 BFL
Recorded By	SMITH
Witnessed By	

Fold Here — This Heading and Log Conform To API RP 31

Changes in Mud Type or Additional Samples					Scale Changes			
Date	Sample No.				Type Log	Depth	Scale Up Hole	Scale Down Hole
Depth-Driller								
Type Fluid in Hole								
Dens. / Visc.								
ph / Fluid Loss		ml		ml				
Source of Sample					Equipment Data			
Rm at Meas. Temp.	at F		at F		Run No.	Tool Type	Pad Type	Tool Pos.	Other
Rmf at Meas. Temp.	at F		at F		ONE	ELECTRIC		FREE	T-101
Rmc at Meas. Temp.	at F		at F						
Source: Rmf / Rmc									
Rm at BHT	at F		at F						
Rmf at BHT	at F		at F						
Rmc at BHT	at F		at F						

REMARKS: WELL DRILLED BY: EATON DRILLING

FORM 115
INVESTIGATION

log # 29665

DIVISION OF WATER RESOURCES
DEPARTMENT OF PUBLIC WORKS
STATE OF CALIFORNIA

SHEET 1

U.S.B.R. NUMBER 13-1E-~~11B~~ 111

WELL LOG

LOCAL DESIGNATION 31

Date Drilled Nov. 8, 1947

LOCATION 1500' S. 1200' W. of N. E. corner Colusa Co.

Colusa Co., Sacto. Valley Dist., Kirkville Quad. -1

OWNER

DATE COMPLETED

DIAMETER OF CASING 14" hole 8" csg Type Rotary

DRILLED BY Valley Drilling Co.

SOURCE OF INFORMATION Driller

INSPECTED WHILE DRILLING SEE FILE NO.

SURFACE ELEVATION 31 ft. 158' Depth

SKETCH

CONFIDENTIAL LOG
Water Code Sec. 13752

DEPTH	ELEVATION OF BOTTOM OF STRATUM	MATERIAL	THICKNESS FEET	% VOIDS	ABSOLUTE VOIDS FEET	TOTAL VOIDS FEET
0	22	Top soil & clay				
22	27	Gravel and sand				
27	136	Clay				
136	158	Gravel				

Plotted and Coded
As Well 13N/1E-11H30

FOR FIELD COPIES USE ALTERNATE LINES

LOG OBTAINED BY DATE

87568 9-32 15M CALIFORNIA STATE PRINTING OFFICE

LOG #2868

ORIGINAL
File Original, Duplicate and Triplicate with the
DIVISION OF WATER RESOURCES
P. O. BOX 1079
SACRAMENTO 5, CALIFORNIA

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS

DIVISION OF WATER RESOURCES

LOCATION NOT CHECKED
SHEET 1

Do Not Fill In
State Well No. 13N/1W-7
Other Well No.
Region

WATER WELL DRILLERS REPORT

(Sections 7076, 7077, 7078, Water Code)

Water Code Sec. 13752

(1) Driller:
Name Aulman and Aulman
Address 1309 Westwood Way
Woodland, Calif.
License No. 109370 Classification C-57

(2) Proposed use or uses *(check)*:
Domestic ☐ Municipal ☐
Irrigation ☒ Industrial ☐
Domestic and Irrigation ☐ Test well ☐
Other

(3) Equipment used *(check)*:
Rotary ☒
Cable ☐
Dug well ☐
Other

Owner:
Name
Address

(4) Type of work *(check)*:
New well ☒ Reconditioning of well ☐
Deepening existing well ☐

(5) Well log:
Total depth of well 180 ft.

Depth From Ground Surface

Give details of formations penetrated, such as silt, peat, muck, sand, gravel, clay, shale, sandstone, hardpan, rock. Include size of gravel (diameter) and sand (fine, medium, coarse), color of material, structure (loose, packed, cemented, soft, hard, brittle).

Surface	ft. to	28	ft.	Soil and clay
28	" "	31	"	Loose medium blue gravel
31	" "	39	"	Yellow sandy clay
39	" "	54	"	Brittle yellow sandy clay
54	" "	72	"	Yellow clay
72	" "	78	"	Brittle yellow sandy clay
78	" "	81	"	Loose fine blue gravel
81	" "	84	"	Yellow clay
84	" "	86	"	Loose fine blue gravel
86	" "	116	"	Yellow clay
116	" "	126	"	Sand and yellow sandy clay
126	" "	143	"	Yellow clay
143	" "	155	"	Brittle yellow sandy clay
155	" "	165	"	Loose medium blue gravel
165	" "	167	"	Hard cemented formation
167	" "	177	"	Loose medium blue gravel
177	" "	180	"	Yellow clay
	" "		"	
	" "		"	
	" "		"	
	" "		"	
	" "		"	
	" "		"	
	" "		"	
	" "		"	

Plotted and Coded
As Well 13N/1W-7G80

If additional space is required, continue on DWR Form No. 246—Supplement, and attach to respective report copies.

(6) Casing left in well:

LENGTH FT.	DIAMETER INCHES	SINGLE, DOUBLE, WELDED, OTHER	LBS. PER FOOT OR GAGE OF CASING	SEATING BELOW GROUND SURFACE, FT.
180	12	single	3/16 inch	180

Type and size of shoe or well ring None Welded joints—☒ Yes ☐ No

DWR Form No. 188 REGIONAL WATER POLLUTION CONTROL BOARD COPY

ORIGINAL
File Original, Duplicate and Triplicate with the
DIVISION OF WATER RESOURCES
P. O. BOX 1079
SACRAMENTO, CALIFORNIA

SHEET 2 2

2/1052

WATER WELL DRILLERS REPORT

(Sections 7076, 7077, 7078, Water Code)

Do Not Fill In
State Well No. 13N/1W-7G
Other Well No.
Region

(7) Perforations:

Type of perforator used Factory

Perforated 108 ft. to 180 ft. Hole size 1½" x 3/16" No. of holes 70 per ft.

" " " " " " " " " " " "

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(8) Water levels:

Depth at which water first encountered 78 ft.

Depth to water before perforating 53 ft.

Depth to water after perforating 53 ft.

Note any change in water level while drilling
None

(9) Well pumping test:

Date of test 6/7/51 By whom Wm. P. Wilson

Depth to water when test started 53 ft.

G.P.M. at beginning of test 550 G.P.M.

Drawdown from standing level 96 ft.

G.P.M. at completion of test 670 G.P.M.

Drawdown at completion of test 83 ft.

Length of time tested Approx. 10 hours

Temperature of water 55 degrees

Was gas present in water? ☐ Yes ☒ No

(10) General:

Was well gravel packed? Yes Size of rock 5/8 inch Thickness of pack 4 inch

Was a surface sanitary seal provided? None

Were any strata sealed against pollution? ☐ Yes ☒ No If yes, attach detailed description.

Strata sealed

Was analysis made of water? ☐ Yes ☒ No If yes, attach copy.

Was electric log made of well? ☐ Yes ☒ No If yes, attach copy.

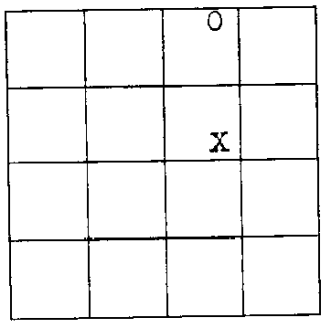
If well abandoned, was it plugged and sealed?

Method of plugging and sealing

CONFIDENTIAL
Section 7076.1, Water Code

(11) Location: L[illegible] by Sugg[illegible]tt, E by Simpson, [illegible] by Johnson, W by Doherty

North



Section No. 7

Township 13 N

Range 1 W

Base & Meridian

Show location of well in Section, thus (X)

Distances to section lines from well, (N) or S 2580 ft. and (E) or W 1450 ft.

Show location of nearest known well, thus (O)

Distance to nearest known well 2000 ft.

(12) Time of work:

Work started date 5/31/51 Completed date 6/8/51

Date of this report 6/9/51

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

[SIGNED] Aulman and Aulman
Well Driller

By

License No. 109870 Classification C-57
July 1, 1950 to
Dated June 30, 1951 Incl. 19

Plotted and Coded

As Well 13N/1W-26B0

REGIONAL WATER POLLUTION CONTROL BOARD COPY

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

PROJECT Lower Colusa Basin Conjunctive Use Invest.
FEATURE Test Hole for Multi-Head Peizometer
LOCATION White Rd. @ Colusa Basin Drainage Canal
CONTRACTOR Eaton Drilling Company
DRILLER Dwayne
DRILL RIG Direct Rotary, Ingersoll-Rand TH-400

HOLE NUMBER LCB-1
DATE DRILLED 12/22 & 23/98
LOGGED BY Chuck Owens CKO
ATTITUDE Vertical
DEPTH TO WATER Unknown (~ 3 ft)
HOLE DEPTH 1,000 ft
ELEVATION ~50 ft MSL

DEPTH	USCS	FIELD CLASSIFICATION AND DESCRIPTION	SY	REMARKS
0	CL	0ə-10ə GRAVELLY LEAN CLAY w/ SAND: Gray; gravel (>15%) is fine (4 mm); sand >15%	3	General: • Drill bit diameter = 6 1/4əə • Drill rods 22ə long, 2½ə dia. with 4ə collars at both ends, so clasts >1ə prevented from reaching surface • Mud rotary method, so all cuttings are saturated and moisture content not noted. • Log is based on cuttings sampled from shaker about every 10ə, but sampling not consistent, plus lag-time error renders elevations of contacts inaccurate – more so with increasing depth. • USBR 5005 Unified Soil Classification System used. Logging Problem: The rotary drilling method mixes cuttings from thin beds together in a mud slurry with any sluffed materials, and the origination depth of samples from the shaker is uncertain due to irregular collection, lag time and manner cuttings are brought to the surface. Thus, thin beds are often not identifiable, contacts are incorrect or uncertain, and soil classification is obstructed.
	GC	10ə-20ə CLAYEY GRAVEL w/ SAND: Brown; sand is coarse to fine ≥15%).	5	
20	CL	20ə-30ə LEAN CLAY: Brown	3	
40	CL	30ə-65ə GRAVELLY LEAN CLAY w/ SAND: Brown; gravel is fine, angular to sub-angular quartz w/ a few clasts to 1½əə sub-rounded volcanics; sand is coarse (>15%) → Probably thin interbeds	3	
60	GP	65ə-80ə POORLY-GRADED GRAVEL: Gray; most gravel (~90%) is fine, but a few 1əə clasts, all is sub-angular to sub-rounded quartz & volcanics → ***Minor Aquifer*** (70ə-80ə best)	15	
80	GP-GC	80ə-120ə POORLY-GRADED GRAVEL w/CLAY: Brown; gravel is fine, sub-rounded to sub-angular (>5%)	5	
100				
120	GC	120ə-150ə CLAYEY GRAVEL: Brown → Many thin, silty interbeds?	5	
140				
160				

State of California
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DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

Project & Feature: Lower Colusa Basin Conjunctive Use

Hole No. LCB-1

DEPTH	USCS	FIELD CLASSIFICATION and DESCRIPTION	SY	REMARKS
160	CL	150ɔ-260ɔ LEAN CLAY: Brown;		
180		190-210: gray, but similar materials		
200		→ Numerous thin, clay/silty interbeds	3	
220				
240				
260	SP	260ɔ-290ɔ POORLY-GRADED SAND: Brown; sand is coarse sub-angular to sub-rounded, mostly quartz; <5% clay/silt; <15% fine gravel		
280		→ ***Producing Zone*** (270ɔ-290ɔ best)	25	
300	GP	290ɔ-310ɔ POORLY-GRADED GRAVEL w/ SAND: Brown; sand is coarse (~40%); gravel is fine (~55%), all is sub-rounded to sub-angular	15	
320	CL/ SC	310ɔ-405ɔ LEAN CLAY w/ SAND & GRAVEL: Brown; sand is coarse and gravel is fine (variable 5-30%), all is sub-rounded & sub-angular		
		→ Numerous interbeds	5	
340		320ɔ-355ɔ: 30% fine gravel		
		355ɔ-375ɔ: ~50% coarse sand		
360				

State of California
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DRILL HOLE LOG

Project & Feature: Lower Colusa Basin Conjunctive Use

Hole No. LCB-2

DEPTH	USCS	FIELD CLASSIFICATION and DESCRIPTION	SY	REMARKS
360		(continued)		
380	CL/ SC	375-405ə: ~15% fine gravel, sub-angular & sub-rounded		
400	GW	405ə-425ə WELL-GRADED GRAVEL w/ SAND: Brown; most gravel is fine, but all sizes up to ½əə; sand is coarse (≥ 15% clay); <5% clay → ***Good Producing Zone***	20	
420	SC	425ə-445ə SANDY CLAY: Brown; sand is coarse (<5%); pebbles up to 1əə	5	
440	SP	445ə-470ə POORLY-GRADED GRAVEL w/ SAND: Brown; gravel is fine; sand is coarse; <10%. → ***Good Producing Zone***	20	
460	CL	470ə-490ə SANDY LEAN CLAY: Brown; sand is coarse, sub-angular & sub-rounded; ~5% subrounded pebbles	3	
480	SC	490ə-510ə CLAYEY SAND w/ GRAVEL: Brown; ~50% / 50% clay and sand/gravel	5	
500	SP	510ə-525ə POORLY-GRADED SAND: Brown; sand is coarse, sub-rounded to sub-angular; ~10-15% clay. → *Minor Aquifer*	20	
520	SC	525ə-555ə SANDY LEAN CLAY w/ GRAVEL: Brown; sand is coarse (30-50%); 5-15% fine gravel → Several sandy/clayey interbeds	5	
540				
560				

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DRILL HOLE LOG

Project & Feature: Lower Colusa Basin Conjunctive Use — Hole No. LCB-1

DEPTH	USCS	FIELD CLASSIFICATION and DESCRIPTION	SY	REMARKS
560				
	CL	555ɜ-605ɜ GRAVELLY LEAN CLAY w/ SAND: Gray; gravel is fine/pebble size; sand is coarse (~15%)		
580		→ several coarse/fine interbeds	5	
600				
	SC	605ɜ-620ɜ SANDY LEAN CLAY w/ GRAVEL: Gray	10	
620		→ *Poor/Minor Aquifer*		
	CL	620ɜ-720ɜ: LEAN CLAY – Gray; coarse sand & pebbles		
		→ several clayey/coarse interbeds		
640		625ɜ-650ɜ: ~15-25% coarse sand		
		650ɜ-660ɜ: ~10% fine gravel, well-graded to ½"		
660			3	
680				
700		690ɜ-720ɜ: ~5-15% fine gravel & coarse sand		
720	SC	720ɜ-730ɜ CLAYEY SAND: Gray-brown; Sand is coarse; <5% pebbles, all sub-angular and sub-rounded	10	
		→ *Poor/Minor Aquifer*		
740	CL	730ɜ-745ɜ SANDY CLAY: Gray-brown; Sand is coarse; <5% pebbles, all sub-angular and sub-rounded	3	
	SC	745ɜ-755ɜ CLAYEY SAND: Gray-brown; Sand is coarse; <5% pebbles, all sub-angular and sub-rounded	10	
		→ *Poor/Minor Aquifer*		
760				

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DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

Project & Feature: Lower Colusa Basin Conjunctive Use

Hole No. LCB-1

DEPTH	USCS	FIELD CLASSIFICATION and DESCRIPTION	SY	REMARKS
760	CL	755ə-840ə SANDY LEAN CLAY: Gray-brown; sand is coarse (~25%); <5% pebbles → Numerous clayey/coarse interbeds	3	
780				
800				
820				
840	SP	840ə-895ə POORLY-GRADED SAND: Gray; sand is coarse sub-angular (<75%); >5% pebbles → ***Producing Zone*** 880-895ə: ~15% pebbles; 5% clay (w/ 75% coarse sand)	25	
860				
880				
900	SW	895ə-930ə WELL-GRADED SAND: Gray; sand is mostly coarse (~75%); ~5% pebbles; ~5% clay; other is medium sand → ***Producing Zone***	25	
920				
940	CL	930ə-945ə SANDY LEAN CLAY: Gray-brown; sand is coarse (~25%); <5% pebbles	3	
960		945ə-960ə POORLY-GRADED SAND: Gray; sand is coarse sub-angular (<75%); >5% pebbles → ***Aquifer***	25	

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

DRILL HOLE LOG

Project & Feature: Lower Colusa Basin Conjunctive Use

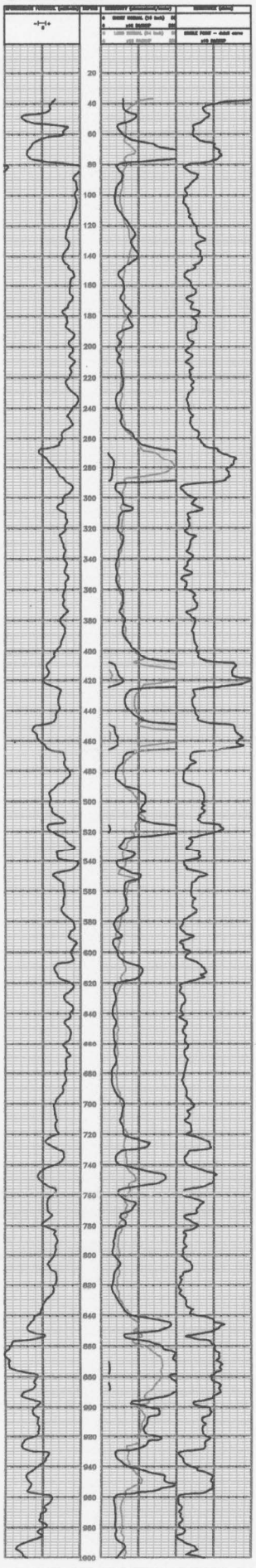
Hole No. LCB-1

DEPTH	USCS	FIELD CLASSIFICATION and DESCRIPTION	SY	REMARKS
960				
	SC	960ə-1000ə CLAYEY SAND: Gray-brown; sand is coarse, sub-angular (~75%); ~20% clay; ~5% pebbles	5	
980				
1000		T.D. = 1,000ə		

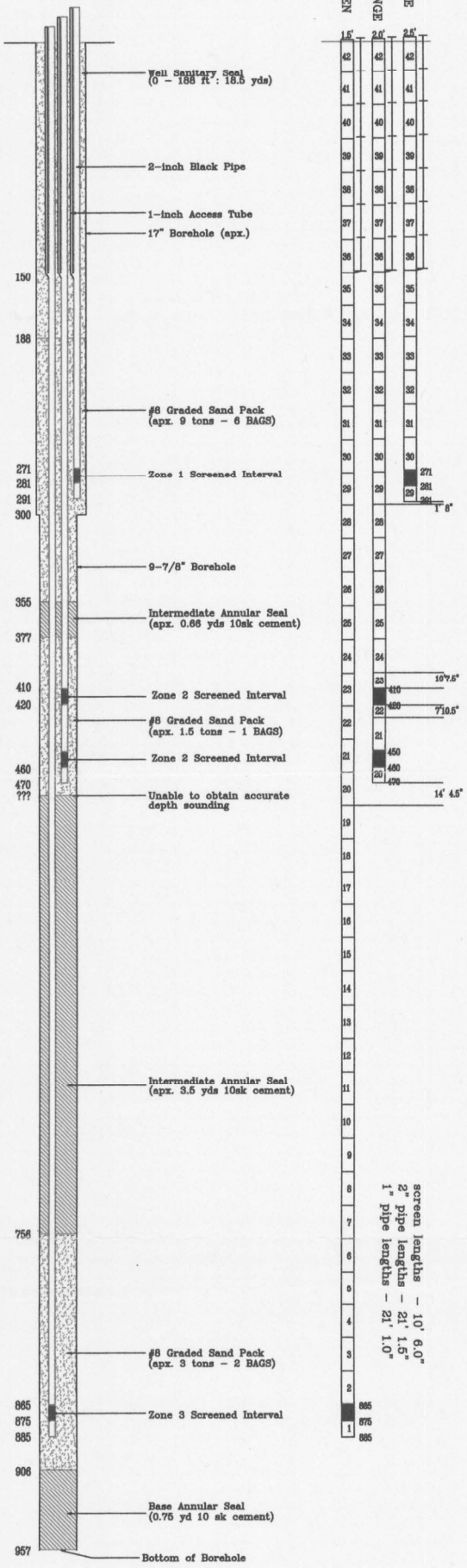
DIRECTIONAL SURVEY
Tabular Listing

Measured Depth	Inclination	Direction	Course Deviation	T.V. Depth	Distance	Bearing
0	0.0	241	0.00	0.00	0.00	0.0
20	0.0	170	0.00	20.00	0.00	0.0
40	0.0	349	0.00	40.00	0.00	0.0
60	0.0	348	0.00	60.00	0.00	0.0
80	0.1	48	0.02	80.00	0.02	48.0
100	0.1	50	0.03	100.00	0.05	48.7
120	0.1	53	0.03	120.00	0.09	49.8
140	0.1	50	0.03	140.00	0.12	50.3
160	0.0	32	0.02	160.00	0.14	50.2
180	0.1	200	0.02	180.00	0.12	54.3
200	0.1	257	0.03	200.00	0.09	56.2
220	0.1	258	0.03	220.00	0.06	44.6
240	0.1	249	0.03	240.00	0.04	17.3
260	0.1	308	0.03	260.00	0.04	334.2
280	0.1	280	0.03	280.00	0.07	316.8
300	0.1	250	0.03	300.00	0.10	301.1
320	0.1	242	0.03	320.00	0.12	287.4
340	0.2	284	0.05	340.00	0.17	282.5
360	0.2	290	0.07	360.00	0.24	283.8
380	0.0	34	0.03	380.00	0.27	284.6
400	0.0	36	0.00	400.00	0.27	284.6
420	0.0	45	0.00	420.00	0.27	284.6
440	0.4	280	0.07	440.00	0.34	283.7
460	0.1	246	0.09	460.00	0.43	281.6
480	0.4	263	0.09	480.00	0.51	278.0
500	0.3	238	0.12	500.00	0.62	273.2
520	0.3	252	0.10	520.00	0.71	269.2
540	0.2	272	0.09	540.00	0.80	268.2
560	0.3	268	0.09	560.00	0.88	268.4
580	0.3	268	0.09	580.00	0.97	268.9
600	0.2	223	0.07	600.00	1.03	267.9
620	0.1	230	0.05	620.00	1.07	266.0
640	0.2	200	0.05	640.00	1.10	263.8
660	0.2	193	0.07	660.00	1.12	260.5
680	0.3	204	0.09	680.00	1.17	256.8
700	0.4	196	0.12	700.00	1.24	252.1
720	0.4	179	0.14	720.00	1.30	246.6
740	0.3	170	0.12	740.00	1.35	241.7
760	0.2	173	0.09	760.00	1.38	238.3
780	0.6	178	0.14	779.99	1.45	233.4
800	0.5	180	0.19	799.99	1.57	227.7
820	0.7	155	0.21	819.99	1.68	221.5
840	0.7	158	0.24	839.99	1.79	214.4
860	0.5	135	0.21	859.99	1.89	208.7
880	0.6	140	0.19	879.99	1.96	203.4
900	0.3	138	0.16	899.99	2.03	199.4
920	0.9	125	0.21	919.99	2.11	194.0
940	1.0	133	0.33	939.98	2.27	186.4
960	0.8	107	0.31	959.98	2.41	179.8
980	0.7	120	0.26	979.98	2.53	174.4
998	1.5	126	0.35	997.98	2.76	168.9

EATON DRILLING CO., INC.

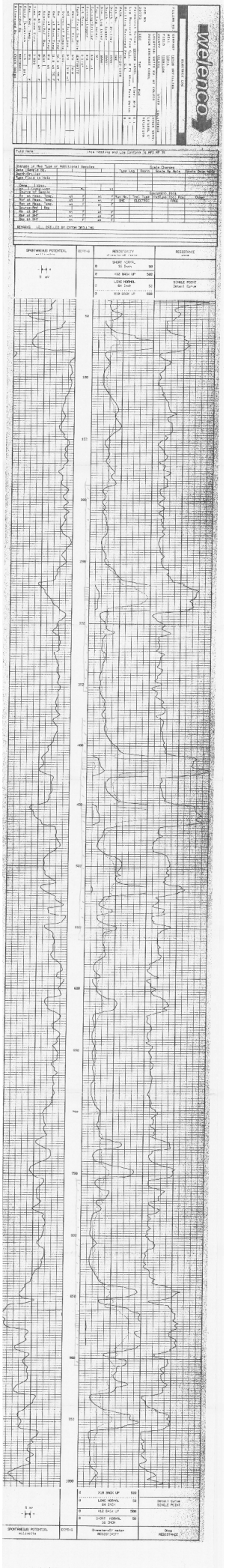


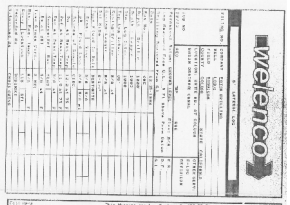
AS BUILT Well Profile
LCB–1 (7038 Mon)

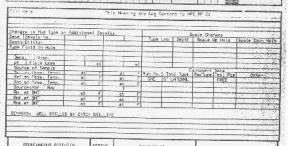


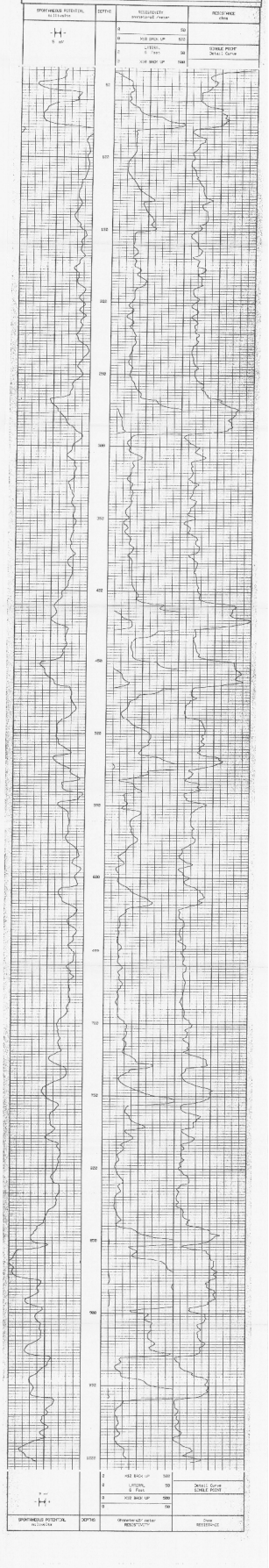
LCB–1
7038pipe

screen lengths – 10' 6.0"
2" pipe lengths – 21' 1.5"
1" pipe lengths – 21' 1.0"


Weatherford
SPONTANEOUS POTENTIAL
millivolts
5 mV
SHORT NORMAL
16 Inch
LONG NORMAL
64 Inch
RESISTIVITY
ohm-meters
RESISTANCE
ohms
SINGLE POINT
Detail Curve
0
10
100
500
50
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000


welenco




SPONTANEOUS POTENTIAL millivolts
DEPTH
RESISTIVITY Uninvaded Zone
RESISTANCE ohms
SINGLE POINT Detail Curve
LATERAL 6 Feet
Operator's Scale
Ohm-m
Ohms

LOCATION NOT CHECKED

ORIGINAL
File Original, Duplicate and Triplicate with the
REGIONAL WATER POLLUTION
CONTROL BOARD No. 5
(Insert appropriate number)

WATER WELL DRILLERS REPORT

(Sections 7076, 7077, 7078, Water Code)

STATE OF CALIFORNIA

CONFIDENTIAL Water Code

Do Not Fill In
No. 40376
State Well No.
Other Well No. 13N/ 22E

(2) LOCATION OF WELL:

County Colusa Owner's number, if any—

R. F. D. or Street No. Near Southwest Corner of the Southeast 1/4 of the Southwest 1/4 of Section 22, Township 13 North, Range 1 West, M. D. B. & M., and being just off the Mumma Road Right of Way

(3) TYPE OF WORK (check):

New well [X] Deepening [ ] Reconditioning [ ] Abandon [ ]

If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

Domestic [ ] Industrial [ ] Municipal [ ]
Irrigation [X] Test Well [ ] Other [ ]

(5) EQUIPMENT:

Rotary [X]
Cable [ ]
Dug Well [ ]

(6) CASING INSTALLED:

SINGLE [X] DOUBLE [ ]

From ft.	to ft.	Diam.	Gage or Wall	If gravel packed: Diameter of Bore	from ft.	to ft.
0	236	12"	3/16"	22"	0	236

Type and size of shoe or well ring Point

Size of gravel: 5/8"

Describe joint Collar and all ~~xxxxxx~~ welded

(7) PERFORATIONS:

Type of perforator used Factory Punched

Size of perforations 1-1/2" in., length, by 3/16" in.

From ft.	to ft.	Perf. per row	Rows per ft.
196	236	4	24

(8) CONSTRUCTION:

Was a surface sanitary seal provided? [ ] Yes [X] No To what depth ft.

Were any strata sealed against pollution? [ ] Yes [X] No If yes, note depth of strata

From ft. to ft.

Method of Sealing None

(9) WATER LEVELS:

Depth at which water was first found 112 ft.

Standing level before perforating 45 ft.

Standing level after perforating 45 ft.

(10) WELL TESTS:

Was a pump test made? [X] Yes [ ] No If yes, by whom? W.P.Wilson

Yield: 1950 gal./min. with 79' T.H. ft. draw down after 8 hrs.

Temperature of water ? Was a chemical analysis made? [ ] Yes [X] No

Was electric log made of well? [ ] Yes [X] No

(11) WELL LOG:

Total depth 236 ft. Depth of completed well 236 ft.

Formation: *Describe by color, character, size of material, and structure.*

ft. to	ft.	
0	20	Soil
20	112	Clay
112	114	Brittle
114	117	Clay
117	122	Brittle Clay
122	138	Gravel
138	142	Clay
142	157	Brittle Sandy
157	160	Brit., some fine Grav.
160	165	Fine Gravel
165	177	Clay
177	181	Brittle
181	195	Sandy Brittle
195	232	Gravel
232	236	Clay

Well Pumped 1900 GPM at 79 ft lift
1200 " " 53 " "

CONFIDENTIAL Section 7076 Water Code

Work started Dec. 26 1956, Completed Dec. 31 1956

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Aulman & Aulman
(Person, firm, or corporation) (Typed or printed)

Address 1309 Westwood Way
Woodland, California

[SIGNED] [signature]
Well Driller

License No. 109870 Dated 8/1/56, 19

95689 3-54 50M QUIN SPO DWR FORM NO. 246 (REV. 3-54)

13N-2W-2

13N/02W-12

ORIGINAL
File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do Not Fill In

№ 115408

State Well No.
Other Well No. CONFIDENTIAL LOG Water Code Sec. 13752

(
N
A
—

(2) LOCATION OF WELL:

County Colusa Owner's number, if any

Township, Range, and Section T13-N, R-2W, Sec. 2

Distance from cities, roads, railroads, etc.

(3) TYPE OF WORK (check):

New Well X Deepening ☐ Reconditioning ☐ Destroying ☐

If destruction, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☐ Municipal ☐
Irrigation XX Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary X
Cable ☐
Other ☐

(6) CASING INSTALLED:

STEEL: OTHER:
SINGLE ☐ DOUBLE ☐

NONE If gravel packed

From ft.	To ft.	Diam.	Gage or Wall	Diameter of Bore	From ft.	To ft.

Size of shoe or well ring: Size of gravel:

Describe joint

(7) PERFORATIONS OR SCREEN: NONE

Type of perforation or name of screen

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.

(8) CONSTRUCTION: NONE

Was a surface sanitary seal provided? Yes ☐ No ☐ To what depth ft.

Were any strata sealed against pollution? Yes ☐ No ☐ If yes, note depth of strata

From ft. to ft.

From ft. to ft.

Method of sealing

(9) WATER LEVELS:

Depth at which water was first found, if known ft.

Standing level before perforating, if known ft.

Standing level after perforating and developing ft.

(10) WELL TESTS:

Was pump test made? Yes ☐ No X If yes, by whom?

eld: gal./min. with ft. drawdown after hrs.

Temperature of water Was a chemical analysis made? Yes ☐ No X

Was electric log made of well? Yes ☐ No X If yes, attach copy

(11) WELL LOG:

Total depth 778 ft. Depth of completed well ft.

Formation: *Describe by color, character, size of material, and structure*

ft. to ft.

TEST HOLE ONLY

0	- 6	Top soil
6	- 18	Gravel in clay
18	- 26	Loose gravel
26	- 34	Gravel in clay
34	- 45	Loose sand and gravel
45	- 76	Gravel in clay
76	- 92	Loose sand and gravel
92	- 182	Yellow clay
182	- 206	Loose sand and gravel
206	- 252	Gravel and clay mixed
252	- 264	Loose gravel and rocks
264	- 376	Hard blue clay
376	- 380	Cemented rock
380	- 386	Loose sand and gravel
386	- 418	Hard yellow clay
418	- 434	Layers, sand & blue clay
434	- 441	Hard blue clay
441	- 446	Sand and gravel
446	- 452	Blue clay
452	- 464	Sand and gravel
464	- 486	Soft yellow clay
486	- 504	Sand and gravel
504	- 532	Hard yellow clay
532	- 536	Broken shale and clay
536	- 544	Hard blue clay
544	- 559	Sand, gravel & shale
559	- 615	Hard blue clay
615	- 631	Broken shale and sand
631	- 646	Hard yellow clay
646	- 658	Gravel and broken shale
658	- 726	Hard yellow clay
726	- 778	Broken shale and clay

Work started 5-12- 19 74 , Completed 5-28- 19 74

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME E. E. LUHDORFF CO., INC.
(Person, firm, or corporation) (*Typed or printed*)

Address P. O. Box 1326
Woodland, California 95695

[SIGNED] (Well Driller)

License No. 276625 Dated 7-10 , 19 74

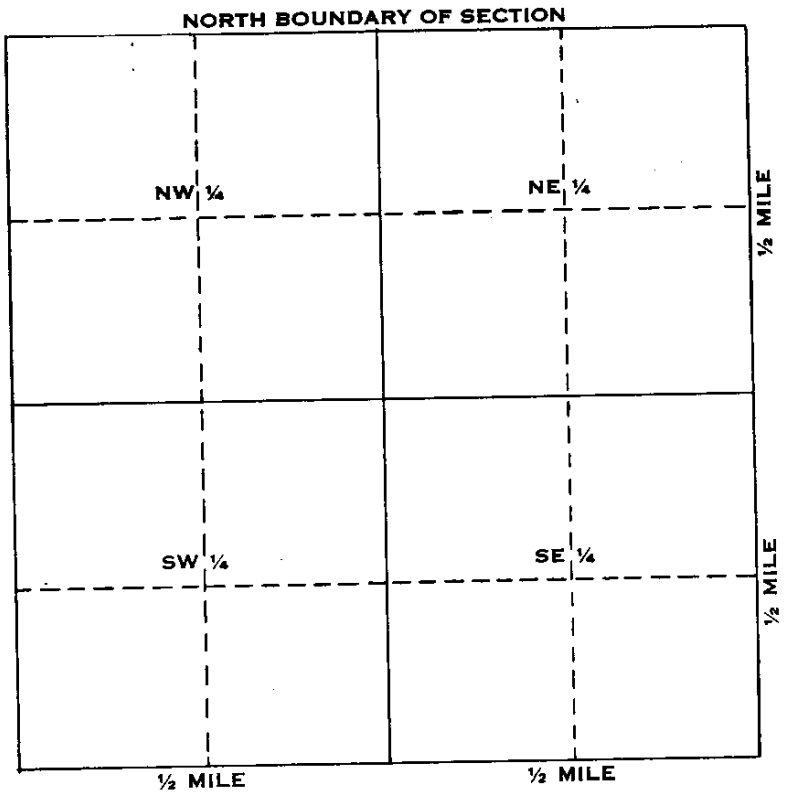
SKETCH LOCATION OF WELL ON REVERSE SIDE

CONFIDENTIAL LOG
Water Code Sec. 13752

DWR 188 (REV. 9-68)

67139-750 8-72 30M TRIP ① T OSP

WELL LOCATION SKETCH

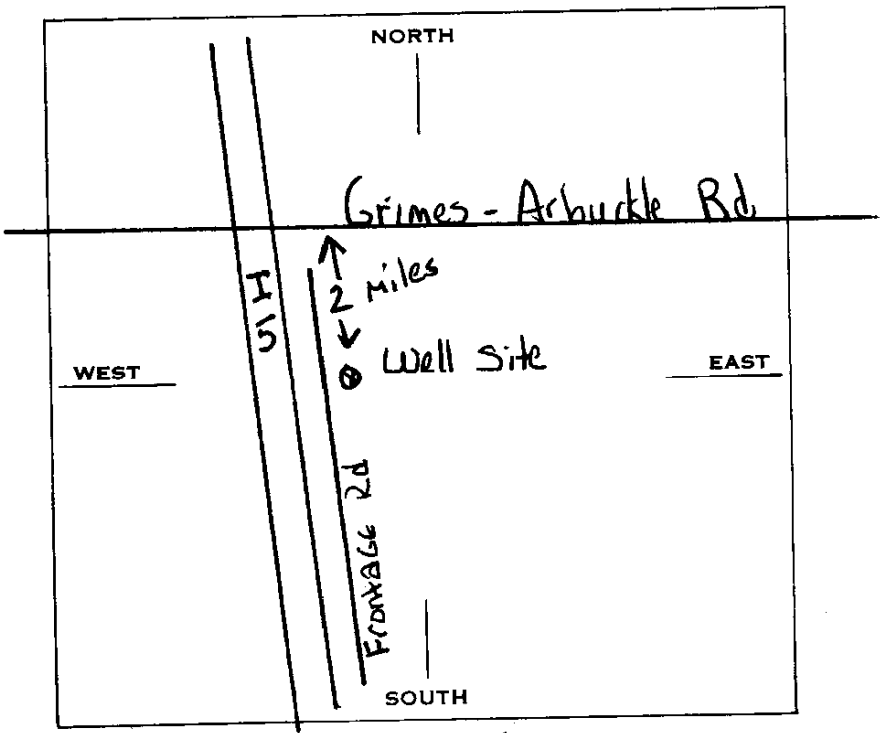


Township 13 N N/S

Range 2 W E/W

Section No. 2

A. Location of well in sectionized areas.
Sketch roads, railroads, streams, or other features as necessary.



B. Location of well in areas not sectionized.
Sketch roads, railroads, streams, or other features as necessary.
Indicate distances.

1974 JUL 11 PM 1 25
DEPT. OF WATER RESOURCES

ORIGINAL
File Original, Duplicate and Triplicate with the
REGIONAL WATER POLLUTION
CONTROL BOARD No. 5
(Insert appropriate number)

WATER WELL DRILLERS REPORT

(Sections 7076, 7077, 7078, Water Code)

STATE OF CALIFORNIA

LOCATION NOT CHECKED

Do Not Fill In
Nº 77457
State Well No.
Other Well No. 3N/2W-15

Water Co

15J1

(2) LOCATION OF WELL:

County Colusa Owner's number, if any—

R. F. D. or Street No.

1/2 mile north & 1/8 mile west
of SE corner in Sec. 15 Twp 13 NR2W

(3) TYPE OF WORK (*check*):

New well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐

If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (*check*):

Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary ☒
Cable ☐
Dug Well ☐

(6) CASING INSTALLED:

SINGLE ☒ DOUBLE ☐

From ft.	to ft.	Diam.	Gage or Wall
0	362	8"	.188

If gravel packed

Diameter of Bore	from ft.	to ft.
18"	0	362

Type and size of shoe or well ring

Size of gravel: Rerun pea gravel

Describe joint Butt welded

(7) PERFORATIONS:

Type of perforator used Machine cut at factory

Size of perforations 1/8 in., length, by 3 in.

From ft.	to ft.	Perf. per row	Rows per ft.
270	362		

(8) CONSTRUCTION:

Was a surface sanitary seal provided? ☐ Yes ☒ No To what depth ft.

Were any strata sealed against pollution? ☐ Yes ☒ No If yes, note depth of strata

From ft. to ft.

Method of Sealing

(9) WATER LEVELS:

Depth at which water was first found ft.

Standing level before perforating ft.

Standing level after perforating ft.

(10) WELL TESTS: m See over for test

Was a pump test made? ☒ Yes ☐ No If yes, by whom E.E.Luhdorff Co.

Yield: gal./min. with ft. draw down after hrs.

Temperature of water Was a chemical analysis made? ☐ Yes ☒ No

Was electric log made of well? ☐ Yes ☒ No

(11) WELL LOG:

Total depth 362 ft. Depth of completed well 362 ft.

Formation: *Describe by color, character, size of material, and structure.*

ft.	to ft.		
0	10	10'	Yellow clay & rocks
10	18	8	Sand & rocks
18	110	92	Yellow clay and rocks
110	118	8	Rocks and gravel
118	181	63	Yellow clay & rocks
181	196	15	Rocks, sand & gravel
196	245	49	Yellow clay & silt
245	249	4	Sand & gravel
249	270	21	Yellow clay & silt
270	291	21	Loose sand & gravel
291	310	19	Blue clay
310	314	4	Loose sand & gravel
314	342	28	Blue clay
342	359	17	Loose rock, gravel
359	362	3	Blue clay

CONFIDENTIAL
Section 7075.1, Water Co.

Work started Aug. 29 1963 Completed Sept. 9 1963

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME E. E. LUHDORFF
(Person, firm, or corporation) (Typed or printed)

Address West Main St.
Woodland, California

[SIGNED] E. E. Luhdorff
Well Driller

License No. 123211 Dated Sept. 23, 1963

57025 8-57 50M QUIN △ GPO DWR 188 (REV. 3-54)

Results of test:

550 GPM @	**200' P.L.**
370	**196**
190	**191**
100	**188**
4 minute return -	**185'**

RECEIVED
REGIONAL WATER POLLUTION
CONTROL BOARD
CENTRAL VALLEY REGION

ORIGINAL
File with DWR

Page 1 of 1

RECEIVED
AUG 21 1992
D.W.R.

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 423344

DWR USE ONLY — DO NOT FILL IN
13N02W20H M
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 254895
Date Work Began 08/03/92 Ended 08/04/92
Local Permit Agency Colusa County Health Dept.
Permit No. 0323 Permit Date

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

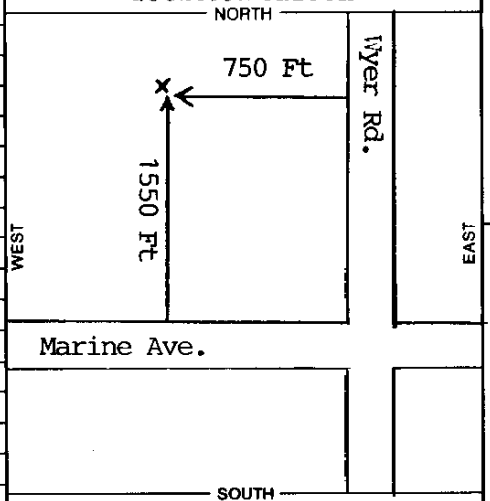
DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	3	Soil
3	16	Gravel
16	30	Clay
30	100	Clay with Streaks of Gravel
100	125	Clay
125	140	Sand & Gravel
140	185	Clay
185	196	Gravel & Sand
196	210	Clay
210	225	Gravel & Sand
225	240	Clay
240	252	Gravel & Sand
252	300	Clay
300	315	Gravel & Sand
315	320	Clay

TOTAL DEPTH OF BORING 320 (Feet)
TOTAL DEPTH OF COMPLETED WELL 320 (Feet)

WELL OWNER

Address 1550 Ft. North of Marine Ave.
City 750 Ft. West of Wyer Road
County Colusa
APN Book 21 Page 130 Parcel 92
or Township 13 N Range 2 W Section 20 H
or Latitude ___ DEG. ___ MIN. ___ SEC. NORTH Longitude ___ DEG. ___ MIN. ___ SEC. WEST

LOCATION SKETCH



Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc.
PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USE(S) (✓)

___ MONITORING
WATER SUPPLY
X Domestic
___ Public
___ Irrigation
___ Industrial
___ "TEST WELL"
___ CATHODIC PROTECTION
___ OTHER (Specify)

DRILLING METHOD Rotary FLUID Mud

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD* ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
** May not be representative of a well's long-term yield.*

CASING(S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL/ GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	200	9"	XX				F-480	5"	1/4"	
200	260	9"		XX			F-480	5"	1/4"	.032
260	300	9"	XX				F-480	5"	1/4"	
300	320	9"		XX			F-480	5"	1/4"	.032

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	25	X			
25	340				Pea Gravel 1/4" X 1/2"

AUG 26 1992

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Vaca Drilling Co./ Del Crew Jr. (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED) 190

ADDRESS P. O. Box 759 CITY Vacaville STATE CA ZIP 95696

Signed Delbert Crew Jr. (WELL DRILLER/AUTHORIZED REPRESENTATIVE) DATE SIGNED 8-10-92 C-57 LICENSE NUMBER 532679

DWR 188 REV. 7-90

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

RECEIVED

ORIGINAL
File with DWR MAY 06 2010

Page 1 of 4

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. E0109311

DWR USE ONLY — DO NOT FILL IN
14N/1E-35
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 8454
Date Work Began 3/29/2010, Ended 4/1/2010 ABCD
Local Permit Agency Colusa County Health Dept
Permit No. 2010-018 Permit Date 3/17/2010

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	5	Top soil
5	42	Brown clay with gravel streaks
42	70	Sand and gravel
70	210	Sand and gravel with brown clay streaks
210	230	Sand and gravel
230	980	Sandy blue clay
980	1000	Black sand with blue clay streaks
1000	1540	Sandy blue clay

TOTAL DEPTH OF BORING 1540 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1015 (Feet)

WELL OWNER

WELL LOCATION

Address 225' W of Wilson Bend Rd & 840' S of
City Fruchtenicht CA
County COLUSA
APN Book 022 Page 130 Parcel 057
Township 14 N Range 1 E Section 35
Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING ✓
TEST WELL
CATHODIC PROTECTION
HEAT EXCHANGE
DIRECT PUSH
INJECTION
VAPOR EXTRACTION
SPARGING
REMEDIATION
OTHER (SPECIFY)

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ____ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ____ (Ft.) & DATE MEASURED ____
ESTIMATED YIELD * ____ (GPM) & TEST TYPE ____
TEST LENGTH ____ (Hrs.) TOTAL DRAWDOWN ____ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
Zone	1									
0	50	14	✓				PVC	2.5	SCH 80	
50	60	14		✓			PVC	2.5	SCH 80	.030
60	70	14	✓				PVC	2.5	SCH 80	
Zone	2									
0	135	14	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	30	✓			Sand Slurry
30	40		✓		Bentonite Seal
40	71			✓	SRI#8 Sand
71	84		✓		Bentonite Seal
84	113			✓	SRI#8 Sand
113	123		✓		Bentonite Seal

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 WEST KENTUCKY AVE ADDRESS — WOODLAND CITY — CA STATE — 95695 ZIP
Signed Mark Damon WELL DRILLER/AUTHORIZED REPRESENTATIVE — 04/29/10 DATE SIGNED — C57 A HIC - 13378 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 2 of 4

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. E0109311

DWR USE ONLY --- DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 8454
Date Work Began 3/29/2010, Ended 4/1/2010
Local Permit Agency Colusa County Health Dept
Permit No. 2010-018 Permit Date 3/17/2010

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	5	Top soil
5	42	Brown clay with gravel streaks
42	70	Sand and gravel
70	210	Sand and gravel with brown clay streaks
210	230	Sand and gravel
230	980	Sandy blue clay
980	1000	Black sand with blue clay streaks
1000	1540	Sandy blue clay

TOTAL DEPTH OF BORING 1540 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1015 (Feet)

WELL LOCATION

Address 225' W of Wilson Bend Rd & 840' S of
City Fruchtenicht CA
County COLUSA
APN Book 022 Page 130 Parcel 057
Township 14 N Range 1 E Section 35
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
135	145	14		✓			PVC	2.5	SCH 80	.030
145	215	14	✓				PVC	2.5	SCH 80	
215	225	14		✓			PVC	2.5	SCH 80	.030
225	245	14	✓				PVC	2.5	SCH 80	
Zone	3									
0	545	14/10	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
123	250			✓	SRI#8 Sand
250	275		✓		Bentonite Seal
275	525			✓	SRI#8 Sand
525	529		✓		Bentonite Seal
529	736			✓	SRI#8 Sand
736	747		✓		Bentonite Seal

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

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Signed Mark Davison 04/29/10 C57 A HIC - 13378
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Page 3 of 4

STATE OF CALIFORNIA
WELL COMPLETION REPORT
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STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 8454
Date Work Began 3/29/2010, Ended 4/1/2010
Local Permit Agency Colusa County Health Dept
Permit No. 2010-018 Permit Date 3/17/2010

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	5	Top soil
5	42	Brown clay with gravel streaks
42	70	Sand and gravel
70	210	Sand and gravel with brown clay streaks
210	230	Sand and gravel
230	980	Sandy blue clay
980	1000	Black sand with blue clay streaks
1000	1540	Sandy blue clay

TOTAL DEPTH OF BORING 1540 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1015 (Feet)

WELL LOCATION

Address 225' Wof Wilson Bend Rd & 840' Sof
City Fruchtenicht CA
County COLUSA
APN Book 022 Page 130 Parcel 057
Township 14 N Range 1 E Section 35
Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING ✓
TEST WELL
CATHODIC PROTECTION
HEAT EXCHANGE
DIRECT PUSH
INJECTION
VAPOR EXTRACTION
SPARGING
REMEDIATION
OTHER (SPECIFY)

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED
ESTIMATED YIELD * — (GPM) & TEST TYPE
TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
545	555	10-3/4		✓			PVC	2.5	SCH 80	.030
555	610	10-3/4	✓				PVC	2.5	SCH 80	
610	620	10-3/4		✓			PVC	2.5	SCH 80	.030
620	695	10-3/4	✓				PVC	2.5	SCH 80	
695	705	10-3/4		✓			PVC	2.5	SCH 80	.030
705	736	10-3/4	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
747	932			✓	SRI#8 Sand
932	937		✓		Bentonite Seal
937	1039			✓	SRI#8 Sand
1039	1049		✓		Bentonite Seal
1049	1060			✓	Native Fill
1060	1440	✓			Sand Slurry

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

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ADDRESS CITY STATE ZIP
Signed Mark Damion 04/29/10 C57 A HIC - 13378
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

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Owner's Well No. 8454
Date Work Began 3/29/2010, Ended 4/1/2010
Local Permit Agency Colusa County Health Dept
Permit No. 2010-018 Permit Date 3/17/2010

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	5	Top soil
5	42	Brown clay with gravel streaks
42	70	Sand and gravel
70	210	Sand and gravel with brown clay streaks
210	230	Sand and gravel
230	980	Sandy blue clay
980	1000	Black sand with blue clay streaks
1000	1540	Sandy blue clay

TOTAL DEPTH OF BORING 1540 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1015 (Feet)

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LOCATION SKETCH

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Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED
ESTIMATED YIELD * — (GPM) & TEST TYPE
TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
Zone	4									
0	985	14/10/8	✓				PVC	2.5	SCH 80	
985	995	8-3/4		✓			PVC	2.5	SCH 80	.030
995	1015	8-3/4	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
1440	1540			✓	Native Fill

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

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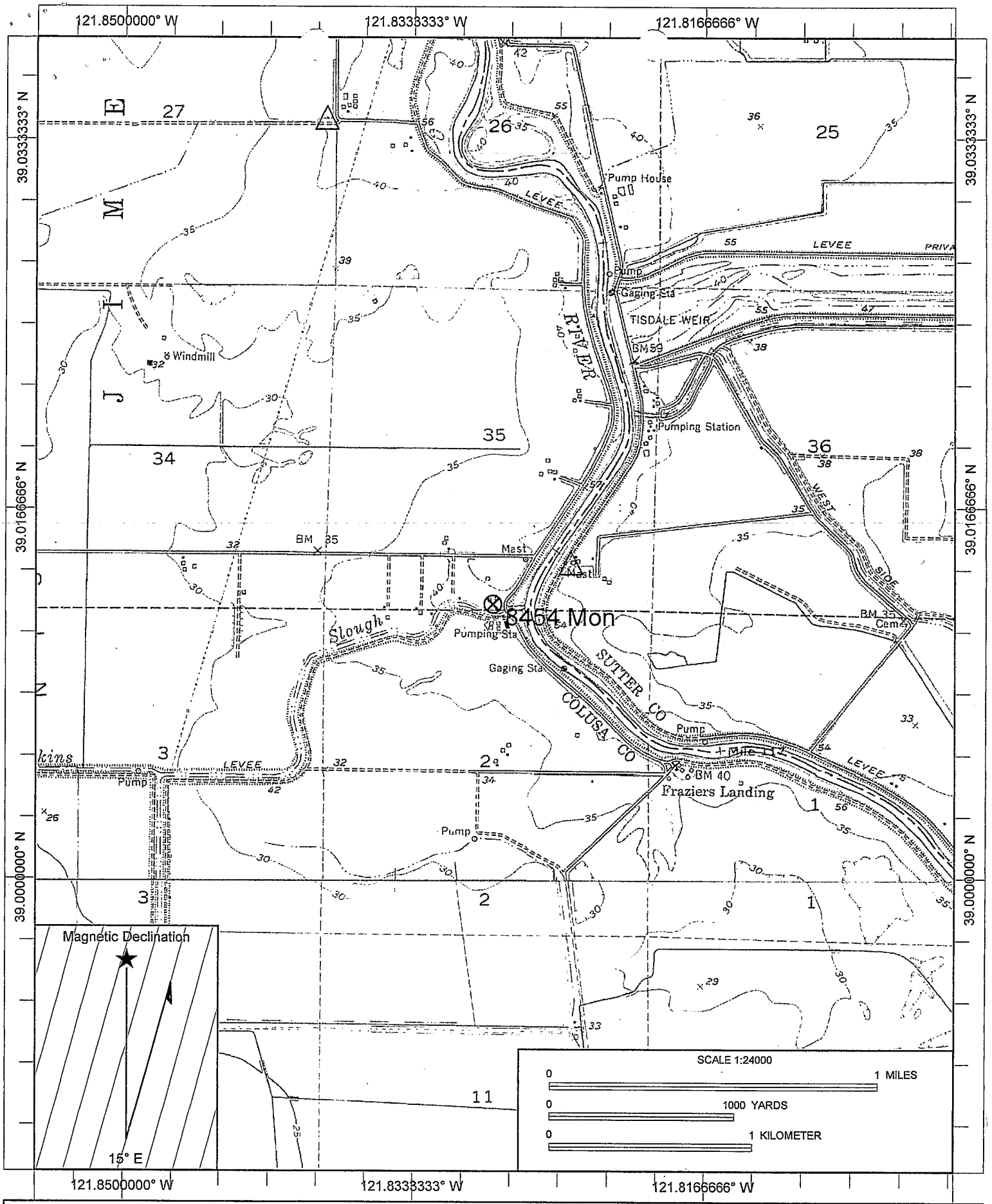
ADDRESS CITY STATE ZIP

Signed Mark Damion 04/29/10 C57 A HIC - 13378
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM



Name: TISDALE WEIR
Date: 3/16/2010
Scale: 1 inch equals 2000 feet

Caption: DWR (RD 108) - Job# 8454 Mon
APN: 022-130-057
T14N R1E s35

Copyright (C) 1997, Maptech, Inc.

May Be 4K3 JUL 13 1946
Probably 1S4K3 Sbarra

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES BRANCH

...S-CAL-T1
May 1948

No. 14/ 1W - ~~4K1~~

Other Nos. Map 53

WELL LOG

We have NO Record of 4K1

State California County Colusa Subarea Grimes

Owner Glenn Morris

Location 2400 feet north, 2150 feet west of S¼ corner (USBR)

Drilled by Aulman Address

Date 5-1942 Casing diam. 16 Land-surf. alt. 34

Source of data Driller (USBR)

(Enter type of well, perforations, yield, and drawdown at end of log)

Correlation	Material	Thickness (feet)	Depth (feet)
	Surface soil	7	7
	Clay, gray	29	36
	Clay, sandy	6	42
	Sandy	4	46
	~~Sandy~~ Gravel	20½	66¼
	~~Gravel~~ Clay, soft	3½	70
	Clay, tough	3	73
	Perforated 46-70'		
	1300 GPM		
	Redwood plug		
	Rotary		
	7.3 feet to water level		

Record by [illegible] Date

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

JUL 13 19[illegible] State No. 14N/1W-4K3

WELL DATA

BRANCH NORTHERN

Owner ERNEST SACHREITER
Address
Tenant
Address

State No. 14N/1W-4K3
Other No.

Type of Well: Hydrograph ☐ Key ☐ Index ☐ Semiannual ☒

Location: County COLUSA Basin COLUSA CO. No. 5-21.04
U.S.G.S. Quad. GRIMES Quad. No. 5-195C
NW ¼ SE ¼ Section 4, Twp. 14N, Rge. 1W (MD) (SB) (H) Base & Meridian 545C
Description 1.40 MI. W/O DRY SLOUGH RD. ON SACHREITER RD, THENCE 50' S/O ℄ OF SACHREITER RD.

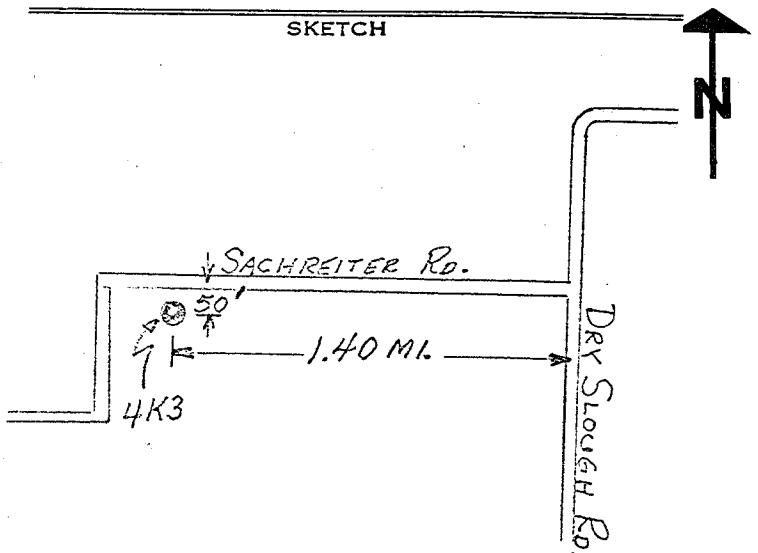
Reference Point description T.O.C. UNDER P.B., N. SIDE

which is @ ft. above / below land surface. Ground Elevation 35.0 ft.
Reference Point Elev. 35.0 ft. Determined from USGS QUAD
Well: Use IRRIG Condition Depth 73 ft.
Casing, size 16 in., perforations 46' TO 70' See Log Attached

Measurements By: DWR ☒ USGS ☐ USBR ☐ County ☐ Irr. Dist. ☐ Water Dist. ☐ Cons. Dist. ☐
Chief Aquifer: Name Depth to Top Aq. Depth to Bot. Aq.
Type of Material Perm. Rating Thickness
Gravel Packed? Yes ☐ No ☐ Depth to Top Gr. Depth to Bot. Gr.
Supp. Aquifer Depth to Top Aq. Depth to Bot. Aq.
Driller AULMAN
Date drilled 1944 Log, filed ✓ USBR Log open (1) confidential (2)
Equipment: Pump, type TURBINE make PEERLESS
Serial No. J31847 Size of discharge pipe 10 in.
Power, Kind ELEC. Make G.E.
H. P. 25 Motor Serial No. NHJ6918274
Elec. Meter No. 80233 Transformer No.
Yield G.P.M. Pumping level ft.

Water Analysis: Min. (1) San. (2) H.M. (3)
Water Levels available: Yes (1) No
Period of Record: Begin End
Collecting Agency:
Prod. Rec. (1) Pump Test (2) Yield (3)

SKETCH



REMARKS

Recorded by: S.H. ADAMS FROM FIELD BK.
Date 4-3-67

DWR 429

USGS-CAL-T1
May 1948

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES BRANCH

No. 14/2W - ~~13N1~~

Other Nos. BR 14-2W-13

WELL LOG

CONFIDENTIAL LOG Water Code Sec. 13752

State California County Colusa Subarea Arbuckle

Owner 3027

Location 1380 ft. north and 375 ft. east of SW corner (USGS)

Drilled by Cooper & Son Address

Date Sept. 1947 Casing diam. 14" Land-surf. alt. 60'

Source of data XXX BR

(Enter type of well, perforations, yield, and drawdown at end of log)

Correlation	Material	Thickness (feet)	Depth (feet)
	Soil	5	5
	Clay, yellow	15	20
	Sand and fine gravel	3	23
	Clay, yellow	8	31
	Clay, sandy brittle	14	45
	Clay, yellow	77	122
	Clay, blue	10	132
	Gravel	35	167
	Clay, sandy yellow	137	297
	Gravel	22	319
	Clay, blue	7	325
	Gravel	12	338
	Clay, sandy yellow	19	357
	Gravel	28	385
	Clay, blue	7	392
	112' of 3/16" x 14" casing		
	260' of 3/16" x 12" casing		
	Perf. 104 - 392		
	Rotary type drill		
	Irrigation		
	Plotted and Coded		
	As Well 14N/2W-13N1		

CONFIDENTIAL LOG Water Code Sec. 13752

3

Record by Date Sheet of

State of California

Well Completion Report

Form DWR 188 Complete 3/19/2020

WCR2020-003773

Owner's Well Number | Date Work Began 07/08/2019 | Date Work Ended 08/07/2019

Local Permit Agency Colusa County Environmental Health

Secondary Permit Agency | Permit Number WP 1189 | Permit Date 07/01/2019

Well Owner (must remain confidential pursuant to Water Code 13752)

Name ARUILL FARMS, LLC,

Mailing Address Hahn Road

City Arbuckle State CA Zip 95912

Planned Use and Activity

Activity New Well

Planned Use Monitoring

Well Location

Address 0 Hahn RD

City Arbuckle Zip 95912 County Colusa

Latitude 39 Deg. 3 Min. 14.44 Sec. N | Longitude -122 Deg. 3 Min. 39.28 Sec. W

Dec. Lat. 39.0540111 Dec. Long. -122.0609111

Vertical Datum NAVD88 Horizontal Datum WGS84

Location Accuracy 5 Ft Location Determination Method GPS

APN 018-180-037-000

Township 14 N

Range 02 W

Section 22

Baseline Meridian Mount Diablo

Ground Surface Elevation 84

Elevation Accuracy Unknown

Elevation Determination Method Surveyed

Borehole Information

Orientation Vertical Specify

Drilling Method Reverse Circulation Drilling Fluid Bentonite

Total Depth of Boring 1200 Feet

Total Depth of Completed Well 1050 Feet

Water Level and Yield of Completed Well

Depth to first water (Feet below surface)

Depth to Static Water Level (Feet) Date Measured

Estimated Yield* (GPM) Test Type

Test Length (Hours) Total Drawdown (feet)

*May not be representative of a well's long term yield.

Geologic Log - USCS/ASTM D2488

Depth from Surface Feet to Feet		Soil Class	Soil Color	Soil Description
0	20	SW Well-graded SAND	Dusky yellow 5Y 6/4	Well-graded sand with gravel. About 55% fine sand; about 20% coarse sand; about 20% gravel; about 5% fines with low plasticity; moist, bulk sample dusky yellow 5Y 6/4; coarseness increases with depth
20	40	CL Lean inorganic CLAY with low plasticity	Yellowish brown 10YR 5/4	Lean Clay with Sand. About 75% fines with low to medium plasticity; about 25% medium sand; moist, bulk sample moderate yellowish brown 10YR 5/4
40	90	CL Lean inorganic CLAY with low plasticity	Yellowish brown 10YR 5/4	Lean Clay. Fines with medium plasticity; trace fine sand; moderate yellowish brown 10YR 5/4, dark gray streaks increase with depth
90	110	GC Clayey GRAVEL	Light olive gray 5Y	Clayey Gravel. 60% hard, subangular gravel; about 40% low to non-plastic clay; moist, bulk sample multi-colored dark gray N3 and light olive gray 5Y 6/1; gravel increases and clay decreases with depth
110	160	CH Fat inorganic clay with moderate to high plasticity	Moderate yellowish brown 10YR 5/4	Fat Clay. Fines with medium to high plasticity; trace fine sand; moist, moderate yellowish brown 10 YR 5/4
160	170	GW Well-graded GRAVEL	Light olive gray 5Y 6/1	Well-graded gravel with Sand. About 70% hard, subangular, multi-colored and dark gray N3 gravel; about 15% coarse sand; about 15% fine sand; dry, bulk sample light olive gray 5Y 6/1
170	280	CH Fat inorganic clay with moderate to high plasticity	Moderate yellowish brown 10YR 5/4	Fat Clay. Fines with high plasticity; moist, moderate yellowish brown 10 YR 5/4

280	300	GW Well-graded GRAVEL	Dark gray N3 and Medium dark gray N4	Well-Graded Gravel w/Sand.75% hard, subangular, multi-colored gray and white gravel; about 15% coarse sand; about 10% medium sand; dry, bulk sample multi-colored, dark gray N3, and medium dark gray N4
300	380	CH Fat inorganic clay with moderate to high plasticity	Light olive gray 5Y 5/2	Fat Clay. Fines with high plasticity; intermittent trace fine sand; moist to saturated, light olive gray 5Y 5/2
380	400	CH Fat inorganic clay with moderate to high plasticity	Dusky yellow green 5GY 5/2	Fat Clay w/Sand. 80% fines with high plasticity; about 10% coarse sand; about 10% medium sand; moist, bulk sample dusky yellow green 5GY 5/2
400	570	CH Fat inorganic clay with moderate to high plasticity	streaks of grayish blue green 5BG 5/2 and dusky yellow green 5GY 5/2	Fat Clay. Fines with high plasticity; moist, grayish olive 10Y 4/2; trace silt from about 500-520'; trace sand from about 550-580'; streaks of grayish blue green 5BG 5/2 and dusky yellow green 5GY 5/2
570	640	SW Well-graded SAND	multi-colored, gray and white	Well-Graded Sand w/gravel. 45% subrounded coarse sand; 35% medium sand;15% hard, subrounded gravel; about 5% fine sand; bulk sample multi-colored, gray and white; coarseness increases with depth
640	780	CH Fat inorganic clay with moderate to high plasticity	light olive gray 5Y 6/1, color change at 730-780' to dark greenish gray 5GY 4/1	Fat Clay. Fines with high plasticity, light olive gray 5Y 6/1, color change at 730-780' to dark greenish gray 5GY 4/1; trace fine sand; moist
780	890	SW Well-graded SAND	Multi-colored, white, gray, and light brown	Well-Graded Sand with Gravel. About 50% medium sand; about 25% coarse sand; about 15% hard, subrounded gravel, multi-colored, white and gray; about 10% fine sand; bulk sample multi-colored, white, gra
890	920	CL Lean inorganic CLAY with low plasticity	Light olive gray 5Y 6/1 and yellowish gray 5Y 8/1	Lean Clay. Fines with medium plasticity; moist, light olive gray 5Y 6/1 and yellowish gray 5Y 8/1; trace sand.
920	950	SW Well-graded SAND	multi-colored, gray and white	Well-Graded Sand w/Gravel. About 35% coarse sand, multi-colored gray and white; about 35% medium sand; about 20% hard, subangular gravel, multi-colored, gray and white; about 10% fine sand; dry
950	1000	CL Lean inorganic CLAY with low plasticity	light blue gray 5Y 6/1	Sandy Lean Clay. About 70% nonplastic fines; about 20% medium sand; about 10% coarse sand; moist, bulk sample light blue gray 5Y 6/1
1000	1020	SW Well-graded SAND	multi-colored, brown, white, and gray	Well-Graded Sand. About 60% hard, medium to coarse sand; about 40% fine sand; bulk sample multi-colored, brown, white, and gray
1020	1040	SW Well-graded SAND	multi-colored, gray, black, and white	Well-Graded Sand. About 50% medium sand; about 35% fine sand; about 15% hard, coarse sand; moist, bulk sample multi-colored, gray, black, and white
1040	1050	CL Lean inorganic CLAY with low plasticity	pale olive 10 6/2	Lean Clay with Sand. About 80% fines with low plasticity; about 20% medium sand; moist, bulk sample pale olive 10 6/2
1050	1080	SW Well-graded SAND	multi-colored, gray and white	Well-Graded Sand. About 35% medium sand; about 35% fine sand; about 10% hard gravel; about 20% hard coarse sand; moist, bulk sample multi-colored, gray and white
1080	1140	SW Well-graded SAND	multi-colored, white, gray, and light brown	Well-Graded Sand. About 50% medium sand; about 30% fine sand; about 10% hard, subangular gravel; about 10% subangular coarse sand; moist, bulk sample multi-colored, white, gray, and light brown
1140	1200	SW Well-graded SAND	multi-colored, light gray, and white	Well-Graded Sand w/Gravel. About 35% medium sand; about 35% fine sand; about 15% hard, subangular gravel; about 15% coarse sand; bulk sample multi-colored, light gray, and white

Casings

Casing #	Depth from Surface Feet to Feet		Casing Type	Material	Casings Specificatons	Wall Thickness (inches)	Outside Diameter (inches)	Screen Type	Slot Size if any (inches)	Description
1	0	1020	Blank	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375			
1	1020	1030	Screen	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375	Milled Slots	0.02	
1	1030	1050	Blank	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375			
2	0	860	Blank	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375			
2	860	870	Screen	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375	Milled Slots	0.02	
2	870	920	Blank	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375			
2	920	930	Screen	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375	Milled Slots	0.02	
2	930	950	Blank	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375			
3	0	580	Blank	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375			
3	580	590	Screen	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375	Milled Slots	0.02	
3	590	610	Blank	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375			
4	0	290	Blank	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375			
4	290	300	Screen	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375	Milled Slots	0.02	
4	300	320	Blank	PVC	OD: 2.375 in. | Thickness: 0.218 in.	0.218	2.375			

Annular Material

Depth from Surface Feet to Feet		Fill	Fill Type Details	Filter Pack Size	Description
0	246	Bentonite	Non Hydrated Bentonite		
246	329	Filter Pack	Other Gravel Pack	8	sand
329	508	Bentonite	Non Hydrated Bentonite		
508	650	Filter Pack	Other Gravel Pack	8	sand
650	781	Bentonite	Non Hydrated Bentonite		
781	961	Filter Pack	Other Gravel Pack	8	sand
961	1007	Bentonite	Non Hydrated Bentonite		
1007	1080	Filter Pack	Other Gravel Pack	8	sand
1080	1200	Other Fill	See description.		native fill

Other Observations:

Borehole Specifications

Depth from Surface Feet to Feet		Borehole Diameter (inches)
0	1200	14.75

Certification Statement

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief

Name: CASCADE DRILLING LP (Person, Firm or Corporation)

PO BOX 1184 (Address) | Woodinville (City) | WA (State) | 90872 (Zip)

Signed: *electronic signature received* (C-57 Licensed Water Well Contractor) | 03/19/2020 (Date Signed) | 1058336 (C-57 License Number)

Attachments

25547_elog_view.bmp - Geophysical Log

DWR Use Only

CSG #	State Well Number	Site Code	Local Well Number

N — Latitude Deg/Min/Sec

W — Longitude Deg/Min/Sec

TRS:

APN:

LOCATION NOT CHECKED

ORIGINAL
File Original, Duplicate and Triplicate with the REGIONAL WATER POLLUTION CONTROL BOARD No. 5
(Insert appropriate number)

WATER WELL DRILLERS REPORT
(Sections 7076, 7077, 7078, Water Code)

STATE OF CALIFORNIA

Do Not Fill In
No. 44455

State Well No. .....
Other Well No. 14N/2W-29J1
Plotted and Coded

N
A

(2) LOCATION OF WELL:

County Colusa 7 Owner's number, if any—
R. F. D. or Street No. N.E. corner of S.E. 1/4 of Sec. 29
T 14 N, R 2 W.

(3) TYPE OF WORK (*check*):

New well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (*check*):

Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☒ Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary ☒
Cable ☐
Dug Well ☐

(6) CASING INSTALLED:

SINGLE ☒ DOUBLE ☐

From ft.	to ft.	Diam.	Gage or Wall
0	412	12	3/16

Type and size of shoe or well ring
Describe joint Butt Welded

If gravel packed

Diameter of Bore	from ft.	to ft.

Size of gravel: 3/4x 1/2"

(7) PERFORATIONS:

Type of perforator used Machine cut at factory
Size of perforations 3/16 in., length, by 3 in.

From ft.	to ft.		Perf. per row	Rows per ft.
119	143			
176	182			
198	208			
215	229			
267	276			
307.5	319.5			
334.5	349.50			
		338 to 412		

(8) CONSTRUCTION:

Was a surface sanitary seal provided? ☐ Yes ☒ No To what depth ft.
Were any strata sealed against pollution? ☐ Yes ☒ No If yes, note depth of strata

From ft.	to ft.

Method of Sealing

(9) WATER LEVELS:

Depth at which water was first found ft.
Standing level before perforating ft.
Standing level after perforating ft.

(10) WELL TESTS: See back of page

Was a pump test made? ☒ Yes ☐ No If yes, by whom? E. E. Luhdorff
Yield: gal./min. with ft. draw down after hrs.
Temperature of water Was a chemical analysis made? ☐ Yes ☒ No
Was electric log made of well? ☐ Yes ☒ No

(11) WELL LOG:

As Well 14N/12W-29J1
Total depth ft. Depth of completed well 412 ft.

Formation: *Describe by color, character, size of material, and structure.*

0 ft. to	8 ft.	8'	Top soil
8 "	21 "	13'	Dry gravel
21 "	36 "	15'	Yellow clay
36 "	58 "	22'	Dry gravel
58 "	65 "	7'	Yellow clay
65 "	74 "	9'	Loose gravel
74 "	110 "	36'	Yellow clay
110 "	115 "	5'	Loose gravel
115 "	124 "	9'	Yellow clay
124 "	138 "	14'	Rocks & gravel
138 "	153 "	15'	Yellow clay
153 "	156 "	3'	Loose gravel
156 "	177 "	21'	Yellow clay
177 "	181 "	4'	Loose gravel
181 "	201 "	20'	Yellow clay
201 "	204 "	3'	Rocks & gravel
204 "	220 "	16'	Yellow clay
220 "	222 "	2'	Rocks & gravel
222 "	228 "	6'	Yellow clay
228 "	238 "	10'	Rocks & gravel
238 "	269 "	31'	Yellow clay
269 "	274 "	5'	Rocks & gravel
274 "	312 "	38'	Yellow clay
312 "	318 "	6'	Rocks & gravel
318 "	336 "	18'	Yellow clay
336 "	339 "	3'	Rocks & gravel
339 "	346 "	7'	Yellow clay
346 "	348 "	2'	Loose gravel
348 "	398 "	50'	Yellow clay
398 "	409 "	11'	Rocks &gravel
409 "	623 "	214'	Blue clay
623 "	626 "	3'	Rocks & gravel
626 "	640 "	14'	Blue clay
640 "	649 "	9'	Loose gravel
649 "	674 "	25'	Blue clay
674 "	680 "	6'	Rocks & gravel
680 "	852 "	172'	Blue clay
852 "	857 "	5'	Rocks & gravel
857 "	882 "	25'	Blue clay
882 "	884 "	2'	Loose gravel
884 "	916 "	32'	Blue clay
916 "	920 "	4'	Rocks & gravel
920 "	924 "	4'	Blue clay

Work started 6-8 19 56. Completed 6-22-56 19

RECEIVED
OCT 26 1956
Water Code

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME E. E. LUHDORFF
(Person, firm, or corporation) (*Typed or printed*)
Address P. O. Box 326, West Main St.
Woodland, California

[SIGNED] E. E. Luhdorff
Well Driller

License No. 123211 Dated Oct. 22, 1953

95689 3-54 50M QUIN ® SPO

#44455

Report No. 196

Owner _____

Pump No. _____

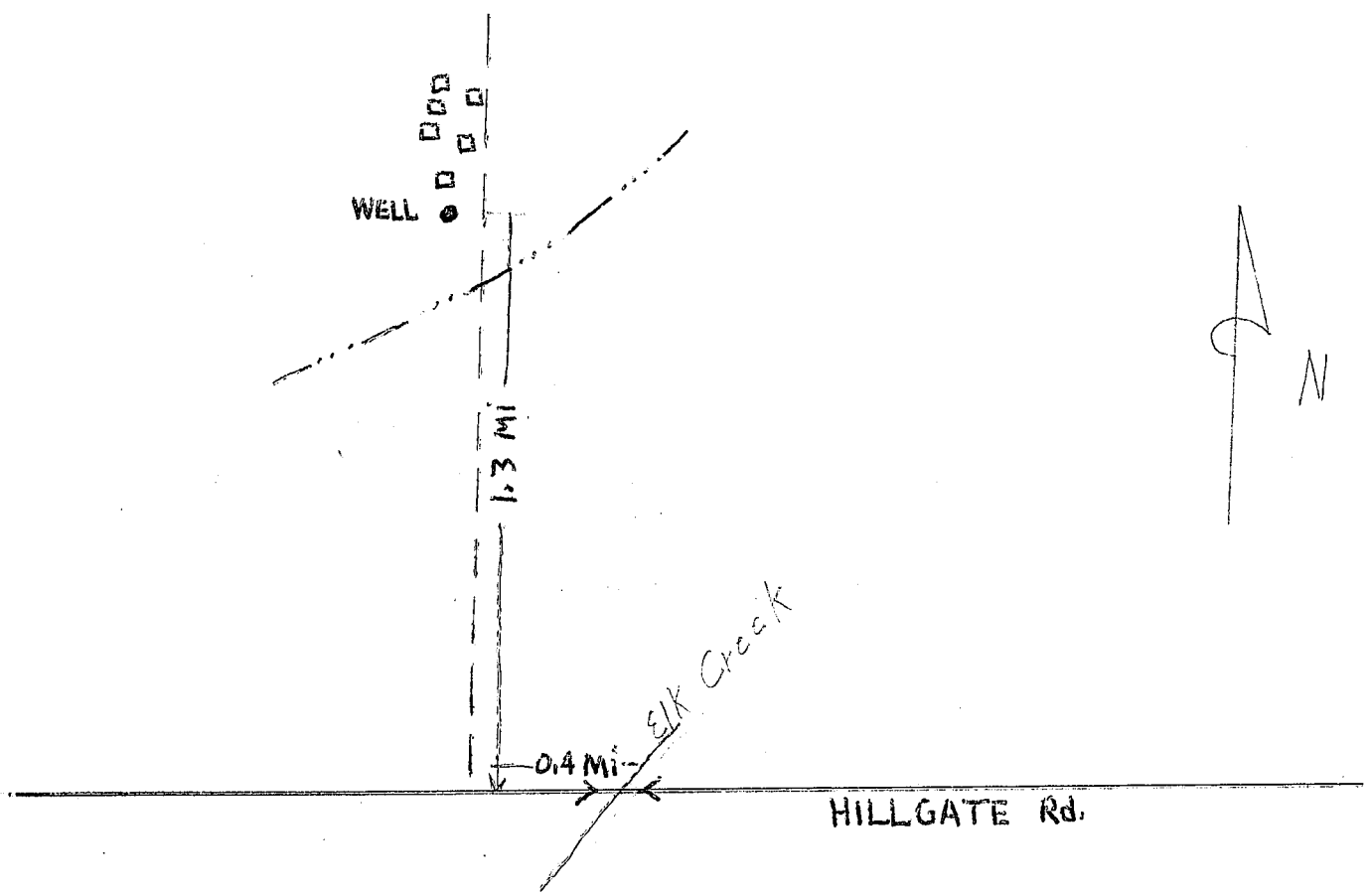
Meter No. 62656

Region 5 ; County COLUSA

Township 14N Range 2W , Section 29 J1 , _____ B&M.

_____ ft. north, _____ ft. west from southeast corner of Section.

SKETCH



DESCRIPTION OR REMARKS

Checked by E. Edwards Date 7-21-55

#44455

Owner H. CHARTI

Pump No.

Meter No. 6265

Results of Well Test as follows:

Water Level 77'

Pumping level	200'	G.P.M.	1125
" "	190'	"	1050
" "	180'	"	960
" "	162'	"	850
" "	151'	"	760

3 minute return 105'

RECEIVED
OCT 2 1956
REGIONAL CONSERVATION
CENTRAL VALLEY

ORIGINAL

File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

14N/3W-14 *Do not fill in*

No. 20032

Notice of Intent No.

Local Permit No. or Date

State Well No. CONFIDENTIAL LOG Water Code Sec. 13752

Other Well No.

(1

Ad

Cit

(2) LOCATION OF WELL (See instructions): 6T-214 W-3225

County Colusa Owner's Well Number

Well address if different from above

Township Range Section

Distance from cities, roads, railroads, fences, etc. Hahn-Cortina Sch. Rd. - 1 mi. W 50' N

WELL LOCATION SKETCH

(3) TYPE OF WORK:

New Well [X] Deepening [ ]
Reconstruction [ ]
Reconditioning [ ]
Horizontal Well [ ]
Destruction [ ] (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:

Domestic [ ]
Irrigation [X]
Industrial [ ]
Test Well [ ]
Stock [ ]
Municipal [ ]
Other [ ]

(5) EQUIPMENT:

Rotary [ ] Reverse [X]
Cable [ ] Air [ ]
Other [ ] Bucket [ ]

(6) GRAVEL PACK:

Yes [X] No [ ] Size pea grav.
Diameter of bore 24"
Packed from 0 to 704 ft.

(7) CASING INSTALLED:

Steel [X] Plastic [ ] Concrete [ ]

From ft.	To ft.	Dia. in.	Gage or Wall
0-	685	16"	OD x .250

(8) PERFORATIONS:

Type of perforation or size of screen

From ft.	To ft.	Slot size
390--480		
500- 590		
614-685		

(9) WELL SEAL:

Was surface sanitary seal provided? Yes [ ] No [ ] If yes, to depth ft.
Were strata sealed against pollution? Yes [ ] No [ ] Interval ft.
Method of sealing

(10) WATER LEVELS:

Depth of first water, if known ft.
Standing level after well completion ft.

(11) WELL TESTS:

Was well test made? Yes [ ] No [ ] If yes, by whom?
Type of test Pump [ ] Bailer [ ] Air lift [ ]
Depth to water at start of test ft. At end of test ft.
Discharge gal/min after hours Water temperature
Chemical analysis made? Yes [ ] No [ ] If yes, by whom?
Wa[illegible]e log made? Yes [X] No [ ] If yes, attach copy to this report

(12) WELL LOG: Total depth 704 ft. Depth of completed well 685 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0-	10	top soil
10-	16	clay
16-	26	gravel
26-	28	clay
28-	38	gravel
38-	56	clay
56-	64	gravel
64-	68	clay
68-	80	gravel
80-	82	clay
82-	98	gravel
98-	102	clay
102-	110	sand
110-	124	sandy clay
124-	156	clay
156-	172	sand
172-	182	clay
182-	190	sandy clay
190-	195	clay
195-	203	sand
203-	214	clay
214-	220	sand
220-	226	clay
226-	242	sand
242-	265	clay
265-	275	sand
275-	392	clay and sandy clay
392-	398	sand
398-	521	clay and sandy clay
521-	536	gravel
536-	548	clay
548-	555	sand
555-	564	clay
564-	581	gravel
581-	624	clay
624-	636	gravel
636-	645	clay
645-	663	gravel
663-	670	clay
670-	678	sand
678-	704	clay

Work started 19 Completed 7--18 19 77

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

SIGNED F. M. Eaton (Well Driller)

NAME Eaton Drilling Co. Inc. (Person, firm, or corporation) (Typed or printed)

Address 20 Kentucky (P. O. Box 975)

City Woodland, California Zip 95695

License No. 133783C57 Date of this report 7-18-1977

DO NOT RELEASE TO PUBLIC UNTIL CONFIDENTIAL LOG WATER CODE SEC. 13752

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM 43816-950 7-76 50M QUAD 1T OSP

14Y/3W-24

ORIGINAL

File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do not fill in

No. 072290

Notice of Intent No.

Local Permit No. or Date

State Well No.

Other Well No.

CONFIDENTIAL LOG
Water Code Sec. 13752

(2) **LOCATION OF WELL** (See instructions):

County Colusa Owner's Well Number W-3649

Well address if different from above

Township 14N Range 3W Section Sec. 24

Distance from cities, roads, railroads, fences, etc. Hahn-Cortina School Rds: 400' W 100' S

WELL LOCATION SKETCH

(3) **TYPE OF WORK:**

New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) **PROPOSED USE:**

Domestic ☒
Irrigation ☐
Industrial ☐
Test Well ☐
Stock ☐
Municipal ☐
Other ☐

(5) **EQUIPMENT:**

Rotary ☐ Reverse ☒
Cable ☐ Air ☐
Other ☐ Bucket ☐

(6) **GRAVEL PACK:**

Yes ☒ No ☐ Size Pea gra.
Diameter of bore 16"
Packed from 0 to 312 ft.

(7) **CASING INSTALLED:**

Steel ☒ Plastic ☐ Concrete ☐

(8) **PERFORATIONS:**

Type of perforation or size of screen

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size
0	312	8 5/8 OD x.188		292-312		8 rows x.125 mesh

(9) **WELL SEAL:**

Was surface sanitary seal provided? Yes ☐ No ☐ If yes, to depth ft.

Were strata sealed against pollution? Yes ☐ No ☐ Interval ft.

Method of sealing

(10) **WATER LEVELS:**

Depth of first water, if known ft.

Standing level after well completion ft.

(11) **WELL TESTS:**

Was well test made? Yes ☐ No ☐ If yes, by whom?

Type of test Pump ☐ Bailer ☐ Air lift ☐

Depth of water at start of test ft. At end of test ft

Discharge gal/min after hours Water temperature

Chemical analysis made? Yes ☐ No ☐ If yes, by whom?

Was electric log made? Yes ☒ No ☐ If yes, attach copy to this report

big hole

(12) **WELL LOG:** Total depth 320 ft. Depth of completed well 312 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	4	top soil
4	20	gravel
20	34	clay
34	80	sand and gravel
80	204	stratas of clay
		stratas of gravel
204	214	gravel
214	266	clay and sandy clay
266	274	gravel
274	284	sandy clay
284	288	sand
288	294	clay
294	310	gravel
310	320	clay and sandy clay

Work started 19 Completed 4-10-81 19

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

SIGNED (Well Driller)

NAME Eaton Drilling Co. Inc.
(Person, firm, or corporation) (Typed or printed)

Address P. O. Box 975 (20 W. Kentucky)

City Woodland, California Zip 95695

License No. 133783C57 Date of this report 4-21, 1981

CONFIDENTIAL
NOT FOR PUBLIC USE
WATER CODE SEC. 13752

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

CONFIDENTIAL LOG
Water Code Sec. 13752

WATER WELL DRILLERS REPORT

(Sections 7079, 7080, 7081, 7082, Water Code)

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

(Misc) Do Not Fill In

Nº 12982

State Well No.

Other Well No. 15N/1W-56

CONFIDENTIAL LOG
Water Code Sec. 13752

(1) OWNER:
Name Colusa County Airport
Address Colusa Calif.

(2) LOCATION OF WELL:
County Colusa Owner's number, if any
Township, Range, and Section
Distance from cities, roads, railroads, etc.

(3) TYPE OF WORK (check):
New Well ☑ Deepening ☐ Reconditioning ☐ Destroying ☐
If destruction, describe material and procedure in Item 11.

(4) PROPOSED USE (check):
Domestic ☑ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:
Rotary ☐
Cable ☑
Other ☐

(6) CASING INSTALLED:
STEEL: OTHER:
SINGLE ☑ DOUBLE ☐

From ft.	To ft.	Diam.	Gage or Wall	Diameter of Bore	If gravel packed From ft.	To ft.
0	75	8"	12 ga			

Size of shoe or well ring: 5x4x8" Size of gravel:
Describe joint B/W

(7) PERFORATIONS OR SCREEN:
Type of perforation or name of screen

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.

(8) CONSTRUCTION:
Was a surface sanitary seal provided? Yes ☑ No ☐ To what depth ft.
Were any strata sealed against pollution? Yes ☐ No ☐ If yes, note depth of strata
From 0 ft. to 75 ft.
From ft. to ft.
Method of sealing Clay

(9) WATER LEVELS:
Depth at which water was first found, if known 20 ft.
Standing level before perforating, if known ft.
Standing level after perforating and developing 20 ft.

(10) WELL TESTS:
Was pump test made? Yes ☐ No ☑ If yes, by whom?
d: gal./min. with ft. drawdown after hrs.
Temperature of water Was a chemical analysis made? Yes ☐ No ☑
Was electric log made of well? Yes ☐ No ☑ If yes, attach copy

(11) WELL LOG:
Total depth 140 ft. Depth of completed well 140 ft.
Formation: *Describe by color, character, size of material, and structure*

ft.	to	
0	10	Top Soil
10	20	Sandy muck
20	30	Clay
30	50	Gravel & Sand
50	55	yellow clay
55	72	Sand & Gravel
72	135	Blue Clay
135	140	Black Sand

This Well is located at the Airport in Colusa.

Plotted and Coded
As Well 15N / 1W - 5680

Work started 8/19 1971, Completed 8/20 1971

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Beaman & Son Pump Co.
(Person, firm, or corporation) (Typed or printed)
Address 470 N. Geo Wash. Blvd.
Yuba City Calif.
[SIGNED] J. D. Beaman
(Well Driller)

License No. 196093 Dated 9/24, 1971

SKETCH LOCATION OF WELL ON REVERSE SIDE

#12982

WATER WELL DRILLERS REPORT

FIELD WORK SHEET

Report No. 12982

Owner Co/USA County Airport

Pump No. —

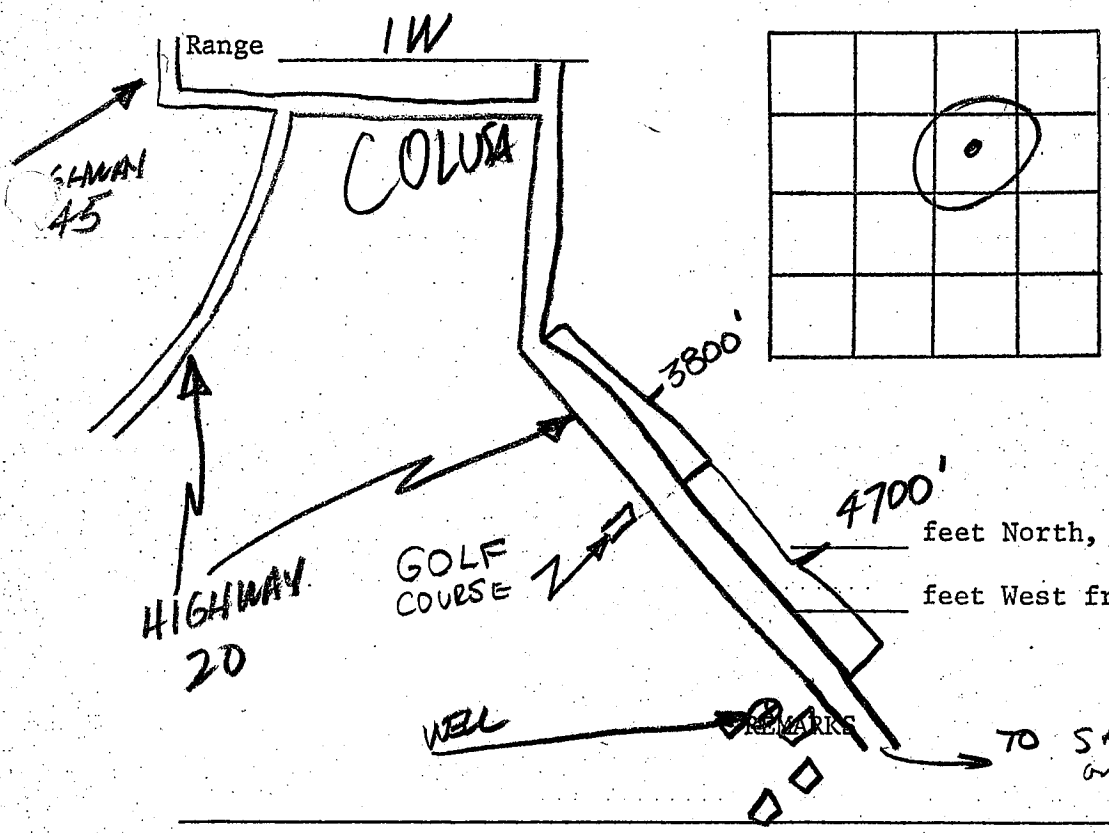
Meter No. _____

LOCATION

Section 5G

Township 15N

Range 1W



4700' feet North,

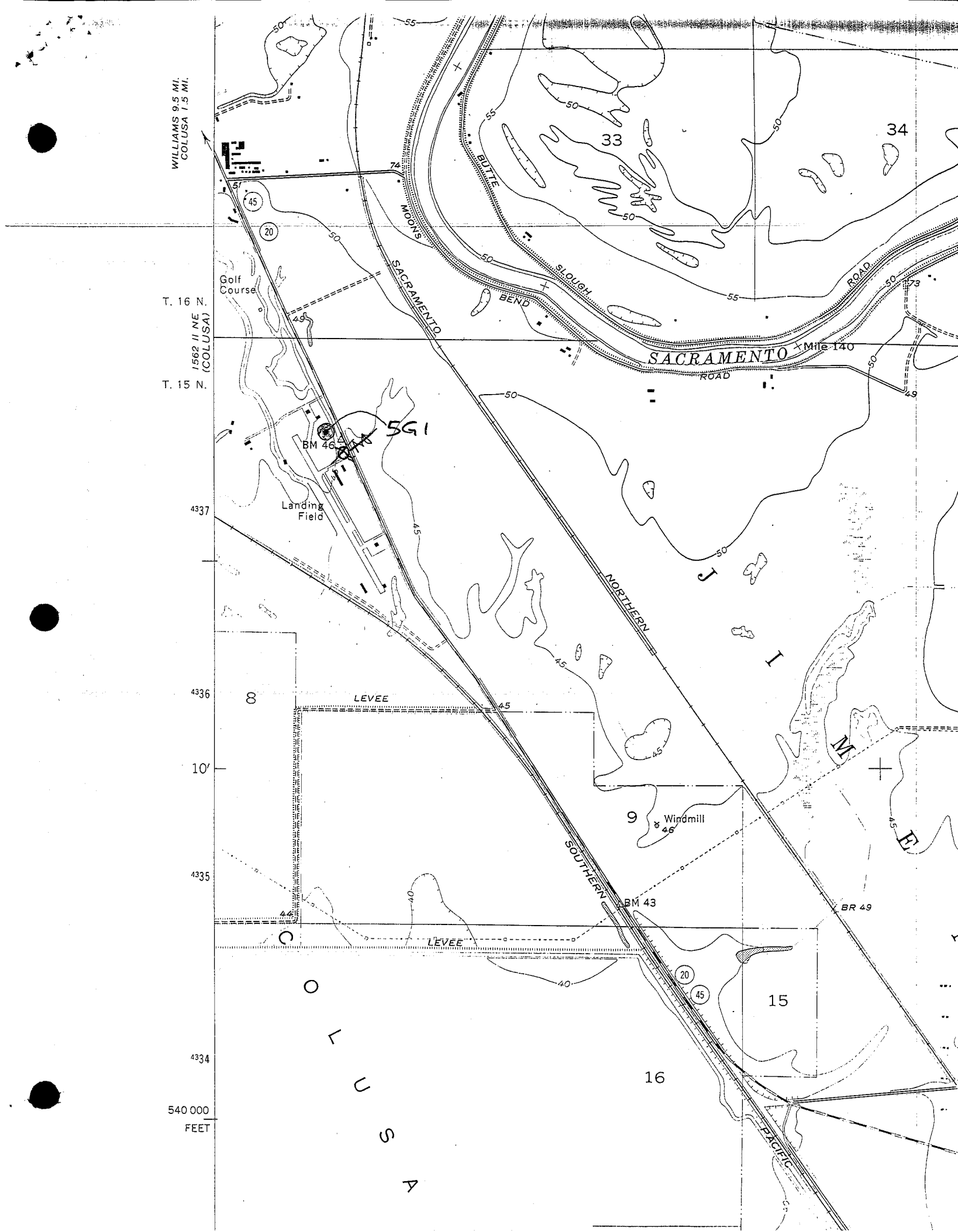
feet West from S. E. corner of Section

location not confirmed by owner - well I think is behind trailer at north gate of airport

Field Checked by

8-13-74

Date



WILLIAMS 9.5 MI.
COLUSA 1.5 MI.
T. 16 N.
1562 II NE (COLUSA)
T. 15 N.
Golf Course
Landing Field
BM 46
5G1
BM 43
Windmill
46
BR 49
SACRAMENTO
MOONS
BUTTE
SLOUGH
BEND
ROAD
SACRAMENTO
ROAD
Mile 140
NORTHERN
SOUTHERN
PACIFIC
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STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

JUL 14 1994

State No. 15N-1W-5G1

WELL DATA

DISTRICT Northern

Owner Colusa Co. Airport
Address Colusa 2915 Hwy. 20 - Colusa
Tenant Caretaker: Connor Davis
Address

State No. 15N/1W-5G1
Other No.

Type of Well: Hydrograph ☐ Key ☐ Index ☐ Semiannual ☐
Location: County Colusa Basin Colusa No.
U.S.G.S. Quad. Meridian Quad. No. 545b
¼ ¼ Section , Twp. , Rge. MD SB Base & Meridian
Description @ the Colusa Co. Airport. SE/ of Colusa on State Hwy 20 about 1 mile. Well is inside an aluminum clad P.H. 100' S/o HWY & 300' W/o gas pumps

Reference Point description Hole T.O.C.

which is T.O 1.4 ft. above below land surface. Ground Elevation 45.0 ft.
Reference Point Elev. 46.0 46.4 ft. Determined from Quad
Well: Use Industrial - Dom. Condition Depth 146 ft.
Casing, size x in., perforations 0-75 CSG, OPEN HOLE T. 140

Measurements By: DWR ☐ USGS ☐ USBR ☐ County ☐ Irr. Dist. ☐ Water Dist. ☐ Cons. Dist. ☐
Chief Aquifer: Name Depth to Top Aq. Depth to Bot. Aq.
Type of Material Perm. Rating Thickness
Gravel Packed? Yes ☐ No ☐ Depth to Top Gr. Depth to Bot. Gr.
Supp. Aquifer Depth to Top Aq. Depth to Bot. Aq.
Driller Beamer & Son Pump Co.
Date drilled 8/20/21 Log, filed #12982 open (1) confidential (2) 12982
Equipment: Pump, type Sub make
Serial No. Size of discharge pipe in.
Power, Kind Make
H. P. Motor Serial No.
Elec. Meter No. Transformer No.
Yield G.P.M. Pumping level ft.

Water Analysis: Min. (1) San. (2) H.M. (3)
Water Levels available: Yes (1) No
Period of Record: Begin 10-21-75 End ACTIVE
Collecting Agency:
Prod. Rec. (1) Pump Test (2) Yield (3)

SKETCH

N

REMARKS

1) ON 11-28-01 I SURVEYED IN A ACCURATE ELEV. TO THE R.P. FROM USGS B.M. . THE R.P. WELL CASING HAD BEEN EXTENDED IN FALL of 2000. No ACCURATE RECORD of THE EXTENSION WAS MADE So I DID THIS. SWH

WELL MEASUREMENT QUALIFICATION
By: P. LORENS 3666 Date 6/11/02
Qualification ~~COMPOSITE~~ Semi-Confined
Confidence: DEFINITE
Water Body: FLOODPLAIN DEPOSITS & older Basin Deposits

Recorded by: J. Bonnimiri
Date June 1989

DWR 429 (Rev. 4/70)

ORIGINAL
File Original, Duplicate and Triplicate with the
REGIONAL WATER POLLUTION
CONTROL BOARD No. 5
(Insert abbrobriate number)

WATER WELL DRILLERS REPORT

(Sections 7076, 7077, 7078, Water Code)

STATE OF CALIFORNIA

LOCATION NOT CHECKED
Do Not Fill In
No. 71038
State Well No.
Other Well No. 15N/2W-19

(1
Na
Ac

(2) LOCATION OF WELL: Lives on Abele Road
County Colusa Owner's number, if any—
R. F. D. or Street No. 30 feet East from Husted road a short way south from Crawford road in the Northwest 1/4 of Section 19, Township 15 North, Range 2 West, M.D.B. & M.

(3) TYPE OF WORK (*check*):
New well [X] Deepening [ ] Reconditioning [ ] Abandon [ ]
If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (*check*):
Domestic [ ] Industrial [ ] Municipal [ ]
Irrigation [X] Test Well [ ] Other [ ]

(5) EQUIPMENT:
Rotary [X]
Cable [ ]
Dug Well [ ]

(6) CASING INSTALLED:
SINGLE [X] DOUBLE [ ]

From ft. to	ft.	Diam.	Gage or Wall	Diameter of Bore	from ft.	to ft.
0	334	14"	3/16	24"	0	334
0	12	24"	"	28"	0	12

The 24 inch cemented in from 12 ft to surface

If gravel packed

Type and size of shoe or well ring Point
Size of gravel: 5/8"
Describe joint all joints welded

(7) PERFORATIONS:
Type of perforator used Factory punched double / standard
Size of perforations 1-1/2" in., length, by 3/16 in.

From ft. to	ft.	Perf. per row	Rows per ft.
162	174	4 per ft	29
174	182	4 " "	29
198	206	4 " "	29
262	274	4 " "	29
290	294	4 " "	29

(8) CONSTRUCTION:
Was a surface sanitary seal provided? [X] Yes [ ] No To what depth from surface to 12 ft. ft.
Were any strata sealed against pollution? [ ] Yes [X] No If yes, note depth of strata
From ft. to ft.
Method of Sealing Cement

(9) WATER LEVELS:
Depth at which water was first found 6 ft.
Standing level before perforating 16 ft.
Standing level after perforating 16 ft.

(10) WELL TESTS:
Was a pump test made? [X] Yes [ ] No If yes, by whom? W.P.Wilson&Sons
Yield: See 11 gal./min. with ft. draw down after ? hrs.
Temperature of water ? Was a chemical analysis made? [ ] Yes [X] No
Was electric log made of well? [ ] Yes [X] No

(11) WELL LOG:
Total depth 334 ft. Depth of completed well 334 ft.
Formation: *Describe by color, character, size of material, and structure.*

ft. to	ft.	
0	3	Soil
3	9	Sand and water
9	31	Clay
31	36	Gravel
36	44	Clay
44	48	Sand
48	61	Sandy clay
61	62	Gravel
62	161	Clay
161	168	Brittle
168	181	Gravel
181	198	Clay
198	206	Sand, some fine gravel
206	261	Clay
261	264	Sand
264	271	Clay
271	273	Clay with fine gravel
273	291	Clay
291	294	Brittle with fine gravel
294	311	Clay
311	329	Gravel

CONFIDENTIAL LOG
Water Code Sec. 13752

Plotted and Coded
As Well 15N/2W-19E80

CONFIDENTIAL
Section 7076.1, Water Code

Yield of well:

2750 GPM 90.5 feet
2115 " 85.0 "
1950 " 82.0 "

3 minute comeback 54 feet

Perforations continued:

310 ft to 314 ft 4 per ft 29 rows
314 " " 334 " 4 " " 29 "

Work started May 3 1962 Completed May 16 1962

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Aulman & Aulman
(Person, firm, or corporation) (Typed or printed)
Address 1309 Westwood Way
Woodland, Calif.
[SIGNED] [signature]
Well Driller
License No. 109870 Dated 7/1/61, 19

57025 8-53 30M QUIN △ SPO DWR 188 (REV. 3-54)

WATER WELL DRILLERS REPORT

FIELD WORK SHEET

Report No. 71038

Owner

Pump No. 1275316

Meter No. NONE

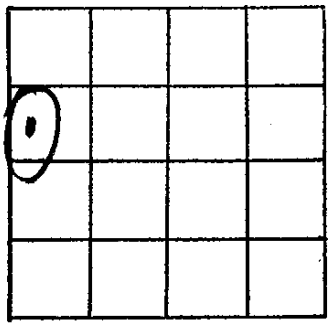
LOCATION

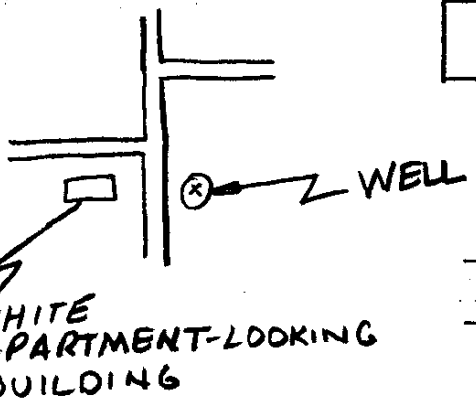
Section 19E

Township 15N

Range 2W

see attached for location





_____ feet North,

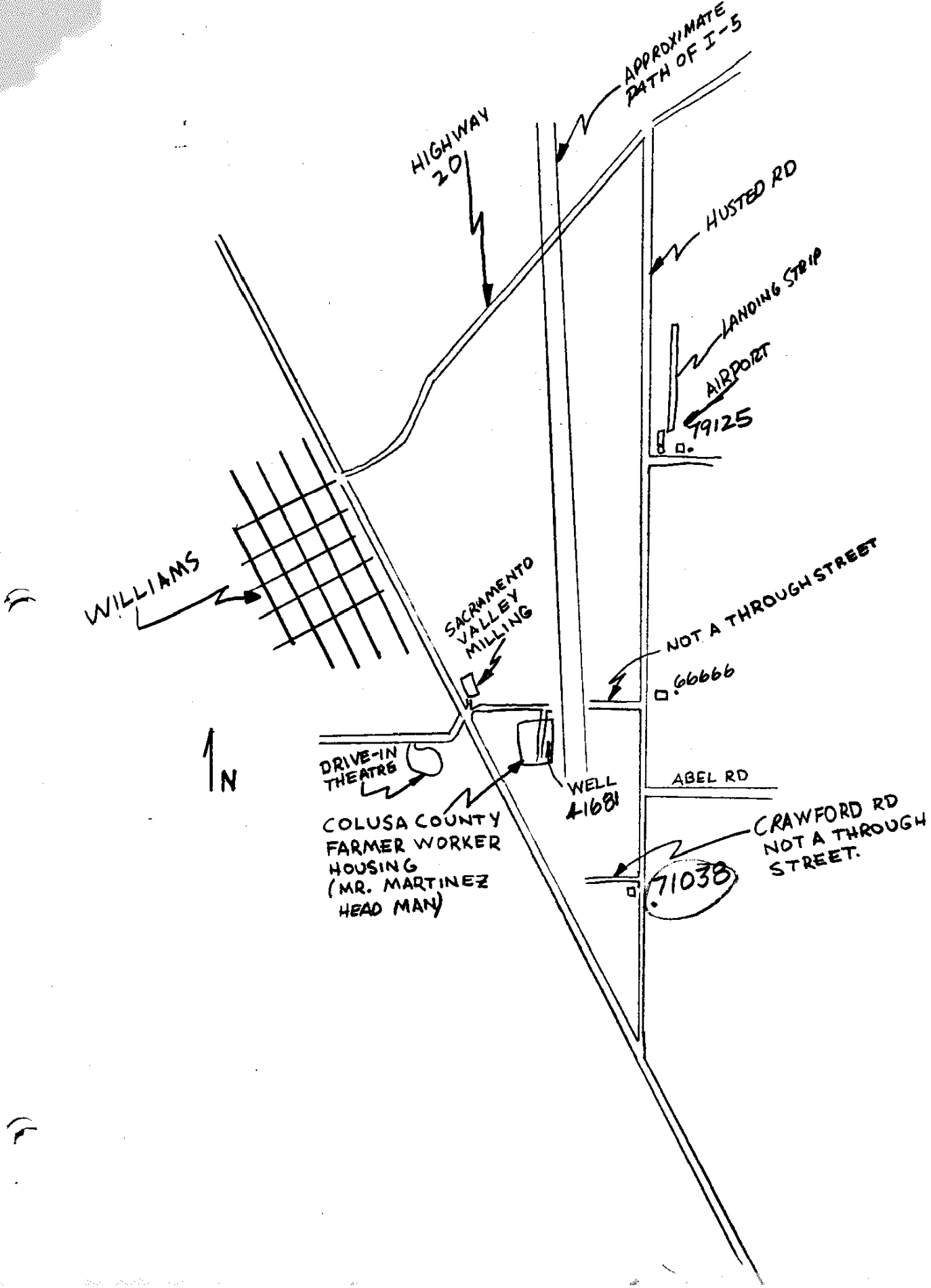
_____ feet West from S. E. corner of Section

REMARKS

measurable by small hole in north side — no PG&E meter number — maybe not being used

Sam
Field Checked by

8-15-74
Date


APPROXIMATE PATH OF I-5
HIGHWAY 20
HUSTED RD
LANDING STRIP
AIRPORT
79125
WILLIAMS
SACRAMENTO VALLEY MILLING
NOT A THROUGH STREET
66666
N
DRIVE-IN THEATRE
WELL 41681
ABEL RD
COLUSA COUNTY FARMER WORKER HOUSING (MR. MARTINEZ HEAD MAN)
CRAWFORD RD NOT A THROUGH STREET.
71038

ORIGINAL
File with DWR

RECEIVED
MAR 05 1993
D.W.R.

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 492125

DWR USE ONLY — DO NOT FILL IN
15N/03W-08M
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Page 1 of 1
Owner's Well No. 6256
Date Work Began 11/30/92 Ended 12/03/92
Local Permit Agency COLUSA CO ENVIRONMENTAL HEALTH
Permit No. _____ Permit Date 11/12/92

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DEPTH TO FIRST WATER _____ (Ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	10	TOP SOIL
10	30	CLAY
30	85	GRAVEL
85	88	CLAY, SOME SAND
88	130	SMALL SANDY GRAVEL
130	250	CLAY
250	350	SAND, MOSTLY CLAY

TOTAL DEPTH OF BORING 360 (Feet)
TOTAL DEPTH OF COMPLETED WELL 350 (Feet)

WELL OWNER

WELL LOCATION

Address .5 MI W OF E CAMP RD & HWY 20
City 35' E OF CANAL
County COLUSA
APN Book 16 Page 060 Parcel 23
or
Township 15N Range 03W Section 08
or
Latitude ___ DEG. ___ MIN. ___ SEC. NORTH Longitude ___ DEG. ___ MIN. ___ SEC. WEST

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc.
PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USE(S) (✓)

___ MONITORING
WATER SUPPLY
___ Domestic
___ Public
X Irrigation
___ Industrial
___ "TEST WELL"
___ CATHODIC PROTECTION
___ OTHER (Specify)

DRILLING METHOD REVERSE FLUID WATER

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL _____ (Ft.) & DATE MEASURED _____
ESTIMATED YIELD* _____ (GPM) & TEST TYPE _____
TEST LENGTH _____ (Hrs.) TOTAL DRAWDOWN _____ (Ft.)
* *May not be representative of a well's long-term yield.*

CASING(S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL/GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	140	28"	X				ASTM-135	12-3/4	.250	
140	250	22"	X				ASTM-135	10-3/4	.250	
250	350	22"		X			HOUSTON CULT	10-3/4		0.050
0	30						T & C	2"		
30	130	28"		X			HOUSTON CULT	16"		0.050

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	20	X			SAND SLURRY
20	150			X	6X16 SAND PACK
150	210			X	GRAVEL
210	360			X	6X16 SAND PACK

MAR 13 1993

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other _____

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING COMPANY, INC. 24
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

20 W. Kentucky Ave. Woodland CA 95695
ADDRESS CITY STATE ZIP

Signed Jim Eaton
WELL DRILLER/AUTHORIZED REPRESENTATIVE

03/04/93 DATE SIGNED

133783C57 C-57 LICENSE NUMBER

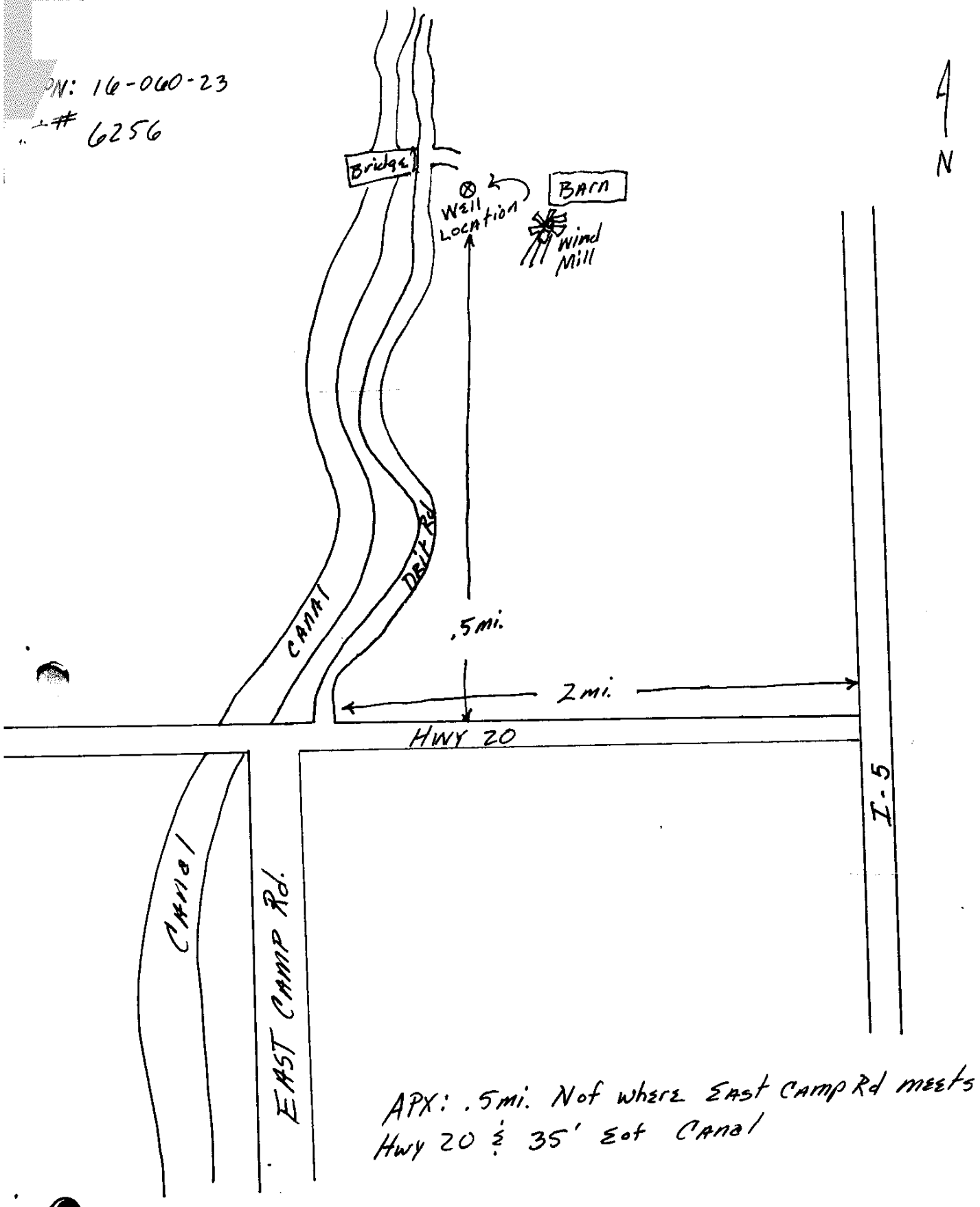
DWR 188 REV. 7-90

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

[redacted]

APN: 16-060-23

Well # 6256



APX: .5mi. N of where East Camp Rd meets Hwy 20 & 35' E of Canal

ORIGINAL
File with DWR

Page 1 of 2

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

Owner's Well No. 15N03W20Q001M No. 802508A

Date Work Began 2-9-09 Ended 2-25-09

Local Permit Agency Colusa County

Permit No. _____ Permit Date _____

DWR USE ONLY — DO NOT FILL IN

15N/03W-20Q

STATE WELL NO./STATION NO.

LATITUDE _____ LONGITUDE _____

APN/TRS/OTHER _____

GEOLOGIC LOG

ORIENTATION (✓) ___ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD _____ FLUID _____

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
		Silt yellow brown ML 10yr 5/4
0	12	100% Silt
12	22	Clay Yellow Brn. CL 10yr 6/6
22	34	Silt Yell Brn ML 10yr 6/6
34	40	Sand w Gravel SW 10yr 6/4
40	44	Clayey Gravel GC 10yr 5/4
44	60	Silt Yellow Brn ML 10yr 5/4
60	65	Clay Yellow Brn CL 10yr 5/4
65	74	Gravel w Sand GW 10yr 5/2
74	81	Clay Yellow Brn CL 10yr 5/6
81	94	Silt w Gravel ML 10yr 5/4
94	110	Clay Yell Brn 10yr 5/4 CL
110	115	Clay Yell Org. 10yr 6/6
115	123	Silt Yell Org. ML 10yr 6/6
123	140	Clay Yell Brn. CL 10yr 6/4
140	145	Silty Gravel w Sand GM 10yr
145	160	Silt Yell Brn ML 10yr 5/4
160	172	Silt Yell Brn ML 10yr 6/2
172	180	Silt Yell Brn ML 10yr 5/4
180	185	Clay Brn CL 10YR 4/4
185	193	Silt Olive Gray ML 5Y 4/1
193	210	Clay Green Gray CL 5GY 4/1
210	220	Silt Green Gray ML 5GY 4/1
220	235	Clay Olive Gray CL 5Y 4/1
235	250	Silt Olive Gray ML 5Y 6/1
250	253	Sand Green Clay SW 5GY 4/1
253	274	Silt Greenish Gray ML 5/4
274	280	Silt Green Gray ML 5GY 4/1
280	300	Silt Green Gray ML 5GY 4/1

TOTAL DEPTH OF BORING 620 (Feet)

TOTAL DEPTH OF COMPLETED WELL 420 (Feet)

WELL LOCATION

Address East Camp & Pumphouse Rds

City Williams

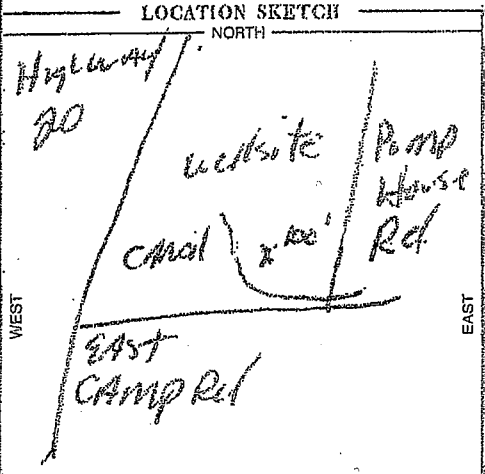
County Colusa

APN Book ___ Page ___ Parcel ___

Township 15N Range 03W Section 20

Latitude ___ DEG. ___ MIN. ___ SEC. NORTH Longitude ___ DEG. ___ MIN. ___ SEC. WEST

LOCATION SKETCH



Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

- ✓ NEW WELL
- MODIFICATION/REPAIR
  - ___ Deepen
  - ___ Other (Specify)
- ___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USES (✓)

WATER SUPPLY
- ___ Domestic ___ Public
- ___ Irrigation ___ Industrial

- MONITORING ✓
- TEST WELL ___
- CATHODIC PROTECTION ___
- HEAT EXCHANGE ___
- DIRECT PUSH ___
- INJECTION ___
- VAPOR EXTRACTION ___
- SPARGING ___
- REMEDIATION ___
- OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE ~ 1793

DEPTH OF STATIC WATER LEVEL A 16.04 B 15.69 (Ft.) & DATE MEASURED ___

ESTIMATED YIELD * 3 (GPM) & TEST TYPE Bailer

TEST LENGTH 2 (Hrs.) TOTAL DRAWDOWN ~ 1 (Ft.)

** May not be representative of a well's long-term yield.*

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	150	12								
150	425	9 7/8								
425	620	6 1/2								
0	30		✓				Sch 80 PVC	2.5	50	
30	80			✓			"	"	"	020
80	90		✓				"	"	"	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	25	✓	✓		
25	29		✓		
29	82				#3 Sand
82	117		✓		Grout
117	121		✓		Chip
121	150				#3 Sand

ATTACHMENTS (✓)

- ___ Geologic Log
- ___ Well Construction Diagram
- ___ Geophysical Log(s)
- ___ Soil/Water Chemical Analyses
- ___ Other _____

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Layne Exploration (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

ADDRESS PO Box 1461 CITY Zamora STATE CA ZIP 95698

Signed _____ (WELL DRILLER/AUTHORIZED REPRESENTATIVE) DATE SIGNED 4-7-09 C-57 LICENSE NUMBER 283326

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page ___ of ___

Owner's Well No. ___

Date Work Began ___ Ended ___

Local Permit Agency ___

Permit No. ___ Permit Date ___

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 802510

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION (✓) ___ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD ___ FLUID ___

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
350	390	Gravel Green Blk SOY 2Y
390	402	Silt Green Gray ML SOY 4Y
402	409	Gravel Org Blk SO SOY BY
409	420	Silt Blue Gray ML SO 4Y
420	448	Silt Blue Gray ML SO 3Y
448	452	Sand Blue Gray SP SO 2Y
452	460	Silt Blue Gray ML SO 3Y
460	480	Silt " " " "
480	505	Silt Blue Gray ML SO 3Y
505	520	Silt Green Gray ML SOY 6Y
520	532	Silt Green Gray ML SO 6Y
532	540	Silt Green Gray ML SO 6Y
540	560	Silt Green " ML SO 6Y
560	570	Silt Blue " ML SO 5Y
570	580	Silt Blue " ML SO 5Y
580	600	Silt Green " ML SOY 6Y
600	620	Silt Green " ML SOY 6Y

TOTAL DEPTH OF BORING 620 (Feet)

TOTAL DEPTH OF COMPLETED WELL 420 (Feet)

WELL OWNER

Name ___

Mailing Address ___

CITY STATE ZIP

WELL LOCATION

Address ___

City ___

County ___

APN Book ___ Page ___ Parcel ___

Township ___ Range ___ Section ___

Latitude ___ DEG. ___ MIN. ___ SEC. NORTH

Longitude ___ DEG. ___ MIN. ___ SEC. WEST

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

___ NEW WELL

MODIFICATION/REPAIR

___ Deepen

___ Other (Specify)

___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USES (✓)

WATER SUPPLY

___ Domestic ___ Public

___ Irrigation ___ Industrial

___ MONITORING

___ TEST WELL

___ CATHODIC PROTECTION

___ HEAT EXCHANGE

___ DIRECT PUSH

___ INJECTION

___ VAPOR EXTRACTION

___ SPARGING

___ REMEDIATION

___ OTHER (SPECIFY)

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___

ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___

TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)

* *May not be representative of a well's long-term yield.*

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	330		✓				PVC	2.5	Sch 80	
330	460			✓			PVC	2.5	Sch 80	020
460	620		✓				PVC	2.5	Sch 80	
0	370		✓				PVC	4.5	Sch 80	
370	410			✓			PVC	4.5	Sch 80	020
410	420		✓				PVC	4.5	Sch 80	020

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
180	354		✓		Grout
354	360		✓		Chips
360	424				#3 Sand
424	620	✓	✓		

ATTACHMENTS (✓)

___ Geologic Log

✓ Well Construction Diagram

___ Geophysical Log(s)

___ Soil/Water Chemical Analyses

___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME WDC Exploration (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

ADDRESS PO Box 161 CITY Zamora STATE CA ZIP 95698

Signed ___ (WELL DRILLER/AUTHORIZED REPRESENTATIVE)

DATE SIGNED 9-17-09 C-57 LICENSE NUMBER 933326

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

DUPLICATE
Driller's Copy

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 726832 A, B, C

DWR USE ONLY — DO NOT FILL IN
16N/02W-05
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7546
Date Work Began 6/9/2003, Ended 6/17/2003
Local Permit Agency COLUSA COUNTY HEALTH DEPT
Permit No. 2003-77 Permit Date 6/3/2003

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID WATER

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	18	OLIVE/BROWN CLAY
18	24	YELLOW/BROWN SILT
24	40	YELLOW/BROWN CLAY
40	66	ORANGE/BROWN CLAY
66	106	YELLOW/BROWN CLAY
106	126	OLIVE/GRAY CLAY
126	170	OLIVE/GRAY CLAY W/SML GRAVEL STREAKS
170	187	WELL GRADED GRAVEL
187	226	YELLOW/BROWN CLAY
226	236	OLIVE/GRAY CLAY
236	260	WELL GRADED GRAVEL W/COBBLE STREAKS
260	306	YELLOW/GRAY CLAY
306	320	OLIVE/GRAY CLAY
320	340	GRN/GRY CLY AND SND W/SML GRVL STRKS
340	346	POORLY GRADED SAND
346	366	GREEN/GRAY CLAY
366	386	GREEN/GRAY CLAY WITH SAND STREAKS
386	426	GREEN/GRAY CLAY AND SAND
426	446	OLIVE/GRAY CLAY AND SAND
446	456	OLIVE/BROWN CLAY AND SAND
456	476	POORLY GRADED GRAVEL WITH SILT
476	486	BLUE/GRAY CLAY
486	534	OLIVE/BROWN CLAY
534	542	WELL GRADED GRAVEL WITH SAND
542	606	YELLOW/GRAY CLAY
606	618	GREEN/GRAY CLAY WITH SAND
618	640	WELL GRADED GRAVEL WITH SAND
640	650	CLAY
650	664	WELL GRADED GRAVEL WITH SAND
664	668	CLAY

TOTAL DEPTH OF BORING 986 (Feet)
TOTAL DEPTH OF COMPLETED WELL 813 (Feet)

WELL OWNER

WELL LOCATION
Address 30 FT S OF MAXWELL RD & .6 MI E OF 4 MILE RD
City CA
County COLUSA
APN Book 030 Page 910 Parcel 010
Township 16 N Range 2 W Section 5
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH
NORTH
e-log on file
WEST
EAST
SOUTH
Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ✓
EXTENSOMETE

WATER LEVEL & YIELD OF COMPLETED WELL
DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	18	36			✓		BLK STEEL	24		
ZONE	1									
0.0	174.1	36/18	✓				PVC	2.5	SCH 80	
174.1	183.7	18		✓			SS WR WR	2.5		0.020
183.7	245.8	18	✓				PVC	2.5	SCH 80	
245.8	255.4	18		✓			SS WR WR	2.5		0.020

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL	FILTER PACK (TYPE/SIZE)
0	18	#103	✓		SAND SLURRY
0	117		✓		HALIBURTON
117	301			✓	#8 GRD SAND
301	433		✓		HALIBURTON
433	535			✓	#8 GRD SAND
535	673		✓		HALIBURTON

JUL 2003

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT
I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY AVE. WOODLAND CA 95695
ADDRESS CITY STATE ZIP
Signed [signature] 07/11/03
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED
C57 A HIC - 133783
C-57 LICENSE NUMBER

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

DUPLICATE
Driller's Copy

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 726832

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7546
Date Work Began 6/9/2003, Ended 6/17/2003
Local Permit Agency COLUSA COUNTY HEALTH DEPT.
Permit No. 2003-77 Permit Date 6/3/2003

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID WATER

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
668	688	WELL GRADED GRAVEL WITH SAND
688	706	GREEN/GRAY CLAY
706	720	GREEN/GRAY CLAY WITH FINE SAND
720	747	POORLY GRADED GRAVEL WITH SAND
747	766	WELL GRADED GRAVEL W/COARSE SAND
766	826	GRAY/GREEN CLAY W/FINE SAND AND SILT
826	846	OLIVE/BROWN CLAY
846	860	GRAY/GREEN CLAY WITH SILT
860	875	POORLY GRADED GRAVEL
875	906	GRAY CLAY W/FINE SAND AND SILT STREAKS
906	946	GRY/BLK CLY W/FINE SAND AND SILT STRKS
946	986	BLU/GRY CLY W/FINE SAND AND SILT STRKS

TOTAL DEPTH OF BORING 986 (Feet)
TOTAL DEPTH OF COMPLETED WELL 813 (Feet)

WELL LOCATION

Address 30 FT S OF MAXWELL RD & .6 MI E OF 4 MILE RD
City CA
County COLUSA
APN Book 030 Page 910 Parcel 010
Township 16 N Range 2 W Section 5
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ✓
EXTENSOMETE

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
255.4	276.6	18	✓				PVC	2.5	SCH 80	
ZONE	2									
0.0	730.0	36/18	✓				BLK STEEL	4		
730.0	750.0	18		✓			MILLSLOT	4		0.060
750.0	813.0	18	✓				BLK STEEL	4		
ZONE	3									

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
673	797			✓	#8 GRD SAND
797	986	✓			SAND SLURRY

AUG 12 2003

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

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20 W. KENTUCKY AVE. ADDRESS WOODLAND CITY CA STATE 95695 ZIP
Signed ___ WELL DRILLER/AUTHORIZED REPRESENTATIVE
07/11/03 DATE SIGNED
C57 A HIC - 133783 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

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DUPLICATE
Driller's Copy
Page 3 of 6

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 726832

DWR USE ONLY --- DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7546
Date Work Began 6/9/2003, Ended 6/17/2003
Local Permit Agency COLUSA COUNTY HEALTH DEPT
Permit No. 2003-77 Permit Date 6/3/2003

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID WATER

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	18	OLIVE/BROWN CLAY
18	24	YELLOW/BROWN SILT
24	40	YELLOW/BROWN CLAY
40	66	ORANGE/BROWN CLAY
66	106	YELLOW/BROWN CLAY
106	126	OLIVE/GRAY CLAY
126	170	OLIVE/GRAY CLAY W/SML GRAVEL STREAKS
170	187	WELL GRADED GRAVEL
187	226	YELLOW/BROWN CLAY
226	236	OLIVE/GRAY CLAY
236	260	WELL GRADED GRAVEL W/COBBLE STREAKS
260	306	YELLOW/GRAY CLAY
306	320	OLIVE/GRAY CLAY
320	340	GRN/GRY CLY AND SND W/SML GRVL STRKS
340	346	POORLY GRADED SAND
346	366	GREEN/GRAY CLAY
366	386	GREEN/GRAY CLAY WITH SAND STREAKS
386	426	GREEN/GRAY CLAY AND SAND
426	446	OLIVE/GRAY CLAY AND SAND
446	456	OLIVE/BROWN CLAY AND SAND
456	476	POORLY GRADED GRAVEL WITH SILT
476	486	BLUE/GRAY CLAY
486	534	OLIVE/BROWN CLAY
534	542	WELL GRADED GRAVEL WITH SAND
542	606	YELLOW/GRAY CLAY
606	618	GREEN/GRAY CLAY WITH SAND
618	640	WELL GRADED GRAVEL WITH SAND
640	650	CLAY
650	664	WELL GRADED GRAVEL WITH SAND
664	668	CLAY

TOTAL DEPTH OF BORING 986 (Feet)
TOTAL DEPTH OF COMPLETED WELL 813 (Feet)

WELL LOCATION

Address 30 FT S OF MAXWELL RD & .6 MI E OF 4 MILE RD
City CA
County COLUSA
APN Book 030 Page 910 Parcel 010
Township 16 N Range 2 W Section 5
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ✓
EXTENSOMETE

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0.0	462.4	36/18	✓				PVC	2.5	SCH 80	
462.4	473.4	18		✓			SS WR WR	2.5		0.020
473.4	494.6	18	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	18	✓			SAND SLURRY
0	117		✓		HALIBURTON
117	301			✓	#8 GRD SAND
301	433				HALIBURTON
433	535			✓	#8 GRD SAND
535	678		✓		HALIBURTON

NOV 12 2003

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

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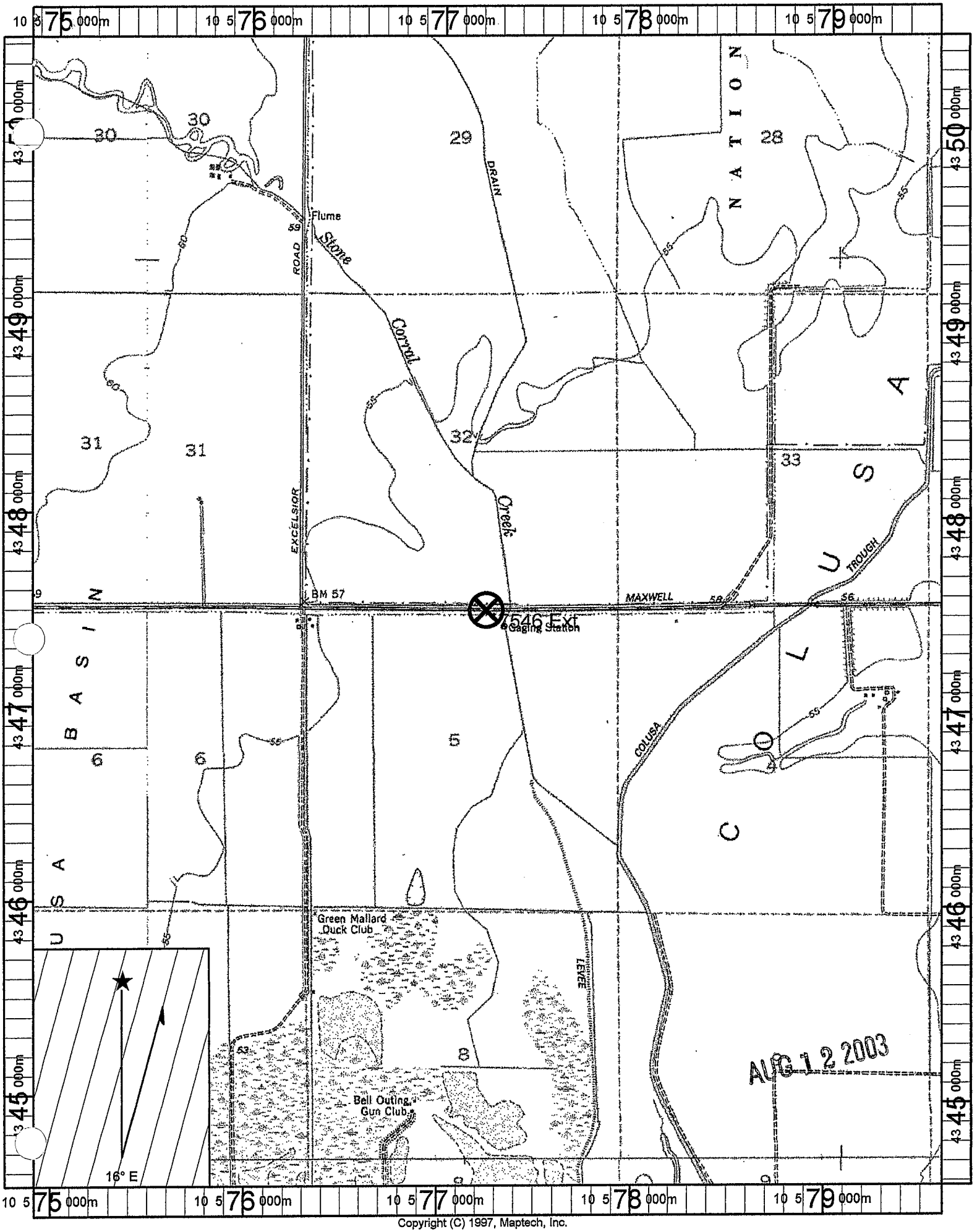
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY AVE WOODLAND CA 95695
ADDRESS CITY STATE ZIP
Signed [signature] 07/11/03
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED
C57 A HIC - 133783
C-57 LICENSE NUMBER

DWR 188 REV. 11-97
IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM



Copyright (C) 1997, Maptech, Inc.

[redacted]

16N/2W-25B2

Date June 17, 1965

Rig No. NE Grussenmeyer

Driller in Charge Clarence Dobbin

Location 3/4 mi west Colusa

Depth of Hole 274 feet. Size 8" Water Level

th of Casing 274 feet.

FORMATION: (State every Stratum and Condition)

n	0	feet to	54	feet	84 - gravel
om	84	feet to	96	feet	hard gravel Clay
om	96	feet to	212	feet	brown clay
rom	212	feet to	270	feet	blue clay
rom	270	feet to	274	feet	coarse gravel
From		feet to		feet	Bottom
From		feet to		feet	
From		feet to		feet	

Remarks:

Owner says This well is perforated at the Bottom 20' only. Bauers

2-Mile Rd Well

16N/03W-14H003-6 M

ORIGINAL
File with DWR

Page 1 of 4

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. E0116237

DWR USE ONLY — DO NOT FILL IN
16N/03W-14
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 8469
Date Work Began 8/16/2010, Ended 8/27/2010 ABCD
Local Permit Agency Colusa County Health Dept
Permit No. WP0000085 Permit Date 8/10/2010

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	5	Top soil
5	660	Sandy brown clay with small gravel streaks
660	1130	Sandy blue clay with sand streaks
1130	1230	Sand and gravel
1230	1350	Sandy blue clay
1350	1440	Black sand with gravel
1440	1500	Blue clay

TOTAL DEPTH OF BORING 1500 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1440 (Feet)

WELL LOCATION

Address 30' Wof 2 Mile Rd & 1.6 Mi Nof
City Lurline Ave CA
County COLUSA
APN Book 014 Page 210 Parcel 005
Township 16 N Range 3 W Section 14
Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)
WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ——— (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ——— (Ft.) & DATE MEASURED ———
ESTIMATED YIELD * ——— (GPM) & TEST TYPE ———
TEST LENGTH ——— (Hrs.) TOTAL DRAWDOWN ——— (Ft.)
May not be representative of a well's long-term yield.

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	CASING (S) TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
Zone	1									
0	295	14	✓				PVC	2.5	SCH 80	
295	305	14		✓			PVC	2.5	SCH 80	.035
305	315	14	✓				PVC	2.5	SCH 80	
Zone	2									
0	720	14	✓				PVC	2.5	SCH 80	

DEPTH FROM SURFACE Ft.	to Ft.	ANNULAR MATERIAL TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	169	✓			Sand Slurry
169	252			✓	SRI#8 Sand
252	270		✓		Bentonite Seal
270	378			✓	SRI#8 Sand
378	383		✓		Bentonite Seal
383	475			✓	SRI#8 Sand

ATTACHMENTS (✓)
— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
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ADDRESS CITY STATE ZIP
Signed [signature] 09/01/10
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED
C57 A 133783
C-57 LICENSE NUMBER

DWR 188 REV. 11-97

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ORIGINAL
File with DWR

Page 2 of 4

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. E0116237

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 8469
Date Work Began 8/16/2010, Ended 8/27/2010
Local Permit Agency Colusa County Health Dept
Permit No. WP0000085 Permit Date 8/10/2010

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft. to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0 – 5	Top soil
5 – 660	Sandy brown clay with small gravel streaks
660 – 1130	Sandy blue clay with sand streaks
1130 – 1230	Sand and gravel
1230 – 1350	Sandy blue clay
1350 – 1440	Black sand with gravel
1440 – 1500	Blue clay

TOTAL DEPTH OF BORING 1500 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1440 (Feet)

WELL LOCATION
Address 30' Wof 2 Mile Rd & 1.6 Mi Nof
City Lurline Ave CA
County COLUSA
APN Book 014 Page 210 Parcel 005
Township 16 N Range 3 W Section 14
Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH
WEST EAST
SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)
WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ——— (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ——— (Ft.) & DATE MEASURED ———
ESTIMATED YIELD * ——— (GPM) & TEST TYPE ———
TEST LENGTH ——— (Hrs.) TOTAL DRAWDOWN ——— (Ft.)
May not be representative of a well's long-term yield.

DEPTH FROM SURFACE Ft. to Ft.	BORE-HOLE DIA. (Inches)	CASING (S) TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
720 – 730	14		✓			PVC	2.5	SCH 80	.035
730 – 740	14	✓				PVC	2.5	SCH 80	
Zone 3									
0 – 1140	10	✓				PVC	2.5	SCH 80	
1140 – 1150	10		✓			PVC	2.5	SCH 80	.035
1150 – 1170	10	✓				PVC	2.5	SCH 80	

DEPTH FROM SURFACE Ft. to Ft.	ANNULAR MATERIAL TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
475 – 515		✓		Bentonite Seal
515 – 700			✓	SRI#8 Sand
700 – 710		✓		Bentonite Seal
710 – 775			✓	SRI#8 Sand
775 – 800		✓		Bentonite Seal
800 – 904			✓	SRI#8 Sand

ATTACHMENTS (✓)
— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other ———
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

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DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	5	Top soil
5	660	Sandy brown clay with small gravel streaks
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1130	1230	Sand and gravel
1230	1350	Sandy blue clay
1350	1440	Black sand with gravel
1440	1500	Blue clay

TOTAL DEPTH OF BORING 1500 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1440 (Feet)

WELL OWNER

Address 30' Wof 2 Mile Rd & 1.6 Mi Nof
City Lurline Ave CA
County COLUSA
APN Book 014 Page 210 Parcel 005
Township 16 N Range 3 W Section 14
Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

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ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)
WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED
ESTIMATED YIELD * — (GPM) & TEST TYPE
TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
1170	1180	10		✓			PVC	2.5	SCH 80	.035
1180	1200	10	✓				PVC	2.5	SCH 80	
Zone	4									
0	1370	8.75	✓				PVC	2.5	SCH 80	
1370	1380	8.75		✓			PVC	2.5	SCH 80	.035
1380	1410	8.75	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
904	922		✓		Bentonite Seal
922	1005			✓	SRI#8 Sand
1005	1026		✓		Bentonite Seal
1026	1078			✓	SRI#8 Sand
1078	1106		✓		Bentonite Seal
1106	1236			✓	SRI#8 Sand

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

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Signed _____ 09/01/10 C57 A 133783
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 4 of 4

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. E0116237

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 8469
Date Work Began 8/16/2010, Ended 8/27/2010
Local Permit Agency Colusa County Health Dept
Permit No. WP0000085 Permit Date 8/10/2010

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	5	Top soil
5	660	Sandy brown clay with small gravel streaks
660	1130	Sandy blue clay with sand streaks
1130	1230	Sand and gravel
1230	1350	Sandy blue clay
1350	1440	Black sand with gravel
1440	1500	Blue clay

TOTAL DEPTH OF BORING 1500 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1440 (Feet)

WELL OWNER

Address 30' Wof 2 Mile Rd & 1.6 Mi Nof
City Lurline Ave CA
County COLUSA
APN Book 014 Page 210 Parcel 005
Township 16 N Range 3 W Section 14
Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)
WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED
ESTIMATED YIELD * — (GPM) & TEST TYPE
TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
1410	1420	8.75		✓			PVC	2.5	SCH 80	.035
1420	1440	8.75	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
1236	1261		✓		Bentonite Seal
1261	1295			✓	SRI#8 Sand
1295	1322		✓		Bentonite Seal
1322	1481			✓	SRI#8 Sand
1481	1488		✓		Bentonite Seal
1488	1500			✓	Native Fill

ATTACHMENTS (✓)

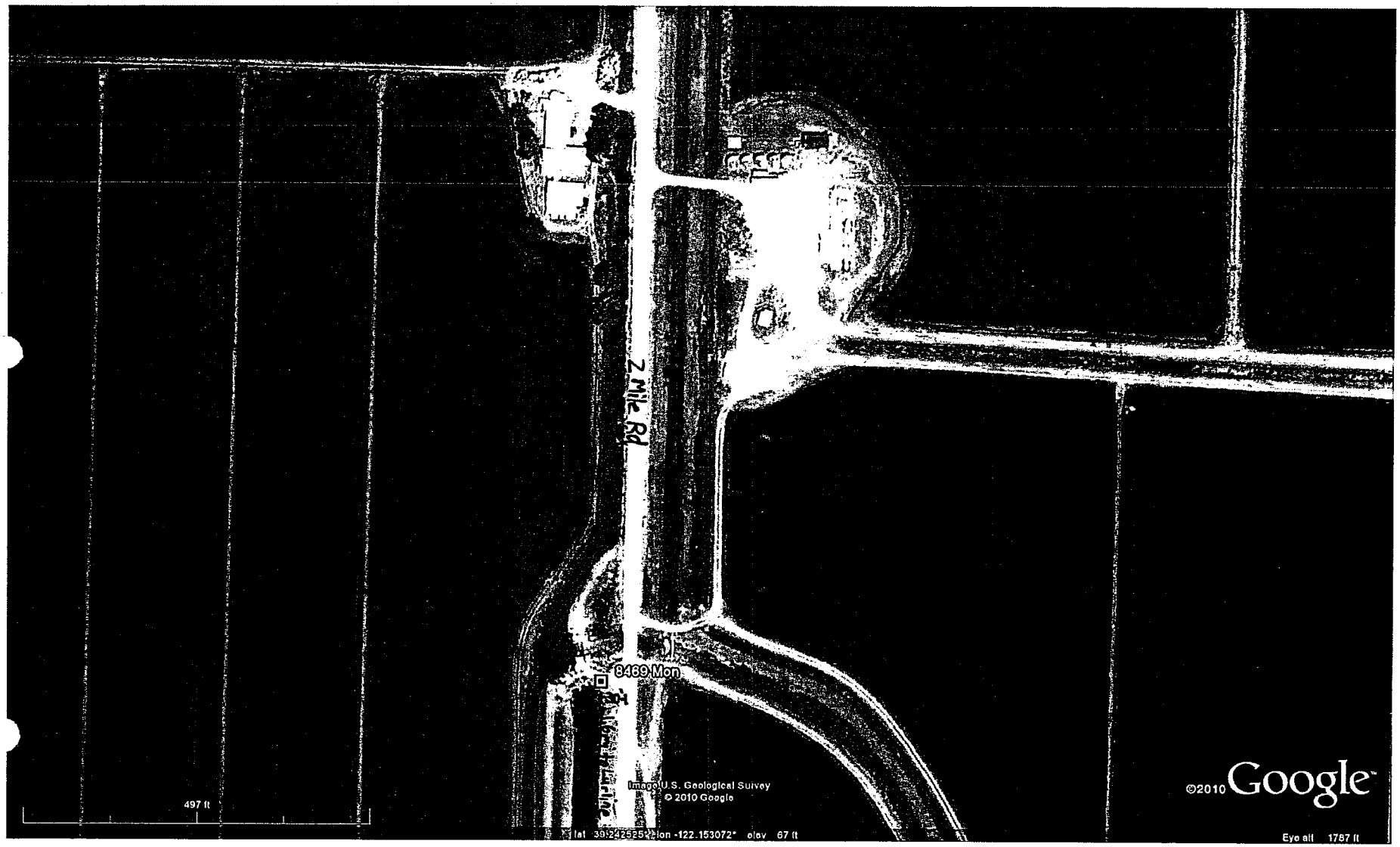
— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

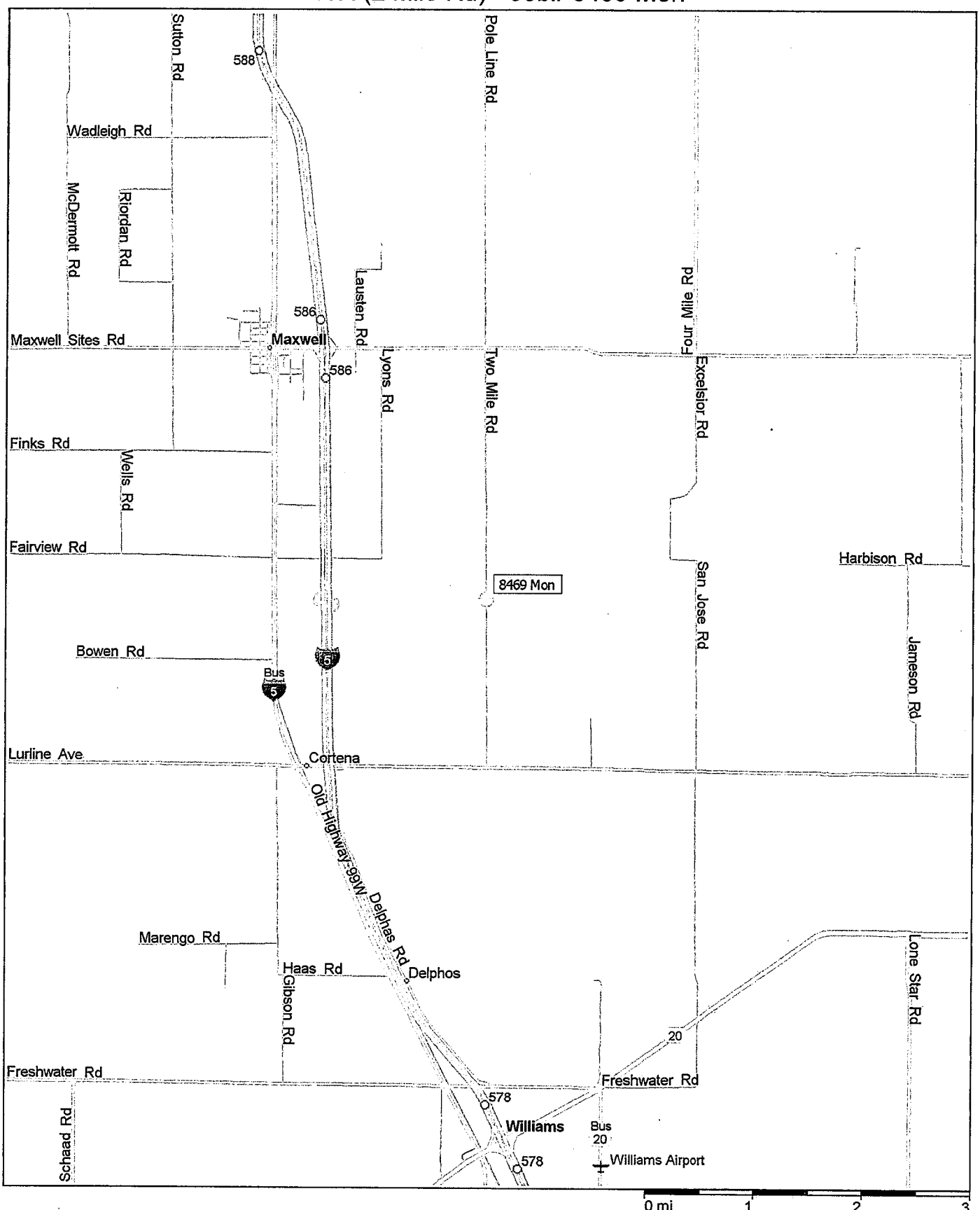
I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. Kentucky Ave ADDRESS — Woodland CITY — CA STATE — 95695 ZIP
Signed _____ WELL DRILLER/AUTHORIZED REPRESENTATIVE — 09/01/10 DATE SIGNED — C57 A 133783 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM


Z Mile Rd
8489 Mon
497 ft
Image U.S. Geological Survey
© 2010 Google
©2010 Google
Eye alt 1787 ft

DWR (2 Mile Rd) - Job# 8469 Mon



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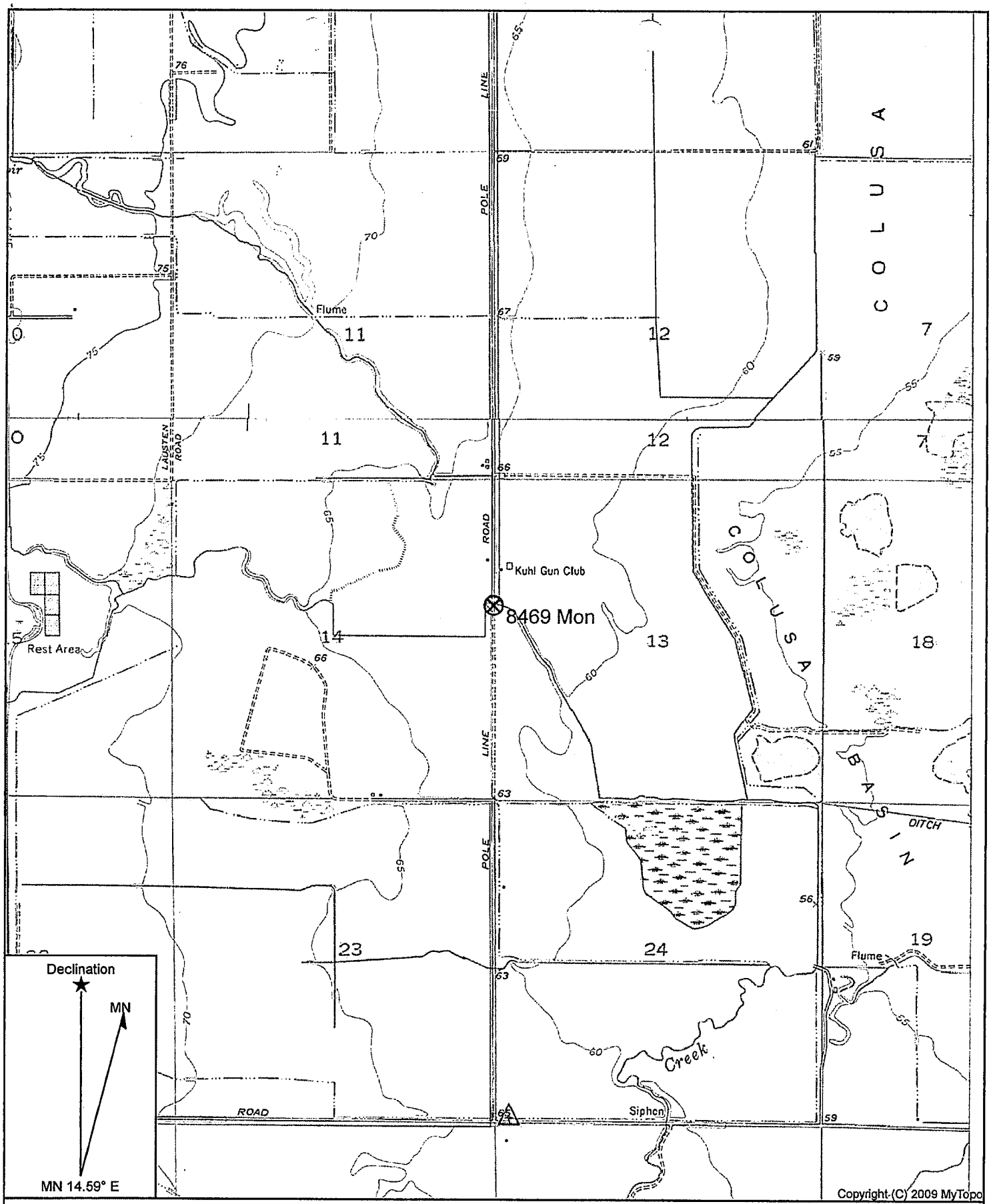


Name: WILLIAMS
Date: 08/09/10
Scale: 1 inch = 2,000 ft.

Location: 039.2415200° N 122.1535400° W
DWR (2 Mile Rd) - Job# 8469 Mon
APN: 014-210-004
T16N R3W s14

LOCATION NOT CHECKED

ORIGINAL
File Original, Duplicate and Triplicate with the
REGIONAL WATER POLLUTION
CONTROL BOARD No. 5
(Insert appropriate number)

WATER WELL DRILLERS REPORT
(Sections 7076, 7077, 7078, Water Code)

STATE OF CALIFORNIA

Do Not Fill In
No 77484
State Well No. 2P
Other Well No. 16N/4W-8

(1) OW
Name
Address

(2) LOCATION OF WELL:
County Colusa Co. Owner's number, if any—
R. F. D. or Street No.
Sec. 11, TWP 16 N, R 4 W
300' west of Mills Orchard Rd.

(3) TYPE OF WORK (*check*):
New well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (*check*):
Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other (stock) ☒

(5) EQUIPMENT:
Rotary ☒
Cable ☐
Dug Well ☐

(6) CASING INSTALLED:
SINGLE ☒ DOUBLE ☐

From ft.	to ft.	Diam.	Gage or Wall
0	203	8-5/8	.188

If gravel packed

Diameter of Bore	from ft.	to ft.
18"	0	203

Type and size of shoe or well ring
Size of gravel: Pea gravel
Describe joint Welded

(7) PERFORATIONS:
Type of perforator used Machine cut at factory
Size of perforations 1/8 in., length, by 3 in.

From ft.	to ft.	Perf. per row	Rows per ft.
112	203		

(8) CONSTRUCTION:
Was a surface sanitary seal provided? ☐ Yes ☒ No To what depth ft.
Were any strata sealed against pollution? ☐ Yes ☒ No If yes, note depth of strata

From ft.	to ft.

Method of Sealing

(9) WATER LEVELS:
Depth at which water was first found ft.
Standing level before perforating ft.
Standing level after perforating ft.

(10) WELL TESTS: See back of page
Was a pump test made? ☒ Yes ☐ No If yes, by whom? E.E.Luhdorff Co.
Yield: gal./min. with ft. draw down after hrs.
Temperature of water Was a chemical analysis made? ☐ Yes ☒ No
Was electric log made of well? ☐ Yes ☒ No

(11) WELL LOG:
Total depth 203 ft. Depth of completed well 203 ft.
Formation: *Describe by color, character, size of material, and structure.*

ft. to	ft.		
0	2	2'	Top soil
2	9	7'	Yellow clay
9	15	6'	Sand, pea gravel & shale
15	75	60'	Yellow clay
75	102	27'	Yellow clay, gravel and shale
102	112	10'	Brown shale
112	117	5'	Sand, pea gravel, shale
117	131	14'	Yellow clay
131	146	15'	Sand, pea gravel, shale
146	203	57'	Sand rock & pea gravel

CONFIDENTIAL LOG
Water Code Sec. 13752

CONFIDENTIAL
Section 7924, Water Code

Plotted and Coded
As Well 16N/4W-8P80

Work started 12-4 1963. Completed 12-12 1963

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME E. E. LUHDORFF
(Person, firm, or corporation) (*Typed or printed*)
Address WEST MAIN STREET
WOODLAND, CALIFORNIA

[SIGNED] E. E. Luhdorff
Well Driller

License No. 123211 Dated Jan. 13, 1964

57025 6-57 50M QUIN △ SPO

DWR 188 (REV. 3-54)

LOCATION NOT CHECKED

Results of Test as follows:

Static level 20'

125 GPM @ 96' Pumping level
150 " @ 116' " "
187 " @ 150' " "

WATER WELL DRILLERS REPORT

(Sections 7076, 7077, 7078, Water Code)

STATE OF CALIFORNIA

Do Not Fill In

No. 77484

State Well No. 2P

Other Well No. 16N/4W-8

Address

(2) LOCATION OF WELL:

County Colusa Co. Owner's number, if any—

R. F. D. or Street No.

Sec. 11, TWP 16 N, R 4 W
300' west of Mills Orchard Rd.

(3) TYPE OF WORK (*check*):

New well ☒ Deepening ☐ Reconditioning ☐ Abandon ☐

If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (*check*):

Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other (stock) ☒

(5) EQUIPMENT:

Rotary ☒
Cable ☐
Dug Well ☐

(6) CASING INSTALLED:

SINGLE ☒ DOUBLE ☐

From ft.	to ft.	Diam.	Gage or Wall
0	203	8-5/8	.188

Type and size of shoe or well ring

Describe joint Welded

If gravel packed

Diameter of Bore	from ft.	to ft.
18"	0	203

Size of gravel: Pea gravel

(7) PERFORATIONS:

Type of perforator used Machine cut at factory

Size of perforations 1/8 in., length, by 3 in.

From ft.	to ft.	Perf. per row	Rows per ft.
112	203		

(8) CONSTRUCTION:

Was a surface sanitary seal provided? ☐ Yes ☒ No To what depth ft.

Were any strata sealed against pollution? ☐ Yes ☒ No If yes, note depth of strata

From ft.	to ft.

Method of Sealing

(9) WATER LEVELS:

Depth at which water was first found ft.

Standing level before perforating ft.

Standing level after perforating ft.

(10) WELL TESTS: See back of page

Was a pump test made? ☒ Yes ☐ No If yes, by whom? E.E.Luhdorff Co.

Yield: gal./min. with ft. draw down after hrs.

Temperature of water Was a chemical analysis made? ☐ Yes ☒ No

Was electric log made of well? ☐ Yes ☒ No

(11) WELL LOG:

Total depth 203 ft. Depth of completed well 203 ft.

Formation: *Describe by color, character, size of material, and structure.*

0 ft. to	2 ft.	2'	Top soil
2 "	9 "	7'	Yellow clay
9 "	15 "	6'	Sand, pea gravel & shale
15 "	75 "	60'	Yellow clay
75 "	102 "	27'	Yellow clay, gravel and shale
102 "	112 "	10'	Brown shale
112 "	117 "	5'	Sand, pea gravel, shale
117 "	131 "	14'	Yellow clay
131 "	146 "	15'	Sand, pea gravel, shale
146 "	203 "	57'	Sand rock & pea gravel

CONFIDENTIAL LOG
Water Code Sec. 13752

CONFIDENTIAL
Section 7032, Water Code

Plotted and Coded

As Well 16N/4W-8P80

Work started 12-4 19 63. Completed 12-12 19 63

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME E. E. LUHDORFF
(Person, firm, or corporation) (*Typed or printed*)

Address WEST MAIN STREET
WOODLAND, CALIFORNIA

[SIGNED] E. E. Luhdorff
Well Driller

License No. 123211 Dated Jan. 13, 19 64

57025 6-57 50M QUIN △ SPO

DWR 188 (REV. 3-54)

WATER WELL DRILLERS REPORT

FIELD WORK SHEET

Report No. 77484

Owner _

Pump No. SCB

Meter No. 3T6731

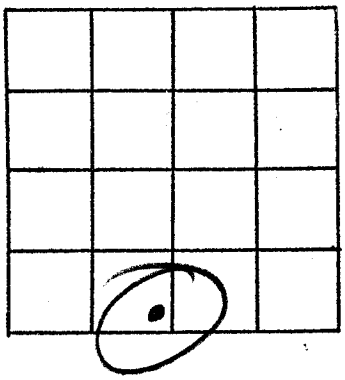
LOCATION

Section 2P

Township 16N

Range 4W

see attached sheet for well location



_____ feet North,

_____ feet West from S. E. corner of Section

REMARKS

measurable

Sam

Field Checked by

8-14-74

Date

Was electric log made of well? ☐ Yes ☒ No

57025 6-57 50M QUIN △ SPO

DWR 188 (REV. 3-54)

TION NOT CHECKED

o Not Fill In

77484 2P

16N 4W

203 ft.

cture.

l

clay

ea gravel & shale

clay

clay, gravel

le

nale

a gravel, shale

clay

a gravel, shale

ck & pea gravel

ENTIAL LOG

de Sec. 13752

FIDENTIAL

Code

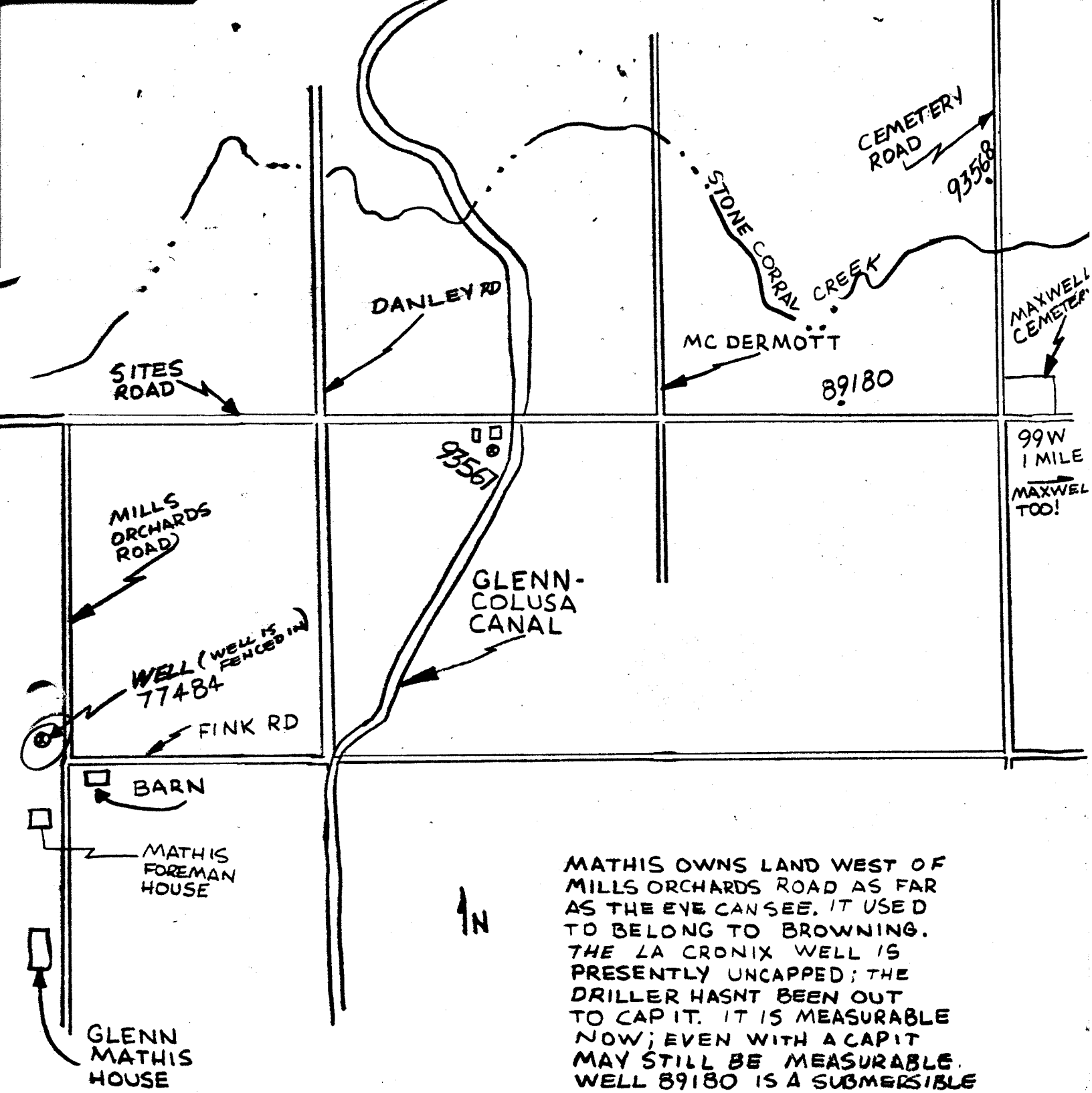
12-12 19 63

report is true to the best of

(Typed or printed)

IA

13 , 19 64



MATHIS OWNS LAND WEST OF MILLS ORCHARDS ROAD AS FAR AS THE EYE CAN SEE. IT USED TO BELONG TO BROWNING. THE LA CRONIX WELL IS PRESENTLY UNCAPPED; THE DRILLER HASNT BEEN OUT TO CAP IT. IT IS MEASURABLE NOW; EVEN WITH A CAP IT MAY STILL BE MEASURABLE. WELL 89180 IS A SUBMERSIBLE LOCATED BEHIND THE LARGE BRICK HOUSE SURROUNDED BY RICE FIELDS.

Sam
Field Checked by

8-14-74
Date

(Typed or printed)

IA

13, 19 64

Was electric log made of well? ☐ Yes ☒ No

57025 6-57 50M QUIN △ SPO

DWR 188 (REV. 3-54)

ORIGINAL
File with DWR

Page 1 of 6

OCT 07 2003

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 726866 A,B,C

DWR USE ONLY — DO NOT FILL IN
17N/02W-09M
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7548

Date Work Began 9/12/2003, Ended 9/22/2003

Local Permit Agency COLUSA COUNTY HEALTH DEPT

Permit No. 2003-78 Permit Date 6/3/2003

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD REVERSE FLUID WATER

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	25	OLIVE GRAY CLAY
25	38	GRAVEL AND SAND
38	61	YELLOW BROWN CLAY
61	76	SAND
76	231	BROWN CLAY
231	272	GRAVEL
272	320	BROWN SAND
320	334	GRAVEL
334	406	OLIVE GRAY CLAY
406	426	YELLOW BROWN CLAY
426	441	OLIVE GRAY CLAY
441	470	SAND
470	496	GRAVEL
496	506	BROWN SAND
506	526	OLIVE GRAY CLAY
526	544	GRAVEL
544	618	OLIVE GRAY CLAY
618	661	GRAVEL WITH SAND
661	688	OLIVE GRAY CLAY
688	736	GRAVEL AND SAND
736	746	DARK GRAY CLAY
746	752	GRAVEL
752	775	GREENISH BLACK CLAY
775	785	SAND
785	801	GRAVEL AND SAND
801	822	BLACK AND GRAY SAND
822	836	GREENISH GRAY CLAY
836	846	SAND
846	866	GREENISH GRAY CLAY
866	880	CLAYEY GRAVEL WITH SAND

TOTAL DEPTH OF BORING 940 (Feet)

TOTAL DEPTH OF COMPLETED WELL 863 (Feet)

WELL LOCATION

Address NOF PACKER RD & WOF HWY 45

City CA

County COLUSA

APN Book 012 Page 160 Parcel 170

Township 17 N Range 2 W Section 9

Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH

E-Log w/ 429

WEST EAST

SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial

MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ✓
EXTENSOMETE

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___

ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___

TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE	1									
0	250	36/18	✓				PVC	2-1/2	SCH 80	
250	260	18		✓			PVC	2-1/2		.02
260	280	18	✓				PVC	2-1/2	SCH 80	
ZONE	2									
0	779	36/18	✓				ASTM-135	4		

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	20	✓			SAND SLURRY
0	190		✓		BENTONITE/LI
190	302			✓	#8 GRD SAND
302	438		✓		BENTONITE/LI
438	578			✓	#8 GRD SAND
578	749		✓		BENTONITE/LI

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

JAN 22 2004

NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

20 W. KENTUCKY AVE. WOODLAND CA 95695
ADDRESS CITY STATE ZIP

Signed Mark Damron
WELL DRILLER/AUTHORIZED REPRESENTATIVE

09/29/03
DATE SIGNED

C57 A HIC - 133783
C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 2 of 6

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 726866

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7548
Date Work Began 9/12/2003, Ended 9/22/2003
Local Permit Agency COLUSA COUNTY HEALTH DEPT
Permit No. 2003-78 Permit Date 6/3/2003

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID WATER

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
880	899	GRAY BROWN SAND
899	940	OLIVE GRAY CLAY

TOTAL DEPTH OF BORING 940 (Feet)
TOTAL DEPTH OF COMPLETED WELL 863 (Feet)

WELL LOCATION

Address NOF PACKER RD & WOF HWY 45
City CA
County COLUSA
APN Book 012 Page 160 Parcel 170
Township 17 N Range 2 W Section 9
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ✓
EXTENSOMETE

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
779	800	18		✓			MILL SLOT	4		.060
800	863	18	✓				ASTM-135	4		
ZONE	3									
0	460	36/18	✓				PVC	2-1/2	SCH 80	
460	470	18		✓			PVC	2-1/2		.020
470	510	18	✓				PVC	2-1/2	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
749	806			✓	#8 GRD SAND
806	940	✓			SAND SLURRY

OCT 22 2003

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY AVE. WOODLAND CA 95695
ADDRESS CITY STATE ZIP
Signed Mark Dawson
WELL DRILLER/AUTHORIZED REPRESENTATIVE
09/29/03 DATE SIGNED
C57 A HIC - 133783 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 3 of 6

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 726866

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7548
Date Work Began 9/12/2003, Ended 9/22/2003
Local Permit Agency COLUSA COUNTY HEALTH DEPT
Permit No. 2003-78 Permit Date 6/3/2003

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD REVERSE FLUID WATER

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	25	OLIVE GRAY CLAY
25	38	GRAVEL AND SAND
38	61	YELLOW BROWN CLAY
61	76	SAND
76	231	BROWN CLAY
231	272	GRAVEL
272	320	BROWN SAND
320	334	GRAVEL
334	406	OLIVE GRAY CLAY
406	426	YELLOW BROWN CLAY
426	441	OLIVE GRAY CLAY
441	470	SAND
470	496	GRAVEL
496	506	BROWN SAND
506	526	OLIVE GRAY CLAY
526	544	GRAVEL
544	618	OLIVE GRAY CLAY
618	661	GRAVEL WITH SAND
661	688	OLIVE GRAY CLAY
688	736	GRAVEL AND SAND
736	746	DARK GRAY CLAY
746	752	GRAVEL
752	775	GREENISH BLACK CLAY
775	785	SAND
785	801	GRAVEL AND SAND
801	822	BLACK AND GRAY SAND
822	836	GREENISH GRAY CLAY
836	846	SAND
846	866	GREENISH GRAY CLAY
866	880	CLAYEY GRAVEL WITH SAND

TOTAL DEPTH OF BORING 940 (Feet)
TOTAL DEPTH OF COMPLETED WELL 863 (Feet)

WELL LOCATION

Address NOF PACKER RD & WOF HWY 45
City CA
County COLUSA
APN Book 012 Page 160 Parcel 170
Township 17 N Range 2 W Section 9
Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING —
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) ✓
EXTENSOMETE

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED
ESTIMATED YIELD * — (GPM) & TEST TYPE
TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
510	520	18		✓			PVC	2-1/2		.020
520	540	18	✓				PVC	2-1/2	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	20	✓			SAND SLURRY
0	190		✓		BENTONITE/LI
190	302			✓	#8 GRD SAND
302	438		✓		BENTONITE/LI
438	578			✓	#8 GRD SAND
578	749		✓		BENTONITE/LI

ATTACHMENTS (✓)

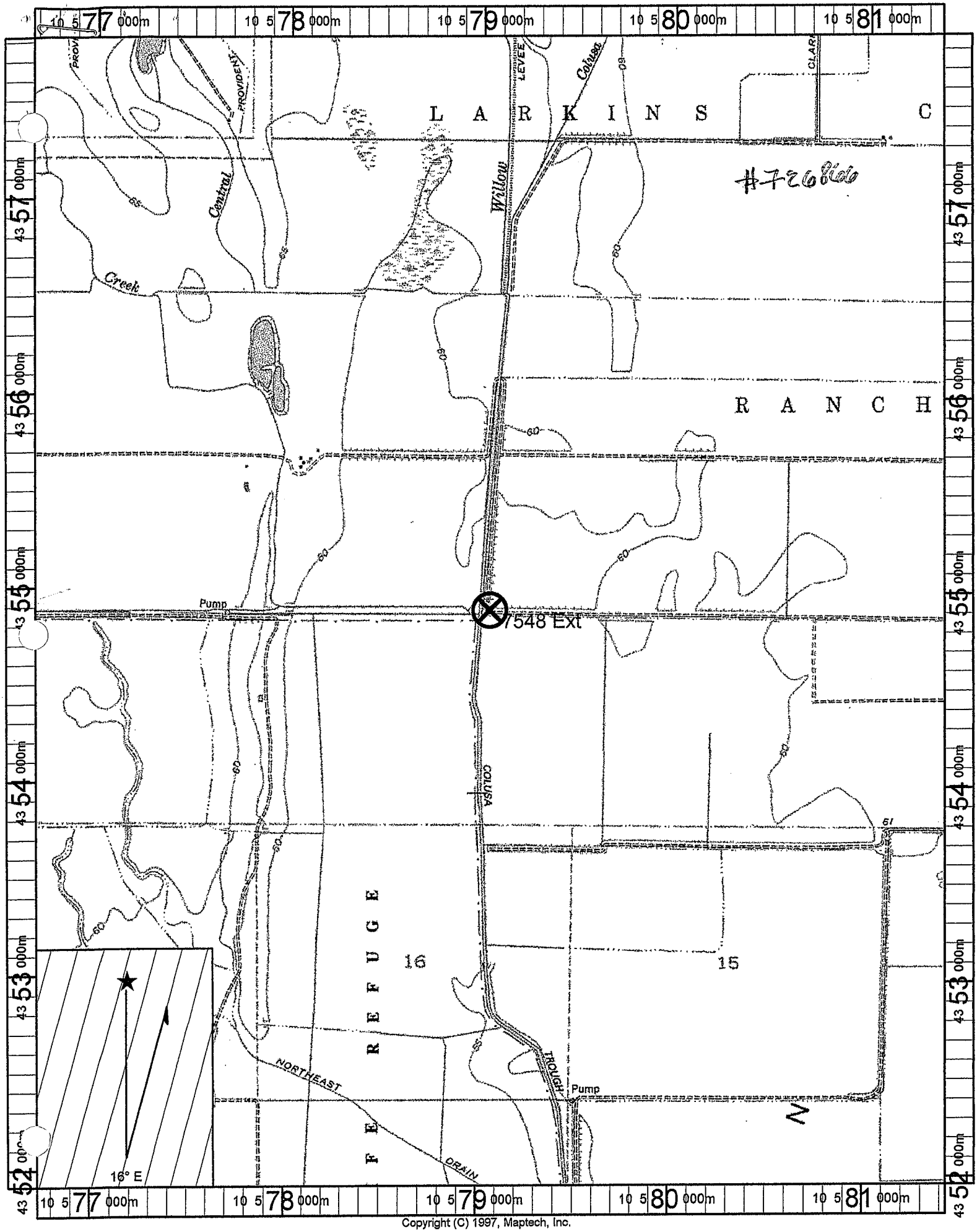
— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY AVE. WOODLAND CA 95695
ADDRESS CITY STATE ZIP
Signed Mark Dawson
WELL DRILLER/AUTHORIZED REPRESENTATIVE
09/29/03 DATE SIGNED
C57 A HIC - 133783 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM



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ORIGINAL
File Original, Duplicate and Triplicate with the
REGIONAL WATER POLLUTION
CONTROL BOARD No. 5
(Insert appropriate number)

WATER WELL DRILLERS REPORT

(Sections 7076, 7077, 7078, Water Code)

STATE OF CALIFORNIA

LOCATION NOT CHECKED
Do Not Fill In
Nº 57983
State Well No.
Other Well No. 1 1 2

(2) LOCATION OF WELL:

County Colusa Owner's number, if any— Well #1
R. F. D. or Street No. R.F.D.
3 miles east & 1 mile north of
Maxwell, Calif.

(3) TYPE OF WORK (*check*):

New well [X] Deepening [ ] Reconditioning [ ] Abandon [ ]
If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (*check*):

Domestic [X] Industrial [ ] Municipal [ ]
Irrigation [ ] Test Well [ ] Other [ ]

(5) EQUIPMENT:

Rotary [ ]
Cable [X]
Dug Well [ ]

(6) CASING INSTALLED:

SINGLE [X] DOUBLE [ ]
From 0 ft. to 159 ft. 6 Diam. 3/16 Gage or Wall

If gravel packed

Diameter of Bore	from ft.	to ft.

Type and size of shoe or well ring 3/8x4x6
Size of gravel:
Describe joint welded

(7) PERFORATIONS:

Type of perforator used torch
Size of perforations ¼ in., length, by 1½ in.
From 157 ft. to 159 ft. Perf. per row Rows per ft.

(8) CONSTRUCTION:

Was a surface sanitary seal provided? [ ] Yes [X] No To what depth ft.
Were any strata sealed against pollution? [ ] Yes [X] No If yes, note depth of strata
From ft. to ft.
Method of Sealing

(9) WATER LEVELS:

Depth at which water was first found 20 ft.
Standing level before perforating ft.
Standing level after perforating ft.

(10) WELL TESTS:

Was a pump test made? [ ] Yes [X] No If yes, by whom?
Yield: gal./min. with ft. draw down after hrs.
Temperature of water Was a chemical analysis made? [ ] Yes [X] No
Was electric log made of well? [ ] Yes [X] No

(11) WELL LOG:

Total depth 182 ft. Depth of completed well 182 ft.
Formation: *Describe by color, character, size of material, and structure.*

ft. to	ft.	
0	39	yellow clay
39	60	sand
60	177	yellow clay
177	181	sand
181		gravel

LOG

CONFIDENTIAL
Section 7076.1, Water Code

Plotted and Coded [illegible] (1974)
As Well 17N/2W - 30K80

Plotted and Coded (1973)
As Well 17N/3W - 36A80

Work started 4/5/ 1960 Completed 4/8/ 1960

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME L.C. Parkison Drilling Co.
(Person, firm, or corporation) (Typed or printed)
Address ~~XXX~~ Box 324
Butte City, California
[SIGNED] Virginia Parkison Owner
Well Driller
License No. 188522 Dated 6/30, 1960

57025 6-57 50M QUIN △ SPO DWR 188 (REV. 5-64)

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

State No. 17N-2W-30J2

WELL DATA

BRANCH

Owner
Address
Tenant
Address

State No.
Other No.

Type of Well: Hydrograph [ ] Key [ ] Index [ ] Semiannual [ ] G.W.M.P.
Location: County Colusa Basin Colusa No. 5-21.04
U.S.G.S. Quad. Maxwell 7½ Quad. No. 178 d
¼ ¼ Section , Twp. , Rge. MD SB Base & Meridian
Description 4 Mi. E/o maxwell on Maxwell Colusa Rd. To Four Mile Rd. N on 4 mile Rd 1¼ mi. To Ranch Rd west. N/w on Ranch Rd. approx. ¼ mi. To Ranch Headquarters. well is in P.H. E/o Barn.

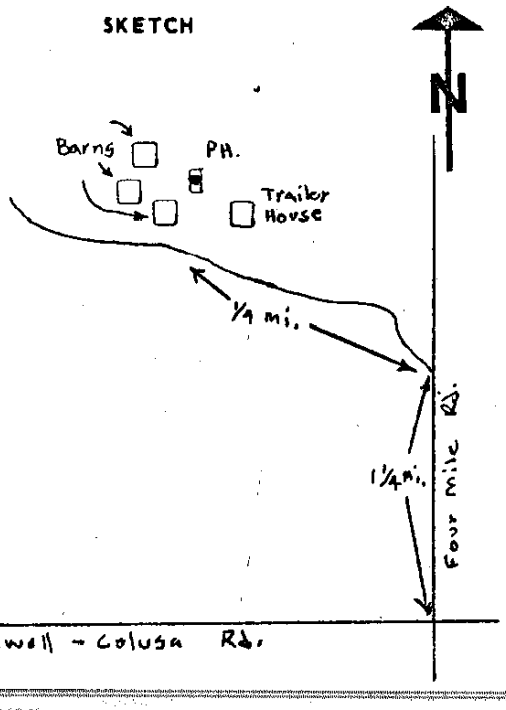
Reference Point description Sample Tap on East side of P.H.

which is ft. above/below land surface. Ground Elevation ft.
Reference Point Elev. ft. Determined from
Well: Use Domi Condition Depth 182 ft.
Casing, size 6 in., perforations 157' To 159'
Cased To 159'

Measurements By: DWR [ ] USGS [ ] USBR [ ] County [ ] Irr. Dist. [ ] Water Dist. [ ] Cons. Dist. [ ]
Chief Aquifer: Name Depth to Top Aq. Depth to Bot. Aq.
Type of Material Perm. Rating Thickness
Gravel Packed? Yes [ ] No [X] Depth to Top Gr. Depth to Bot. Gr.
Supp. Aquifer Depth to Top Aq. Depth to Bot. Aq.
Driller L. C. Parkinson Drilling Co. Butte City
Date drilled 4-8-60 Log, filed open (1) confidential (2) 57983
Equipment: Pump, type Subm. make Barnes
Serial No. Size of discharge pipe 2 in.
Power, Kind Elec. Make
H. P. 2 Motor Serial No. 436T200-10
Elec. Meter No. 69036 Transformer No.
Yield G.P.M. Pumping level ft.

Water Analysis: Min. (1) San. (2) H.M. (3)
Water Levels available: Yes (1) No
Period of Record: Begin End
Collecting Agency:
Prod. Rec. (1) Pump Test (2) Yield (3)

SKETCH



REMARKS

Recorded by:
Date

ORIGINAL
File with DWR

WATER WELL DRILLERS REPORT

(Sections 7079, 7080, 7081, 7082, Water Code)

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

CONFIDENTIAL LOG
Water Code Sec. 13752

Do Not Fill In

№ 49451

State Well No.
Other Well No. 17N/3W-8

Well # 2

(2) LOCATION OF WELL:

County Colusa Owner's number, if any
Township, Range, and Section T17N R3W S8
Distance from cities, roads, railroads, etc. 200' North of Lenahan Rd.

(3) TYPE OF WORK (check):

New Well ☒ Deepening ☐ Reconditioning ☐ Destroying ☐
If destruction, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

Domestic ☒ Industrial ☐ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary ☐
Cable ☒
Other ☐

(6) CASING INSTALLED:

STEEL: OTHER:
SINGLE ☒ DOUBLE ☐

If gravel packed

From ft.	To ft.	Diam.	Gage or Wall	Diameter of Bore	From ft.	To ft.
0	130	6"	.188			

Size of shoe or well ring: homemade Size of gravel:
Describe joint welded

(7) PERFORATIONS OR SCREEN:

Type of perforation or name of screen torch

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.
125	130		4	4x¼

(8) CONSTRUCTION:

Was a surface sanitary seal provided? Yes ☐ No ☒ To what depth ft.
Were any strata sealed against pollution? Yes ☐ No ☐ If yes, note depth of strata
From ft. to ft.
From ft. to ft.
Method of sealing blank casing

(9) WATER LEVELS:

Depth at which water was first found, if known 20 ft.
Standing level before perforating, if known ft.
Standing level after perforating and developing 20 ft.

(10) WELL TESTS:

Was pump test made? Yes ☐ No ☒ If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
Temperature of water Was a chemical analysis made? Yes ☐ No ☐
Was electric log made of well? Yes ☐ No ☒ If yes, attach copy

(11) WELL LOG:

Total depth ft. Depth of completed well 151 ft.
Formation: *Describe by color, character, size of material, and structure*

ft.	to	ft.	
0'	to	6'	Top Soil
6'	to	14'	Yellow Clay
14'	to	30'	Sand Yellow Clay
30'	to	50'	Yellow Clay
50'	to	60'	Red Clay
60'	to	82'	Sand Yellow Clay
82'	to	87'	Red Clay
87'	to	94'	Sand Red Clay
94'	to	140'	Red Clay
140'	to	147'	Sand Red Clay
147'	to	151'	Sand & Gravel

CONFIDENTIAL LOG
Water Code Sec. 13752

~~Plotted and Coded and Field Located~~
As Well 17N / 3W - 8R81
~~Plotted and Coded~~
As Well 17N / 3W - 8Q80

Work started 3-24 19 72, Completed 3-29 19 72

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Squier Drilling & Pump Service
(Person, firm, or corporation) (Typed or printed)
Address P.O. Box 56
Butte City, California 95920
[SIGNED] Testin Squier
(Well Driller)
License No. 215570 Dated April 3, 19 72

SKETCH LOCATION OF WELL ON REVERSE SIDE

DWR 188 (REV. 9-65)

56391-950 10-65 50M TRIP ① △ OSP

WATER WELL DRILLERS REPORT

FIELD WORK SHEET

Report No. 49451 / -01

Owner

Pump No. SUB

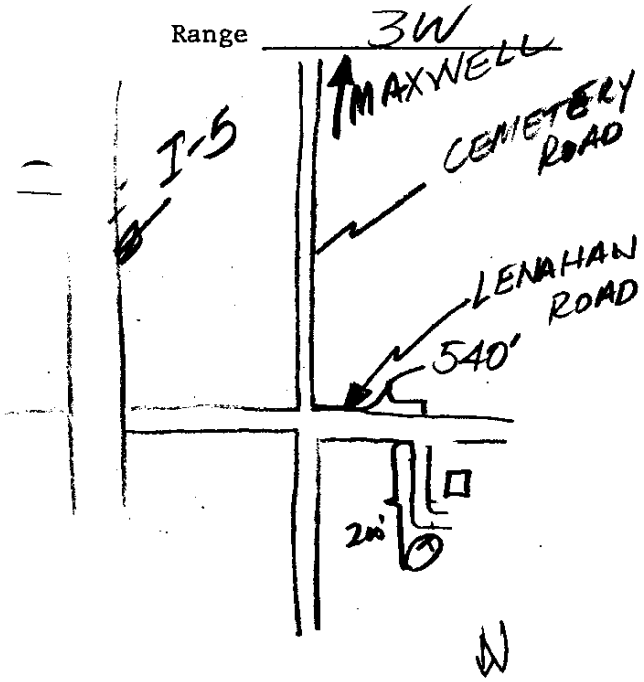
Meter No. —

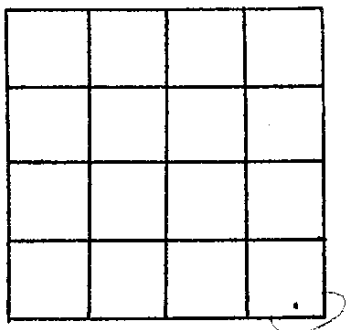
LOCATION

Section 8R

Township 17N

Range 3W





_____ feet North,

_____ feet West from S. E. corner of Section

REMARKS

well is 540 west of Cemetery & Lenahan and 200' north of Lenahan

measurable

Sam

Field Checked by

8-12-74

Date

17N/3W-32 H

ORIGINAL
File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do Not Fill In

No. 93568

State Well No. CONFIDENTIAL LOG

Other Well No. Water Code Sec. 13752

(2) LOCATION OF WELL:

County Colusa Owner's number, if any

Township, Range, and Section

Distance from cities, roads, railroads, etc. 2 mi W. & 3/4 mi N. of Maxwell on Cemetery Road

(3) TYPE OF WORK (check):

New Well ☑ Deepening ☐ Reconditioning ☐ Destroying ☐

If destruction, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☑ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary ☑
Cable ☐
Other ☐

(6) CASING INSTALLED:

STEEL: ☑ OTHER: ☐
SINGLE ☑ DOUBLE ☐

From ft.	To ft.	Diam.	Gage or Wall	Diameter of Bore	From ft.	To ft.
0	112	6 5/8	10 Ga.	12	0	140

If gravel packed

Size of shoe or well ring:

Size of gravel: 3/4

Describe joint Butt welded

(7) PERFORATIONS OR SCREEN:

Type of perforation or name of screen 3/16 x 1½ Punched

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.
68	72		8	3/16 x 1½
104	112			

(8) CONSTRUCTION:

Was a surface sanitary seal provided? Yes ☑ No ☐ To what depth 40 ft.

Were any strata sealed against pollution? Yes ☑ No ☐ If yes, note depth of strata

From 0 ft. to 40 ft.

From ft. to ft.

Method of sealing Cement

(9) WATER LEVELS:

Depth at which water was first found, if known ft.

Standing level before perforating, if known ft.

Standing level after perforating and developing 8 ft.

(10) WELL TESTS:

Was pump test made? Yes ☑ No ☐ If yes, by whom? Air jetted approx 200 GPM.

Yield: gal./min. with ft. drawdown after hrs.

Temperature of water 68 Was a chemical analysis made? Yes ☐ No ☑

Was electric log made of well? Yes ☐ No ☑ If yes, attach copy

(11) WELL LOG:

Total depth 140 ft. Depth of completed well 112 ft.

Formation: *Describe by color, character, size of material, and structure*

ft.	to	ft.	
0	–	18	Yellow Clay
18	–	32	Sand & Gravel
32	–	70	Yellow Clay
70	–	71	Sand & Gravel
71	–	105	Yellow Clay
105	–	108	Sandy Clay & Gravel
108	–	112	Yellow Clay
112	–	140	Blue Clay

CONFIDENTIAL LOG
Water Code Sec. 13752

Plotted and Coded

As Well 17N/3W-32H80

Work started 3/29 19 74, Completed 3/29 19 74

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME Western Well Drilling Co
(Person, firm, or corporation) (Typed or printed)

Address P.O. Box 470 Willows

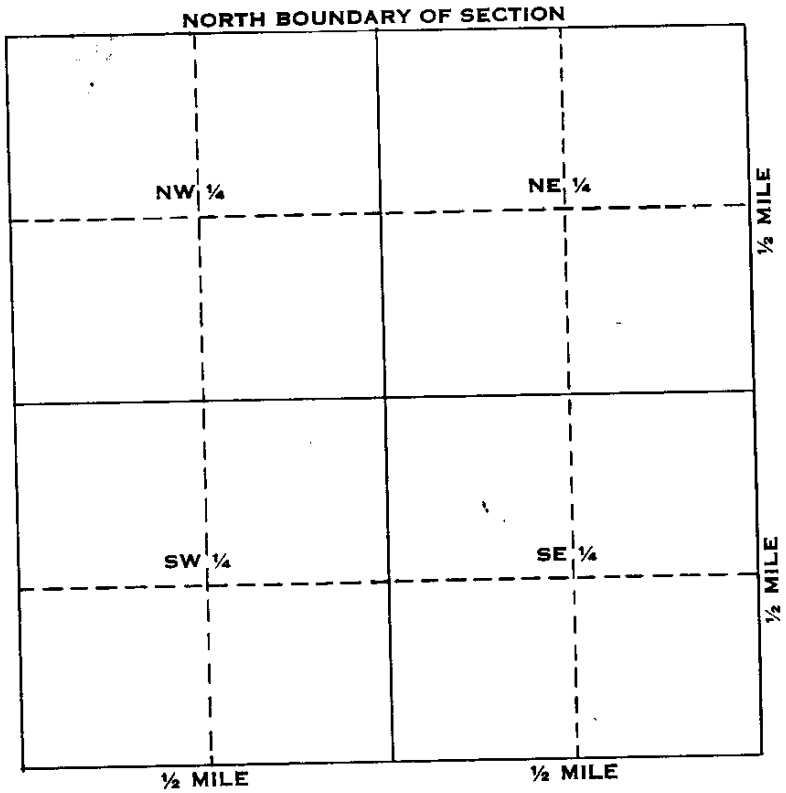
[SIGNED] Ralph J. Smith
(Well Driller)

License No. 195165 Dated 4/6, 19 74

SKETCH LOCATION OF WELL ON REVERSE SIDE

25179-980 9-68 50M TRIP △D OSP

WELL LOCATION SKETCH

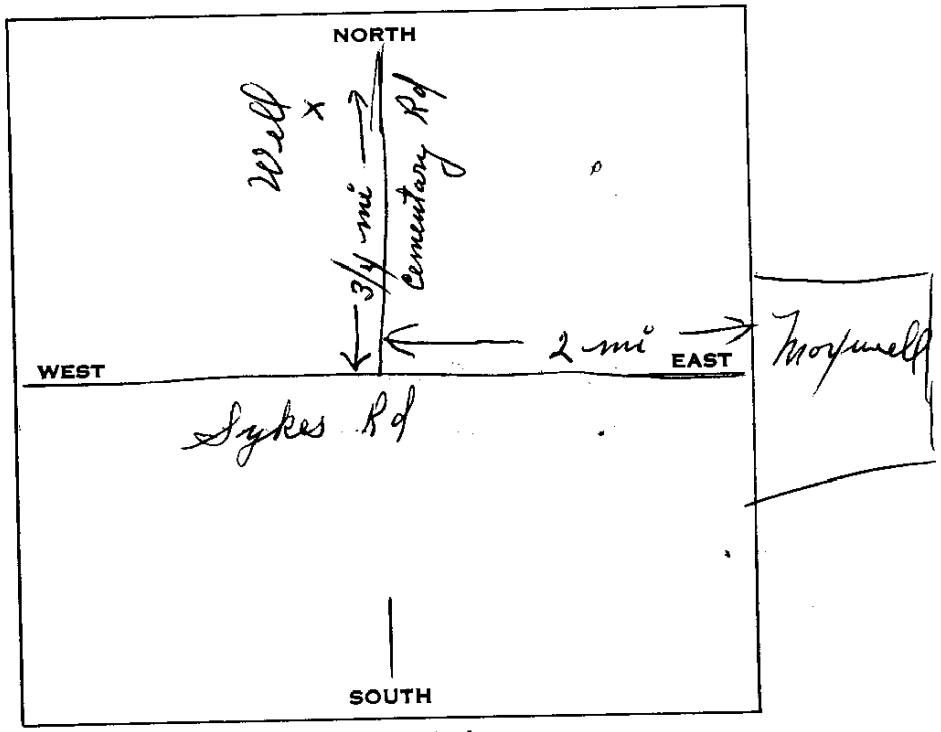


Township _____ N/S

Range _____ E/W

Section No. _____

A. Location of well in sectionized areas.
Sketch roads, railroads, streams, or other features as necessary.



B. Location of well in areas not sectionized.
Sketch roads, railroads, streams, or other features as necessary.
Indicate distances.



WATER WELL DRILLERS REPORT

FIELD WORK SHEET

Report No. 93568

Owner

Pump No. SUB

Meter No.

1100 ~~[illegible]~~ 4 Bridge

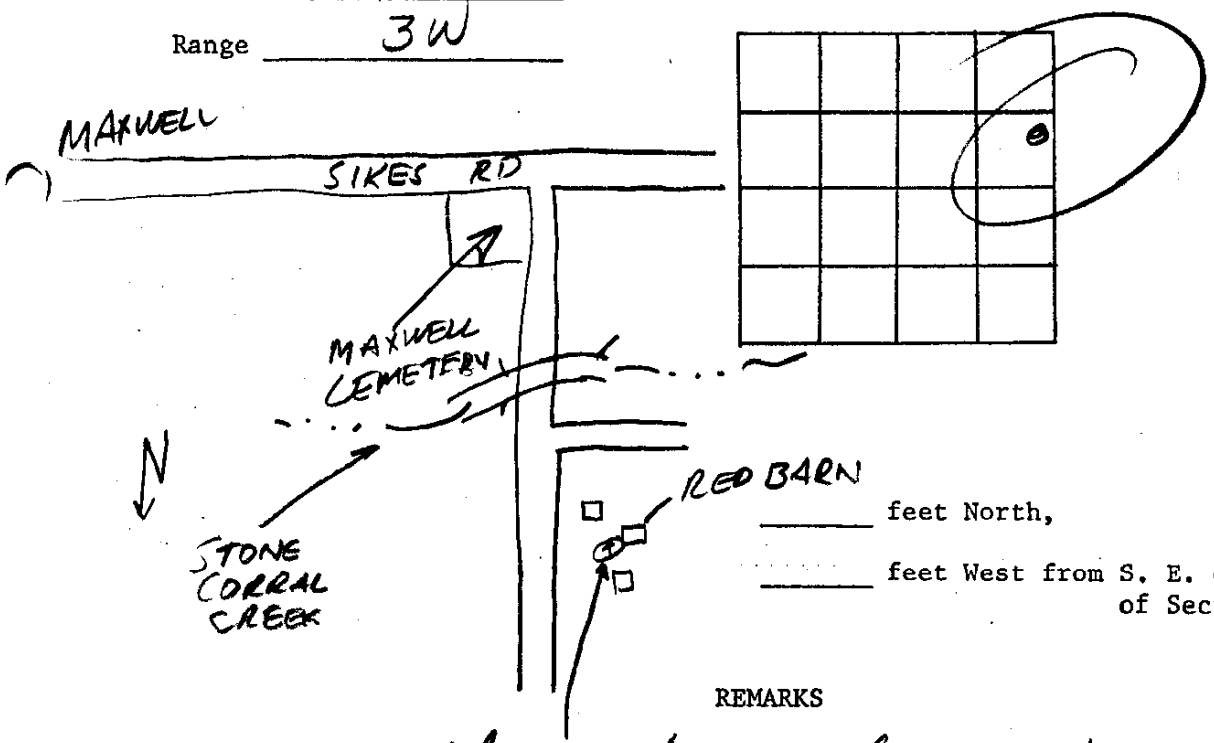
see attached for more location

LOCATION

Section 32H

Township 17N

Range 3W



_____ feet North,

_____ feet West from S. E. corner of Section

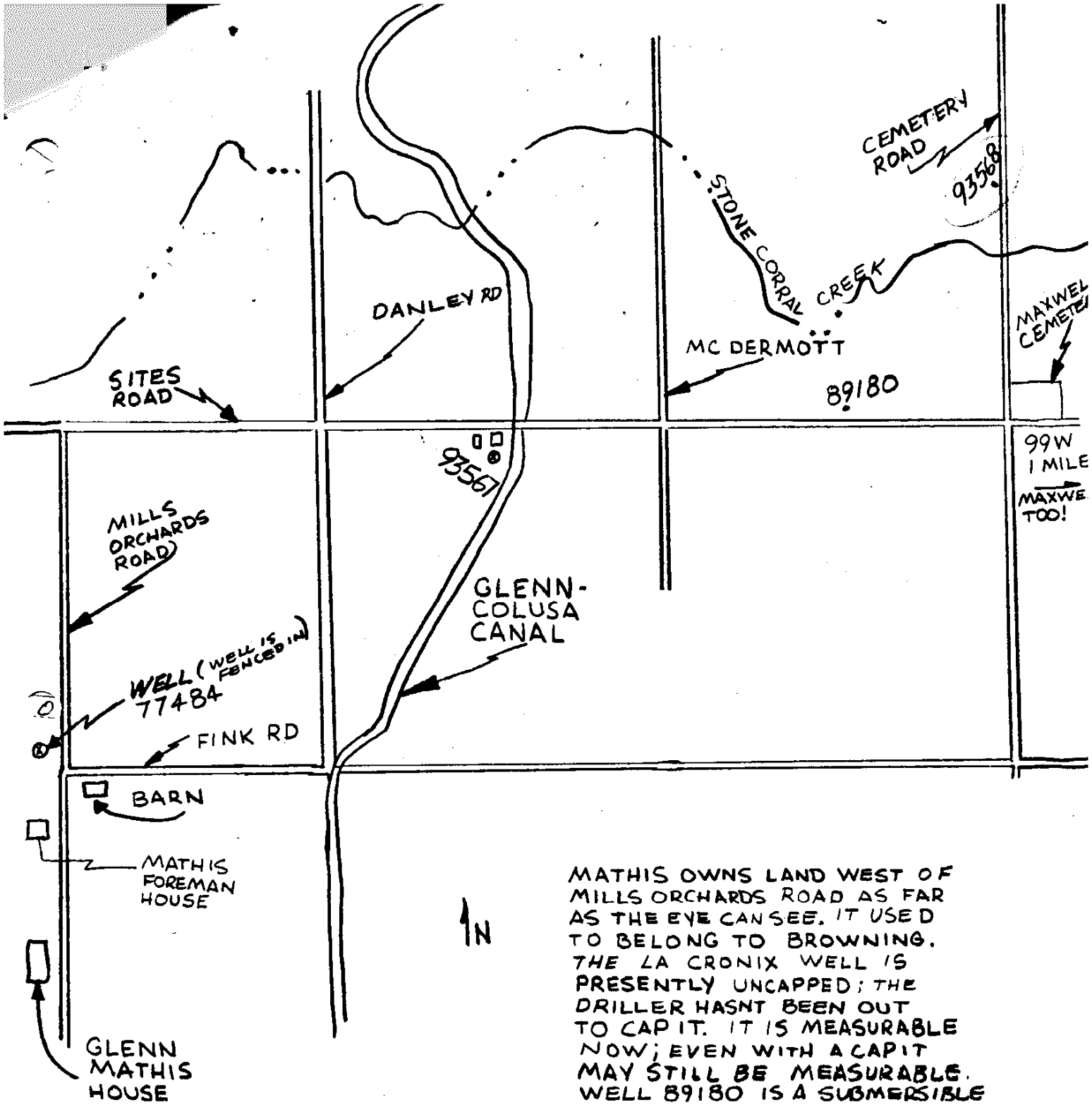
REMARKS

measurable - the well is on the west side of tin shed (which east of red barn

Sam

Field Checked by

8-12-74



MATHIS OWNS LAND WEST OF MILLS ORCHARDS ROAD AS FAR AS THE EYE CAN SEE. IT USED TO BELONG TO BROWNING. THE LA CRONIX WELL IS PRESENTLY UNCAPPED; THE DRILLER HASNT BEEN OUT TO CAP IT. IT IS MEASURABLE NOW; EVEN WITH A CAP IT MAY STILL BE MEASURABLE. WELL 89180 IS A SUBMERSIBLE LOCATED BEHIND THE LARGE BRICK HOUSE SURROUNDED BY RICE FIELDS.

EL

ORIGINAL
File with DWR

Page 1 of 12

STATE OF CALIFORNIA
WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. E045412

DWR USE ONLY -- DO NOT FILL IN
18N/02W-18
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7986
Date Work Began 9/5/2006, Ended 9/14/2006
Local Permit Agency GLENN COUNTY HEALTH DEPT
Permit No. MW 247-06 Permit Date 6/15/2006

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	20	DARK BROWN CLAY
20	100	SILTY ORANGE BROWN CLAY
100	170	SILTY YELLOW BROWN CLAY WITH FINE SAND
170	210	TAN CLAY WITH MINIMUM SAND
210	280	BROWN TAN CLAY WITH COARSE SAND
280	400	BROWN TAN CLAY WITH SAND
400	520	SOFT YELLOW BROWN CLAY WITH COARSE SAND
520	700	SAND AND GRAVEL WITH BRITTLE YELLOW BROWN CLAY
700	710	BLUE CLAY WITH SAND AND GRAVEL
710	720	SOFT YELLOW BROWN CLAY WITH SAND AND GRAVEL
720	760	SOFT BLUE GRAY CLAY WITH SAND AND GRAVEL
760	800	SOFT YELLOW CLAY WITH SAND
800	850	SOFT YELLOW CLAY WITH BRITTLE GRAY CLAY AND SAND
850	1025	BRITTLE GRAY BROWN CLAY WITH SAND AND GRAVEL
1025	1040	COARSE SAND
1040	1195	BRITTLE GRAY BROWN CLAY WITH SAND AND GRAVEL STREAKS

TOTAL DEPTH OF BORING 1200 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1000 (Feet)

WELL LOCATION

Address .93 MI NOF RD 68 & 525' EOF NORMAN RD
City CA
County GLENN
APN Book 013 Page 280 Parcel 001
Township 18 N Range 2 W Section 18
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE	1									
0	246	14	✓				PVC F480	2.5	SCH 80	
246	256	14		✓			PVC F480	2.5	SCH 80	.030
256	266	14	✓				PVC F480	2.5	SCH 80	
ZONE	2									
0	510	14	✓				PVC F480	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	130	✓			SAND SLURRY
130	134		✓		BENTONITE S
134	223			✓	SRI#8 SAND
223	235		✓		BENTONITE S
235	280			✓	SRI#8 SAND
280	290		✓		BENTONITE S

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
ADDRESS 20 WEST KENTUCKY AVE CITY WOODLAND STATE CA ZIP 95695
Signed Mark Damion WELL DRILLER/AUTHORIZED REPRESENTATIVE
DATE SIGNED 10/05/06
C-57 LICENSE NUMBER C57 A HIC - 133783

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. E045412

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7986
Date Work Began 9/5/2006, Ended 9/14/2006
Local Permit Agency GLENN COUNTY HEALTH DEPT
Permit No. MW 247-06 Permit Date 6/15/2006

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	20	DARK BROWN CLAY
20	100	SILTY ORANGE BROWN CLAY
100	170	SILTY YELLOW BROWN CLAY WITH FINE SAND
170	210	TAN CLAY WITH MINIMUM SAND
210	280	BROWN TAN CLAY WITH COARSE SAND
280	400	BROWN TAN CLAY WITH SAND
400	520	SOFT YELLOW BROWN CLAY WITH COARSE
		SAND
520	700	SAND AND GRAVEL WITH BRITTLE YELLOW
		BROWN CLAY
700	710	BLUE CLAY WITH SAND AND GRAVEL
710	720	SOFT YELLOW BROWN CLAY WITH SAND
		AND GRAVEL
720	760	SOFT BLUE GRAY CLAY WITH SAND AND
		GRAVEL
760	800	SOFT YELLOW CLAY WITH SAND
800	850	SOFT YELLOW CLAY WITH BRITTLE GRAY
		CLAY AND SAND
850	1025	BRITTLE GRAY BROWN CLAY WITH SAND
		AND GRAVEL
1025	1040	COARSE SAND
1040	1195	BRITTLE GRAY BROWN CLAY WITH SAND
		AND GRAVEL STREAKS

TOTAL DEPTH OF BORING 1200 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1000 (Feet)

WELL LOCATION

Address .93 MI NOF RD 68 & 525' EOF NORMAN RD
City CA
County GLENN
APN Book 013 Page 280 Parcel 001
Township 18 N Range 2 W Section 18
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public ___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
510	520	14		✓			PVC F480	2.5	SCH 80	.030
520	530	14	✓				PVC F480	2.5	SCH 80	
ZONE	3									
0	620	14	✓				PVC F480	2.5	SCH 80	
620	630	14		✓			PVC F480	2.5	SCH 80	.030
630	670	14	✓				PVC F480	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
290	488			✓	SRI#8 SAND
488	500		✓		BENTONITE S
500	543			✓	SRI#8 SAND
543	553		✓		BENTONITE S
553	598			✓	SRI#8 SAND
598	608		✓		BENTONITE S

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 WEST KENTUCKY AVE WOODLAND CA 95695
ADDRESS CITY STATE ZIP
Signed Mark Dawson 10/05/06 C57 A HIC - 133783
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. **E045412**

DWR USE ONLY -- DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7986
Date Work Began 9/5/2006, Ended 9/14/2006
Local Permit Agency GLENN COUNTY HEALTH DEPT
Permit No. MW 247-06 Permit Date 6/15/2006

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	20	DARK BROWN CLAY
20	100	SILTY ORANGE BROWN CLAY
100	170	SILTY YELLOW BROWN CLAY WITH FINE SAND
170	210	TAN CLAY WITH MINIMUM SAND
210	280	BROWN TAN CLAY WITH COARSE SAND
280	400	BROWN TAN CLAY WITH SAND
400	520	SOFT YELLOW BROWN CLAY WITH COARSE
		SAND
520	700	SAND AND GRAVEL WITH BRITTLE YELLOW
		BROWN CLAY
700	710	BLUE CLAY WITH SAND AND GRAVEL
710	720	SOFT YELLOW BROWN CLAY WITH SAND
		AND GRAVEL
720	760	SOFT BLUE GRAY CLAY WITH SAND AND
		GRAVEL
760	800	SOFT YELLOW CLAY WITH SAND
800	850	SOFT YELLOW CLAY WITH BRITTLE GRAY
		CLAY AND SAND
850	1025	BRITTLE GRAY BROWN CLAY WITH SAND
		AND GRAVEL
1025	1040	COARSE SAND
1040	1195	BRITTLE GRAY BROWN CLAY WITH SAND
		AND GRAVEL STREAKS

TOTAL DEPTH OF BORING 1200 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1000 (Feet)

WELL LOCATION

Address .93 MI NOF RD 68 & 525 EOF NORMAN RD
City CA
County GLENN
APN Book 013 Page 280 Parcel 001
Township 18 N Range 2 W Section 18
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
670	680	14		✓			PVC F480	2.5	SCH 80	.030
680	700	14	✓				PVC F480	2.5	SCH 80	
ZONE	4									
0	975	14/8-3/4	✓				PVC F480	2.5	SCH 80	
975	985	8-3/4		✓			PVC F480	2.5	SCH 80	.030
985	1000	8-3/4	✓				PVC F480	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
608	693			✓	SRI#8 SAND
693	716		✓		BENTONITE S
716	930			✓	SRI#8 SAND
930	944		✓		BENTONITE S
944	996			✓	SRI#8 SAND
996	1002		✓		BENTONITE S

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
ADDRESS 20 WEST KENTUCKY AVE CITY WOODLAND STATE CA ZIP 95695
Signed Mark D Dawson WELL DRILLER/AUTHORIZED REPRESENTATIVE
DATE SIGNED 10/05/06
C-57 LICENSE NUMBER C57 A HIC - 133783

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. E045412

DWR USE ONLY -- DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7986

Date Work Began 9/5/2006, Ended 9/14/2006

Local Permit Agency GLENN COUNTY HEALTH DEPT

Permit No. MW 247-06 Permit Date 6/15/2006

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	20	DARK BROWN CLAY
20	100	SILTY ORANGE BROWN CLAY
100	170	SILTY YELLOW BROWN CLAY WITH FINE SAND
170	210	TAN CLAY WITH MINIMUM SAND
210	280	BROWN TAN CLAY WITH COARSE SAND
280	400	BROWN TAN CLAY WITH SAND
400	520	SOFT YELLOW BROWN CLAY WITH COARSE SAND
520	700	SAND AND GRAVEL WITH BRITTLE YELLOW BROWN CLAY
700	710	BLUE CLAY WITH SAND AND GRAVEL
710	720	SOFT YELLOW BROWN CLAY WITH SAND AND GRAVEL
720	760	SOFT BLUE GRAY CLAY WITH SAND AND GRAVEL
760	800	SOFT YELLOW CLAY WITH SAND
800	850	SOFT YELLOW CLAY WITH BRITTLE GRAY CLAY AND SAND
850	1025	BRITTLE GRAY BROWN CLAY WITH SAND AND GRAVEL
1025	1040	COARSE SAND
1040	1195	BRITTLE GRAY BROWN CLAY WITH SAND AND GRAVEL STREAKS

TOTAL DEPTH OF BORING 1200 (Feet)

TOTAL DEPTH OF COMPLETED WELL 1000 (Feet)

WELL LOCATION

Address .93 MI NOF RD 68 & 525 EOF NORMAN RD

City CA

County GLENN

APN Book 013 Page 280 Parcel 001

Township 18 N Range 2 W Section 18

Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial

MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___

ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___

TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE 1										
0	246	14	✓				PVC F480	2.5	SCH 80	
246	256	14		✓			PVC F480	2.5	SCH 80	.030
256	266	14	✓				PVC F480	2.5	SCH 80	
ZONE 2										
0	510	14	✓				PVC F480	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
1002	1200			✓	NATIVE FILL

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

ADDRESS 20 WEST KENTUCKY AVE CITY WOODLAND STATE CA ZIP 95695

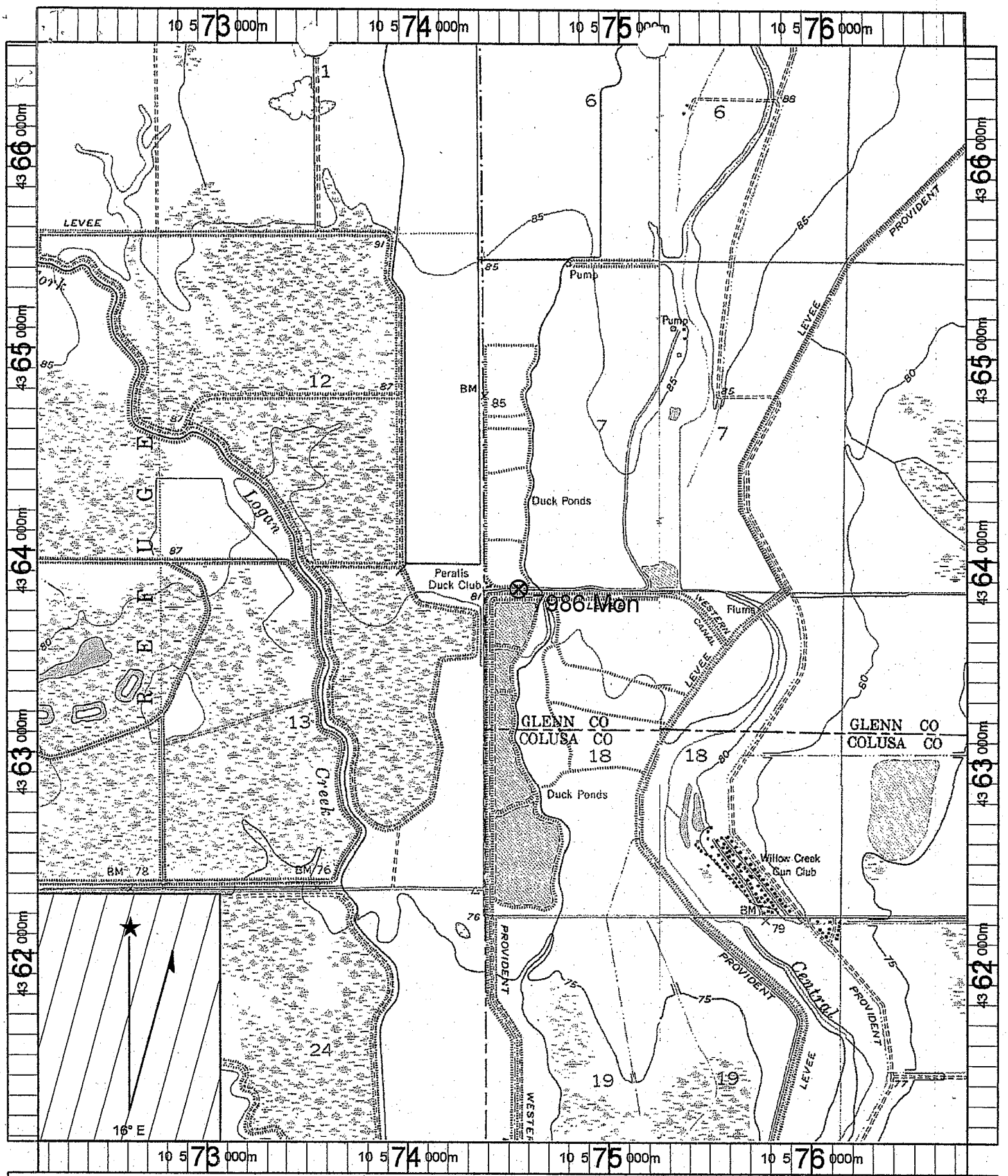
Signed Mark A Davison
WELL DRILLER/AUTHORIZED REPRESENTATIVE

DATE SIGNED 10/05/06

C-57 LICENSE NUMBER C57 A HIC - 133783

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM



Name: LOGANDALE
Date: 6/12/2006
Scale: 1 inch equals 2000 feet

Caption: DWR (GCID) - Job# 7986 Mon
APN: 013-280-001 (103 acres)
T18N R2W s18

Copyright (C) 1997, Maptech, Inc.

18N/02W-36M

ORIGINAL

File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do not fill in

No. 177869

Notice of Intent No.

Local Permit No. or Date

State Well No.

Other Well No.

(2) LOCATION OF WELL (See instructions):

County Colusa Owner's Well Number

Well address if different from above

Township 18 N Range 2 W Section 36

Distance from cities, roads, railroads, fences, etc.

Extreme Notheast corner of Secion 36

WELL LOCATION SKETCH

(3) TYPE OF WORK:

New Well ☒ Deepening ☐

Reconstruction ☐

Reconditioning ☐

Horizontal Well ☐

Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:

Domestic ☐

Irrigation ☒

Industrial ☐

Test Well ☐

Stock ☐

Municipal ☐

Other ☐

(5) EQUIPMENT:

Rotary ☐ Reverse ☐

Cable ☒ Air ☐

Other ☐ Bucket ☐

(6) GRAVEL PACK:

Yes ☐ No ☒ Size

Diameter of bore

Packed from to ft.

(7) CASING INSTALLED:

Steel ☒ Plastic ☐ Concrete ☐

(8) PERFORATIONS:

Type of perforation or size of screen

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size
0	234	18	1/4	88	128	1/4" mills Knife
230	410	16	8-GA	195	225	1/4" mills Knife
				240	340	1/4" mills Knife

(9) WELL SEAL:

Was surface sanitary seal provided? Yes ☐ No ☒ If yes, to depth ft.

Were strata sealed against pollution? Yes ☒ No ☐ Interval ft.

Method of sealing Clay Seal

(10) WATER LEVELS:

Depth of first water, if known 40 ft.

Standing level after well completion 38 ft.

(11) WELL TESTS:

Was well test made? Yes ☒ No ☐ If yes, by whom? Valley Pump

Type of test Pump ☒ Bailer ☐ Air lift ☐

Depth to water at start of test 38 ft. At end of test 36 ft

Discharge 3400 gal/min after 90 hours Water temperature

Chemical analysis made? Yes ☐ No ☒ If yes, by whom?

Was electric log made? Yes ☐ No ☒ If yes, attach copy to this report

(12) WELL LOG:

Total depth 455 ft. Depth of completed well 455 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	9	top soil
9	38	Brown Clay
38	41	gravel
41	88	Brown Clay
88	127	Sand & Gravel
127	196	Blue Clay
196	224	River Rock
224	268	Blue clay
268	310	Sand & Gravel
310	446	Blue Clay
446	455	Shale & Gravel

CONFIDENTIAL
NOT FOR PUBLIC USE
WATER CODE SEC. 13752

DEC 3 1985

Work started Jan 2 1985 Completed Jan 16 1985

WELL DRILLER'S STATEMENT: 00281

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

SIGNED [signature] (Well Driller)

NAME Valley Pump & motor Works Inc. (Person, firm, or corporation) (Typed or printed)

Address 470 No. Geo. Wash Blvd

City Yuba City CA Zip 95991

License No. 256384 Date of this report May 16, 1985

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

OCT 19 2004

ORIGINAL
File with DWR

Page 1 of 6

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 726952A B

DWR USE ONLY — DO NOT FILL IN
19N/02W-08
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7679
Date Work Began 7/19/2004, Ended 7/23/2004
Local Permit Agency GLENN COUNTY HEALTH DEPT
Permit No. MW 206-04 Permit Date 5/3/2004

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID WATER

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	68	TAN BROWN CLAY
68	92	SAND AND GRAVEL
92	160	TAN BROWN CLAY
160	202	TAN BROWN SILTY CLAY
202	226	GRAVEL AND SAND
226	240	BLUE CLAY
240	260	TAN BROWN CLAY
260	298	TAN BROWN SILTY CLAY WITH SAND
298	374	TAN BROWN CLAY WITH SAND
374	462	TAN BROWN SILTY CLAY WITH SAND
462	468	GRAVEL
468	556	TAN BROWN CLAY WITH SILTY SAND
556	600	TAN BROWN SILTY CLAY
600	638	SANDSTONE AND CLAYEY SAND
638	776	TAN BROWN SILTY CLAY
776	796	GRAVEL
796	822	LIGHT TAN CLAY
822	826	SANDSTONE
826	856	LIGHT TAN CLAY WITH FINE SAND
856	882	GRAVEL
882	936	TAN BROWN SILTY,CLAYEY FINE SAND
936	965	GRAVEL AND SAND WITH BLUE TAN SILTY CLAY
965	1000	BLUE SILTY SANDY CLAY

TOTAL DEPTH OF BORING 1000 (Feet)
TOTAL DEPTH OF COMPLETED WELL 939.7 (Feet)

WELL LOCATION

Address SOF HWY 162 & EOF C/R R
City CA
County GLENN
APN Book 016 Page 210 Parcel 012
Township 19 N Range 2 W Section 8
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE	1									
0	77	24/18	✓				PVC C200	2.5	SCH 80	
77	87	18		✓			PVC C200	2.5	SCH 80	.030
87	97	18	✓				PVC C200	2.5	SCH 80	
ZONE	2									
0	208	24/18	✓				PVC C200	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	59	✓			SAND SLURRY
0	136			✓	SRI#8 SAND
136	171		✓		BENTONITE S
171	265			✓	SRI#8 SAND
265	829		✓		BENTONITE S
829	910			✓	SRI#8 SAND

MAY 04 2005

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO. (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY AVE. ADDRESS — WOODLAND CITY — CA STATE — 95695 ZIP
Signed ___ WELL DRILLER/AUTHORIZED REPRESENTATIVE — 09/16/04 DATE SIGNED — C57 A HIC - 133783 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 726952

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./ STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

Owner's Well No. 7679

Date Work Began 7/19/2004, Ended 7/23/2004

Local Permit Agency GLENN COUNTY HEALTH DEPT

Permit No. MW 206-04 Permit Date 5/3/2004

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD REVERSE FLUID WATER

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	68	TAN BROWN CLAY
68	92	SAND AND GRAVEL
92	160	TAN BROWN CLAY
160	202	TAN BROWN SILTY CLAY
202	226	GRAVEL AND SAND
226	240	BLUE CLAY
240	260	TAN BROWN CLAY
260	298	TAN BROWN SILTY CLAY WITH SAND
298	374	TAN BROWN CLAY WITH SAND
374	462	TAN BROWN SILTY CLAY WITH SAND
462	468	GRAVEL
468	556	TAN BROWN CLAY WITH SILTY SAND
556	600	TAN BROWN SILTY CLAY
600	638	SANDSTONE AND CLAYEY SAND
638	776	TAN BROWN SILTY CLAY
776	796	GRAVEL
796	822	LIGHT TAN CLAY
822	826	SANDSTONE
826	856	LIGHT TAN CLAY WITH FINE SAND
856	882	GRAVEL
882	936	TAN BROWN SILTY,CLAYEY FINE SAND
936	965	GRAVEL AND SAND WITH BLUE TAN SILTY CLAY
965	1000	BLUE SILTY SANDY CLAY

TOTAL DEPTH OF BORING 1000 (Feet)

TOTAL DEPTH OF COMPLETED WELL 939.7 (Feet)

WELL LOCATION

Address SOF HWY 162 & EOF C/R R

City CA

County GLENN

APN Book 016 Page 210 Parcel 012

Township 19 N Range 2 W Section 8

Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH

WEST EAST

SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if **necessary. PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial

MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___

ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___

TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)

May not be representative of a well's long-term yield.

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	CASING (S) TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
208	218	18		✓			PVC C200	2.5	SCH 80	.030
218	228	18	✓				PVC C200	2.5	SCH 80	
~~ONE~~	3									
0	290.6	24/18	✓				ASTM-135	4	.312	
290.6	299.9	18					COMP SEC			
299.9	720.9	18	✓				ASTM-135	4	.312	

DEPTH FROM SURFACE Ft.	to Ft.	ANNULAR MATERIAL TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
910	1000	✓			SAND SLURRY

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

20 W. KENTUCKY AVE. WOODLAND CA 95695
ADDRESS CITY STATE ZIP

Signed Mark Damian 09/16/04 C57 A HIC - 133783
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 3 of 6

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 726952

DWR USE ONLY --- DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7679
Date Work Began 7/19/2004, Ended 7/23/2004
Local Permit Agency GLENN COUNTY HEALTH DEPT
Permit No. MW 206-04 Permit Date 5/3/2004

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID WATER

DEPTH FROM SURFACE Ft. to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0 – 68	TAN BROWN CLAY
68 – 92	SAND AND GRAVEL
92 – 160	TAN BROWN CLAY
160 – 202	TAN BROWN SILTY CLAY
202 – 226	GRAVEL AND SAND
226 – 240	BLUE CLAY
240 – 260	TAN BROWN CLAY
260 – 298	TAN BROWN SILTY CLAY WITH SAND
298 – 374	TAN BROWN CLAY WITH SAND
374 – 462	TAN BROWN SILTY CLAY WITH SAND
462 – 468	GRAVEL
468 – 556	TAN BROWN CLAY WITH SILTY SAND
556 – 600	TAN BROWN SILTY CLAY
600 – 638	SANDSTONE AND CLAYEY SAND
638 – 776	TAN BROWN SILTY CLAY
776 – 796	GRAVEL
796 – 822	LIGHT TAN CLAY
822 – 826	SANDSTONE
826 – 856	LIGHT TAN CLAY WITH FINE SAND
856 – 882	GRAVEL
882 – 936	TAN BROWN SILTY,CLAYEY FINE SAND
936 – 965	GRAVEL AND SAND WITH BLUE TAN SILTY CLAY
965 – 1000	BLUE SILTY SANDY CLAY

TOTAL DEPTH OF BORING 1000 (Feet)
TOTAL DEPTH OF COMPLETED WELL 939.7 (Feet)

WELL LOCATION

Address SOF HWY 162 & EOF C/R R
City CA
County GLENN
APN Book 016 Page 210 Parcel 012
Township 19 N Range 2 W Section 8
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if **necessary. PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

DEPTH FROM SURFACE Ft. to Ft.	BORE-HOLE DIA. (Inches)	CASING (S) TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
720.9 – 730.2	18					COMP SEC			
730.2 – 856.6	18	✓				ASTM-135	4	.312	
856.6 – 876.6	18		✓			DBL MILLSL	4	.312	.060
876.6 – 939.7	18	✓				ASTM-135	4	.312	

DEPTH FROM SURFACE Ft. to Ft.	ANNULAR MATERIAL TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0 – 59	✓			SAND SLURRY
0 – 136			✓	SRI#8 SAND
136 – 171		✓		BENTONITE S
171 – 265			✓	SRI#8 SAND
265 – 829		✓		BENTONITE S
829 – 910			✓	SRI#8 SAND

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY AVE. WOODLAND CA 95695
ADDRESS CITY STATE ZIP
Signed Mark Damion 09/16/04 C57 A HIC - 133783
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

RECEIVED
DEC 20 1994
D.W.R.

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 581475

DWR USE ONLY — DO NOT FILL IN
19N/02W-32M
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Page ___ of ___
Owner's Well No. ___
Date Work Began 11/7/94 Completed 11/11/94
Local Permit Agency Glenn County Environmental Health
Permit No. 59698 Permit Date 10/17/94

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	7	Clay
7	17	Gravel
17	25	Clay
25	33	Gravel
33	44	Clay
44	46	Gravel
46	120	Clay
120	124	Small gravel
124	160	Clay
160	190	Gravel, cobblestones
190	197	Clay
197	251	Gravel, cobblestones
251	265	Clay
265	270	Gravel
270	274	Small gravel
274	300	Clay

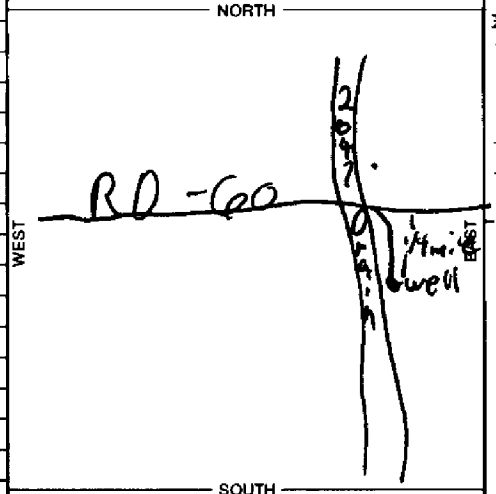
TOTAL DEPTH OF BORING 300 (Feet)
TOTAL DEPTH OF COMPLETED WELL 260 (Feet)

WELL OWNER

WELL LOCATION

Address 3/4 - 1 mi. West of SS on ~~64~~ 60
City 4 Corners
County Glenn
APN Book 13 Page 22 Parcel 0 - 018
or Township ___ Range ___ Section ___
or Latitude ___ DEG. MIN. SEC. NORTH Longitude ___ DEG. MIN. SEC. WEST

LOCATION SKETCH



Illustrate or Describe Distance of Well from Landmarks such as Roads, Buildings, Fences, Rivers, etc.
PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USE(S) (✓)

___ MONITORING
WATER SUPPLY
___ Domestic
___ Public
X Irrigation
___ Industrial
___ "TEST WELL"
___ CATHODIC PROTECTION
___ OTHER (Specify)

DRILLING METHOD Reverse Rotary FLUID Water

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH OF STATIC WATER LEVEL 94 (Ft.) & DATE MEASURED 12-7-94
ESTIMATED YIELD* 5000 (GPM) & TEST TYPE turbine
TEST LENGTH 10 (Hrs.) TOTAL DRAWDOWN 70 (Ft.)
** May not be representative of a well's long-term yield.*

CASING(S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL/GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	100	28	x				steel	20	.250	
100	160	28	x				steel	16	.250	
160	260	28		x			steel	16		.080

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	35	x			
35	260				3/8" grave
				DEL	

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Sullivan Drilling (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED) 1768

P.O. Box 1448 ADDRESS Corning CITY CA STATE 96021 ZIP

Signed Charlie Sullivan WELL DRILLER/AUTHORIZED REPRESENTATIVE 12/14/94 DATE SIGNED 656504 C-57 LICENSE NUMBER

DWR 188 REV. 7-90

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

~~ORIGINAL~~ MAY 3 1 2005
File with DWR

Page 1 of 1

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 816220

DWR USE ONLY — DO NOT FILL IN
19W/04W-14
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7821
Date Work Began 3/15/2005, Ended 3/17/2005
Local Permit Agency GLENN COUNTY HEALTH DEPT
Permit No. MW226-05 Permit Date 2/15/2005

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	9	TOP SOIL
9	20	SANDY CLAY
20	30	YELLOW CLAY
30	42	LOOSE SAND AND GRAVEL
42	64	SANDY BROWN CLAY
64	70	YELLOW CLAY
70	400	BLUE CLAY WITH SAND
400	425	SAND WITH BLUE CLAY
425	494	BLUE CLAY WITH SAND
494	502	TIGHT SAND WITH SMALL GRVEL
502	750	BLUE CLAY WITH BRITTLE CLAY STREAKS
750	758	SAND WITH BLUE CLAY
758	863	SILTY BLUE CLAY WITH SAND
863	1010	BLUE/PURPLE CLAY WITH HARD CLAY STREAK

TOTAL DEPTH OF BORING 366 (Feet)
TOTAL DEPTH OF COMPLETED WELL 65 (Feet)

WELL LOCATION

Address .35 MI WOF ROAD BB & 1.5 MI SOF HWY 162
City CA
County GLENN
APN Book 018 Page 030 Parcel 032
Township 19 N Range 4 W Section 14
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	45	8	✓				PVC ASTM	2-1/2	F480	
45	55	8		✓			PVC ASTM	2-1/2	F480	.030
55	65	8	✓				PVC ASTM	2-1/2	F480	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	21.5	✓			SAND SLURRY
21.5	25		✓		BENTONITE C
25	147			✓	SRI#8 SAND
147	160		✓		BENTONITE C
160	209			✓	SRI#8 SAND
209	366	✓			SAND SLURRY

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY AVE. WOODLAND CA 95695
ADDRESS CITY STATE ZIP
Signed Mark Damion 05/12/05
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED
C57 A HIC - 133783
C-57 LICENSE NUMBER

DWR 188 REV. 11-97
IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

20N/2W-11A1

A2

REGION

COUNTY Glenn

NEAR

DEPT. OF WATER RESOURCES

Log# 3669

BASIN 20N/2W 11

OTHER NOS. SCF 5

A3

WELL LOG

LOCATION 1,050' West and 5,200' North of SW corner, NE¼ NE¼ of Sec. 11, T20N R2W

DRILLED BY CalTrans for DWR ADDRESS P. O. Box 607, Red Bluff, CA 96080

DRILLING METHOD Rotary GRAVEL PACKED 0-700' DATE COMPLETED 9-2-76

SIZE OF CASING-DEPTH hole 4¾" TO 70' & 4½" TO 700' DATE STARTED DRILLING-WATER AT 8-30-76

PERFORATIONS @ 70-90' (A1), @ 140-160' (A2), @ 490-510' (A3) SIZE 1½" PVC PIPES

WATER LEVEL BEFORE PERFORATING AFTER

TEST DATA: DISCHARGE G. P. M. DRAWDOWN FT. HOURS RUN

OTHER DATA AVAILABLE: WATER LEVEL RECORD ANALYSIS

SURFACE ELEV. 120' DATUM MSL SOURCE OF INFORMATION Geologist

DEPTH	ELEV. OF BOTTOM OF STRATUM	MATERIAL	THICKNESS	SP. YIELD %
0-3'		soil	3'	
3-70		yellow clay with some gravel	67	
70-92		medium-small gravel	22	
92-109		graveley brown clay	11	
109-160		medium-small gravel with thin beds of fine gravel	51	
160-258		sandy brown clay	98	
258-283		coarse sand with medium-small gravel	25	
283-303		brown sandy clay	20	
303-335		fine sand beds (thin) with brown clay	32	
335-350		coarse sand and medium-small gravel with brown clay	15	
350-388		brown clay with medium sand	38	
388-398		fine sand	10	
398-405		fine sand with brown clay	8	
405-412		fine sand	7	
412-438		fine sand with brown clay	26	
438-450		fine-coarse sand	12	
450-456		brown silty clay	6	
456-480		fine-coarse sand	24	
480-515		medium-small gravel beds (1' thick) in medium sands	35	
515-526		brown silty clay with sand	11	
526-578		fine-medium sand with brown clay	52	
578-592		medium coarse sand with small gravel	14	
592-598		sandy brown clay	6	
598-608		medium-small gravel with thin sandy brown clay beds	10	
608-624		medium coarse gravel with coarse sand	16	

FOR FIELD COPIES USE ALTERNATE LINES

LOG OBTAINED BY Jorge Martinez DATE 10-4-76 SHEET 1 OF 2

Log # 3669

DEPARTMENT OF WATER RESOURCES

Stony Creek Fan

WELL LOG

LOCAL DESIGNATION SCF 5

DEPTH	ELEVATION OF BOTTOM OF STRATUM	MATERIAL	THICKNESS FEET	% VOIDS	ABSOLUTE VOIDS FEET	TOTAL VOIDS FEET
624-638'		fine sand with layers of brown clay	14'			
638-700		blue silty clay with fine sand	32			

FOR FIELD COPIES USE ALTERNATE LINES

20N/02W-18

ORIGINAL
File with DWR

Page ___ of ___

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

Owner's Well No. G-1

No. 801448A,B,C,D

Date Work Began 1/3/01, Ended 1/23/02

Local Permit Agency Glenn Co

Permit No. MW 120-01 Permit Date

DWR USE ONLY — DO NOT FILL IN

20N/02W-18R (5-7) M

STATE WELL NO./STATION NO.

QUARTER OF QUARTER OF SECTION

LATITUDE well LONGITUDE

APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION (✓) ___ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD Rotary FLUID Mud

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	70	Brown to tan Clay
70	80	Coarse Sand
80	130	Blue Grey Clay
130	180	Sand & gravel
180	290	Light Brown Clay
290	295	Sand
295	445	Brown to tan Clay
445	451	Sand
451	490	Brown Clay
490	500	Sand
500	515	Yellow to tan Clay
515	525	Sand
525	575	Yellow Clay
575	580	Sand
580	630	Yellow to Tan Clay
630	655	Sand
655	695	Yellow to Tan Clay
695	705	Silt/Tuff Deposit
705	750	Yellow to Tan Clay
750	805	Brown siltstone w/Tuff Fragments
805	822	Green/Grey Siltstone
822	840	Lt. Grey Clay
840	905	Brown Siltstone with Clay
905	940	Sand w/Basalt Chips
940	950	Blue/Grey Clay
950	977	Volcanic Sands
977	1020	Lt Green to Yellow Clay

TOTAL DEPTH OF BORING 1020 (Feet)

TOTAL DEPTH OF COMPLETED WELL 1000 (Feet)

WELL LOCATION

Address Co. Rd R & Co. Rd 39

City Glenn

County Glenn

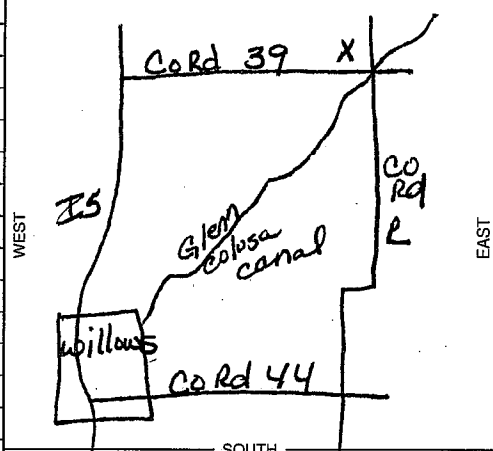
APN Book 019 Page 220 Parcel 011

Township ___ Range ___ Section ___

Latitude ___ DEG. ___ MIN. ___ SEC. NORTH

Longitude ___ DEG. ___ MIN. ___ SEC. WEST

LOCATION SKETCH



Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial

MONITORING X
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___

ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___

TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)

** May not be representative of a well's long-term yield.*

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
Please see attach. Log										

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)

Rec'd 4 2002

ATTACHMENTS (✓)

___ Geologic Log
X Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Spectrum Exploration (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

ADDRESS P.O. Box 471 CITY Zamora STATE Ca ZIP 95698

Signed Charlie Borchers WELL DRILLER/AUTHORIZED REPRESENTATIVE

DATE SIGNED 3/18/02 C-57 LICENSE NUMBER 512268

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

#801448

Casing

Deep Well

Ft. to Ft.	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
1000 – 980		Blank	Steel	2"	Sch 40	
980 – 970		Screen	Steel	2"	Sch 40	.020
970 – 930		Blank	Steel	2"	Sch 40	
930 – 920		Screen	Steel	2"	Sch 40	.020
920 - +6"		Blank	Steel	2"	Sch 40	

A

#2 Well

Ft. to Ft.	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
675 – 655		Blank	Steel	2"	Sch 40	
655 – 635		Screen	Steel	2"	Sch 40	.020
635 - +1		Blank	Steel	2"	Sch 40	

B

Middle Well

Ft. to Ft.	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
545 – 525		Blank	Steel	2"	Sch 40	
526 – 515		Screen	Steel	2"	Sch 40	.020
515 – 460		Blank	Steel	2"	Sch 40	
460 – 450		Screen	Steel	2"	Sch 40	.020
450 - +2.5		Blank	Steel	2"	Sch 40	

C

Shallow Well

Ft. to Ft.	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
201 – 180		Blank	Steel	2"	Sch 40	
180 – 170		Screen	Steel	2"	Sch 40	.020
170 – 150		Blank	Steel	2"	Sch 40	
150 – 140		Screen	Steel	2"	Sch 40	.020
140 - +2		Blank	Steel	2"	Sch 40	

D

Annular Material

Ft. to Ft.	Type
100 – 925	#8 Sand
925 – 917	#60 Sand
917 – 902	Hot Batch Grout
902 – 513	Cement Grout
531 – 403	#8 Sand
403 – 393	#60 Sand
393 – 283	Cement Grout
283 – 171	#8 Sand
171 – 163	#60 Sand
163 – 101	Cement Grout
101 – 35	# 8 Sand
35 – 31	#60 Sand
31 – Surface	Cement Grout

20N/02W-25

ORIGINAL
File with DWR

Page ___ of ___

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

DWR USE ONLY — DO NOT FILL IN
20N/02W 25 F(1-4) M
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. G-2
Date Work Began 10/3/01, Ended 1/23/02 No. 782025A,B,L,D
Local Permit Agency Glenn Co
Permit No. MW121-01 Permit Date 10/1/01

GEOLOGIC LOG

ORIENTATION (✓) ___ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ___ FLUID ___

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	20	Sand
20	60	Lt. Brown Clay
60	80	Sands & Gravels
80	190	Brown Clay
190	200	Coarse Sand
200	250	Brown Clay
250	260	Sand
260	410	Blue/Grey Clay
410	440	Sand
440	450	Blue/Grey Clay
450	480	Sand
480	510	Blue/Grey Clay
510	520	Sand & Gravel
520	930	Blue/Grey Clay
930	960	Sand
960	1000	Blue/Grey Clay

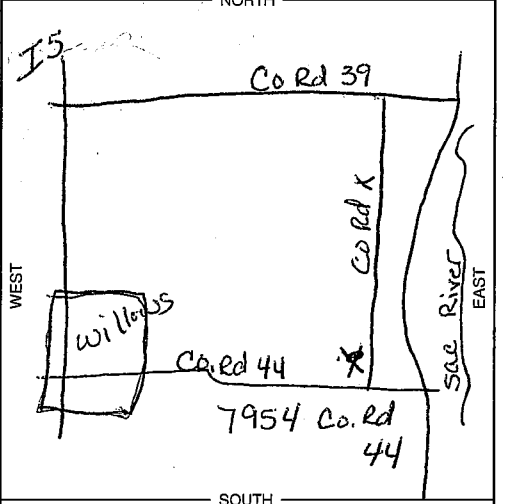
TOTAL DEPTH OF BORING 1000 (Feet)
TOTAL DEPTH OF COMPLETED WELL 980 (Feet)

WELL OWNER

WELL LOCATION

Address 7954 Co Rd 44
City Glenn
County Glenn
APN Book 019 Page 110 Parcel 025-9
Township ___ Range ___ Section ___
Latitude ___ DEG. ___ MIN. ___ SEC. NORTH Longitude ___ DEG. ___ MIN. ___ SEC. WEST

LOCATION SKETCH



*Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.***

ACTIVITY (✓)

X NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING X
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE Airlift
TEST LENGTH 1 (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
** May not be representative of a well's long-term yield.*

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
Please see attached log										

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)

DEC 24 2002

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Spectrum Exploration Inc (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
ADDRESS P.O. Box 471 CITY Zamora STATE Ca ZIP 95698
Signed Charlise Borchers (WELL DRILLER/AUTHORIZED REPRESENTATIVE) DATE SIGNED 3/18/03 C-57 LICENSE NUMBER 512268

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

#782025

Casing

Deep Well

A

Ft. to Ft.	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
980 - 960		Blank	Steel	2"	Sch 40	
960 – 940		Screen	Steel	2"	Sch 40	.020
940 – +6"		Blank	Steel	2"	Sch 40	

#2 Well

B

Ft. to Ft.	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
490 – 470		Blank	Steel	2"	Sch 40	
470 – 460		Screen	Steel	2"	Sch 40	.020
460 – 430		Blank	Steel	2"	Sch 40	
430 – 420		Screen	Steel	2"	Sch 40	.020
420 - +1		Blank	Steel	2"	Sch 40	

Middle Well

C

Ft. to Ft.	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
280 – 260		Blank	Steel	2"	Sch 40	
260 – 250		Screen	Steel	2"	Sch 40	.020
250 – 200		Blank	Steel	2"	Sch 40	
200 – 190		Screen	Steel	2"	Sch 40	.020
190 - +2.5		Blank	Steel	2"	Sch 40	

Shallow Well

D

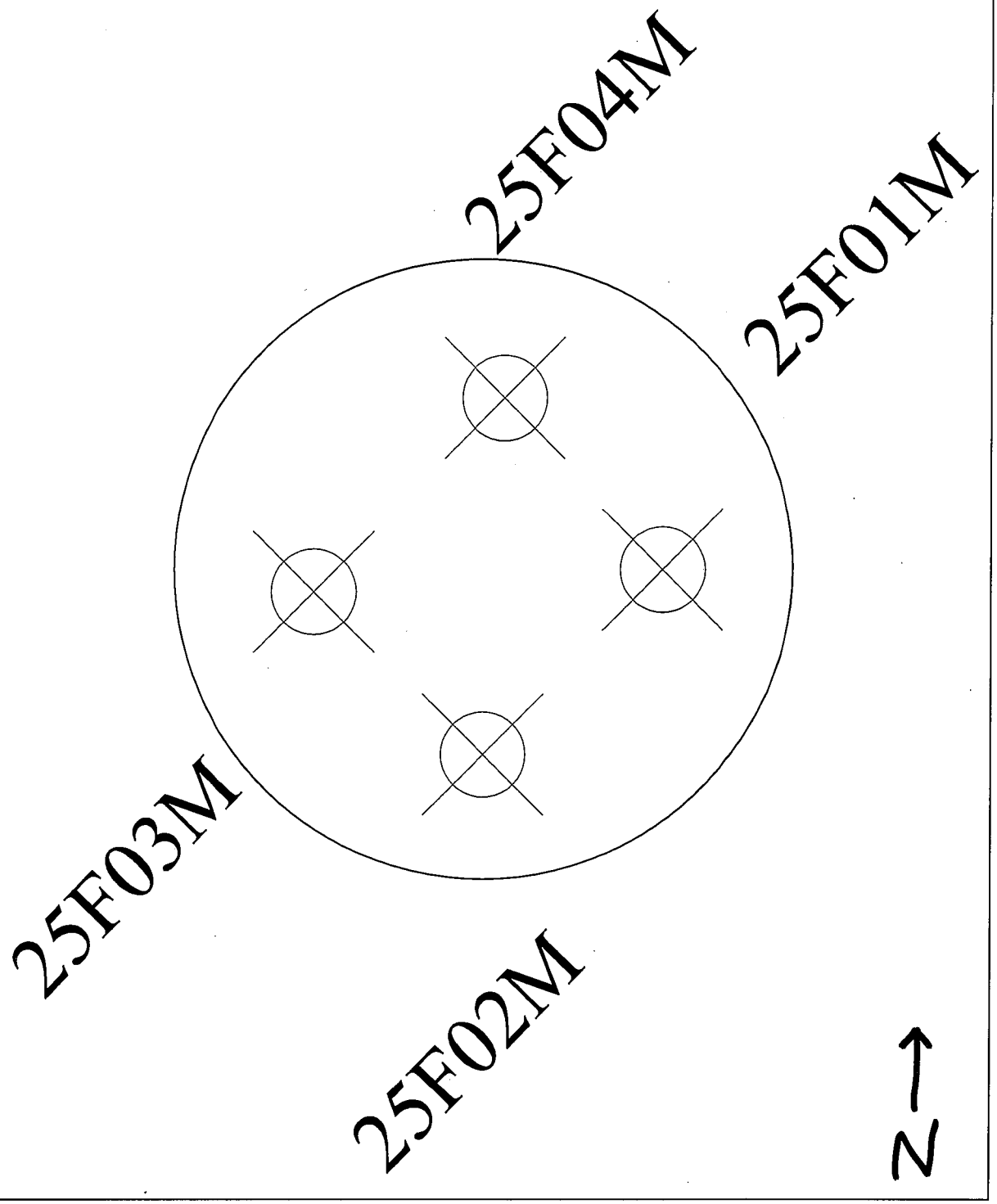
Ft. to Ft.	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
85 – 65		Blank	Steel	2"	Sch 40	
65 – 55		Screen	Steel	2"	Sch 40	.020
55 - +2		Blank	Steel	2"	Sch 40	

Annular Material

Ft. to Ft.	Type
985 - 925	#8 Sand
925 - 500	Cement Grout
500 - 400	#8 Sand
400 – 285	Cement Grout
285 – 170	#8 Sand
170 – 85	Cement Grout
85 – 45	#8 Sand
45 – Surface	Cement Grout

#782025

20N02W-Mirande Farms (G-2)



STATE OF CALIFORNIA - RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

FEATURE Quadruple Completion Monitoring Well HOLE NUMBER GZ Miranda Farms LOCATION Glenn County, County Rd 44 and County Rd X UTM COORDINATES UTM 10 S 0583104 4379316

TYPE OF HOLE Reverse Mud Rotary TYPE OF RIG Homemade TOTAL DEPTH 1000 ft DATE STARTED 10/15/01 DATE COMPLETED 01/23/02

CONTRACTOR Spectrum Exploration Inc. DRILL FOREMAN Sundar & Dan DRILL HELPER(S) Kanpay ect. NUMBER OF COMPLETIONS 4

INSPECTED BY K. Staton & D. Stamoles PROJECT Butte/Glenn Online 2001 COMMENTS 9.5 inch test hole drilled 10/15/01 to 10/19/01 well construction from 12/13/01 to 01/23/02

DEPTH (FEET)	LITHOLOGY	DESCRIPTION
0		Sand
50		Light Brown Clay
		Sand & Gravel
100		Brown Clay
150		
200		Coarse Grained Sand
		Brown Clay
250		Well Graded Sand
300		Blue/Grey Clay
350		
400		Poorly Graded Sand
		Blue/Grey Clay
450		

Cement Grout (surface to 31 ft)

#60 Sand (31 ft to 35 ft)

#8 Sand (35 ft to 101 ft)

Cement Grout (101 ft to 163 ft)

#60 Sand (163 ft to 171 ft)

#8 Sand (171 ft to 283 ft)

Cement Grout (283 ft to 393 ft)

#60 Sand (393 ft to 403 ft)

#8 Sand (403 ft to 513 ft)

Black Steel Conductor Casing 1/4-Inch Wall Thickness to 35 ft

Centralizers

Stainless Steel Wire Wrap Screen 0.020-Inch Opening 20 ft Section.

Centralizer

1-Inch Black Steel Airline

21 ft Sediment Trap

Centralizers

Stainless Steel Wire Wrap Screen 0.020-Inch Opening 10 ft Sections.

Centralizer

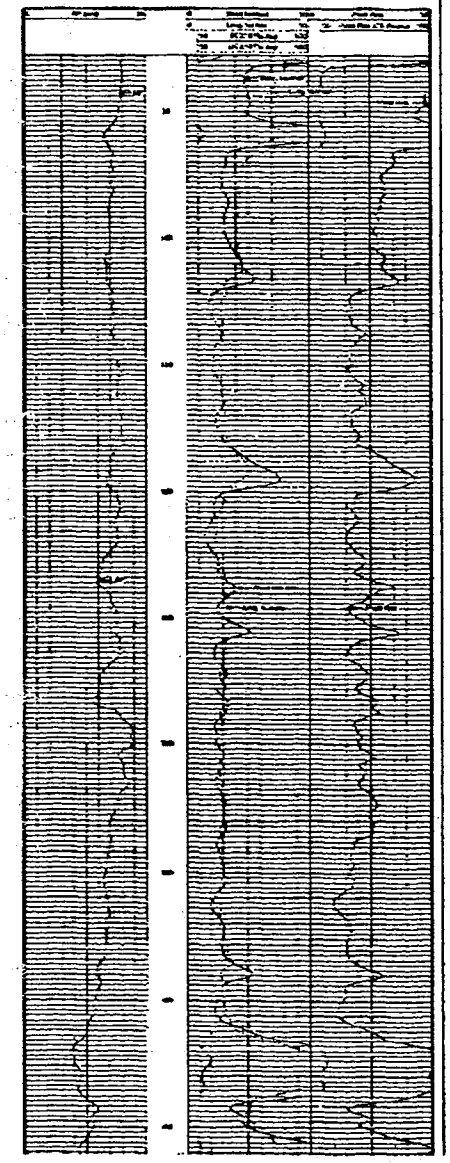
Stainless Steel Wire Wrap Screen 0.020-Inch Opening 10 ft Section.

Centralizer

1-Inch Black Steel Airline

21 ft Sediment Trap

Stainless Steel Wire Wrap Screen 0.020-Inch Opening 10 ft Section.



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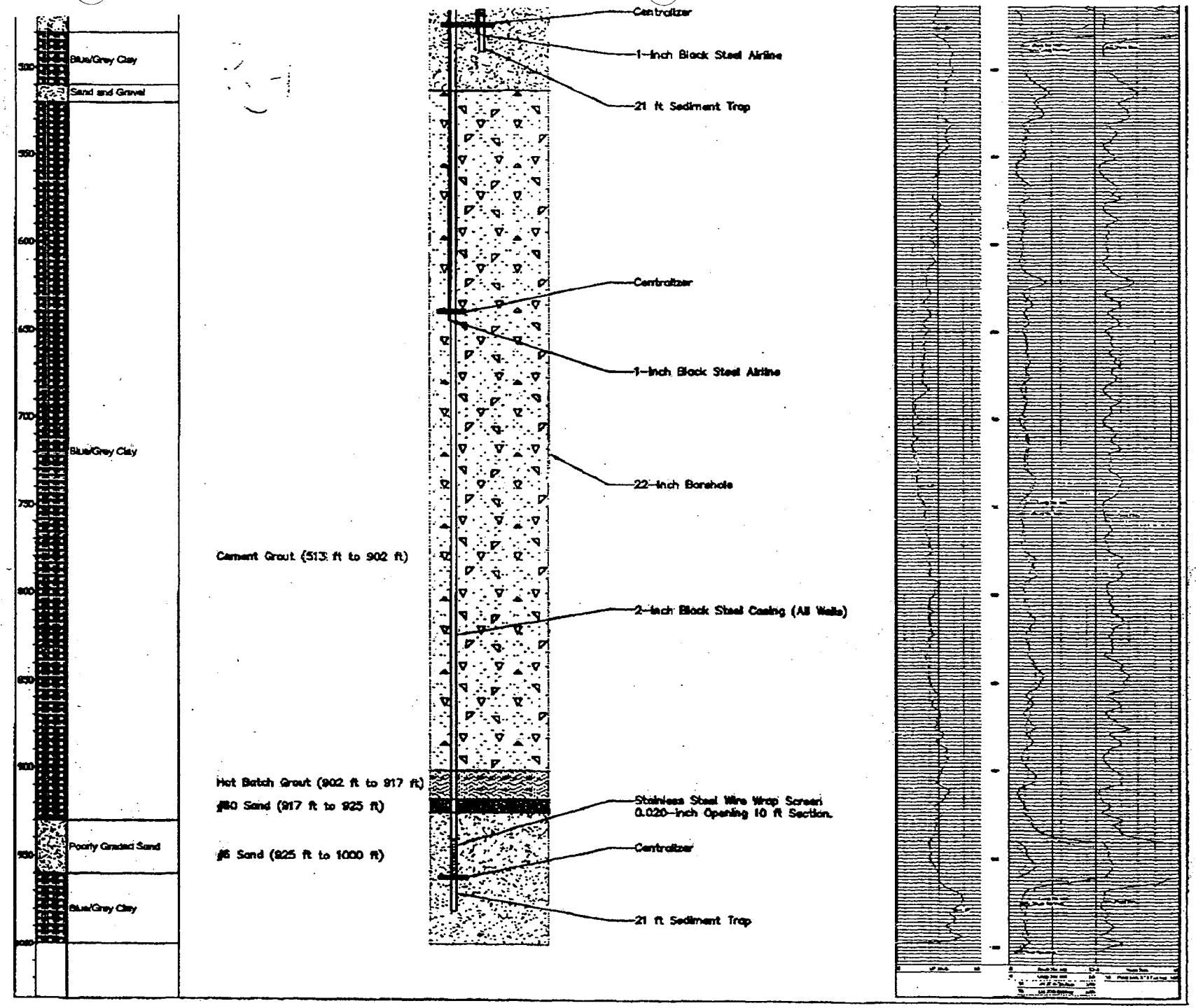

Blue/Grey Clay
Sand and Gravel
Blue/Grey Clay
Poorly Graded Sand
Blue/Grey Clay
Centralizer
1-Inch Black Steel Airline
21 ft Sediment Trap
Centralizer
1-Inch Black Steel Airline
22-Inch Borehole
Cement Grout (513 ft to 902 ft)
2-Inch Black Steel Casing (All Wells)
Hot Batch Grout (902 ft to 917 ft)
#80 Sand (917 ft to 925 ft)
#6 Sand (925 ft to 1000 ft)
Stainless Steel Wire Wrap Screen
0.020-Inch Opening 10 ft Section
Centralizer
21 ft Sediment Trap

#782025

REGION

COUNTY Glenn

NEAR

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

BASIN 5-21.02

DWR No. 20N/2W-33B MD B & M

OTHER Nos

SCF-6

WELL LOG

36086

LOCATION 1 mile west from intersection of "Rd V" and "Rd 46"; and 2200' north of intersection of "Rd 46" and irrigation road west of Lewis home, west side of road

DRILLED BY Caltrans for DWR ADDRESS Northern Division, Red Bluff, Ca.

DRILLING METHOD Rotary GRAVEL PACKED yes DATE COMPLETED 8/15/77 - 8/23/77

SIZE OF CASING DEPTH 10 5/8" hole; 3" casing 0-20'; 6" casing 0-320' STRUCK WATER AT 74'

PERFORATIONS 100'-120'; 200-320' SIZE 6" casing No.

WATER LEVEL BEFORE PERFORATING AFTER

TEST DATA: DISCHARGE G. P. M. DRAWDOWN FT. HOURS RUN

OTHER DATA AVAILABLE: WATER LEVEL RECORD ANALYSIS

SURFACE ELEV. 103' DATUM MSL SOURCE OF INFORMATION Geologist

DEPTH	ELEV. OF BOTTOM OF STRATUM	MATERIAL	THICKNESS	SP. YIELD %	
0-8'		Sandy brown soil	8'		
8-15'		Brown clay	7'		
15-20'		Pea Gravel lense	5'		
20-42'		Sandy brownish-yellow clay w/minor gravel	22'		
42-46'		Brown clay, very little fine sand	4'		
46-70'		Sandy brown clay	24'		
70-84'		Coarse sand and pea gravel w/minor brown clay	14'		
84-86'		Brown clay	2'		
86-92'		Coarse sand and pea gravel	6'		
92-98'		Brown silty clay	6'		
98-120'		Coarse sand and pea gravel	22'		
120-144'		Sandy clay (red-brown, green-brown, and buff-brown)	24'		
144-160'		Silty clay (red-brown and green-brown)	16'		
160-170'		Pea gravel	10'		
170-188'		Silty clay w/minor fine sand (green-black and green-brown)	18'		
188-198'		Greenish-brown clay	10'		
198'-218'		Red-brown and green-brown clayey sand w/minor pea gravel lenses	20'		
218-223'		Greenish brown clay	5'		
223-236'		Greenish brown clayey sand	13'		
236-240'		Pea Gravel	4'		
240-260'		Whiteish-tan clayey sand w/minor gravel lenses	20'		
260-261'		Pea Gravel	1'		
261-268'		Whiteish-tan clayey sand	7'		
268'-282'		Pea gravel and coarse sand	14'		

OBTAINED BY Peter Stroud DATE 9/19/77 SHEET 1 OF 2

FOR FIELD COPIES USE ALTERNATE LINES

203

FORM 263A
INVESTIGATION

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

SHEET 2

NUMBER SCF-6

WELL LOG

LOCAL DESIGNATION

DEPTH	ELEVATION OF BOTTOM OF STRATUM	MATERIAL	THICKNESS FEET	% VOIDS	ABSOLUTE VOIDS FEET	TOTAL VOIDS FEET
282-288'		Silty buff clay	6'			
288-310'		Pea gravel and coarse sand	22'			
310-326'		Brown clayey gravel (no water)	16'			
		*Note: There is a 10' section of drill pipe at the bottom of this hole.				

FOR FIELD COPIES USE ALTERNATE LINES

APPLIED GEOLOGICAL ENGINEERING, INC.
8065 CALLISON RD.
NEWCASTLE, CA 95658
(916) 663-2696

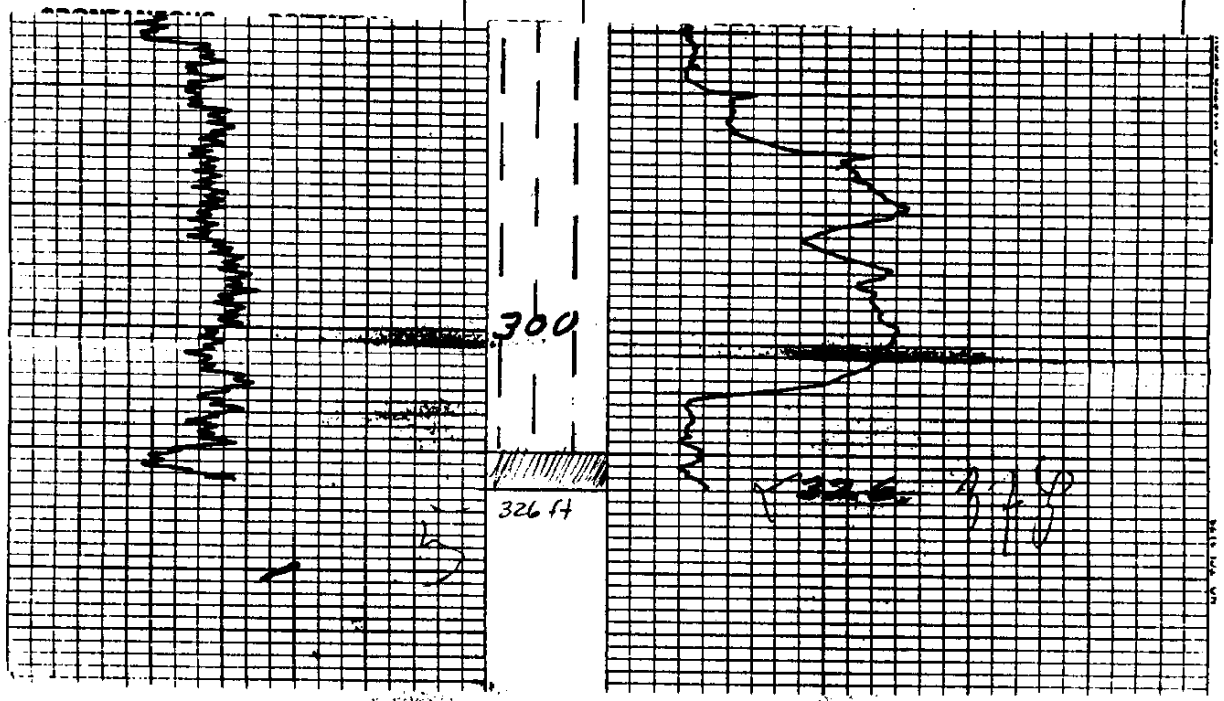
ELECTRICAL WELL LOG

Company CALIFORNIA STATE DIVISION OF WATER RESOUARCE Red Bluff, Dist. Test Hole No. SCF-6

County Glenn State Ca. Elevation 120 Location Sec. 33, T20N, R2 W.

	Run No. 1	Run No. 2
Date	Aug. 24, 1977	
First Reading	10	
Last Reading	326	
Footage Logged	316	
Bottom (Driller)	325	
Casing (From Log)	-	
Casing (Driller)	-	
Casing Size	-	
Bit Size:	10	
Bit Size:		

MUD	Run No. 1	Run No. 2
Nature	Natural + Bentonite	
Density		
Viscosity	40 + @ °F	@ °F
Resistivity	40 @ 72 °F	@ °F
Res. @ BHT	@ °F	@ °F
pH		
Circ. Temp.		
S.H. Temp		
Logged by	Paulsen	
Witnessed by	Lorene, Pearson	



ORIGINAL
File with DWR

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. E057712

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO. 20N/10W30-7
LATITUDE / LONGITUDE
APN/TRS/OTHER

Owner's Well No. 8123
Date Work Began 6/4/2007, Ended 6/18/2007
Local Permit Agency GLENN COUNTY HEALTH DEPT
Permit No. MW 280-07 Permit Date 5/31/2007

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	10	TOP SOIL
10	40	BROWN CLAY WITH SAND AND GRAVEL
40	130	YELLOW BROWN CLAY WITH SAND STREAKS
130	140	SAND AND GRAVEL
140	250	YELLOW BROWN CLAY WITH SAND STREAKS
250	260	SAND AND GRAVEL
260	310	YELLOW BROWN CLAY WITH SAND STREAKS
310	465	YELLOW BROWN CLAY WITH SAND AND GRAVEL
465	485	SAND AND GRAVEL WITH BLUE CLAY
485	500	SAND AND GRAVEL
500	530	BLUE CLAY WITH SAND
530	625	BLUE AND YELLOW CLAY MIX WITH SAND AND GRAVEL STREAKS
625	700	SAND AND GRAVEL WITH YELLOW AND BLUE CLAY MIX
700	865	YELLOW BROWN AND BLUE CLAY MIX WITH SAND AND GRAVEL
865	1000	GRAY CLAY WITH SAND AND GRAVEL STREAK
1000	1050	SAND AND GRAVEL
1050	1200	SAND AND GRAVEL WITH BLUE GRAY CLAY
1200	1300	YELLOW ORANGE CLAY WITH SAND AND GRAVEL STREAKS
1300	1395	SOFT YELLOW GRAY CLAY WITH SAND AND GRAVEL
1395	1400	HARD ROCK

TOTAL DEPTH OF BORING 1400 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1034 (Feet)

WELL OWNER

WELL LOCATION
Address 50' EOF RD D & .46 MI SOF RD 35
City CA
County GLENN
APN Book 020 Page 210 Parcel 008
Township 20 N Range 3 W Section 7
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH
NORTH / WEST / EAST / SOUTH
Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if **necessary. PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL
DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE	1									
0	118	16	✓				PVC	2.5	SCH 80	
118	128	16		✓			PVC	2.5	SCH 80	.030
128	138	16	✓				PVC	2.5	SCH 80	
ZONE	2									
0	380	16/14	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	84	✓			SAND SLURRY
84	95		✓		BENTONITE C
95	160			✓	SRI#8 SAND
160	176		✓		BENTONITE C
176	318			✓	SRI#8 SAND
318	352		✓		BENTONITE C

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT
I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
ADDRESS 20 WEST KENTUCKY AVE CITY WOODLAND STATE CA ZIP 95695
Signed Mark Damion WELL DRILLER/AUTHORIZED REPRESENTATIVE
DATE SIGNED 07/06/07
C-57 LICENSE NUMBER C57 A HIC - 133783

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

OCT 17 2002

Page 1 of 2

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 726740, A

DWR USE ONLY — DO NOT FILL IN
21N/02W-01M
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7448-1
Date Work Began 8/26/2002, Ended 9/6/2002
Local Permit Agency GLENN CNTY HEALTH DEPT.
Permit No. MW-139-02 Permit Date 8/21/2002

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	10	WELL GRADED SAND W/SILT AND FINE GRVL
10	20	WELL GRADED SAND WITH FINE GRAVEL
20	50	POORLY GRADED SAND AND GRAVEL
50	60	POORLY GRADED SND AND GRVL W/TAN CLY
60	70	POORLY GRADED SAND WITH GRAVEL
70	80	POORLY GRADED GRAVEL
80	100	GRAY/BROWN CLAY WITH SAND AND GRAVEL
100	110	POORLY GRADED SAND
110	120	POORLY GRADED SAND WITH FINE GRAVEL
120	150	POORLY GRADED GRAVEL
150	160	GRAVEL AND SAND W/YELLOW STICKY CLAY
160	190	YELLOW CLAY WITH GRAVEL AND SAND
190	200	POORLY GRADED GRAVEL W/SAND AND CLAY
200	230	YELLOW CLAY WITH SAND AND GRAVEL
230	240	YELLOW SILTY CLAY
240	250	YELLOW SILTY CLAY W/SAND AND GRAVEL
250	260	SMALL GRAVEL WITH SAND AND SILTY CLAY
260	270	POORLY GRADED GRAVEL WITH SAND
270	280	POORLY GRADED GRAVEL
280	300	GRAVEL
300	310	GRAVEL WITH FINE SAND
310	340	GRAVEL
340	350	TUSCAN ROCK WITH GRAVEL AND SAND
350	370	TUSCAN ROCK W/SANDSTONE, QUARTZ,
		OTHER METAMORPHICS, TUFF, BASALT, SAND
370	380	COARSE SAND
380	450	TUSCAN AND METAMORPHIC RCK W/SND, CLY
450	460	SILTSTONE WITH GRAVEL, QUARTZ, RED
		CHERT, AND VOLCANICS
460	555	MIXED COLORED CLAY WITH GRAVEL

TOTAL DEPTH OF BORING 600 (Feet)
TOTAL DEPTH OF COMPLETED WELL 578 (Feet)

WELL LOCATION

Address .25 MI SOF C/R 24 & .75 MI EOF C/R V V
City CA
County GLENN
APN Book 037 Page 360 Parcel 060
Township 22N / 21N Range 2 W Section 15 01
Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED
ESTIMATED YIELD * — (GPM) & TEST TYPE
TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE	1									
0	232	12					ACCESS TB	1		
0	547	12/8	✓				SCH 40	2		
547	557	8		✓			SS SCREE	2		.030
557	578	8	✓				SCH 40	2		
ZONE	2									

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	220	✓			SAND SLURRY
220	230		✓		CHIPS
230	385			✓	#8 GRD SAND
385	505	✓			SAND SLURRY
505	600			✓	#8 GRD SAND

OCT 22 2002

ATTACHMENTS (✓)
— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO. (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY ADDRESS WOODLAND CITY CA STATE 95695 ZIP
Signed WELL DRILLER/AUTHORIZED REPRESENTATIVE 10/03/02 DATE SIGNED 133783-C57A C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 726740

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7448-1
Date Work Began 8/26/2002, Ended 9/6/2002
Local Permit Agency GLENN CNTY HEALTH DEPT.
Permit No. MW-139-02 Permit Date 8/21/2002

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
555	575	GRAVEL
575	605	MIXED COLORED CLAY W/SAND AND GRAVEL

TOTAL DEPTH OF BORING 600 (Feet)
TOTAL DEPTH OF COMPLETED WELL 578 (Feet)

WELL LOCATION

Address .25 MI SOF C/R 24 & .75 MI EOF C/R V V
City CA
County GLENN
APN Book 037 Page 360 Parcel 060
Township 22 N Range 2 W Section 15
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	230	12					ACCESS TB	1		
0	297	12	✓				SCH 40	2		
297	307	12		✓			SS SCREE	2		.030
307	318	12	✓				SCH 40	2		

ANNULAR MATERIAL

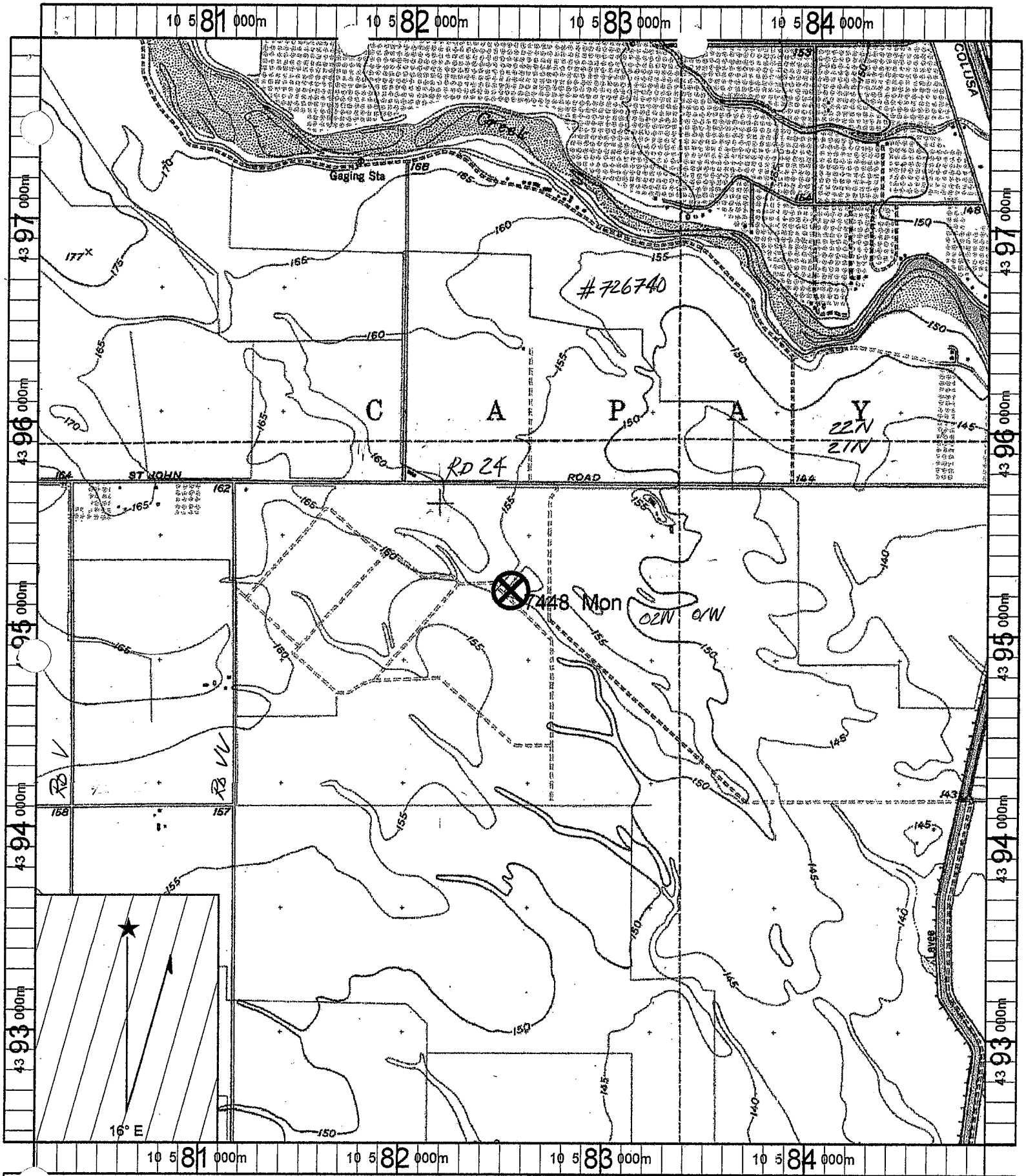
DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	220	✓			SAND SLURRY
220	230		✓		CHIPS
230	385			✓	#8 GRD SAND
385	505	✓			SAND SLURRY
505	600			✓	#8 GRD SAND

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY ADDRESS — WOODLAND CITY — CA STATE — 95695 ZIP
Signed ___ WELL DRILLER/AUTHORIZED REPRESENTATIVE
10/03/02 DATE SIGNED
133783-C57A C-57 LICENSE NUMBER

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM



Name: HAMILTON CITY
Date: 8/15/2002
Scale: 1 inch equals 2000 feet

Caption: Glenn Co. (St. Johns Farms)
Job# 7448 Mon
APN: 037-360-06

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ORIGINAL
File with DWR

Page 1 of 2

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instructions Page Two

No. 726741

Owner's Well No. 7448-2

Date Work Began 8/26/2002 Ended 9/6/2002

Local Permit Agency GLENN CNTY HEALTH DEPT

Permit No. MW-139-02 Permit Date 8/21/2002

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION: ✓ VERTICAL HORIZONTAL ANGLE (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE ft.	to ft.	DESCRIPTION (Describe material, grain size, color, etc.)
0	10	WELL GRADED SAND W/SILT AND FINE GRVL
10	20	WELL GRADED SAND W TH FINE GRAVEL
20	50	POORLY GRADED SAND AND GRAVEL
50	60	POORLY GRADED SND AND GRVL WITAN CLY
60	70	POORLY GRADED SAND WITH GRAVEL
70	80	POORLY GRADED GRAVEL
80	100	GRAY/BROWN CLAY WITH SAND AND GRAVEL
100	110	POORLY GRADED SAND
110	120	POORLY GRADED SAND WITH FINE GRAVEL
120	150	POORLY GRADED GRAVEL
150	160	GRAVEL AND SAND W/YELLOW STICKY CLAY
160	190	YELLOW CLAY WITH GRAVEL AND SAND
190	200	POORLY GRADED GRAVEL W/SAND AND CLAY
200	230	YELLOW CLAY WITH SAND AND GRAVEL
230	240	YELLOW SILTY CLAY
240	250	YELLOW SILTY CLAY W/SAND AND GRAVEL
250	260	SMALL GRAVEL WITH SAND AND SILTY CLAY
260	270	POORLY GRADED GRAVEL WITH SAND
270	280	POORLY GRADED GRAVEL
280	300	GRAVEL
300	310	GRAVEL WITH FINE SAND
310	340	GRAVEL
340	350	TUSCAN ROCK WITH GRAVEL AND SAND
350	370	TUSCAN ROCK W/SANDSTONE, QUARTZ, OTHER METAMORPHICS, TUFF BASALT, SAND
370	380	COARSE SAND
380	450	TUSCAN AND METAMORPHIC RCK W/SND, CLY
450	460	SILTSTONE WITH GRAVEL QUARTZ, RED CHERT, AND VOLCANICS
460	555	MIXED COLORED CLAY WITH GRAVEL

TOTAL DEPTH OF BORING 125 Feet

TOTAL DEPTH OF COMPLETED WELL 124 Feet

WELL LOCATION

Address 25 MI SOF C/R 24 & 75 MI EOF C/R V V

City CA

County GLENN

APN Book 037 Page 360 Parcel 050

Township 22 N Range 2 W Section 35

Latitude DEG MIN SEC Longitude DEG MIN SEC

LOCATION SKETCH

NORTH

WEST EAST

SOUTH

Please provide scale or indicate distance of survey lines

ACTIVITY

✓ NEW WELL

MODIFICATION/REPAIR

Deepen

Other (Specify)

DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY

Domestic Public

Irrigation Industrial

MONITORING ✓

TEST WELL

CATHODIC PROTECTION

HEAT EXCHANGE

DIRECT PUSH

INJECTION

VAPOR EXTRACTION

SPARGING

REMEDIATION

OTHER (SPECIFY)

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER Ft. BELOW SURFACE

DEPTH OF STATIC WATER LEVEL Ft. & DATE MEASURED

ESTIMATED YIELD GPM & TEST TYPE

TEST LENGTH Hrs. TOTAL DRAWDOWN Ft.

Man not to scale

CASING(S)

DEPTH FROM SURFACE ft.	to ft.	BORE-HOLE DIA (inches)	BLANK	SCREEN	CASING CENTER FILL PIPE	MATERIAL GRADE	MATERIAL DIAMETER (inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (inches)
ZONE	1								
0	55	15				ACCESS TB	1		
0	109	15	✓			SCH 40	2		
109	119	15		✓		SS SCREE	2		030
119	124	15	✓			SCH 40	2		
ZONE	2								

ANNULAR MATERIAL

DEPTH FROM SURFACE ft.	to ft.	CEMENT GROUT	BENTONITE CHIPS	BENTONITE PELLETS	FILTER PACK TYPE AND SIZE
0	46	✓			SAND SLURRY
46	80			✓	#8 GRD SAND
80	100		✓		CHIPS
100	119			✓	#6 GRD SAND
119	125		✓		CHIPS

ATTACHMENTS

Geologic Log

Well Construction Diagram

Geophysical Log(s)

Soil/Water Chemical Analyses

Other

ATTACH ADDITIONAL INFORMATION, IF EXISTS.

CERTIFICATION STATEMENT

I/We, the undersigned, certify that this report is complete and accurate to the best of my/our knowledge and belief.

NAME EATON DRILLING CO.

(PERSON, FIRM OR CORPORATION) (TYPED OR PRINTED)

20 W KENTUCKY WOODLAND CA 95695

ADDRESS CITY STATE ZIP

Signed WELL DRILLER/AUTHORIZED REPRESENTATIVE

10/03.02 133783 C57A

DATE SIGNED CONTRACTOR'S LICENSE NUMBER

DWR 188 REV. 10/97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 2 of 2

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instructions for completion

No. 726741

Owner's Well No. 7448-2

Date Work Began 8-26/2002 Ended 9/6/2002

Local Permit Agency GLENN CNTY HEALTH DEPT

Permit No MW-139-02 Permit Date 8/21/2002

LOCAL USE ONLY — DO NOT FILL IN

STATE WELL NO./STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION ✓ VERTICAL HORIZONTAL ANGLE (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE ft.	to ft.	DESCRIPTION (Describe color, texture, grain size, and major water-bearing zones)
555	575	GRAVEL
575	605	MIXED COLORED CLAY W/SAND AND GRAVEL

TOTAL DEPTH OF BORING 125 Feet

TOTAL DEPTH OF COMPLETED WELL 124 Feet

WELL LOCATION

Address .25 MI SOF C/R 24 & 75 MI EOF C/R V V

City CA

County GLENN

APN Book 037 Page 360 Parcel 060

Township 22 N Range 2 W Section 15

Latitude DEG MIN SEC Longitude DEG MIN SEC

LOCATION SKETCH

NORTH

WEST EAST

SOUTH

Please provide sketch showing distance from property lines, roads, and identify nearest cross street. PLEASE BE YOUR OWN ENGINEER

✓ NEW WELL

MODIFICATION/REPAIR

Describe

Other (Specify)

DESTRUCTION (Describe Procedures and Materials Used)

ATTACH GEOLOGIC LOG

PLANNED USES (✓)

WATER SUPPLY

Domestic Public

Irrigation Monitoring

MONITORING ✓

TEST WELL

CATHODIC PROTECTION

HEAT EXCHANGE

DIRECT PUSH

INJECTION

VAPOR EXTRACTION

SPARGING

REMEDIATION

OTHER (SPECIFY)

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL (Ft.) & DATE MEASURED

ESTIMATED YIELD (GPM) & TEST TYPE

TEST LENGTH (Hrs.) TOTAL DRAWDOWN (Ft.)

Was a pump test made? (If yes, attach copy)

CASING(S)

DEPTH FROM SURFACE ft.	to ft.	BORE HOLE DIA (inches)	TYPE: BLANK	TYPE: SCREEN	MATERIAL GRADE	NOMINAL DIAMETER (inches)	GAUGE OR WALL THICKNESS	SLOT SIZE if any (inches)
0	55	15			ACCESS TS.	1		
0	55	15	✓		SCH 40	2		
55	65	15		✓	SS SCREE	2		.030
65	75	15	✓		SCH 40	2		

ANNULAR MATERIAL

DEPTH FROM SURFACE ft.	to ft.	CEMENT GROUT (Lbs.)	BENTONITE (✓)	CHIPS (✓)	FILTER PACK (TYPE SIZE)
0	46	✓			SAND SLURRY
46	80			✓	#8 GRD SAND
80	100		✓		CHIPS
100	119			✓	#8 GRD SAND
119	125		✓		CHIPS

ATTACHMENTS

Geologic Log

Well Construction Diagram

Geophysical Log(s)

Soil/Water Chemical Analyses

Other

ATTACH ADDITIONAL INFORMATION, IF EXISTS

CERTIFICATION STATEMENT

I/We, the undersigned, certify that this report is complete and accurate to the best of my/our knowledge and belief

NAME EATON DRILLING CO (PERSON, FIRM OR CORPORATION) (TYPED OR PRINTED)

28 W. KENTUCKY ADDRESS WOODLAND CITY CA STATE 95695 ZIP

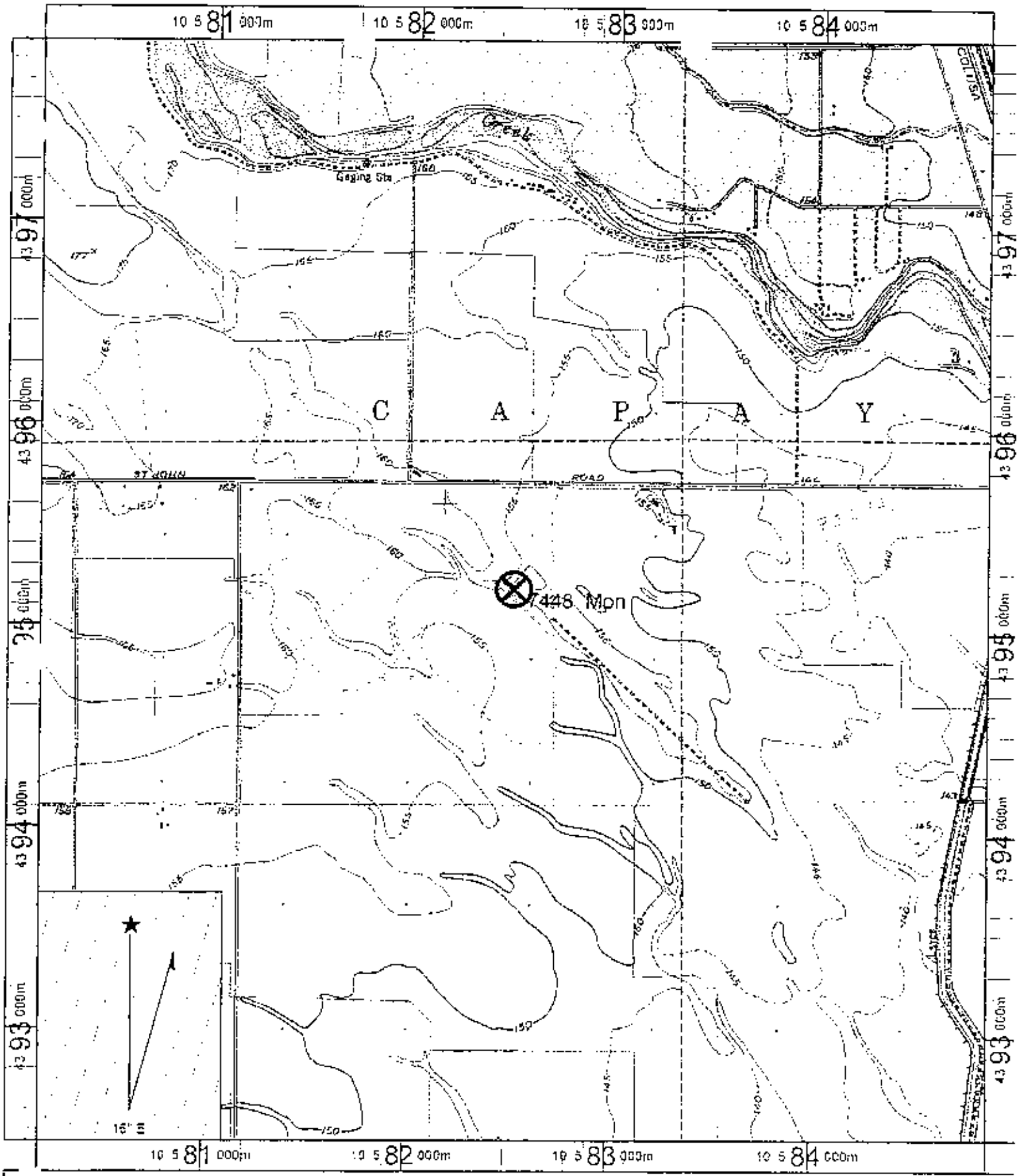
Signed WELL DRILLER/AUTHORIZED REPRESENTATIVE 10/03/02 DATE SIGNED 133783-C57A C-57 LICENSE NUMBER

USE ADDITIONAL SHEETS IF NECESSARY

ATTACH ADDITIONAL INFORMATION, IF EXISTS. FAILURE TO PROVIDE COMPLETE AND ACCURATE INFORMATION MAY RESULT IN RETURN OF WELL REPORT FOR CORRECTION AND DELAY IN PROCESSING.

SEND COMPLETED FORM TO: DEPARTMENT OF WATER RESOURCES, WELL STANDARDS BRANCH, P.O. BOX 942836, SACRAMENTO, CA 94236-0001, (916) 653-1602

DWR 188 (REV. 10-98)



Name: HAMILTON CITY
Date: 8/15/2002
Scale: 1 inch equals 2000 feet

Caption: Glenn Co. (St. Johns Farms)
Job# 7448 Mon
APN: 037-360-06

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ORIGINAL
File with DWR

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. E044112

DWR USE ONLY --- DO NOT FILL IN

STATE WELL NO./ STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

Owner's Well No. 7987

Date Work Began 7/12/2006, Ended 7/28/2006

Local Permit Agency GLENN COUNTY HEALTH DEPT

Permit No. MW248-06 Permit Date 6/14/2006

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	3	TOP SOIL
3	20	SAND AND GRAVEL
20	110	3/4" GRAVEL WITH YELLOW BROWN CLAY
110	150	YELLOW BROWN CLAY
150	290	YELLOW BROWN CLAY WITH SAND AND GRAVEL
290	330	LOOSE GRAVEL WITH SAND
330	460	SOFT GRAY CLAY WITH SAND AND GRAVEL
460	500	BRITTLE YELLOW AND GRAY CLAY MIX WITH COARSE SAND
500	620	BRITTLE YELLOW CLAY WITH SAND AND GRAVEL
620	920	BRITTLE GRAY CLAY WITH SAND AND GRAVEL
920	1200	SOFT SILTY GRAY CLAY WITH SAND STREAKS

TOTAL DEPTH OF BORING 1200 (Feet)

TOTAL DEPTH OF COMPLETED WELL 948 (Feet)

WELL LOCATION

Address .5 MI SOF RD 24 & .67 MI EOF RD S

City CA

County GLENN

APN Book 023 Page 220 Parcel 005

Township 21 N Range 2 W Section 4 18

Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR

___ Deepen

___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY

___ Domestic ___ Public

___ Irrigation ___ Industrial

MONITORING ✓

TEST WELL ___

CATHODIC PROTECTION ___

HEAT EXCHANGE ___

DIRECT PUSH ___

INJECTION ___

VAPOR EXTRACTION ___

SPARGING ___

REMEDIATION ___

OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___

ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___

TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE	1									
+2.5	57	14	✓				PVC F480	2.5	SCH 80	
57	67	14		✓			PVC F480	2.5	SCH 80	.030
67	77	14	✓				PVC F480	2.5	SCH 80	
ZONE	2									
+2	165	14	✓				PVC F480	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)

Next Page

ATTACHMENTS (✓)

___ Geologic Log

___ Well Construction Diagram

___ Geophysical Log(s)

___ Soil/Water Chemical Analysis

___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

20 WEST KENTUCKY AVE ADDRESS WOODLAND CITY CA STATE 95695 ZIP

Signed Mark Damion WELL DRILLER/AUTHORIZED REPRESENTATIVE

09/05/06 DATE SIGNED

C57 A HIC - 133783 C-57 LICENSE NUMBER

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. E044112

DWR USE ONLY --- DO NOT FILL IN

STATE WELL NO./ STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

Owner's Well No. 7987

Date Work Began 7/12/2006, Ended 7/28/2006

Local Permit Agency GLENN COUNTY HEALTH DEPT

Permit No. MW248-06 Permit Date 6/14/2006

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	3	TOP SOIL
3	20	SAND AND GRAVEL
20	110	3/4" GRAVEL WITH YELLOW BROWN CLAY
110	150	YELLOW BROWN CLAY
150	290	YELLOW BROWN CLAY WITH SAND AND GRAVEL
290	330	LOOSE GRAVEL WITH SAND
330	460	SOFT GRAY CLAY WITH SAND AND GRAVEL
460	500	BRITTLE YELLOW AND GRAY CLAY MIX WITH COARSE SAND
500	620	BRITTLE YELLOW CLAY WITH SAND AND GRAVEL
620	920	BRITTLE GRAY CLAY WITH SAND AND GRAVEL
920	1200	SOFT SILTY GRAY CLAY WITH SAND STREAKS

TOTAL DEPTH OF BORING 1200 (Feet)

TOTAL DEPTH OF COMPLETED WELL 948 (Feet)

WELL LOCATION

Address .5 MI SOF RD 24 & .67 MI EOF RD S

City CA

County GLENN

APN Book 023 Page 220 Parcel 005

Township 21 N Range 2 W Section 4

Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH

WEST EAST

SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial

MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___

ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___

TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
165	175	14		✓			PVC F480	2.5	SCH 80	.030
175	269	14	✓				PVC F480	2.5	SCH 80	
269	279	14		✓			PVC F480	2.5	SCH 80	.030
279	289	14	✓				PVC F480	2.5	SCH 80	
ZONE +1.5	3 673.5	14	✓				PVC F480	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	41	✓			SAND SLURRY
41	45		✓		BENTONITE C
45	99			✓	SRI#8 SAND
99	104		✓		BENTONITE C
104	130			✓	SRI#8 SAND
130	135		✓		BENTONITE C

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

20 WEST KENTUCKY AVE ADDRESS | WOODLAND CITY | CA STATE | 95695 ZIP

Signed Mark Damron WELL DRILLER/AUTHORIZED REPRESENTATIVE | 09/05/06 DATE SIGNED | C57 A HIC - 133783 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. E044112

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./ STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

Owner's Well No. 7987

Date Work Began 7/12/2006, Ended 7/28/2006

Local Permit Agency GLENN COUNTY HEALTH DEPT

Permit No. MW248-06 Permit Date 6/14/2006

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	3	TOP SOIL
3	20	SAND AND GRAVEL
20	110	3/4" GRAVEL WITH YELLOW BROWN CLAY
110	150	YELLOW BROWN CLAY
150	290	YELLOW BROWN CLAY WITH SAND AND GRAVEL
290	330	LOOSE GRAVEL WITH SAND
330	460	SOFT GRAY CLAY WITH SAND AND GRAVEL
460	500	BRITTLE YELLOW AND GRAY CLAY MIX WITH COARSE SAND
500	620	BRITTLE YELLOW CLAY WITH SAND AND GRAVEL
620	920	BRITTLE GRAY CLAY WITH SAND AND GRAVEL
920	1200	SOFT SILTY GRAY CLAY WITH SAND STREAKS

TOTAL DEPTH OF BORING 1200 (Feet)

TOTAL DEPTH OF COMPLETED WELL 948 (Feet)

WELL LOCATION

Address .5 MI SOF RD 24 & .67 MI EOF RD S

City CA

County GLENN

APN Book 023 Page 220 Parcel 005

Township 21 N Range 2 W Section 4

Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR

— Deepen

— Other (Specify)

— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY

— Domestic — Public — Irrigation — Industrial

MONITORING ✓

TEST WELL —

CATHODIC PROTECTION —

HEAT EXCHANGE —

DIRECT PUSH —

INJECTION —

VAPOR EXTRACTION —

SPARGING —

REMEDIATION —

OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED

ESTIMATED YIELD * — (GPM) & TEST TYPE

TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
673.5	683.5	14		✓			PVC F480	2.5	SCH 80	.030
683.5	693.5	14	✓				PVC F480	2.5	SCH 80	
693.5	703.5	14		✓			PVC F480	2.5	SCH 80	.030
703.5	713.5	14	✓				PVC F480	2.5	SCH 80	
ZONE +1	4 928	14/8-3/4	✓				PVC F480	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
135	327			✓	SRI#8 SAND
327	335		✓		BENTONITE C
335	647	✓			SAND SLURRY
647	653		✓		BENTONITE C
653	715			✓	SRI#8 SAND
715	736		✓		BENTONITE C

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO. (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

ADDRESS 20 WEST KENTUCKY AVE CITY WOODLAND STATE CA ZIP 95695

Signed Mark Davison WELL DRILLER/AUTHORIZED REPRESENTATIVE

DATE SIGNED 09/05/06

C-57 LICENSE NUMBER C57 A HIC - 133783

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. E044112

DWR USE ONLY -- DO NOT FILL IN

STATE WELL NO./ STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

Owner's Well No. 7987

Date Work Began 7/12/2006, Ended 7/28/2006

Local Permit Agency GLENN COUNTY HEALTH DEPT

Permit No. MW248-06 Permit Date 6/14/2006

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	3	TOP SOIL
3	20	SAND AND GRAVEL
20	110	3/4" GRAVEL WITH YELLOW BROWN CLAY
110	150	YELLOW BROWN CLAY
150	290	YELLOW BROWN CLAY WITH SAND AND GRAVEL
290	330	LOOSE GRAVEL WITH SAND
330	460	SOFT GRAY CLAY WITH SAND AND GRAVEL
460	500	BRITTLE YELLOW AND GRAY CLAY MIX WITH COARSE SAND
500	620	BRITTLE YELLOW CLAY WITH SAND AND GRAVEL
620	920	BRITTLE GRAY CLAY WITH SAND AND GRAVEL
920	1200	SOFT SILTY GRAY CLAY WITH SAND STREAKS

TOTAL DEPTH OF BORING 1200 (Feet)

TOTAL DEPTH OF COMPLETED WELL 948 (Feet)

WELL LOCATION

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City CA

County GLENN

APN Book 023 Page 220 Parcel 005

Township 21 N Range 2 W Section 4

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LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
— Deepen
— Other (Specify)

— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial

MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED

ESTIMATED YIELD * — (GPM) & TEST TYPE

TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
928	938	8-3/4		✓			PVC F480	2.5	SCH 80	.030
938	948	8-3/4	✓				PVC F480	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
736	902	✓			SAND SLURRY
902	914		✓		BENTONITE C
914	964			✓	SRI#8 SAND
964	977		✓		BENTONITE C
977	1200			✓	NATIVE FILL

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

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(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

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Signed Mark Damron
WELL DRILLER/AUTHORIZED REPRESENTATIVE

09/05/06 DATE SIGNED

C57 A HIC - 133783 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

WELL COMPLETION REPORT

No. 801406

Glenn

912/02

GEOLOGIC LOG

Rotary Mud

DESCRIPTION

0	20	Fine Sand & some coarse sand & Silt
20	30	Sand & Gravel
30	40	Sand & Coarse Sand w/some gravel
40	45	Clay
45	58	gravelly Sand
58	94	Tan Silty clay
94	98	Clayey gravel
98	122	Tan clay
122	132	gravel
132	139	Tan clay
139	149	Sandy gravelly clay
149	169	Tan clay
169	176	Clayey gravel
176	192	Tan clay
192	202	gravel
202	227	Tan clay
227	232	Clayey Sand & gravel
232	292	Lt. yellow-Brown clay
292	304	Sandy gravel
304	316	Lt yellow-Brown clay
316	342	Gravel & Sand with clay
342	344	Sand
344	366	Clayey Sand
366	428	Lt. yellow Brown Clay
428	434	Sand
434	442	Lt. yellow-Brown Clay
442	452	Gravel
452	518	Lt yellow Brown Clay
518	520	Sandy gravel

* Triple Completion dual 12dup 2 underside 3-Shallow

520

4403

WELL LOCATION

Rd 25 & 00

Glenn

Glenn

023 020 028

LOCATION SKETCH

X

Rd 25

ACTIVITY

X

PLANNED USES

X

CASING

*Comp							
1.	473/442	462, Surface	X	Steel	24"	Sch 40	—
	452	442	X	S.S	2"		0.032"
2.	153/122	132, Surface	X	Steel	24"	Sch 40	—
	132	122	X	S.S	2"		0.032
3	75, 44	54, Surface	X	Steel	2"	Sch 40	—
	54	44	X	S.S	2"		0.032

ANNULAR MATERIAL

490	428		#8 Sand
428	161	X	
161	105		#2 Sand
105	73	X	
73	34		#2 Sand
34	0	X	

COMMENTS

CERTIFICATION STATEMENT

Spectrum Exploration

PO Box 471 Zamora CA 95698

Marlise Borches 4/25/02 512268

Casing

Deep Well

Ft to Ft	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
473 - 452		Blank	Steel	2"	Sch 40	
452 – 442		Screen	Steel	2"	Sch 40	020
442 – –		Blank	Steel	2"	Sch 40	
203 - -		Blank	Steel	1"	Sch 40	

Middle Well

Ft to Ft	Borehole Dia	Type	Material Grade	Internal Dia	Gauge	Slot Size
153 – 132		Blank	Steel	2"	Sch 40	
132 – 122		Screen	Steel	2"	Sch 40	020
122 - -		Blank	Steel	2"	Sch 40	
123 - -		Blank	Steel	1"	Sch 40	

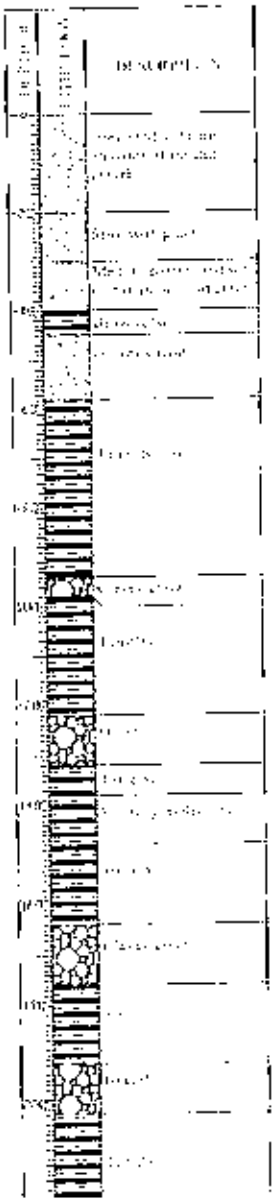
Shallow Well

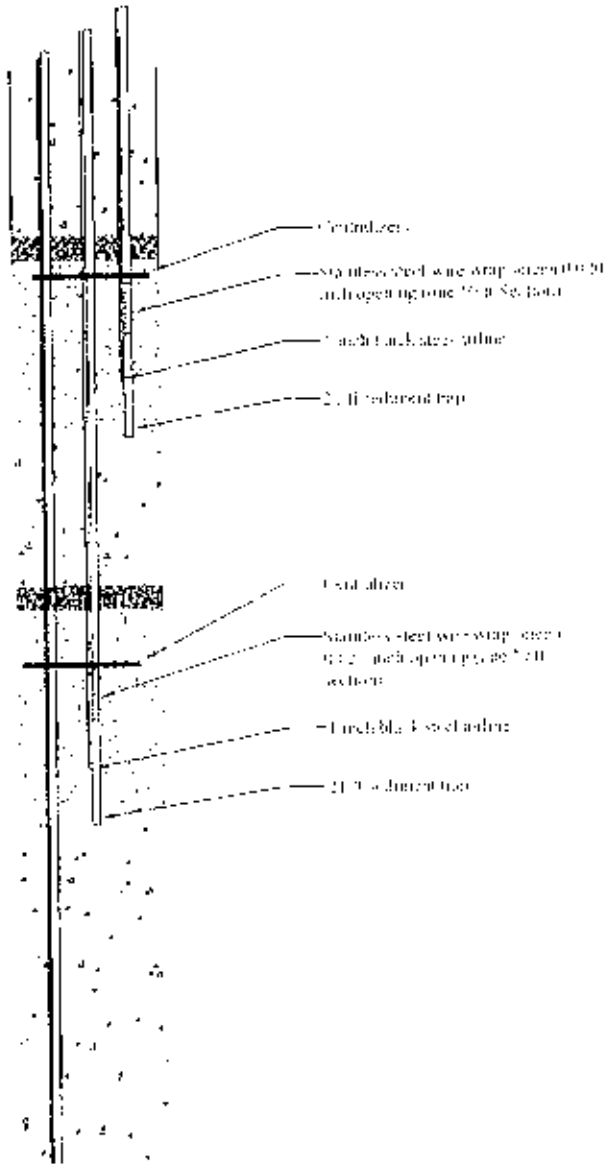
Ft to Ft	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
75 – 54		Blank	Steel	2"	Sch 40	
54 - 44		Screen	Steel	2"	Sch 40	020
44 - -		Blank	Steel	2"	Sch 40	
05 - -		Blank	Steel	1"	Sch 40	

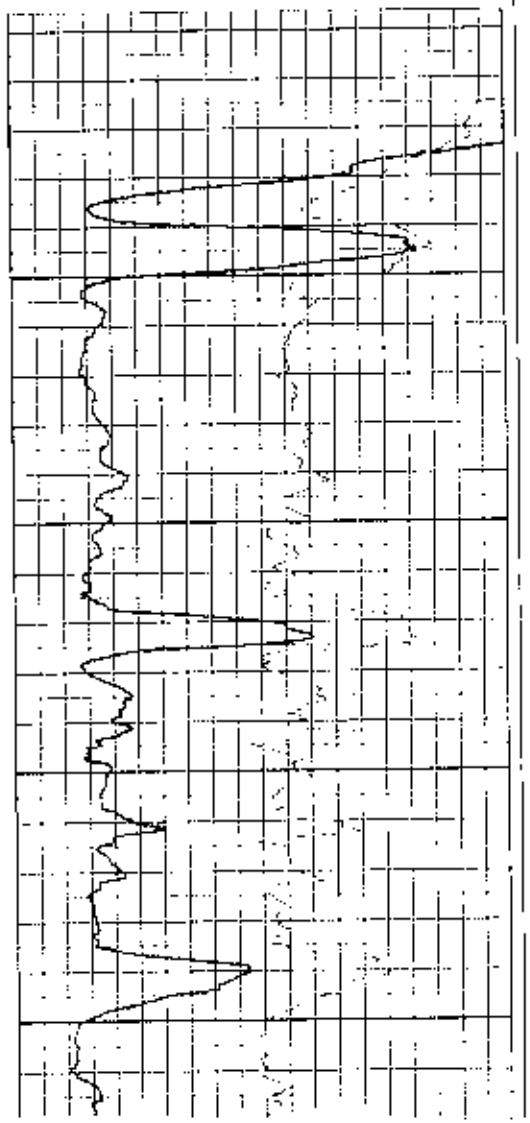
Annular Material

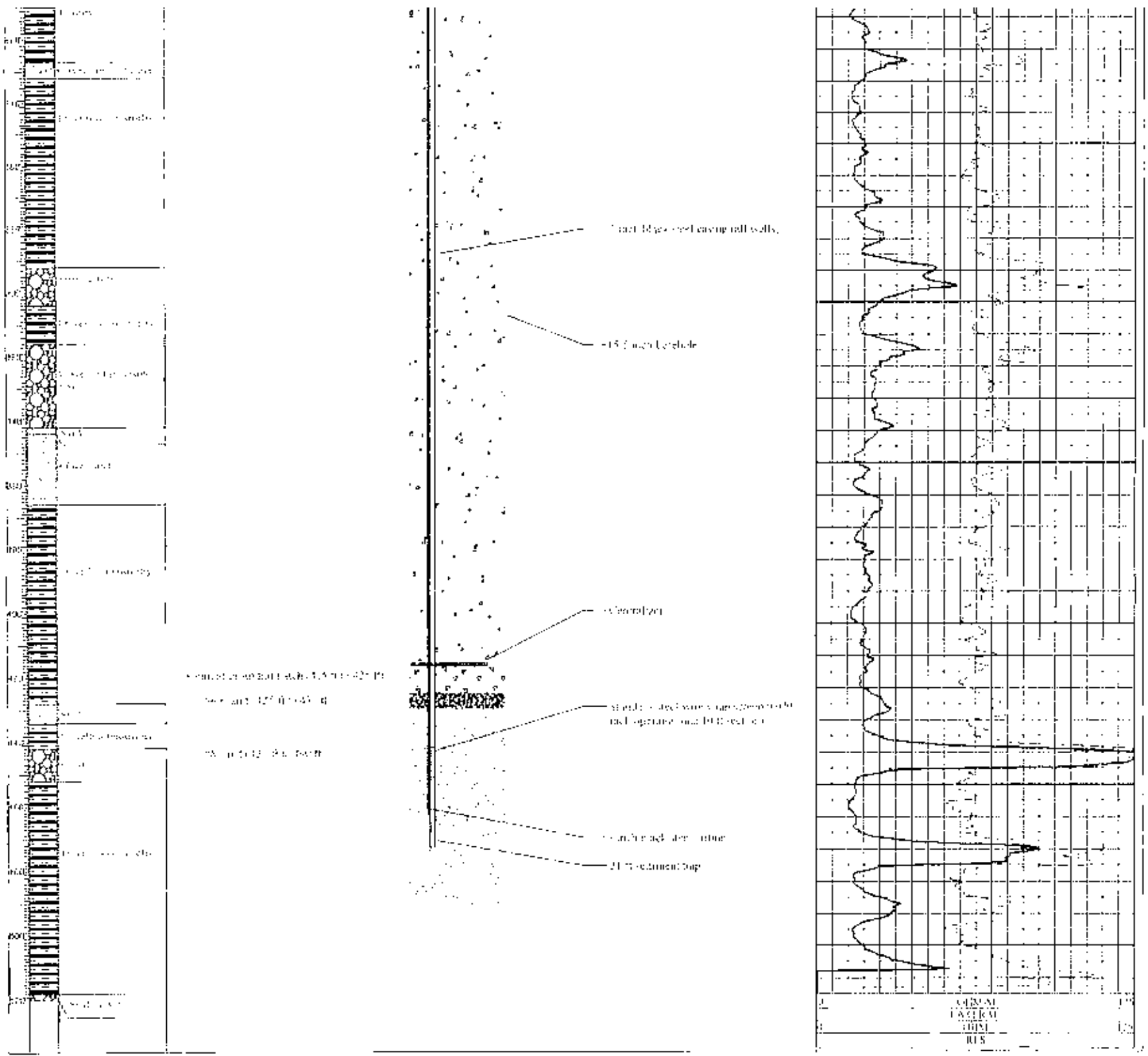
Ft to Ft.	Type

STATE OF CALIFORNIA - RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SOUTHEASTERN DISTRICT









ORIGINAL
File with DWR

AUG 08 2002

Page 1 of 3

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 726724 ~~A,B,C~~ A,B,C

DWR USE ONLY — DO NOT FILL IN
21N/02W-33M
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7450
Date Work Began 7/11/2002, Ended 7/19/2002
Local Permit Agency GLENN COUNTY HEALTH DEPT.
Permit No. MW134-02 Permit Date 6/25/2002

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD REVERSE FLUID WATER

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	20	BROWN/YELLOW CLAY
20	36	STICKY BROWN/YELLOW CLAY
36	48	PALE OLIVE CLAY
48	60	DARK YELLOW/BROWN CLAY
60	80	SUBANGULAR TO ROUNDED GRAVEL
80	100	SILTY SANDY CLAY
100	133	SILTY SANDY CLAY WITH ROUNDED GRAVEL
133	160	POORLY GRADED, ROUNDED TO SUBROUNDED GRAVEL
160	190	DUSKY YELLOW/BROWN SILTY CLAY
190	209	DUSKY YELLOW/BROWN SILTY CLAY WITH SIL AND SAND
209	229	MEDIUM BROWN/YELLOW CLAY
229	240	POORLY SORTED GRAVEL WITH VERY COARSE SAND
240	250	GRAVEL
250	260	YELLOW/BROWN CLAY
260	270	BLUE/GREEN CLAY
270	280	GRAVELLY CLAY
280	290	BLUE/GREEN CLAY AND GRAVELLY SAND
290	310	BLUE/GREEN CLAY
310	320	GRAVEL AND CLAY
320	330	BLUE/GREEN SILTY CLAY
330	340	CLAY AND GRAVEL
340	430	BLUE/GREEN CLAY
430	469	BLUE/GREEN CLAY WITH GRAVEL AND SAND
469	529	GREEN/BLUE CLAY
529	549	GRAVEL AND SAND
549	589	VERY STICKY BLUE/GREEN CLAY WITH FINE SA
589	689	BLUE/GREEN CLAY WITH COARSE SAND

TOTAL DEPTH OF BORING 1020 (Feet)
TOTAL DEPTH OF COMPLETED WELL 974.2 (Feet)

WELL LOCATION

Address .4 MI N OF C/R 33 & W OF C/R S
City CA
County GLENN
APN Book 023 Page 190 Parcel 010
Township 21 N Range 2 W Section 33
Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR — Deepen — Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY — Domestic — Public — Irrigation — Industrial
MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) ✓ EXTENSOMETE

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED
ESTIMATED YIELD * — (GPM) & TEST TYPE
TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
MON	1									
0	161.1	36/18					ACCESS TB	1	SCH 40	
0	140	36/18	✓				BLCK PIPE	2	SCH 40	
140	150	18		✓			STL STEEL	2		.020
150	171.1	18	✓				BLCK PIPE	2	SCH 40	
MON	2									

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	40	✓			SAND SLURRY
0	95.5		✓		HALLIBURTON
95.5	210			✓	#8 GRD SAND
210	507.5		✓		HALLIBURTON
507.5	577			✓	#8 GRD SAND
577	796		✓		HALLIBURTON

AUG 12

A

ATTACHMENTS (✓)
— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO. (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY ADDRESS — WOODLAND CITY — CA STATE — 95695 ZIP
Signed Mark Dawson WELL DRILLER/AUTHORIZED REPRESENTATIVE — 08/07/02 DATE SIGNED — 133783-C57A C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

AUG 08 2002

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 726724

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7450
Date Work Began 7/11/2002, Ended 7/19/2002
Local Permit Agency GLENN COUNTY HEALTH DEPT.
Permit No. MW134-02 Permit Date 6/25/2002

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID WATER

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
689	705	GRAVEL
705	780	BLUE/GREEN CLAY
780	790	POORLY SORTED GRAVEL AND COARSE SAND
790	850	BLUE/GREEN CLAY
850	870	POORLY SORTED SUBANGULAR TO ROUNDED GRAVEL
870	940	POORLY SORTED GRAVEL WITH PYRITE
940	960	GRAY CEMENTED SILTY CLAY
960	980	DARK GRAY SILT TO FINE SAND
980	1000	GRAY/BLUE CLAY WITH FINE SAND
1000	1020	SAND AND GRAVEL

TOTAL DEPTH OF BORING 1020 (Feet)
TOTAL DEPTH OF COMPLETED WELL 974.2 (Feet)

WELL LOCATION

Address .4 MI N OF C/R 33 & W OF C/R S
City CA
County GLENN
APN Book 023 Page 190 Parcel 010
Township 21 N Range 2 W Section 33
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

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ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
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HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ✓
EXTENSOMETE

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
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CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	328	36/18					ACCESS TB	1	SCH 40	
0	540	36/18	✓				BLCK PIPE	2	SCH 40	
540	550	18		✓			STL STEEL	2		.020
550	571.1	18	✓				BLCK PIPE	2	SCH 40	
EXT	1									
0	869	36/18	✓				BLCK PIPE	4	SCH 40	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
796	929.3			✓	#8 GRD SAND
929.3	1020		✓		25% LIME

AUG 2002

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

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ORIGINAL
File with DWR

AUG 08 2002

Page 3 of 3

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 726724

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APN/TRS/OTHER

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Local Permit Agency GLENN COUNTY HEALTH DEPT.
Permit No. MW134-02 Permit Date 6/25/2002

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD REVERSE FLUID WATER

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	20	BROWN/YELLOW CLAY
20	36	STICKY BROWN/YELLOW CLAY
36	48	PALE OLIVE CLAY
48	60	DARK YELLOW/BROWN CLAY
60	80	SUBANGULAR TO ROUNDED GRAVEL
80	100	SILTY SANDY CLAY
100	133	SILTY SANDY CLAY WITH ROUNDED GRAVEL
133	160	POORLY GRADED, ROUNDED TO
		SUBROUNDED GRAVEL
160	190	DUSKY YELLOW/BROWN SILTY CLAY
190	209	DUSKY YELLOW/BROWN SILTY CLAY WITH
		SIL AND SAND
209	229	MEDIUM BROWN/YELLOW CLAY
229	240	POORLY SORTED GRAVEL WITH VERY
		COARSE SAND
240	250	GRAVEL
250	260	YELLOW/BROWN CLAY
260	270	BLUE/GREEN CLAY
270	280	GRAVELLY CLAY
280	290	BLUE/GREEN CLAY AND GRAVELLY SAND
290	310	BLUE/GREEN CLAY
310	320	GRAVEL AND CLAY
320	330	BLUE/GREEN SILTY CLAY
330	340	CLAY AND GRAVEL
340	430	BLUE/GREEN CLAY
430	469	BLUE/GREEN CLAY WITH GRAVEL AND SAND
469	529	GREEN/BLUE CLAY
529	549	GRAVEL AND SAND
549	589	VERY STICKY BLUE/GREEN CLAY WITH FINE SA
589	689	BLUE/GREEN CLAY WITH COARSE SAND

TOTAL DEPTH OF BORING 1020 (Feet)
TOTAL DEPTH OF COMPLETED WELL 974.2 (Feet)

WELL LOCATION

Address .4 MI N OF C/R 33 & W OF C/R S
City CA
County GLENN
APN Book 023 Page 190 Parcel 010
Township 21 N Range 2 W Section 33
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ✓
EXTENSOMETE

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
869	890	18		✓			MILLSLOT	4		
890	974.2	18	✓				BLCK PIPE	4	SCH 40	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	40	✓			SAND SLURRY
0	95.5		✓		HALLIBURTON
95.5	210			✓	#8 GRD SAND
210	507.5		✓		HALLIBURTON
507.5	577			✓	#8 GRD SAND
577	796		✓		HALLIBURTON

AUG

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

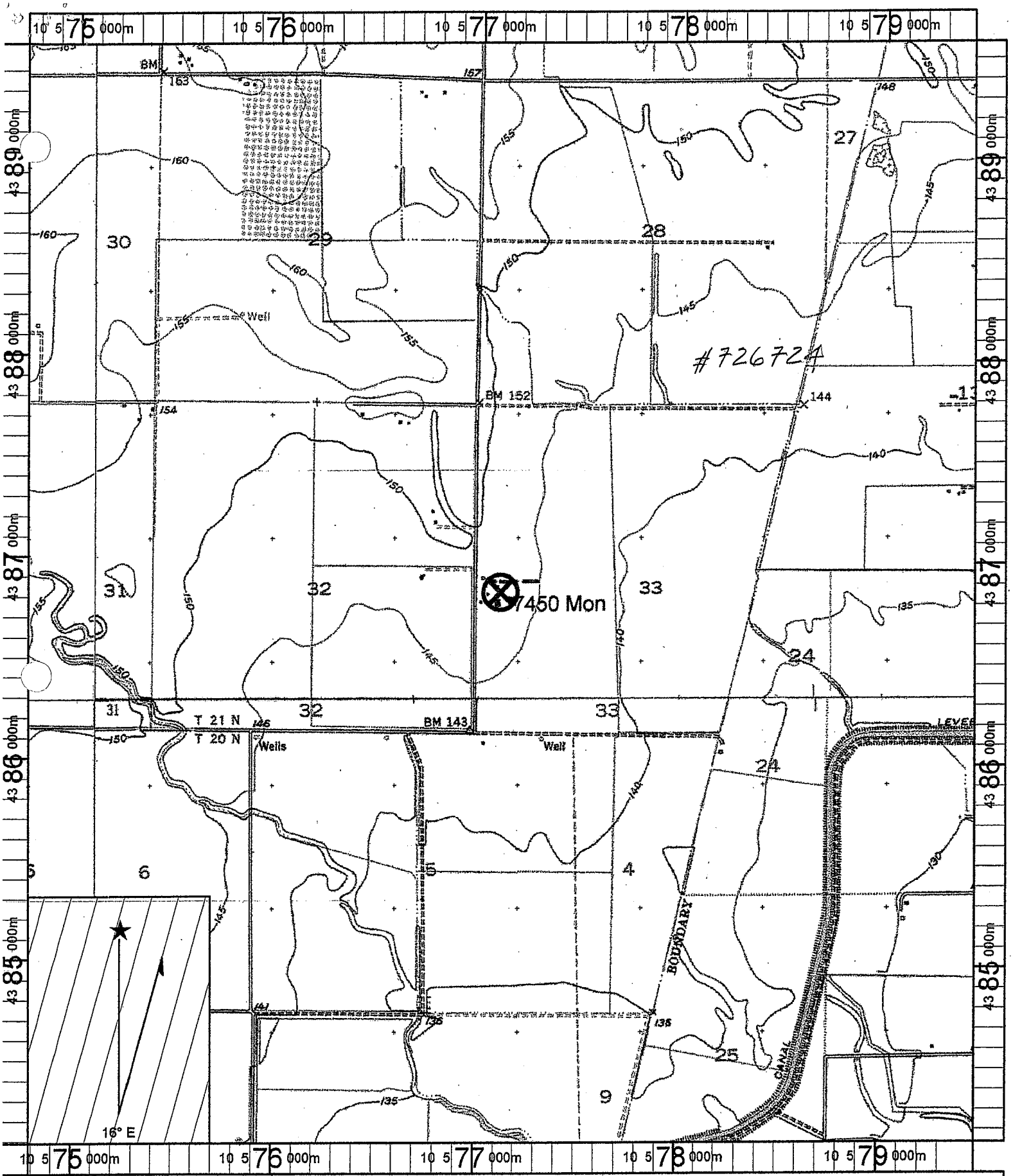
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

20 W. KENTUCKY ADDRESS — WOODLAND CITY — CA STATE — 95695 ZIP

Signed ___ WELL DRILLER/AUTHORIZED REPRESENTATIVE — 08/07/02 DATE SIGNED — 133783-C57A C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM



ne: HAMILTON CITY
e: 8/7/2002
Scale: 1 inch equals 2000 feet

Location: 10 577107 E 4386837 N
Caption: Glenn County
Job# 7450 Mon
APN: 23-19-1

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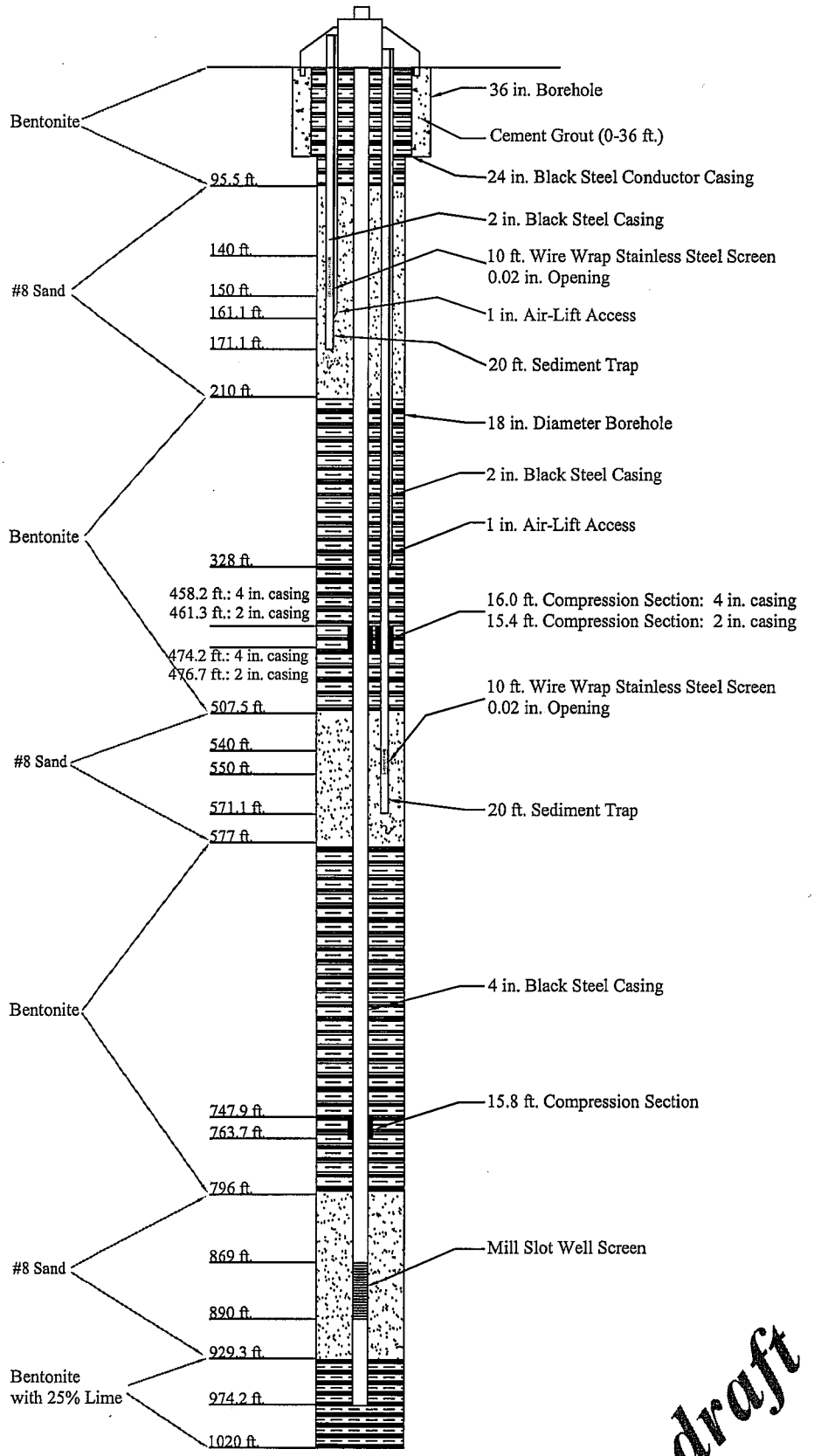
STATE OF CALIFORNIA - RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

PROJECT	Glenn County AB 303 Monitoring Well Project	HOLE NUMBER	GC_AB 303-1	NUMBER OF COMPLETIONS	3	CONTRACTOR	Eaton Drilling
FEATURE	Extensometer/Triple Completion Monitoring Well	TOTAL DEPTH	1020 ft	TYPE OF HOLE	Reverse Rotary	DRILL FOREMAN	Gary Frost
LOCATION	Glenn County, County Road S and County Road 30	DATE STARTED	7/12/02	TYPE OF RIG		INSPECTED BY	Staton, McManus & Lawrence
UTM COORDINATES	577199, 4387045 NAD 83	DATE COMPLETED	7/24/02	COMMENTS	Test hole drilled to 1020 ft.; well completed to 974.2 ft.		

#726724



draft

21N/02W-36M

ORIGINAL
File with DWR

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

WATER WELL DRILLERS REPORT

Do not fill in
No. 315494

ce of Intent No. _____
Local Permit No. or Date B5768

State Well No. _____
Other Well No. 90215-1

(2) LOCATION OF WELL (See instructions): A7
County Glenn Owner's Well Number DMW-2
Well address if different from above _____
Township 21N Range 2W Section 36
Distance from cities, roads, railroads, fences, etc. _____
APN#: 23-08-041

See Attached

WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well [X] Deepening [ ]
Reconstruction [ ]
Reconditioning [ ]
Horizontal Well [ ]
Destruction [ ] (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic [ ]
Irrigation [ ]
Industrial [ ]
Test Well [ ]
Municipal [ ]
Other [X]
(Describe) Monitoring

(5) EQUIPMENT:
Rotary [X] Reverse [ ]
Cable [ ] Air [ ]
Other [ ] Bucket [ ]

(6) GRAVEL PACK: Monterey
Yes [X] No [ ] Size 6 x 12
Diameter of bore 12
Packed from 110 to 155 ft.

(7) CASING INSTALLED:
Steel [X] Plastic [ ] Concrete [ ]

From ft.	To ft.	Dia. in.	Gage or Wall
0	120	6	3/16
140	145	6	3/16

(8) PERFORATIONS:
Type of perforation or size of screen

From ft.	To ft.	Slot size
120	140	.050

(9) WELL SEAL:
Was surface sanitary seal provided? Yes [X] No [ ] If yes, to depth 110 ft.
Were strata sealed against pollution? Yes [ ] No [ ] Interval _____ ft.
Method of sealing _____

(10) WATER LEVELS:
Depth of first water, if known _____ ft.
Standing level after well completion _____ ft.

(11) WELL TESTS:
Was well test made? Yes [ ] No [X] If yes, by whom? _____
Type of test Pump [ ] Bailer [ ] Air lift [ ]
to water at start of test _____ ft. At end of test _____ ft.
Discharge _____ gal/min after _____ hours Water temperature _____
Chemical analysis made? Yes [ ] No [X] If yes, by whom? _____
Was electric log made Yes [ ] No [X] If yes, attach copy to this report

(12) WELL LOG: Total depth 155 ft. Completed depth 145 ft.

from ft.	to ft.	Formation (Describe by color, character, size or material)
0	15	Brn sandy clay
15	25	Brn sandy clay and gravel
25	34	Grey clay and sand
34	40	Clay
40	55	Clay sand and gravel
55	68	Gravel
68	130	Gravel and clay
130	155	Gravel

Work started 3-22 19 89 Completed 3-24 19 89

WELL DRILLER'S STATEMENT: 153

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief

Signed _____ (Well Driller)
NAME Maggiora Bros. Drilling, Inc. (Person, firm, or corporation) (Typed or printed)
Address 595 Airport Blvd.
City Watsonville, CA ZIP 95076
License No. 249957 Date of this report 6-30-89

CONFIDENTIAL
NOT FOR PUBLIC USE
WATER CODE SEC. 13752

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

DWR 188 (REV. 12-86) 86 96355

ORIGINAL
File with DWR

MAR 02 2004

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 726894

Page 1 of 1

DWR USE ONLY — DO NOT FILL IN
21N/03W-01M
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7617 MON

Date Work Began 12/10/2003, Ended 12/17/2003

Local Permit Agency GLENN COUNTY HEALTH DEPT.

Permit No. MW 188-03 Permit Date 12/16/2003

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	2	TOPSOIL
2	70	SAND AND GRAVEL
70	82	YELLOW BROWN CLAY W/SAND AND GRAVEL
82	100	SAND AND GRAVEL
100	190	YELLOW BRWN CLY W/SND AND GRVL STRKS
190	230	BLUE CLAY W/SAND AND GRAVEL STREAKS
230	254	SAND AND GRAVEL
254	324	BLUE CLAY WITH SAND
324	340	SAND AND GRAVEL
340	780	BLUE CLAY W/SAND AND GRAVEL STREAKS
780	800	BLACK SAND AND GRAVEL
800	808	DARK GRAY BRITTLE CLAY
808	830	BLACK SAND AND GRAVEL
830	894	BRITTLE DARK GRAY CLAY WITH SAND
894	920	BLACK SAND AND GRAVEL
920	1038	LIGHT GRAY CLAY W/SAND AND GRVL STRKS
1038	1066	BLACK SAND WITH SMALL GRAVEL
1066	1100	LIGHT GRAY CLAY WITH SAND STREAKS

TOTAL DEPTH OF BORING 1530 (Feet)

TOTAL DEPTH OF COMPLETED WELL 255 (Feet)

WELL LOCATION

Address 50 FT N OF C/R 25 & 3.5 MI E OF I-5

City CA

County GLENN

APN Book 024 Page 020 Parcel 015

Township 21 N Range 3 W Section 1

Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial

MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___

ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___

TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	235	6-5/8	✓				PVC	2	SCH 40	
235	245	6-5/8		✓			PVC	2	SCH 40	.030
245	255	6-5/8	✓				PVC	2	SCH 40	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	204	✓			SAND SLURRY
204	263			✓	#8 GRD SAND
263	271		✓		CHIPS
271	360			✓	#8 GRD SAND
360	1530	✓			SAND SLURRY

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

20 W. KENTUCKY AVE. ADDRESS — WOODLAND CITY — CA STATE — 95695 ZIP

Signed ___ WELL DRILLER/AUTHORIZED REPRESENTATIVE — 12/18/03 DATE SIGNED — C57 A HIC - 133783 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

21N/03W-23

ORIGINAL
File with DWR

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

DWR USE ONLY — DO NOT FILL IN
21N03W23D(1-3)M
STATE WELL NO./STATION NO.
TRIPLICATE COMPLETION
LATITUDE LONGITUDE
APN/TRS/OTHER

Page ___ of ___
Owner's Well No. WELL A
No. 801404A,B,C
Date Work Began 3/20/02 Ended 3/29/02
Local Permit Agency Glenn Co Health Dept.
Permit No. ___ Permit Date 3/12/02

GEOLOGIC LOG

ORIENTATION (✓) ___ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD Rotary FLUID Mud

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain size, color, etc.*
0	20	med. to Coarse Sand
20	30	gravel
30	38	gravel w/ fine to coarse Sand
38	39	gravel and Sand
39	40	Clay
40	60	gravel with fine to coarse Sand
60	70	gravel & Sand.
70	80	gravel w/ med. Sand & Clay
80	140	Lt Brown to Tan Clay w/ gravel
140	150	Sand w/ gravel & Clay
150	160	Gravel & Med. to Coarse Sand
160	170	gravel & Tan to Brown Clay
170	180	Tan/Brown Clay w/ gravel
180	190	Clay & Gravel w/ med. Sand
190	220	Gravel w/ tan to Brown Clay
220	320	Clay w/ minor amounts of gravel
320	330	gravel w/ tan/Brown Clay Slightly gravel
330	340	Gravel w/ Tan/Brown Clay
340	360	Clay
360	370	gravel w/ minor amounts of clay & Sand
370	460	Clay w/ minor amounts of gravel
460	500	Clay w/ minor amounts of Sand & gravel

* This well was constructed w/ 3 completions
1 = deep 2 = moderate 3 = Shallow
393.5' 191.5' 93.5'

TOTAL DEPTH OF BORING 420 (Feet) 420'
TOTAL DEPTH OF COMPLETED WELL 393.5 (Feet)

WELL LOCATION

Address Co Road M
City Artois
County Glenn
APN Book 024 Page 050 Parcel 014-9
Township ___ Range ___ Section ___
Latitude ___ DEG. ___ MIN. ___ SEC. NORTH
Longitude ___ DEG. ___ MIN. ___ SEC. WEST

LOCATION SKETCH

NORTH
Rd M
X
Co. Rd 30
WEST EAST
SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

X NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY *(Describe Procedures and Materials Under "GEOLOGIC LOG")*

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING X
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
* *May not be representative of a well's long-term yield.*

CASING (S)

Comp.*	DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
1.	393, 363	373, Surface		X				Steel	2"	Sch 40	—
	373	363			X			SS.	2"		0.020
2.	191, 142	162-152, 142-0		X				Steel	2"	Sch 40	
	170, 152	160, 142			X			S.S.	2"		0.020
3	93, 42	72, Surface		X				Steel	2"	Sch 40	
	72	42			X			S.S.	2"		0.020

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
420	339				#8 Sand
339	200	✓			
200	127				#8 Sand
127	84	✓			
84	33				#8 Sand
33	0	✓			

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME Spectrum Exploration Inc (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
ADDRESS P.O. Box 471 CITY Zamora STATE CA ZIP 95698
Signed Charlene Borches WELL DRILLER/AUTHORIZED REPRESENTATIVE
DATE SIGNED 4/18/02 C-57 LICENSE NUMBER 512268

DEC 04 2002

DWR 188 REV. 11-97 IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

Department of Water Resources
Van Tol Deep

801404

Casing

Deep Well

Ft. to Ft.	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
393.5- 373		Blank	Steel	2"	Sch 40	
373 – 363		Screen	Steel	2"	Sch 40	.020
363 – +1'		Blank	Steel	2"	Sch 40	

A

Middle Well

Ft. to Ft.	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
191.5 – 170		Blank	Steel	2"	Sch 40	
170 – 160		Screen	Steel	2"	Sch 40	.020
160 – 152		Blank	Steel	2"	Sch 40	
152 – 142		Screen	Steel	2"	Sch 40	.020
142 - +1.5'		Blank	Steel	2"	Sch 40	

B

Shallow Well

Ft. to Ft.	Borehole Dia.	Type	Material Grade	Internal Dia	Gauge	Slot Size
93.5 – 72		Blank	Steel	2"	Sch 40	
72 – 42		Screen	Steel	2"	Sch 40	.020
42 - +2		Blank	Steel	2"	Sch 40	

C

Annular Material

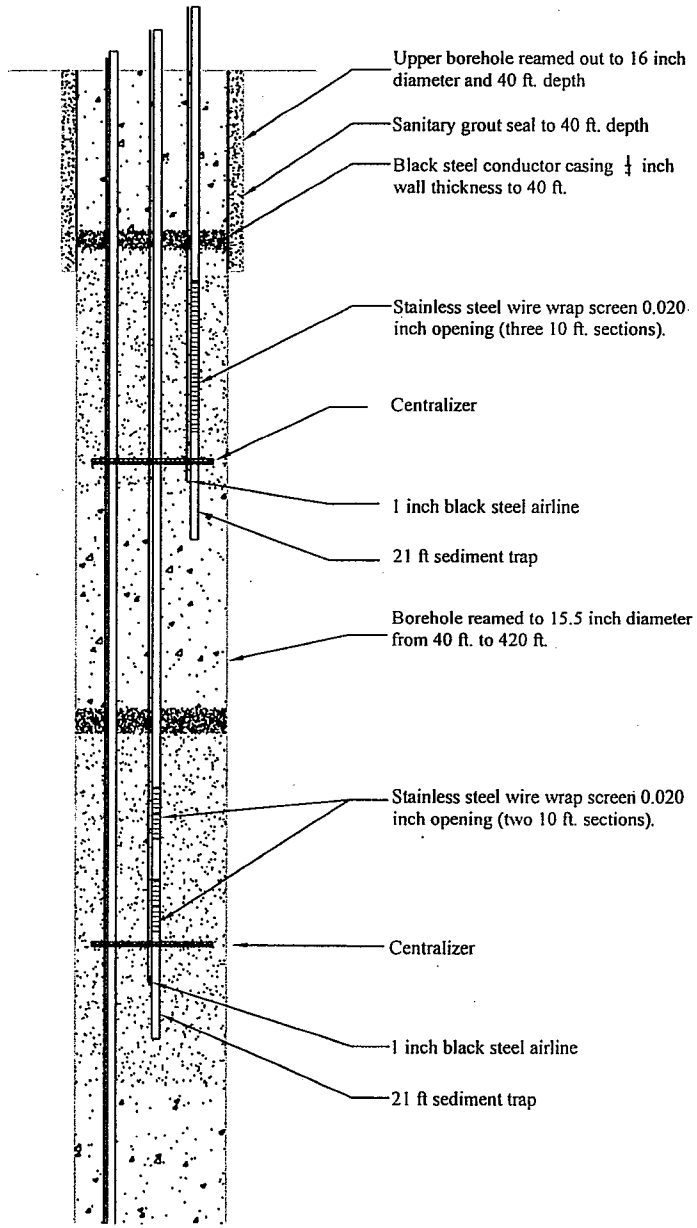
Ft. to Ft.	Type
393.5 - 353	#8 Sand
353 – 345	#60 Sand
345 - Surface	Cement Grout

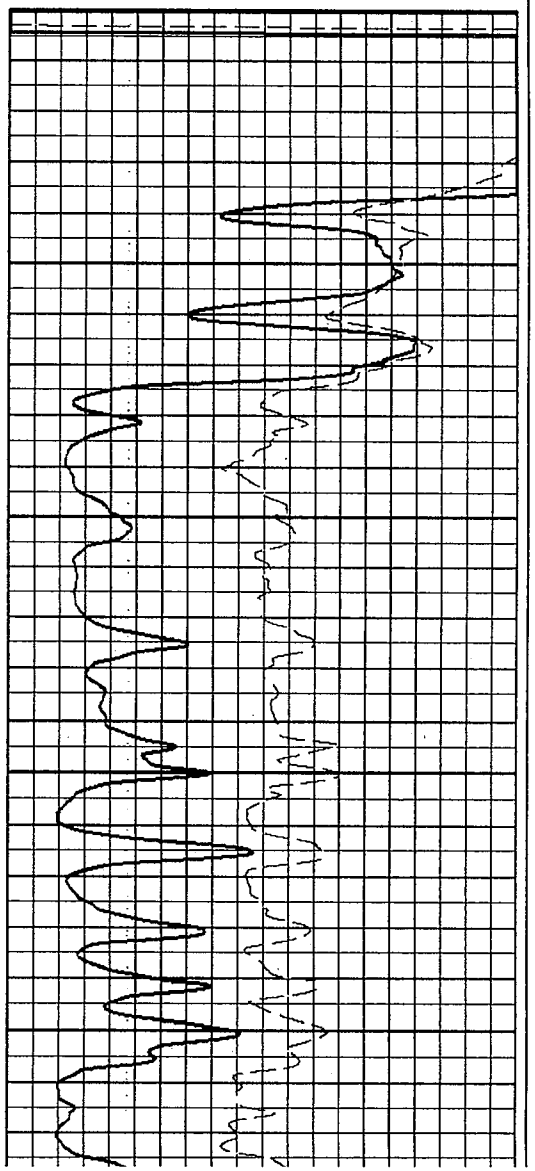
STATE OF CALIFORNIA - RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

STATE WELL NUMBERS: 21N03W23D01M-Deep Zone
21N03W23D02M-Middle Zone
21N03W23D03M-Shallow Zone

PROJECT	Stony Creek Recharge Pilot Project	HOLE NUMBER	Well A - Van Tol Site	NUMBER OF COMPLETIONS	3	CONTRACTOR	Spectrum Exploration, Inc.
FEATURE	Triple Completion Monitoring Well	TOTAL DEPTH	420 ft	TYPE OF HOLE	Direct Rotary	DRILL FOREMAN	Randy Criner
LOCATION	Glenn County, County Rd 27 and County Rd M	DATE STARTED	3/20/02	TYPE OF RIG	Ingersoll Rand	INSPECTED BY	Kelly Staton
UTM COORDINATES	UTM 10 NAD 83 570561, 4391143	DATE COMPLETED	3/29/02	COMMENTS	Test hole drilled to 500 ft.; well completed to 393 ft.		

DEPTH (ft.)	DESCRIPTION
0	Poorly graded medium sand, sub-angular to sub- rounded
20	Poorly graded gravel with fine to med. sand of metam. origin, sub-angular to sub-rounded clasts
	Gravel and sand
40	Clay
	Gravel with fine to coarse-grained sand
60	Gravel and fine to coarse-grained sand
	Gravel with minor amount of clay and sand
80	
	Lt. brown to tan clay with gravel and sand
100	
120	
140	Sand with gravel and clay
	Gravel and medium to coarse sand
160	Gravel and tan to brown clay
	Tan/brown clay with gravel
180	Tan/brown clay with gravel and med. sand
200	Gravel with tan to brown clay
220	





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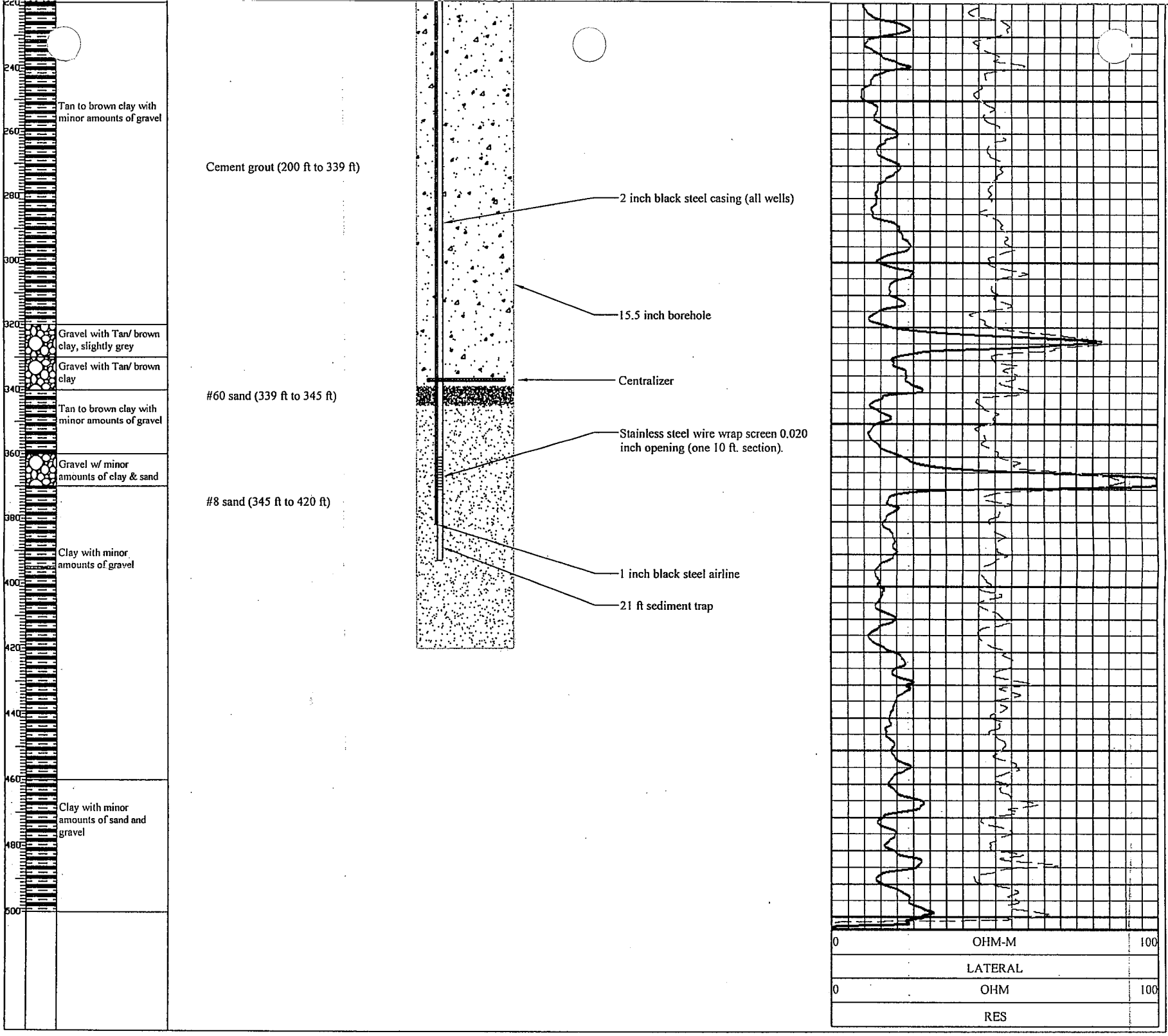

240
260
280
300
320
340
360
380
400
420
440
460
480
500
Tan to brown clay with minor amounts of gravel
Gravel with Tan/ brown clay, slightly grey
Gravel with Tan/ brown clay
Tan to brown clay with minor amounts of gravel
Gravel w/ minor amounts of clay & sand
Clay with minor amounts of gravel
Clay with minor amounts of sand and gravel
Cement grout (200 ft to 339 ft)
#60 sand (339 ft to 345 ft)
#8 sand (345 ft to 420 ft)
2 inch black steel casing (all wells)
15.5 inch borehole
Centralizer
Stainless steel wire wrap screen 0.020 inch opening (one 10 ft. section).
1 inch black steel airline
21 ft sediment trap
0
OHM-M
100
LATERAL
0
OHM
100
RES

#801404

ORIGINAL
File with DWR

Page 1 of 6 MAY 31 2005

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 816224

DWR USE ONLY — DO NOT FILL IN
21N/03W-34J
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7786
Date Work Began 3/7/2005, Ended 3/14/2005
Local Permit Agency GLENN COUNTY HEALTH DEPT
Permit No. IRW280-04 Permit Date 11/4/2004

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft. to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0 – 6	TOPSOIL
6 – 24	SAND AND SMALL GRAVEL
24 – 33	TAN CLAY
33 – 45	SANDY BROWN CLAY WITH SAND AND GRAVE
	STREAKS
45 – 90	SAND AND GRAVEL WITH BROWN CLAY STREA
90 – 145	SANDY YELLOW CLAY
145 – 152	SAND AND GRAVEL
152 – 210	SANDY YELLOW CLAY
210 – 333	TAN CLAY WITH SAND
333 – 342	SAND AND SMALL GRAVEL
342 – 400	TAN CLAY WITH SAND
400 – 440	TAN CLAY WITH SAND AND GRAVEL STREAKS
440 – 580	TAN CLAY WITH SAND
580 – 585	SAND AND GRAVEL
585 – 620	TAN CLAY WITH SAND
620 – 635	SAND AND GRAVEL
635 – 650	SANDY TAN CLAY
650 – 656	SAND AND GRAVEL
656 – 678	SANDY TAN CLAY
678 – 688	SAND AND GRAVEL
688 – 750	SANDY TAN CLAY
750 – 860	TAN CLAY
860 – 960	SANDY TAN CLAY WITH SAND AND GRAVEL
	STREAKS
960 – 1100	BROWN CLAY WITH HARD CLAY STREAKS
1100 – 1140	BLUE CLAY WITH SAND
1140 – 1170	SAND WITH BLUE CLAY STREAKS
1170 – 1200	BLUE CLAY WITH BRITTLE CLAY STREAKS

TOTAL DEPTH OF BORING 1020 (Feet)
TOTAL DEPTH OF COMPLETED WELL 980 (Feet)

WELL LOCATION
Address .1 MI NOF RD 33 & .4 MI WOF DETOUR RD
City CA
County GLENN
APN Book 024 Page 130 Parcel 009
Township 21 N Range 3 W Section 34
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH
NORTH / WEST / EAST / SOUTH
Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL
DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft. to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE 1									
0 – 60	12	✓				PVC F-480	2.5	SCH 80	
60 – 70	12		✓			PVC F-480	2.5	SCH 80	.030
70 – 80	12	✓				PVC F-480	2.5	SCH 80	
ZONE 2									
0 – 620	12/10	✓				PVC F-480	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft. to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0 – 40	✓			SAND SLURRY
40 – 45		✓		BENTONITE C
45 – 100			✓	SRI#8 SAND
100 – 105		✓		BENTONITE C
105 – 135	✓			SAND SLURRY
135 – 560			✓	GRAVEL FILL

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT
I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO. (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY AVE. (ADDRESS) WOODLAND (CITY) CA (STATE) 95695 (ZIP)
Signed Mark Damon (WELL DRILLER/AUTHORIZED REPRESENTATIVE) 05/23/05 (DATE SIGNED) C57 A HIC - 133783 (C-57 LICENSE NUMBER)

DWR 188 REV. 11-97
IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 2 of 6

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 816224

DWR USE ONLY — DO NOT FILL IN
21N/03W-34
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7786
Date Work Began 3/7/2005, Ended 3/14/2005
Local Permit Agency GLENN COUNTY HEALTH DEPT
Permit No. IRW280-04 Permit Date 11/4/2004

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft. to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0 – 6	TOPSOIL
6 – 24	SAND AND SMALL GRAVEL
24 – 33	TAN CLAY
33 – 45	SANDY BROWN CLAY WITH SAND AND GRAVE
	STREAKS
45 – 90	SAND AND GRAVEL WITH BROWN CLAY STREA
90 – 145	SANDY YELLOW CLAY
145 – 152	SAND AND GRAVEL
152 – 210	SANDY YELLOW CLAY
210 – 333	TAN CLAY WITH SAND
333 – 342	SAND AND SMALL GRAVEL
342 – 400	TAN CLAY WITH SAND
400 – 440	TAN CLAY WITH SAND AND GRAVEL STREAKS
440 – 580	TAN CLAY WITH SAND
580 – 585	SAND AND GRAVEL
585 – 620	TAN CLAY WITH SAND
620 – 635	SAND AND GRAVEL
635 – 650	SANDY TAN CLAY
650 – 656	SAND AND GRAVEL
656 – 678	SANDY TAN CLAY
678 – 688	SAND AND GRAVEL
688 – 750	SANDY TAN CLAY
750 – 860	TAN CLAY
860 – 960	SANDY TAN CLAY WITH SAND AND GRAVEL
	STREAKS
960 – 1100	BROWN CLAY WITH HARD CLAY STREAKS
1100 – 1140	BLUE CLAY WITH SAND
1140 – 1170	SAND WITH BLUE CLAY STREAKS
1170 – 1200	BLUE CLAY WITH BRITTLE CLAY STREAKS

TOTAL DEPTH OF BORING 1020 (Feet)
TOTAL DEPTH OF COMPLETED WELL 980 (Feet)

WELL LOCATION

Address 1 MI NOF RD 33 & .4 MI WOF DETOUR RD
City CA
County GLENN
APN Book 024 Page 130 Parcel 009
Township 21 N Range 3 W Section 34
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft. to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
620 – 630	10		✓			PVC F-480	2.5	SCH 80	.030
630 – 650	10	✓				PVC F-480	2.5	SCH 80	
650 – 660	10		✓			PVC F-480	2.5	SCH 80	.030
660 – 680	10	✓				PVC F-480	2.5	SCH 80	
680 – 690	10		✓			PVC F-480	2.5	SCH 80	.030
690 – 710	10	✓				PVC F-480	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft. to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
560 – 590	✓			SAND SLURRY
590 – 720			✓	SRI#8 SAND
720 – 900	✓			SAND SLURRY
900 – 1020			✓	SRI#8 SAND

ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY AVE. WOODLAND CA 95695
ADDRESS CITY STATE ZIP
Signed Mark L Davison
WELL DRILLER/AUTHORIZED REPRESENTATIVE
05/23/05 DATE SIGNED
C57 A HIC - 133783 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 3 of 6

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 816224

DWR USE ONLY — DO NOT FILL IN
21N/03W-34
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7786
Date Work Began 3/7/2005, Ended 3/14/2005
Local Permit Agency GLENN COUNTY HEALTH DEPT
Permit No. IRW280-04 Permit Date 11/4/2004

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	6	TOPSOIL
6	24	SAND AND SMALL GRAVEL
24	33	TAN CLAY
33	45	SANDY BROWN CLAY WITH SAND AND GRAVE
		STREAKS
45	90	SAND AND GRAVEL WITH BROWN CLAY STREA
90	145	SANDY YELLOW CLAY
145	152	SAND AND GRAVEL
152	210	SANDY YELLOW CLAY
210	333	TAN CLAY WITH SAND
333	342	SAND AND SMALL GRAVEL
342	400	TAN CLAY WITH SAND
400	440	TAN CLAY WITH SAND AND GRAVEL STREAKS
440	580	TAN CLAY WITH SAND
580	585	SAND AND GRAVEL
585	620	TAN CLAY WITH SAND
620	635	SAND AND GRAVEL
635	650	SANDY TAN CLAY
650	656	SAND AND GRAVEL
656	678	SANDY TAN CLAY
678	688	SAND AND GRAVEL
688	750	SANDY TAN CLAY
750	860	TAN CLAY
860	960	SANDY TAN CLAY WITH SAND AND GRAVEL
		STREAKS
960	1100	BROWN CLAY WITH HARD CLAY STREAKS
1100	1140	BLUE CLAY WITH SAND
1140	1170	SAND WITH BLUE CLAY STREAKS
1170	1200	BLUE CLAY WITH BRITTLE CLAY STREAKS

TOTAL DEPTH OF BORING 1020 (Feet)
TOTAL DEPTH OF COMPLETED WELL 980 (Feet)

WELL LOCATION

Address .1 MI NOF RD 33 & .4 MI WOF DETOUR RD
City CA
County GLENN
APN Book 024 Page 130 Parcel 009
Township 21 N Range 3 W Section 34
Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED
ESTIMATED YIELD * — (GPM) & TEST TYPE
TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE	3									
0	930	12/10	✓				PVC F-480	2.5	SCH 80	
930	960	10		✓			PVC F-480	2.5	SCH 80	.030
960	980	10	✓				PVC F-480	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	40	✓			SAND SLURRY
40	45		✓		BENTONITE C
45	100			✓	SRI#8 SAND
100	105		✓		BENTONITE C
105	135	✓			SAND SLURRY
135	560			✓	GRAVEL FILL

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY AVE. WOODLAND CA 95695
ADDRESS CITY STATE ZIP
Signed Mark Damion 05/23/05 C57 A HIC - 133783
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

OCT 17 2002

Page 1 of 2

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 726739, A

DWR USE ONLY — DO NOT FILL IN
21N/04W-12A
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7449
Date Work Began 8/19/2002, Ended 8/23/2002
Local Permit Agency GLENN CNTY HEALTH DEPT
Permit No. MW133-02 Permit Date 6/25/2002

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	10	WELL GRADED SAND AND GRAVEL
10	20	LIGHT BROWN CLAY
20	30	LIGHT BROWN CLAY W/FINE SAND AND GRVL
30	40	WELL GRADED GRVL W/SND AND LT BRN CLY
40	50	WELL GRADED SND AND GRVL W/SOME CLY
50	60	LIGHT BROWN CLAY WITH SAND AND GRAVEL
60	70	BROWN CLAY WITH SAND AND GRAVEL
70	80	TAN CLAY
80	100	BROWN CLAY
100	110	LIGHT BROWN CLAY
110	120	LIGHT BROWN CLY W/SAND, GRAVEL, SILT
120	130	LT BRN CLY W/FINE SILTSTONE, SAND, GRVL
130	140	LT BROWN CLAY W/FINE SAND AND GRAVEL
140	160	LT BRN CLAY W/SAND, GRAVEL, SILTSTONE
160	170	SAND WITH LIGHT BROWN CLAY
170	190	SILSTONE WITH TAN CLAY AND SAND
190	200	FINE SAND WITH COARSE SAND AND TAN CLY
200	220	LT BRN CLAY W/SILTSTONE, SAND, GRAVEL
220	230	WELL GRADED SAND WITH CLAY
230	250	POORLY GRADED SAND AND GRAVEL
250	260	PPORLY GRADED SAND WITH FINE GRAVEL
260	270	POORLY GRADED SAND WITH CLAY
270	280	WELL GRADED SND W/FINE GRVL, TAN CLAY
280	300	SILSTONE WITH SAND
300	310	SILT WITH SAND AND GRAVEL
310	320	POORLY GRADED SAND WITH CLAY
320	340	WELL GRADED SAND WITH FINE GRAVEL
340	350	WELL GRADED SAND W/SILSTONE, TAN CLAY
350	360	SILT WITH SAND, GRAVEL, AND CLAY
360	400	GRAVEL WITH SILTSTONE

TOTAL DEPTH OF BORING 640 (Feet)
TOTAL DEPTH OF COMPLETED WELL 629 (Feet)

WELL LOCATION

Address SOF C/R 25 & EOF C/R D
City CA
County GLENN
APN Book 024 Page 200 Parcel 210
Township 21 N Range 4 W Section 12
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE 1										
0	240	12-1/4					ACCESS TB	1		
0	247	12-1/4	✓				SCH 40	2		
247	257	12-1/4		✓			STL STEEL	2		.030
257	278	12-1/4	✓				SCH 40	2		
ZONE 2										

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	208	✓			SAND SLURRY
208	219		✓		CHIPS
219	323			✓	#8 GRD SAND
323	548	✓			SAND SLURRY
548	559		✓		CHIPS
559	640			✓	#8 GRD SAND

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief

OCT 22 2002

NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY WOODLAND CA 95695
ADDRESS CITY STATE ZIP
Signed ___ 10/01/02
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED
133783-C57A
C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

Page 2 of 2

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 726739

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7449
Date Work Began 8/19/2002, Ended 8/23/2002
Local Permit Agency GLENN CNTY HEALTH DEPT
Permit No. MW133-02 Permit Date 6/25/2002

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
400	510	SILTSTONE, SAND WITH GRAVELS
510	530	COARSE SAND
530	540	GRAVEL
540	550	GRAVEL WITH COARSE SAND
550	560	SILTSTONE WITH GRAVEL AND SAND
560	570	COARSE SAND
570	580	MEDIUM GRAINED SAND
580	640	COARSE SAND AND GRAVEL

TOTAL DEPTH OF BORING 640 (Feet)
TOTAL DEPTH OF COMPLETED WELL 629 (Feet)

WELL LOCATION

Address SOF C/R 25 & EOF C/R D
City CA
County GLENN
APN Book 024 Page 200 Parcel 210
Township 21 N Range 4 W Section 12
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (inches)
0	240	12-1/4					ACCESS TB	1		
0	598	12-1/4	✓				SCH 40	2		
598	608	12-1/4		✓			STL STEEL	2		.030
608	629	12-1/4	✓				SCH 40	2		

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	208	✓			SAND SLURRY
208	219		✓		CHIPS
219	323			✓	#8 GRD SAND
323	548	✓			SAND SLURRY
548	559		✓		CHIPS
559	640			✓	#8 GRD SAND

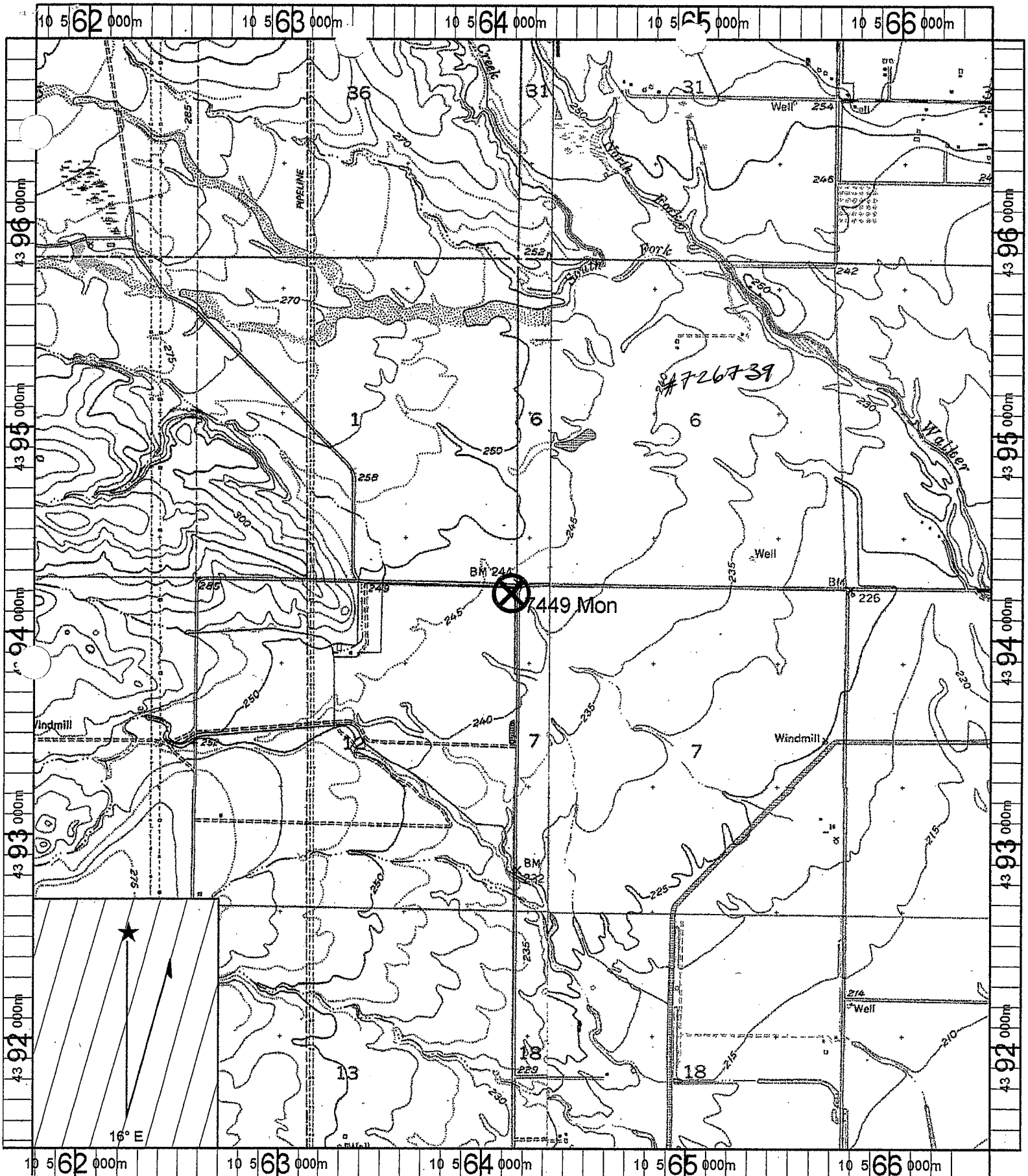
ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 W. KENTUCKY ADDRESS — WOODLAND CITY — CA STATE — 95695 ZIP
Signed ___ WELL DRILLER/AUTHORIZED REPRESENTATIVE
10/01/02 DATE SIGNED
133783-C57A C-57 LICENSE NUMBER

DWR 188 REV. 11-97
IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM



Name: FRUTO NE
Date: 6/21/2002
Scale: 1 inch equals 2000 feet

Caption: Glenn County
Job# 7449
APN: 24-200-21

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ORIGINAL
File with DWR JAN 0 8 2010

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

Page 1 of 3

No. E0103388 AB

DWR USE ONLY — DO NOT FILL IN
21N/04W-12
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 8434

Date Work Began 11/23/2009, Ended 12/3/2009

Local Permit Agency Glenn County Health Dept

Permit No. MW 319-09 Permit Date 11/19/2009

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	5	Top soil
5	65	Sand and gravel
65	170	Sandy brown clay
170	180	Sand and gravel
180	230	Sandy brown clay
230	260	Sand and gravel
260	275	Sandy brown clay
275	280	Sand and gravel
280	370	Sandy brown clay
370	380	Sand and gravel
380	515	Sandy blue clay
515	540	Sand with small gravel
540	650	Sandy blue clay with small gravel
650	879	Sandy blue clay
879	900	Small gravel
900	950	Sandy blue clay
950	1080	Black sand

TOTAL DEPTH OF BORING 1080 (Feet)

TOTAL DEPTH OF COMPLETED WELL 1070 (Feet)

WELL LOCATION

Address 70' Sof Road 25 & 70' Wof Road D

City CA

County GLENN

APN Book 024 Page 200 Parcel 021

Township 21 N Range 4 W Section 12 (A 3-4)

Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH

BIG. Farms
W
Replacement

WEST EAST

SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
— Deepen
— Other (Specify)

— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial

MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED

ESTIMATED YIELD * — (GPM) & TEST TYPE

TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
Zone	1									
0	520	10-3/4	✓				PVC	2.5	SCH 80	
520	530	10-3/4		✓			PVC	2.5	SCH 80	.030
530	590	10-3/4	✓				PVC	2.5	SCH 80	
590	600	10-3/4		✓			PVC	2.5	SCH 80	.030
600	630	10-3/4	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	265	✓			Sand Slurry
265	285		✓		Bentonite Seal
285	480			✓	SRI#8 Sand
480	496		✓		Bentonite Seal
496	658			✓	SRI#8 Sand
658	675		✓		Bentonite Seal

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

20 WEST KENTUCKY AVE WOODLAND CA 95695
ADDRESS CITY STATE ZIP

Signed Mark Davies 12/31/09 C57 A HIC - 13378
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

JAN 0 8 2009

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. E0103388

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Page 2 of 3

Owner's Well No. 8434

Date Work Began 11/23/2009, Ended 12/3/2009

Local Permit Agency Glenn County Health Dept

Permit No. MW 319-09 Permit Date 11/19/2009

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	5	Top soil
5	65	Sand and gravel
65	170	Sandy brown clay
170	180	Sand and gravel
180	230	Sandy brown clay
230	260	Sand and gravel
260	275	Sandy brown clay
275	280	Sand and gravel
280	370	Sandy brown clay
370	380	Sand and gravel
380	515	Sandy blue clay
515	540	Sand with small gravel
540	650	Sandy blue clay with small gravel
650	879	Sandy blue clay
879	900	Small gravel
900	950	Sandy blue clay
950	1080	Black sand

TOTAL DEPTH OF BORING 1080 (Feet)

TOTAL DEPTH OF COMPLETED WELL 1070 (Feet)

WELL LOCATION

Address 70' Sof Road 25 & 70' Wof Road D

City CA

County GLENN

APN Book 024 Page 200 Parcel 021

Township 21 N Range 4 W Section 12

Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
— Deepen
— Other (Specify)

— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial

MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ——— (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ——— (Ft.) & DATE MEASURED ———

ESTIMATED YIELD * ——— (GPM) & TEST TYPE ———

TEST LENGTH ——— (Hrs.) TOTAL DRAWDOWN ——— (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
630	640	10-3/4		✓			PVC	2.5	SCH 80	.030
640	660	10-3/4	✓				PVC	2.5	SCH 80	
Zone	2									
0	955	10 / 8	✓				PVC	2.5	SCH 80	
955	975	8-3/4		✓			PVC	2.5	SCH 80	.030
975	1030	8-3/4	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
675	870			✓	SRI#8 Sand
870	911		✓		Bentonite Seal
977	1080			✓	SRI#8 Sand

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other ———

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

20 WEST KENTUCKY AVE ADDRESS — WOODLAND CITY — CA STATE — 95695 ZIP

Signed ——— WELL DRILLER/AUTHORIZED REPRESENTATIVE — 12/31/09 DATE SIGNED — C57 A HIC - 13378 C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

ORIGINAL
File with DWR

JAN 0 8 2009

Page 3 of 3

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. E0103388

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 8434
Date Work Began 11/23/2009, Ended 12/3/2009
Local Permit Agency Glenn County Health Dept
Permit No. MW 319-09 Permit Date 11/19/2009

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	5	Top soil
5	65	Sand and gravel
65	170	Sandy brown clay
170	180	Sand and gravel
180	230	Sandy brown clay
230	260	Sand and gravel
260	275	Sandy brown clay
275	280	Sand and gravel
280	370	Sandy brown clay
370	380	Sand and gravel
380	515	Sandy blue clay
515	540	Sand with small gravel
540	650	Sandy blue clay with small gravel
650	879	Sandy blue clay
879	900	Small gravel
900	950	Sandy blue clay
950	1080	Black sand

TOTAL DEPTH OF BORING 1080 (Feet)
TOTAL DEPTH OF COMPLETED WELL 1070 (Feet)

WELL LOCATION

Address 70' Sof Road 25 & 70' Wof Road D
City CA
County GLENN
APN Book 024 Page 200 Parcel 021
Township 21 N Range 4 W Section 12
Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG"

PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED
ESTIMATED YIELD * — (GPM) & TEST TYPE
TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
1030	1050	8-3/4		✓			PVC	2.5	SCH 80	.030
1050	1070	8-3/4	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)

ATTACHMENTS (✓)

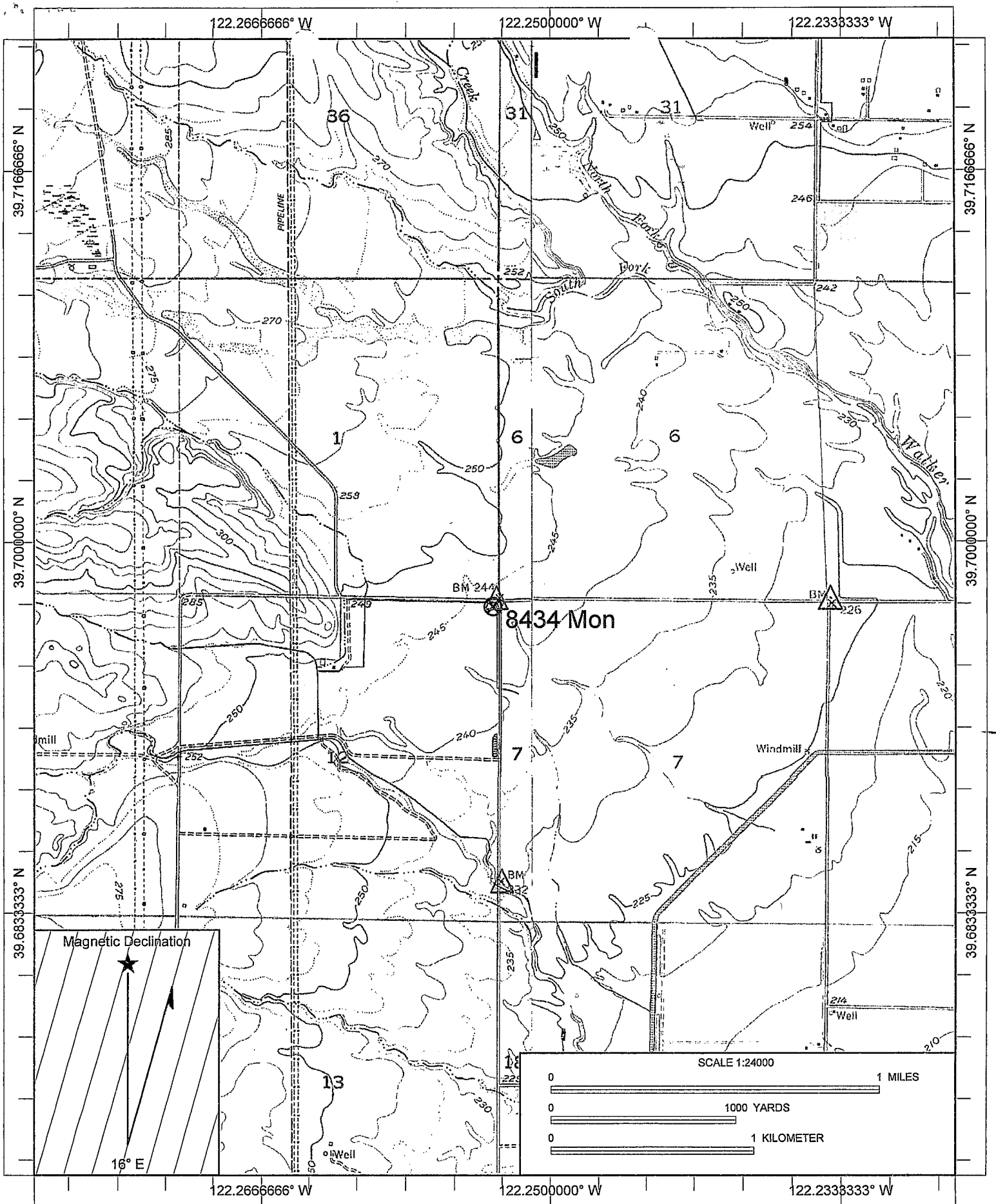
— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
20 WEST KENTUCKY AVE WOODLAND CA 95695
ADDRESS CITY STATE ZIP
Signed [signature] 12/31/09
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED
C57 A HIC - 13378
C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM



Name: FRUTO NE
Date: 11/17/2009
Scale: 1 inch equals 2000 feet

Caption: DWR (Big W) - Job# 8434 Mon
APN: 024-200-021
T21N R4W s12

Copyright (C) 1997, Maptech, Inc.

ORIGINAL
File with DWR

JUN 30 2004

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet

No. 726922

DWR USE ONLY — DO NOT FILL IN
22N/02W-30
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Page 1 of 3

Owner's Well No. 7677 MON

Date Work Began 5/6/2004, Ended 5/14/2004

Local Permit Agency GLENN COUNTY HEALTH DEPT

Permit No. MW207-04 Permit Date 5/3/2004

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft. to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0 – 20	SAND AND GRAVEL
20 – 60	TAN SILTY CLAY
60 – 70	SAND AND GRAVEL
70 – 120	TAN SILTY CLAY
120 – 160	SAND AND GRAVEL
160 – 220	TAN/BROWN SILTY CLAY
220 – 240	MED-CRS SAND
240 – 260	MED-CRS SAND WITH CLAY
260 – 320	TAN SILTY CLAY
320 – 360	POORLY GRD VOLCANIC SAND
360 – 380	POORLY SRTD SAND IN A VOLCANIC ASHY CLY
380 – 400	POORLY GRD SAND AND GRAVEL
400 – 480	POORLY SRTD SAND AND GRAVEL W/CLAY
480 – 520	MED-CRS SAND WITH CLAY
520 – 540	POORLY GRD SAND
540 – 580	TAN CLAY
580 – 620	POORLY GRD SAND AND GRAVEL
620 – 640	TAN/BLUE CLAY W/POORLY GRD GRAVEL
640 – 660	BLUE CLAY W/POORLY GRD SAND
660 – 680	NED-CRS SAND W/METAMORPHIC GRAVEL
680 – 760	BLUE CLAY W/SAND AND GRAVEL
760 – 780	TAN/BROWN CLAY
780 – 800	DARK BLUE/GRAY CLAY W/FINE SAND
800 – 820	MED-CRS SAND W/BLUE CLAY
820 – 900	MED-CRS BLACK SAND AND GRAVEL
900 – 1020	TUSCAN CLAY AND ASH W/SOME FINE SAND

TOTAL DEPTH OF BORING 920 (Feet)

TOTAL DEPTH OF COMPLETED WELL 900 (Feet)

WELL LOCATION

Address 75 FT N OF C/R 18 & .9 MI E OF C/R P

City CA

County GLENN

APN Book 046 Page 310 Parcel 060

Township 22 N Range 2 W Section 30

Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
___ Domestic ___ Public
___ Irrigation ___ Industrial

MONITORING ✓
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___

ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___

TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft. to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE 1									
0 – 45	12	✓				PVC	2.5	SCH 80	
45 – 55	12		✓			PVC	2.5	SCH 80	.030
55 – 60	12	✓				PVC	2.5	SCH 80	
60 – 70	12		✓			PVC	2.5	SCH 80	.030
70 – 80	12	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft. to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0 – 31	✓			SAND SLURRY
31 – 88			✓	#8 GRD SAND
88 – 114	✓			SAND SLURRY
114 – 291			✓	#8 GRD SAND
291 – 307	✓			SAND SLURRY
307 – 725			✓	PEA GRAVEL

AUG 17 2004

ATTACHMENTS (✓)

___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analysis
___ Other ___

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

20 W. KENTUCKY AVE. WOODLAND CA 95695
ADDRESS CITY STATE ZIP

Signed ___ 06/01/04
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED

C57 A HIC - 133783
C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

IGINAL
e with DWR

Page 2 of 3

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 726922

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./ STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

Owner's Well No. 7677 MON

Date Work Began 5/6/2004, Ended 5/14/2004

Local Permit Agency GLENN COUNTY HEALTH DEPT.

Permit No. MW207-04 Permit Date 5/3/2004

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	20	SAND AND GRAVEL
20	60	TAN SILTY CLAY
60	70	SAND AND GRAVEL
70	120	TAN SILTY CLAY
120	160	SAND AND GRAVEL
160	220	TAN/BROWN SILTY CLAY
220	240	MED-CRS SAND
240	260	MED-CRS SAND WITH CLAY
260	320	TAN SILTY CLAY
320	360	POORLY GRD VOLCANIC SAND
360	380	POORLY SRTD SAND IN A VOLCANIC ASHY CLY
380	400	POORLY GRD SAND AND GRAVEL
400	480	POORLY SRTD SAND AND GRAVEL W/CLAY
480	520	MED-CRS SAND WITH CLAY
520	540	POORLY GRD SAND
540	580	TAN CLAY
580	620	POORLY GRD SAND AND GRAVEL
620	640	TAN/BLUE CLAY W/POORLY GRD GRAVEL
640	660	BLUE CLAY W/POORLY GRD SAND
660	680	NED-CRS SAND W/METAMORPHIC GRAVEL
680	760	BLUE CLAY W/SAND AND GRAVEL
760	780	TAN/BROWN CLAY
780	800	DARK BLUE/GRAY CLAY W/FINE SAND
800	820	MED-CRS SAND W/BLUE CLAY
820	900	MED-CRS BLACK SAND AND GRAVEL
900	1020	TUSCAN CLAY AND ASH W/SOME FINE SAND

TOTAL DEPTH OF BORING 920 (Feet)

TOTAL DEPTH OF COMPLETED WELL 900 (Feet)

WELL LOCATION

Address 75 FT N OF C/R 18 & .9 MI E OF C/R P

City CA

County GLENN

APN Book 046 Page 310 Parcel 060

Township 22 N Range 2 W Section 30

Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
— Deepen
— Other (Specify)

— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial

MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER — (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL — (Ft.) & DATE MEASURED

ESTIMATED YIELD * — (GPM) & TEST TYPE

TEST LENGTH — (Hrs.) TOTAL DRAWDOWN — (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE	2									
0	130	12	✓				PVC	2.5	SCH 80	
130	140	12		✓			PVC	2.5	SCH 80	.030
140	150	12	✓				PVC	2.5	SCH 80	
150	160	12		✓			PVC	2.5	SCH 80	.030
160	250	12	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
725	789	✓			SAND SLURRY
789	920			✓	#8 GRD SAND

AUG 17 2004

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO.

IGINAL
le with DWR

Page 3 of 3

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 726922

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./ STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

Owner's Well No. 7677 MON

Date Work Began 5/6/2004, Ended 5/14/2004

Local Permit Agency GLENN COUNTY HEALTH DEPT

Permit No. MW207-04 Permit Date 5/3/2004

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0	20	SAND AND GRAVEL
20	60	TAN SILTY CLAY
60	70	SAND AND GRAVEL
70	120	TAN SILTY CLAY
120	160	SAND AND GRAVEL
160	220	TAN/BROWN SILTY CLAY
220	240	MED-CRS SAND
240	260	MED-CRS SAND WITH CLAY
260	320	TAN SILTY CLAY
320	360	POORLY GRD VOLCANIC SAND
360	380	POORLY SRTD SAND IN A VOLCANIC ASHY CLY
380	400	POORLY GRD SAND AND GRAVEL
400	480	POORLY SRTD SAND AND GRAVEL W/CLAY
480	520	MED-CRS SAND WITH CLAY
520	540	POORLY GRD SAND
540	580	TAN CLAY
580	620	POORLY GRD SAND AND GRAVEL
620	640	TAN/BLUE CLAY W/POORLY GRD GRAVEL
640	660	BLUE CLAY W/POORLY GRD SAND
660	680	NED-CRS SAND W/METAMORPHIC GRAVEL
680	760	BLUE CLAY W/SAND AND GRAVEL
760	780	TAN/BROWN CLAY
780	800	DARK BLUE/GRAY CLAY W/FINE SAND
800	820	MED-CRS SAND W/BLUE CLAY
820	900	MED-CRS BLACK SAND AND GRAVEL
900	1020	TUSCAN CLAY AND ASH W/SOME FINE SAND

TOTAL DEPTH OF BORING 920 (Feet)

TOTAL DEPTH OF COMPLETED WELL 900 (Feet)

WELL LOCATION

CITY

Address 75 FT N OF C/R 18 & .9 MI E OF C/R P

City CA

County GLENN

APN Book 046 Page 310 Parcel 060

Township 22 N Range 2 W Section 30

Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH

WEST

EAST

SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. **PLEASE BE ACCURATE & COMPLETE.**

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR

— Deepen

— Other (Specify)

— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY

— Domestic — Public

— Irrigation — Industrial

MONITORING ✓

TEST WELL —

CATHODIC PROTECTION —

HEAT EXCHANGE —

DIRECT PUSH —

INJECTION —

VAPOR EXTRACTION —

SPARGING —

REMEDIATION —

OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL (Ft.) & DATE MEASURED

ESTIMATED YIELD * (GPM) & TEST TYPE

TEST LENGTH (Hrs.) TOTAL DRAWDOWN (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
250	260	12		✓			PVC	2.5	SCH 80	.030
260	275	12	✓				PVC	2.5	SCH 80	
ZONE	3									
0	850	12/10	✓				PVC	2.5	SCH 80	
850	880	10		✓			PVC	2.5	SCH 80	.030
880	900	10	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	31	✓			SAND SLURRY
31	88			✓	#8 GRD SAND
88	114	✓			SAND SLURRY
114	291			✓	#8 GRD SAND
291	307	✓			SAND SLURRY
307	725				PEA GRAVEL

AUG 1

ATTACHMENTS (✓)

— Geologic Log

— Well Construction Diagram

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO. (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

WOODLAND CA 95695

JUN 30 2004

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Page 1 of 3

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 726923

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./ STATION NO. 22N/03W-24

LATITUDE LONGITUDE

APN/TRS/OTHER

Owner's Well No. 7678 MON

Date Work Began 5/17/2004, Ended 5/27/2004

Local Permit Agency GLENN COUNTY HEALTH DEPT.

Permit No. MW208-04 Permit Date 5/3/2004

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft. to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0 10	POORLY GRD SAND
10 20	SAND AND GRAVEL
20 40	GRAVEL W/CRS SAND
40 50	MED-CRS SAND W/GRAVEL
50 60	MED-CRS SAND
60 70	LARGE GRAVEL W/FINE-CRS SAND
70 80	MED-CRS SAND W/GRAVEL
80 120	TAN SILTY CLAY
120 130	TAN SILTY CLAY W/SAND AND GRAVEL
130 140	MED SAND W/SILTY TAN CLAY
140 150	MED SAND
150 250	MED-CRS SAND W/GRAVEL
250 270	TAN SILTY CLAY
270 280	TAN SILTY CLAY W/MED-CRS SAND
280 300	TAN SILTY CLAY
300 310	TAN SILTY CLAY W/MED-CRS SAND
310 320	TAN SILTY CLAY
320 340	TAN SILTY CLAY W/MED SAND
340 350	TAN SILTY CLAY W/CRS-FINE SAND AND GRVL
350 360	TAN SILTY CLAY W/MED SAND
360 380	SAND
380 410	TAN SILTY CLAY
410 420	MED SAND W/CLAY, HARD SPOT @ 420 FT
420 440	TAN SILTY CLAY W/MED-CRS SAND
440 460	TAN SILTY CLAY
460 490	MED-CRS SAND
490 520	TAN STICKY CLAY
520 540	MED SAND W/SOME GRAVEL
540 590	TAN STICKY CLAY
590 630	TAN/BLUE CLAY

TOTAL DEPTH OF BORING 860 (Feet)

TOTAL DEPTH OF COMPLETED WELL 840 (Feet)

WELL LOCATION

Address 125 FT N OF HWY 32 & 1000 FT E OF C/R N

City CA

County GLENN

APN Book 046 Page 150 Parcel 036

Township 22 N Range 3 W Section 24

Latitude DEG. MIN. SEC. DEG. MIN. SEC.

LOCATION SKETCH

NORTH / WEST / EAST / SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR
— Deepen
— Other (Specify)

— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial

MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ——— (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ——— (Ft.) & DATE MEASURED ———

ESTIMATED YIELD * ——— (GPM) & TEST TYPE ———

TEST LENGTH ——— (Hrs.) TOTAL DRAWDOWN ——— (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft. to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
ZONE 1									
0 50	12	✓				PVC	2.5	SCH 80	
50 60	12		✓			PVC	2.5	SCH 80	.030
60 70	12	✓				PVC	2.5	SCH 80	
ZONE 2									
0 130	12	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft. to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0 30	✓			SAND SLURRY
30 80				#8 GRD SAND
80 99				CHIPS
99 225			✓	#8 GRD SAND
225 248		✓		CHIPS
248 625			✓	#8 GRD SAND

AUG 17 2004

ATTACHMENTS (✓)

— Geologic Log
— Well Construction Diagram
— Geophysical Log(s)
— Soil/Water Chemical Analysis
— Other

ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO.
(PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)

20 W. KENTUCKY AVE. WOODLAND CA 95695
ADDRESS CITY STATE ZIP

Signed [signature] 06/01/04
WELL DRILLER/AUTHORIZED REPRESENTATIVE DATE SIGNED

C57 A HIC - 133783
C-57 LICENSE NUMBER

DWR 188 REV. 11-97

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

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Page 2 of 3

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 726923

DWR USE ONLY -- DO NOT FILL IN
STATE WELL NO./ STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

Owner's Well No. 7678 MON
Date Work Began 5/17/2004, Ended 5/27/2004
Local Permit Agency GLENN COUNTY HEALTH DEPT
Permit No. MW208-04 Permit Date 5/3/2004

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL — HORIZONTAL — ANGLE — (SPECIFY)
DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft.	to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
630	640	MED SAND
640	650	BLUE CLAY W/MED-CRS SAND
650	690	BLUE CLAY
690	700	MED-CRS SAND
700	710	BLUE/TAN CLAY
710	740	MED SAND
740	800	BRITTLE BLUE CLAY
800	820	MED-CRS SAND
820	880	BRITTLE BLUE CLAY
880	900	MED SAND
900	950	BLUE CLAY
950	1020	VOLCANIC ASH AND CLAY

TOTAL DEPTH OF BORING 860 (Feet)
TOTAL DEPTH OF COMPLETED WELL 840 (Feet)

WELL LOCATION

Address 125 FT N OF HWY 32 & 1000 FT E OF C/R N
City CA
County GLENN
APN Book 046 Page 150 Parcel 036
Township 22 N Range 3 W Section 24
Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH
NORTH / WEST / EAST / SOUTH
Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
— Deepen
— Other (Specify)
— DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)
WATER SUPPLY
— Domestic — Public
— Irrigation — Industrial
MONITORING ✓
TEST WELL —
CATHODIC PROTECTION —
HEAT EXCHANGE —
DIRECT PUSH —
INJECTION —
VAPOR EXTRACTION —
SPARGING —
REMEDIATION —
OTHER (SPECIFY) —

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___
ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___
TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)
May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
130	150	12		✓			PVC	2.5	SCH 80	.030
150	170	12	✓				PVC	2.5	SCH 80	
170	180	12		✓			PVC	2.5	SCH 80	.030
180	195	12	✓				PVC	2.5	SCH 80	
ZONE 0	3 800	12/10	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft.	to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
625	772	✓			SAND SLURRY
772	860			✓	#8 GRD SAND

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ATTACHMENTS (✓)
— Geologic Log

CERTIFICATION STATEMENT
I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

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Page 3 of 3

STATE OF CALIFORNIA

WELL COMPLETION REPORT

Refer to Instruction Pamphlet

No. 726923

DWR USE ONLY — DO NOT FILL IN

STATE WELL NO./ STATION NO.

LATITUDE LONGITUDE

APN/TRS/OTHER

Owner's Well No. 7678 MON

Date Work Began 5/17/2004, Ended 5/27/2004

Local Permit Agency GLENN COUNTY HEALTH DEPT.

Permit No. MW208-04 Permit Date 5/3/2004

GEOLOGIC LOG

ORIENTATION (✓) ✓ VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)

DRILLING METHOD ROTARY FLUID MUD

DEPTH FROM SURFACE Ft. to Ft.	DESCRIPTION *Describe material, grain, size, color, etc.*
0 10	POORLY GRD SAND
10 20	SAND AND GRAVEL
20 40	GRAVEL W/CRS SAND
40 50	MED-CRS SAND W/GRAVEL
50 60	MED-CRS SAND
60 70	LARGE GRAVEL W/FINE-CRS SAND
70 80	MED-CRS SAND W/GRAVEL
80 120	TAN SILTY CLAY
120 130	TAN SILTY CLAY W/SAND AND GRAVEL
130 140	MED SAND W/SILTY TAN CLAY
140 150	MED SAND
150 250	MED-CRS SAND W/GRAVEL
250 270	TAN SILTY CLAY
270 280	TAN SILTY CLAY W/MED-CRS SAND
280 300	TAN SILTY CLAY
300 310	TAN SILTY CLAY W/MED-CRS SAND
310 320	TAN SILTY CLAY
320 340	TAN SILTY CLAY W/MED SAND
340 350	TAN SILTY CLAY W/CRS-FINE SAND AND GRVL
350 360	TAN SILTY CLAY W/MED SAND
360 380	SAND
380 410	TAN SILTY CLAY
410 420	MED SAND W/CLAY, HARD SPOT @ 420 FT
420 440	TAN SILTY CLAY W/MED-CRS SAND
440 460	TAN SILTY CLAY
460 490	MED-CRS SAND
490 520	TAN STICKY CLAY
520 540	MED SAND W/SOME GRAVEL
540 590	TAN STICKY CLAY
590 630	TAN/BLUE CLAY

TOTAL DEPTH OF BORING 860 (Feet)

TOTAL DEPTH OF COMPLETED WELL 840 (Feet)

WELL LOCATION

Address 125 FT N OF HWY 32 & 1000 FT E OF C/R N

City CA

County GLENN

APN Book 046 Page 150 Parcel 036

Township 22 N Range 3 W Section 24

Latitude ___ DEG. ___ MIN. ___ SEC. ___ DEG. ___ MIN. ___ SEC.

LOCATION SKETCH

NORTH

WEST

EAST

SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)

✓ NEW WELL

MODIFICATION/REPAIR

___ Deepen

___ Other (Specify)

___ DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")

PLANNED USES (✓)

WATER SUPPLY

___ Domestic ___ Public

___ Irrigation ___ Industrial

MONITORING ✓

TEST WELL ___

CATHODIC PROTECTION ___

HEAT EXCHANGE ___

DIRECT PUSH ___

INJECTION ___

VAPOR EXTRACTION ___

SPARGING ___

REMEDIATION ___

OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL

DEPTH TO FIRST WATER ___ (Ft.) BELOW SURFACE

DEPTH OF STATIC WATER LEVEL ___ (Ft.) & DATE MEASURED ___

ESTIMATED YIELD * ___ (GPM) & TEST TYPE ___

TEST LENGTH ___ (Hrs.) TOTAL DRAWDOWN ___ (Ft.)

May not be representative of a well's long-term yield.

CASING (S)

DEPTH FROM SURFACE Ft. to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CONDUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
800 820	10		✓			PVC	2.5	SCH 80	.030
820 840	10	✓				PVC	2.5	SCH 80	

ANNULAR MATERIAL

DEPTH FROM SURFACE Ft. to Ft.	TYPE CEMENT (✓)	BENTONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0 30	✓		✓	SAND SLURRY
30 80			✓	#8 GRD SAND
80 99		✓		CHIPS
99 225		✓		#8 GRD SAND
225 248			✓	CHIPS
248 625			✓	#8 GRD SAND

AUG 17 2004

ATTACHMENTS (✓)

___ Geologic Log

___ Well Construction Diagram

CERTIFICATION STATEMENT

I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.

NAME EATON DRILLING CO

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Appendix 4B

Colusa Subbasin 2020 Groundwater Quality Monitoring Network Wells

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Table 4B-1. Groundwater Quality Monitoring Network Wells				
County	Well ID	Agency	Latitude [a]	Longitude
Glenn	**1100404-001[b]**	**Del Oro Water Company – Black Butte District**	**39.75970**	**-122.22526**
Glenn	1100405-001	Black Butte Mobile Home Park	39.75373	-122.21006
Glenn	**1110001-001**	**City of Orland**	**39.73808**	**-122.17203**
Glenn	1110001-002	City of Orland	39.73808	-122.17203
Glenn	1110001-005	City of Orland	39.73820	-122.19538
Glenn	1110001-008	City of Orland	39.73977	-122.17549
Glenn	1110001-009	City of Orland	39.75348	-122.19639
Glenn	1110001-017	City of Orland	39.75399	-122.19034
Glenn	1100413-002	Country Leisure Mobile Estates	39.74592	-122.13595
Glenn	1100444-001	Orland Estates Mobile Home Park	39.74015	-122.20960
Glenn	1100444-002	Orland Estates Mobile Home Park	39.74012	-122.20972
Glenn	1100445-002	Orland Mobile Home Park	39.73423	-122.19709
Glenn	1100436-002	Orland Oaks Mobile Home Park	39.75274	-122.21581
Glenn	1100452-001	Shady Oaks Trailer Park	39.76262	-122.19667
Glenn	1100254-003	Voyles Trailer Park	39.53352	-122.19526
Glenn	1100237-003	Willows Mobile Home Community & RV Park	39.52326	-122.23170
Glenn	1100203-001	Artois Community Service District	39.61738	-122.19492
Glenn	**1100203-002**	**Artois Community Service District**	**39.62235**	**-122.19494**
Glenn	1110003-003	Cal-Water Service Company - Willows	39.51426	-122.19905
Glenn	1110003-006	Cal-Water Service Company - Willows	39.53016	-122.20706
Glenn	**1110003-007**	**Cal-Water Service Company - Willows**	**39.50981**	**-122.19533**
Glenn	1110003-008	Cal-Water Service Company - Willows	39.52162	-122.21130
Glenn	1110003-009	Cal-Water Service Company - Willows	39.51903	-122.18713
Glenn	0600013-001	Colusa County Water Works District #2 – Princeton	39.40283	-122.01008
Glenn	**0600013-002**	**Colusa County Water Works District #2 – Princeton**	**39.40916**	**-122.00992**
Colusa	**0610003-003**	**Maxwell Public Utility District**	39.27650	-122.18944
Colusa	**0610002-002**	**City of Colusa**	**39.21073**	**-122.01404**
Colusa	0610002-003	City of Colusa	39.20768	-122.01175
Colusa	0610002-004	City of Colusa	39.20114	-122.02074
Colusa	0610002-005	City of Colusa	39.20293	-122.00906
Colusa	0610002-006	City of Colusa	39.21461	-122.01429
Colusa	**0610004-004**	**City of Williams**	**39.15214**	**-122.14661**
Colusa	0610004-009	City of Williams	39.15742	-122.13924
Colusa	0610004-011	City of Williams	39.15203	-122.13548
Colusa	**0600008-001**	**Colusa County Water Works District #1 – Grimes**	**39.07209**	**-121.89445**
Colusa	0610001-001	Arbuckle Public Utility District	39.01261	-122.05584
Colusa	0610001-002	Arbuckle Public Utility District	39.01677	-122.06172
Colusa	**0610001-004**	**Arbuckle Public Utility District**	**39.01997**	**-122.05846**
Colusa	0610001-005	Arbuckle Public Utility District	39.01662	-122.07124
Colusa	**0605011-001**	**Del Oro Water Company – Arbuckle District**	**39.00503**	**-122.06048**
Glenn	**25A1M**	**California Rice Commission [c]**	**39.56459**	**-122.02759**
Glenn	**32J1M**	**California Rice Commission**	**39.54292**	**-122.09912**
Glenn	**23E1M**	**California Rice Commission**	**39.49160**	**-122.05584**
Glenn	**25E1M**	**California Rice Commission**	**39.47299**	**-122.16428**
Glenn	**25R1M**	**California Rice Commission**	**39.47080**	**-122.13686**
Glenn	**12G2M**	**California Rice Commission**	**39.42900**	**-122.03237**
Colusa	**14G1M**	**California Rice Commission**	**39.28179**	**-122.17190**
Colusa	**35M1M**	**California Rice Commission**	**39.18317**	**-122.07808**
Colusa	**03E1M**	**California Rice Commission**	**39.14835**	**-122.07927**
Colusa	**16R1M**	**California Rice Commission**	**39.71070**	**-122.10610**
Glenn	**SVWQC00005**	**Sacramento Valley Water Quality Coalition [d]**	**39.01040**	**-122.06760**
Colusa	**SVWQC00019**	**Sacramento Valley Water Quality Coalition**	**39.37720**	**-122.01330**
Colusa	**SVWQC00021**	**Sacramento Valley Water Quality Coalition**	**38.96060**	**-122.01810**
Colusa	**SVWQC00006**	**Sacramento Valley Water Quality Coalition**	**39.75970**	**-122.22526**

(a) Latitude and longitude are reported in North American Datum of 1983 (NAD 83), decimal degrees.

(b) Bolded wells are those that were selected to be included in the representative groundwater quality monitoring network. The representative groundwater quality monitoring network and its corresponding wells are discussed more in Section 4.2.5 of this GSP.

(c) Central Valley Regional Water Quality Control Board. 2016.

(d) Luhdorff and Scalmanini. 2019.

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Appendix 5A

Colusa Groundwater Authority and Glenn Groundwater Authority Technical Advisory Committees Records of Decision for Sustainable Management Criteria

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INTRODUCTION

This appendix documents the decision-making process and adoption of the Colusa Subbasin Sustainable Management Criteria (SMC) by the Colusa Groundwater Authority and Glenn Groundwater Authority Technical Advisory Committees (referred to as the Joint TAC).

A record of decision is provided for each of the sustainability indicators applicable to the Colusa Subbasin (Subbasin):

1. Chronic Lowering of Groundwater Levels
2. Reduction of Groundwater Storage
3. Seawater Intrusion (not applicable to the Colusa Subbasin)
4. Degraded Water Quality
5. Land Subsidence
6. Depletions of Interconnected Surface Water

Colusa Groundwater Authority and Glenn Groundwater Authority Technical Advisory Committees Record of Decision

SUSTAINABILITY INDICATOR #1: CHRONIC LOWERING OF GROUNDWATER LEVELS

Decision Record

At their joint meeting on May 13, 2021, the Colusa Groundwater Authority (CGA) Technical Advisory Committee (TAC) and Glenn Groundwater Authority (GGA) TAC each voted unanimously to recommend to their respective boards the criteria listed below for setting quantitative Sustainable Management Criteria (SMC) for groundwater Sustainability Indicator #1: Chronic Lowering of Groundwater Levels. These actions were taken in relation to Agenda Item 4.a.i. with the roll call vote documented in the meeting minutes.

The SMC for Chronic Lowering of Groundwater Levels will be calculated and conditioned as follows. The calculation will be made individually for each of the 48 representative monitoring wells comprising the Groundwater Level monitoring network. Water levels are defined as the depth to groundwater below ground surface.

1) Minimum Thresholds will be set equal to the lower of the following two calculated water levels:
    a. 50 percent of the historical range in observed water levels below the observed low water level, AND,
    b. The 20th percentile depth of domestic wells in the Thiessen polygon represented by each monitoring well. This means that 20 percent of the domestic wells are shallower and 80 percent deeper than the 20th percentile depth.
2) Measurable Objectives will be calculated as the average of the most recent five (5) years of available groundwater levels. The calculated water level is fixed and is not a running average that changes over time.
3) An Undesirable Result will be detected when water levels in 25 percent or more (at least 12) of the 48 representative monitoring wells fall below their respective Minimum Thresholds continuously for 24 months. The 12 wells must be the same subset of wells, not any combination of 12 wells.
4) To ensure operational compatibility with adjoining subbasins, the Minimum Thresholds and Measurable Objectives for monitoring wells near subbasin boundaries will be reviewed and adjusted, as needed, in consultation with representatives of adjoining subbasin Groundwater Sustainability Agencies.

Adoption Record

The TAC decisions were presented to and adopted by their respective Boards as follows:

- CGA: Approved May 25, 2021
- GGA: Approved June 16, 2021

Colusa Groundwater Authority and Glenn Groundwater Authority Technical Advisory Committees Record of Decision

SUSTAINABILITY INDICATOR #2: REDUCTION OF GROUNDWATER STORAGE

Decision Record

At their joint meeting on April 23, 2021, the Colusa Groundwater Authority (CGA) Technical Advisory Committee (TAC) and Glenn Groundwater Authority (GGA) TAC the Consultant Team recommended to the TACs that Sustainable Management Criteria (SMC) for groundwater Sustainability Indicator #2: Reduction of Groundwater Storage be addressed using Sustainability Indicator #1: Groundwater Levels as a proxy indicator, as allowed under DWR's Groundwater Sustainability Plan regulations.

The CGA TAC and GGA TAC each voted unanimously to recommend to their respective boards that SMC for groundwater Sustainability Indicator #2: Reduction of Groundwater Storage be addressed by proxy as described above. These actions were taken in relation to Agenda Item 4.b.i. with the roll call vote documented in the meeting minutes.

Supporting Rationale

The Consultant Team explained that the freshwater aquifers in the Colusa Subbasin are deep relative to existing well infrastructure and the Measurable Objectives (MOs) and Minimum Thresholds (MTs) under consideration for Sustainability Indicator #1: Groundwater Levels. Large volumes of fresh groundwater would remain in storage even if MTs were reached. Therefore, the MTs and MOs adopted for Groundwater Levels are protective of Groundwater Storage.

Adoption Record

The TAC decisions were presented to and adopted by their respective Boards as follows:

- CGA: Approved May 25, 2021
- GGA: Approved May 10, 2021

Colusa Groundwater Authority and Glenn Groundwater Authority Technical Advisory Committees Record of Decision

SUSTAINABILITY INDICATOR #3: SEAWATER INTRUSION

Seawater intrusion is not considered to be an applicable sustainability indicator for the Colusa Subbasin. Thus, SMC were not established for seawater intrusion.

Seawater intrusion is not currently occurring in the Subbasin, and is not likely to occur due to the substantial distance between the Subbasin and the Pacific Ocean, bays, deltas, or inlets.

Colusa Groundwater Authority and Glenn Groundwater Authority Technical Advisory Committees Record of Decision

SUSTAINABILITY INDICATOR #4: DEGRADED WATER QUALITY

Decision Record

At their joint meeting on April 9, 2021, the Colusa Groundwater Authority (CGA) Technical Advisory Committee (TAC) and Glenn Groundwater Authority (GGA) TAC each voted to recommend to their respective boards to adopt a policy not to adopt quantitative Sustainable Management Criteria (SMC) for groundwater Sustainability Indicator #4: Degraded Water Quality, and instead to improve the water quality monitoring network and adopt quantitative SMC in the 2027 Groundwater Sustainability Plan (GSP) update.

Subsequent to the April 9 meeting, additional information became available causing the Consultant Team to reconsider its earlier advice to the TACs. The new information included an opinion provided by GGA counsel and results of the Department of Water Resources evaluations of GSPs prepared for other groundwater subbasins. Based on this additional information, the Consultant Team changed its approach and recommended to the TACs at their June 11, 2021, meeting that quantitative SMC for water quality be developed for Sustainability Indicator #4.

At the June 11, 2021, Joint TAC meeting, each TAC voted unanimously, with Ben King of the CGA TAC abstaining, to recommend to their respective boards the criteria listed below for setting quantitative SMCs for Sustainability Indicator #4. These actions were taken in relation to Agenda Item 4.a.i. with the roll call vote documented in the meeting minutes.

The SMCs for Degraded Water Quality pertain to salinity only, applicable to each of 23 representative monitoring wells, are as follows:

1) The Minimum Threshold will be 900 µS/cm[1] (the recommended California Secondary Maximum Contaminant Level) OR the pre-2015 historical maximum measured salinity.
2) The Measurable Objective will be 700 µS/cm (corresponding to an agricultural water quality objective providing for no yield reduction for crops commonly grown in the Colusa Subbasin).
3) An Undesirable Result will be detected when salinity (as indicated by electrical conductivity) in 25 percent of the representative monitoring wells (6 of 23 monitoring wells) exceeds the Minimum Threshold for two (2) consecutive years.

[1] µS/cm stands for micro Siemens per centimeter, a measure of the electrical conductivity (EC) of water. 1,000 µS/cm is equal to approximately 640 parts per million of total dissolved solids in water.

Clarifying Points

The foregoing SMC were established with the TACs' understanding that 23 representative monitoring wells are not sufficient for long-term, sustainable management of the Colusa Subbasin and that additional new or existing wells will need to be added to the monitoring network over time. Additionally, the TACs acknowledge that the SMC will need to be reviewed and evaluated, and potentially refined, as additional monitoring wells are added, and additional data is collected and analyzed.

Adoption Record

The TAC decisions were presented to and adopted by their respective Boards as follows:

- CGA: Approved July 8, 2021
- GGA: Approved June 16, 2021, and approved as amended July 12, 2021

Colusa Groundwater Authority and Glenn Groundwater Authority Technical Advisory Committees Record of Decision

SUSTAINABILITY INDICATOR #5: LAND SUBSIDENCE

Decision Record

At their joint meeting on April 9, 2021, the Colusa Groundwater Authority (CGA) Technical Advisory Committee (TAC) and Glenn Groundwater Authority (GGA) TAC each voted unanimously to recommend to their respective boards the criteria for setting quantitative Sustainable Management Criteria (SMCs) for groundwater Sustainability Indicator #5: Land Subsidence. These actions were taken in relation to Agenda Item 4.b.ii. with the roll call vote documented in the meeting minutes.

In September 2021, the Consultant Team prepared revised recommendations for the land subsidence SMCs to bring those SMCs into closer alignment with neighboring subbasins. Revisions to the quantitative SMCs for groundwater Sustainability Indicator #5: Land Subsidence were presented to and adopted by the CGA and GGA Boards in September and October 2021. During this process, the GGA Board recommended one additional revision regarding the process used to determine whether undesirable results have occurred.

The GGA Board voted unanimously to adopt the amended land subsidence SMCs listed below at their Board meeting on October 11, 2021. These actions were taken in relation to Agenda Item 9.e. with the roll call vote documented in the meeting minutes.

The CGA voted unanimously to adopt the amended land subsidence SMCs at their Board meeting on September 28, 2021, and amended again at the Board meeting on October 26, 2021.[2] These actions were taken in relation to Agenda Item 5 (September 28, 2021) and Agenda Item 7 (October 26, 2021) with the roll call vote documented in the corresponding meeting minutes.

The SMCs for Land Subsidence are as follows. The SMCs are applicable to each of 63 land subsidence monitoring benchmarks belonging to the Sacramento Valley Height Modernization Project.

1) The Minimum Threshold (MT) rate of subsidence at all 63 land subsidence benchmarks is 0.5 feet per five years.
2) The Measurable Objective (MO) rate of subsidence at all 63 land subsidence benchmarks is 0.25 feet per five years.
3) An Undesirable Result is considered to occur when the MT is exceeded at 20 percent (13 of 63) of the land subsidence monitoring benchmarks.

[2] The CGA adopted the revised land subsidence SMCs recommended by the Consultant Team as presented at their September 28, 2021 Board meeting. The CGA later adopted the land subsidence SMCs as revised by the GGA and presented at their October 26, 2021 CGA Board meeting.

Additionally, the GSAs will evaluate adding subsidence monitoring benchmarks, especially in areas of concern and will review InSAR data annually (regulations do not require subsidence reporting in annual reports).

Supporting Rationale and Clarifying Points

1) The SMCs will be reviewed and adjusted to account for potential changes in subsidence rates brought about by implementation of PMAs and future groundwater resource development. The extent of subsidence-prone areas, which may be underlain by sediments that have greater susceptibility to subsidence due to groundwater withdrawal, will continue to be delineated as data gaps are filled through the ongoing subsidence monitoring programs (using data from benchmarks, extensometers and InSAR surveys) and subsidence-prone sediments are characterized during drilling for well construction, extensometer installation or other subsurface investigations needed for the development of specific PMAs.
2) The GSAs expect that projects and management actions would be implemented before the MT rates are reached.
3) DWR reports that the probable error in the subsidence values reported for the monitoring benchmarks is ±0.17 feet, meaning that for any reported value, the actual subsidence value is likely to fall in a range between plus or minus 0.17 feet of the reported value. The selected MO subsidence rate of 0.25 feet per five year is deliberately greater than the reported probable error of ±0.17 feet as a means of avoiding false exceedance of the MO.

Adoption Record

The revised SMC were presented to and adopted by their respective Boards as follows:

- CGA: Approved April 27, 2021, and approved as amended September 28, 2021, and October 26, 2021
- GGA: Approved May 10, 2021, and approved as amended October 11, 2021

Colusa Groundwater Authority and Glenn Groundwater Authority Technical Advisory Committees Record of Decision

SUSTAINABILITY INDICATOR #6: DEPLETIONS OF INTERCONNECTED SURFACE WATER

Decision Record

At their joint meeting on May 19, 2021, the Colusa Groundwater Authority (CGA) Technical Advisory Committee (TAC) and Glenn Groundwater Authority (GGA) TAC each voted to recommend to their respective boards certain criteria for setting quantitative Sustainable Management Criteria (SMCs) for groundwater Sustainability Indicator #6: Depletions of Interconnected Surface Water. The vote of the GGA TAC was unanimous. The vote of the CGA TAC was "yes" for all members except Bill Vanderwaal who voted no. These actions were taken in relation to Agenda Item 4.a.i. with the roll call vote documented in the meeting minutes.

Subsequent to the TACs' May 19 decisions, the CGA Board acted to adopt the CGA TAC's recommendation with a certain modification of the Undesirable Result (UR) criteria. Additionally, the Consultant Team conducted additional analyses to better understand the connectivity of Stony Creek surface water to underlying groundwater, and to address surface water depletion in the Colusa Basin Drain. (Prior surface water depletion discussions had only addressed Stony Creek and the Sacramento River.) The modified UR criteria and results of these additional analyses along with associated recommendations were presented by the Consultant Team to the TACs at their joint meeting on June 11, 2021.

At the June 11, 2021, joint TAC meeting, each TAC voted unanimously to recommend to their respective boards the criteria listed below for setting quantitative Sustainable Management Criteria (SMCs) for groundwater Sustainability Indicator #6: Depletions of Interconnected Surface Water. These actions were taken in relation to Agenda Item 4.a.ii. with the roll call vote documented in the meeting minutes.

The SMCs for Depletions of Interconnected Surface Water will be set or calculated and conditioned as follows. The calculation will be made individually for each of the 12 representative monitoring wells comprising the surface water depletion monitoring network. Water levels are defined as the depth to groundwater below ground surface.

1) Minimum Thresholds will be calculated as the Fall 2015 observed water level minus 10 feet, with the observed Fall 2015 water level being the level recorded closest to October 15, 2015.
2) Measurable Objectives will be calculated as the average of the most recent five (5) years of available, measured groundwater levels. The calculated water level is fixed and is not a running average that changes over time.
3) An Undesirable Result will be detected when water levels in 25 percent of the representative monitoring wells (3 of 12 monitoring wells) fall below their respective Minimum Thresholds continuously for 24 months. The 3 wells must be the same subset of wells, not any combination of 3 wells.

4) To ensure operational compatibility with adjoining subbasins, the Minimum Thresholds and Measurable Objectives for monitoring wells near subbasin boundaries will be reviewed and adjusted, as needed, in consultation with representatives of adjoining subbasin Groundwater Sustainability Agencies.

The foregoing SMCs were established with the TACs' understanding that 12 representative monitoring wells are not sufficient for long-term, sustainable management of the Colusa Subbasin and that additional new or existing wells will need to be added to the monitoring network over time. Additionally, the TACs acknowledge that the SMCs will need to be reviewed and evaluated, and potentially refined, as additional wells are added, and additional data is collected and analyzed.

Adoption Record

The TAC decisions were presented to and adopted by their respective Boards as follows:

- CGA: Approved June 22, 2021
- GGA: Approved June 16, 2021

Appendix 5B

Process and Rationale for Setting Minimum Thresholds and Measurable Objectives for Groundwater Levels and Depletions of Interconnected Surface Waters

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Specialists in Agricultural Water Management
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Technical Memorandum

To: Colusa Groundwater Authority and Glenn Groundwater Authority

From: Davids Engineering and Woodard & Curran

Date: November 30, 2021

Subject: **Process and Rationale for Setting Minimum Thresholds and Measurable Objectives for Groundwater Levels and Depletions of Interconnected Surface Waters**

Introduction

Sustainable Management Criteria (SMC) for the Colusa Subbasin (Subbasin) have been established in consultation with the Technical Advisory Committees of the two groundwater sustainability agencies in the Subbasin, those being the Colusa Groundwater Authority (CGA) and Glenn Groundwater Authority (GGA). SMC consist of the following: the Sustainability Goal adopted for the Subbasin; Undesirable Results describing significant and unreasonable effects to be avoided; quantitative Minimum Thresholds (MTs) that define conditions that, if exceeded, may cause Undesirable Results; and quantitative Measurable Objectives (MOs) to achieve the Sustainability Goal of the Subbasin. Undesirable results, MTs, and MOs are all established in relation to the six sustainability indicators referenced in the GSP Emergency Regulations, five of which are applicable in the Colusa Subbasin.

This Technical Memorandum (TM) documents the process and rationale for setting MTs and MOs for two specific sustainability indicators: Chronic Lowering of Groundwater Levels (Groundwater Levels), and Depletions of Interconnected Surface Water (Streamflow Depletion). As specified in 23 CCR 354.28(c)(6), Streamflow Depletion MTs and MOs shall be based on "the rate or volume of surface water depletions caused by groundwater use that has adverse impacts on beneficial uses of the surface water and may lead to undesirable results." However, the regulations also allow the use of groundwater levels as a proxy for streamflow rates or volumes. Because the location and accuracy of existing stream gages on the Sacramento River and its tributaries are not sufficient to directly analyze streamflow accretions and depletions with respect to the Colusa Subbasin, water levels were used as a proxy. Analyses of streamflow depletions in the Colusa Subbasin are described in the GSP and in Appendix 3G of the GSP. Thus, both of the sustainability indicators addressed in this TM involve groundwater levels and are therefore related. In particular, for representative monitoring network wells that are included in the monitoring networks for both indicators, there are two MTs and MOs. Both are valid with respect to their associated indicator but operationally the shallower MTs and MOs will govern.

The discussion of MOs and MTs for Groundwater Levels and Streamflow Depletion follow, preceded by a brief description of the outreach process used for SMC development (not just for Groundwater Levels and Streamflow Depletion, but also for other sustainability indicators and other GSP development tasks), and brief statements of the Sustainability Goal and Undesirable Results for the two sustainability indicators addressed here.

Outreach and Public Involvement Process

Outreach and public involvement in support of SMC development in the Colusa Subbasin were achieved primarily through a series of public meetings with the Technical Advisory Committees (TACs) formed by the Colusa Groundwater Authority (CGA) and Glenn Groundwater Authority (GGA), respectively. The meetings were publicly noticed on the CGA and GGA websites, with agendas noting action items posted in advance of each meeting, and minutes prepared following each meeting. The technical topics and content for each meeting were developed by the Colusa Subbasin GSP Technical Team led by Davids Engineering, with Woodard & Curran serving as the lead SMC subconsultant. The TACs met together, with the meetings referred to as Joint TAC meetings.

Joint TAC meetings were held approximately monthly, with a total of 13 meetings held between May 8, 2020, and June 11, 2021. SMC were addressed at nine of the 13 meetings, and at all of the seven meetings held between January 8 and June 11, 2021. TAC members engaged in a very thorough, thoughtful, and constructive manner, giving consideration to all interests in the Subbasin involved with or affected by groundwater use and management, including domestic well users, disadvantaged communities, small disadvantaged communities, California Native American Tribes, and environmental beneficial uses and users. This engagement process and consideration for these stakeholders is documented in Chapter 2 of the GSP, as well as meeting minutes and related materials available online.[1] SMC were ultimately vetted and approved by both the CGA and GGA Boards at open Board meetings. Public notice was given in advance of those meetings. The decision records for the SMC are documented in Appendix 5A of the GSP.

Members of the public were welcome to attend the Joint TAC and open Board meetings and were encouraged to express their opinions, suggestions, and comments on the SMC, as well as other aspects of the GSP. Members of the public attended and participated in most Joint TAC meetings, including those in which SMC were discussed.

Sustainability Goal

The Sustainability Goal for the Colusa Subbasin as accepted by the TACs and adopted by the CGA and GGA is:

> *…to maintain, through a cooperative and partnered approach, locally managed sustainable groundwater resources to preserve and enhance the economic viability, social well-being and culture of all Beneficial Uses and Users, without experiencing undesirable results.*

Undesirable Results

The undesirable results statements proposed for Groundwater Levels and Streamflow Depletion, respectively, are as follows:

- The undesirable result for the chronic lowering of groundwater levels is a result that would cause significant and unreasonable reduction in the long-term viability of beneficial uses and users over the planning and implementation horizon of this GSP.

[1] CGA meeting materials are available at: https://colusagroundwater.org/meetings/.
GGA meeting materials are available at: https://www.countyofglenn.net/dept/planning-community-development-services/water-resources/glenn-groundwater-authority/gga.

- The undesirable result for the depletion of interconnected surface water is a result that causes significant and unreasonable adverse effects on beneficial uses and users of interconnected surface waters within the Colusa Subbasin over the planning and implementation horizon of this GSP.

Additional consideration for undesirable results is discussed in Chapter 5 of the GSP.

Measurable Objectives

MOs represent the desired conditions for sustainable operation of the Subbasin while MTs define conditions that are to be avoided because of the risk that Undesirable Results could occur if the MTs are exceeded. For both sustainability indicators addressed in this TM, the MOs were set as the numerical average of all recorded groundwater levels over the most recent five years of record available for each well. For all but four wells, the most recent five years of record ends in Spring 2020. Setting MOs in this manner reflects the GSAs' intention to operate the Subbasin without persistent declines below recent historical groundwater levels, consistent with the Sustainable Groundwater Management Act (SGMA).

Minimum Thresholds

The rationale and parameters considered in establishing MTs for Groundwater Levels and Streamflow Depletion are discussed below in respective sections.

Groundwater Levels

The primary parameters and general objectives considered in establishing Groundwater Levels MTs were:

1. Avoiding significant and unreasonable impacts to shallow (primarily domestic) wells: setting MT groundwater levels shallow enough to be reasonably protective of a majority of existing domestic wells.
2. Avoiding significant and unreasonable effects on groundwater dependent ecosystems (GDEs): setting MT groundwater levels shallow enough to be reasonably protective of GDEs and potential GDEs.
3. Avoiding significant and unreasonable impacts to (constraints on) conjunctive management of Colusa Subbasin surface water and groundwater supplies: setting MT groundwater levels deep enough to allow a range of operational flexibility that ensures adequate water supply reliability over variable, wet and dry hydrologic conditions.

Available GDE mapping was analyzed and GDE areas ranked with regard to their likelihood of actually being dependent on groundwater as opposed to being sustained by streamflow or applied irrigation water. However, due to lack of reliable shallow groundwater elevation data, the analysis was inconclusive[2] and objectives 1 and 3, above, became the primary focus for setting Groundwater Level MTs. However, GDEs were still considered in the selection of Streamflow Depletion SMC and monitoring sites (see below). To reconcile potential conflicts between objectives 1 and 3, setting MTs involved striking balance and compromise between them to reasonably protect domestic well users while also supporting ongoing conjunctive management of the Subbasin.

[2] The lack of shallow groundwater data is identified as a data gap and will be addressed along with other data gaps during plan implementation.

For each of the 48 wells in the Groundwater Level representative monitoring network, Thiessen polygons were drawn around each well and the depths of all domestic wells expressed as an exceedance function. For example, the 20 percent exceedance for the domestic wells in any given polygon is the depth at which 20 percent of the wells are shallower and 80 percent deeper, meaning 80 percent of the wells would be protected and 20 percent would be subject to potential stranding if groundwater levels fell to the 20 percent exceedance depth. Information about existing domestic well infrastructure in the Colusa Subbasin was obtained from Well Completion Reports (WCR) available in DWR's database[3]. The WCR database generally includes all historical wells that have been reported in the system, which may include old wells that are no longer operational, have been refurbished, or have been dewatered for many years, long preceding conditions in 2015. The data is self-reported, and some data entries are incomplete. As such, the domestic well inventory for the Subbasin is incomplete and will be addressed with other data gaps in the Subbasin to support GSP implementation (see Chapters 4, 6 and 7). The analysis to support setting MT was developed considering these limitations.

The analyses of well completion depths conducted to support the MT development process is conservative and protective of beneficial uses because it included domestic wells that were shallower than the historic low groundwater level in each polygon. As documented in Appendix 5C, for the Subbasin as a whole, approximately 46 percent of the domestic wells in the WCR database are shallower than the pre-2015 historical groundwater levels as defined by the Groundwater Level representative monitoring network. Many of these shallow wells may no longer be used or they may have been deepened because they would have otherwise been dry at times prior to 2015. Including these shallow, and potentially unused or deepened wells in the well depth analysis, resulted in Groundwater Level MTs that are shallower than they would have been if the wells had been excluded.

As described in Chapter 4 of the GSP, data gaps related to domestic wells will be addressed in future GSP updates, and this analysis may be refined with new information. Based on the available information at the time of GSP development, technical team analysis, and TAC discussion, a 20 percent exceedance threshold emerged as being reasonable for protection of existing domestic well infrastructure.

For the same 48 representative monitoring wells, historical water levels, generally for the period from spring 2000 to spring 2020 (subject to availability for any particular well), were reviewed and analyzed as a basis for understanding how groundwater levels have fluctuated and when historical minimum groundwater levels have occurred. In particular, the magnitude of the range of historical fluctuation was regarded as an indicator of how the well has behaved over wet and dry hydrologic periods, and whether there are any persistent upward or downward trends. For many wells, especially those relatively far from streams, groundwater levels have trended downward since approximately the mid-2000s and record low groundwater levels were observed in the fall of 2015 following back-to-back critically dry years. These observations led to the approach of alternatively setting MTs at historical low levels plus some percentage of the observed groundwater level range to allow for conjunctive operation of the Subbasin during droughts. The TACs considered 20 percent and 50 percent of historical range as the increment to add to the observed historical low groundwater level. After careful review of the 48 well records, 50 percent of historical range below the historical low was selected as an MT that would allow the range of fluctuation necessary to manage through future dry periods while avoiding undesirable results. To support evaluation of Groundwater Level MTs, the technical team developed an economic analysis of the costs (additional pumping costs, domestic well replacement costs) and benefits (avoided costs of other projects and management actions) associated with the proposed MTs. The analysis illustrated the direct monetary cost-benefit tradeoffs of setting MTs at different levels. The central

[3] Available at: https://data.cnra.ca.gov/dataset/well-completion-reports

conclusion was that the additional cost of raising the MT for most monitoring wells was substantially greater than the additional benefit to groundwater users in the Subbasin. Results of this analysis were presented to the TAC at a public meeting held on May 13, 2021 and are described in more detail in Appendix 5C of the GSP.

Hydrographs for the 48 wells in the Groundwater Level representative monitoring well network are provided in Attachment A illustrating both possible MTs: one based on the 20th percentile domestic well depth exceedance and the other on 50 percent of historical range below the historical low. The two MTs are shown in relation to available historical data for each well. For 13 of the wells, the lower of the MTs is represented by the 50 percent of range below the historical low with the lower MT for the remaining 35 wells represented by 20th percentile domestic well depth exceedance. Based on the information in these graphs and supporting analysis by the technical team, the technical team recommended, and the TACs accepted, adopting the lower of the two MTs as the governing threshold.

For the 13 wells with MTs based on 50 percent of historical range below the historical low, it was possible that more than 20 percent of domestic wells would be shallower than the MT, and therefore would be at risk of dewatering. An additional analysis was developed to quantify the share of domestic wells that could potentially be affected under the selected MT. The inventory of domestic wells for each polygon was screened to remove wells that were shallower than the historical low groundwater level observed prior to January 1, 2015. These wells would have been dewatered based on historical groundwater levels that occurred in the Subbasin prior to the implementation of SGMA. The proportion of the remaining wells that are shallower than the proposed MT was calculated for each polygon. In aggregate, less than 20 percent of domestic wells are shallower than the proposed MT. This was viewed as an acceptable balance between avoiding significant and unreasonable impacts to domestic (and other shallow) wells and allowing sufficient flexibility for conjunctive management of Subbasin surface and groundwater supplies, given the uncertainty of available information on domestic wells in the WCR database. As described in Chapter 4 of the GSP, data gaps related to domestic wells will be addressed in future GSP updates, and this analysis may be refined with new information.

It is important to emphasize that groundwater levels will be managed for MOs, which are generally set substantially above MTs. MTs define the levels that would not be exceeded to avoid Undesirable Results. However, recognizing the importance of protecting domestic wells in the Subbasin, the GSP includes a potential management action in which the GSAs would develop a domestic well mitigation program[5]. This would provide an additional safety net for domestic well users by providing potential compensation for impacts to domestic wells that are associated with GSP implementation.

A hydrograph series showing the selected MT relative to historical water levels at each representative monitoring well is presented in Attachment B.

Streamflow Depletion

As explained in the Introduction, Streamflow Depletion MTs are based on groundwater levels as a proxy for streamflow depletion volume or rate. The basic rationale postulated, evaluated, and recommended by the Environmental Defense Fund (EDF) in support of using groundwater levels as a proxy for depletion volumes or rates is that adverse impacts to surface water uses and users can be avoided if

[5] See Chapter 6, Section 6.5.2 of the GSP.

groundwater gradients and levels near interconnected streams are maintained at levels that existed when implementation of the SGMA began in 2015[6].

Only 12 wells could be identified that were considered to reasonably represent groundwater levels near the three major, potentially interconnected streams in the Subbasin, based on an assessment of their proximity to the streams and the depth to the bottom of their screened interval. The 12 wells were selected based on the following criteria developed using recommendations in the EDF report:

- Located greater than 2,000 feet and not more than 5 miles from an interconnected stream
- Depth to bottom of screened interval less than or equal to 200 feet

The three streams are: Stony Creek, which borders the Subbasin to the north; the Sacramento River, which mostly borders the Subbasin to the east but also runs through a portion of the Subbasin (approximately between Princeton and Colusa); and, the Colusa (Basin) Drain, which originates in and flows southward out of the Subbasin at the Colusa-Yolo Subbasin boundary (county line). The 12 wells are not considered adequate for long-term sustainable groundwater management but are determined to be the best available monitoring sites at this time for evaluating streamflow depletion. Additional dedicated near-stream shallow monitoring wells are needed and will be designed and installed during GSP implementation.

Nevertheless, quantitative MTs were established for these wells as described below. These MTs are considered to be provisional pending additional data collection and analysis and updating and refining the C2VSim FG-Colusa model.

Three *alternative* MTs were evaluated for the 12 wells currently in the Streamflow Depletion representative monitoring network, as follows:

1. The observed Fall 2015 groundwater level (on the date closest to October 15), OR
2. 20 percent of the historical range in groundwater levels below the observed Fall 2015 groundwater level (depth to water), OR
3. 10 feet below the observed Fall 2015 groundwater level (on the date closest to October 15).

The first MT is consistent with the EDF recommendation that aims to avoid or minimize incremental post-SGMA effects on stream depletions but prevents any opportunity for exercising groundwater storage, such as might be needed during prolonged droughts. The second MT is based on a similar concept as that used for Groundwater Levels, where the MT is set at 20 percent of the historical range below the observed Fall 2015 water level. However, historical water levels in most near-stream wells are generally stable and do not fluctuate much. Thus, the historical range is typically small, and the resulting MT was still very constraining on the ability to exercise groundwater storage when needed. Finally, due to concerns among TAC members regarding overly constrained groundwater operations, a third MT was introduced defined as 10 feet deeper than the Fall 2015 groundwater level at each well.

A series of hydrographs showing all three alternative MTs in relation to historical groundwater levels at each of the 12 wells is presented in Attachment C. For all wells, the highest MT is represented by the Fall 2015 water level. The lowest MT is represented by the 10 feet deeper than Fall 2015 groundwater level at 10 of the 13 wells. For the three wells where the 20 percent of historical range below the

[6] Environmental Defense Fund, (EDF), 2018, Addressing Regional Surface Water Depletions in California: A Proposed Approach for Compliance with the Sustainable Groundwater Management Act. Available online at http://edf.org/california-surface-water-report.

observed Fall 2015 groundwater level is the deepest MT, the margin between the two deepest MTs is typically small.

Based on careful consideration of the alternative Streamflow Depletion MTs and evaluation of historical groundwater levels at the wells, the TAC selected the MT defined as 10 feet deeper than the observed Fall 2015 water level. A series of hydrographs showing the selected MT relative to historical groundwater levels is presented in Attachment D.

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Appendix 5C

Economic Analysis of Groundwater Level Minimum Thresholds

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Technical Memorandum

To: Glenn and Colusa County Groundwater Authorities

From: ERA Economics

Date: November 24, 2021

Subject: Economic Benefit-Cost Analysis of Potential Groundwater Level Minimum Thresholds

Introduction

Sustainable Management Criteria (SMC) for the Colusa Subbasin (Subbasin) were established in consultation with the Technical Advisory Committees (TACs) of the Colusa Groundwater Authority (CGA) and Glenn Groundwater Authority (GGA). SMCs consist of the following: the Sustainability Goal adopted for the Subbasin; Undesirable Results describing significant and unreasonable effects to be avoided; quantitative Minimum Thresholds (MTs) that define conditions that, if exceeded, may cause Undesirable Results; and quantitative Measurable Objectives (MOs) to achieve the Sustainability Goal of the Subbasin. Undesirable Results, MTs, and MOs are all established in relation to the six sustainability indicators referenced in the GSP Emergency Regulations, five of which are applicable in the Subbasin.

Subbasin MTs were developed with substantial public and technical team input. A total of 13 joint meetings of the TACs were held between May 8, 2020, and June 11, 2021, and SMCs were addressed at 9 of the 13 meetings. This included all 7 meetings held between January 8 and June 11, 2021. Several technical analyses were developed to evaluate potential MTs. This appendix describes an economic analysis of MTs that was developed and presented to the TAC at the June 11, 2021 meeting.

The Subbasin MTs are described in detail in Chapter 5 and Appendices 5A and 5B. The general approach to setting MTs for Groundwater Levels was developed with consideration for both the historical groundwater levels at each well and the distribution of shallow (primarily domestic) well depths in the area surrounding the well. Potential MTs were considered based on a percent margin below historical lows or domestic well depths. These were set to balance avoiding significant and unreasonable impacts to domestic wells while also allowing sufficient flexibility for conjunctive management of Subbasin surface and groundwater supplies.

To support evaluation of MTs, an economic analysis was developed to assess whether it would be cost-effective to set MTs higher (or lower) than the MTs based on the lower of 50 percent below the historical low groundwater level or 20th percentile of domestic well depths.

This appendix describes the economic analysis, assumptions, and results considered for evaluating potential Groundwater Level MTs. The reconnaissance-level economic analysis was based on the data available for GSP development and the simplifying assumptions described in the sections below. Important assumptions include: (i) the analysis was developed for MTs, not MOs that the Subbasin will be managed for and are substantially higher than MTs, (ii) only a subset of costs and benefits (pumping cost, well replacement cost, avoided costs of projects and management actions (PMA)) associated with PMA implementation and potentially dewatered domestic were considered, and (iii) the example PMA considered was demand management (reducing pumping). The analysis can be refined and expanded as GSP data gaps are addressed and additional information

becomes available. It is also noted that the GSP includes additional potential actions for monitoring potential impacts to domestic wells, as described in Section 6.5.2.1, Domestic Well Mitigation Program.

Economic Analysis Overview

A benefit-cost analysis was developed to monetize and compare the benefits and costs to groundwater users in the Subbasin under the Groundwater Level MTs. It was developed as a reconnaissance-level assessment to establish preliminary costs and benefits associated with different level MTs. There are additional benefits and costs associated with MTs that relate to four other sustainability indicators defined in the GSP Emergency Regulations that are applicable to the Subbasin that were not considered in this analysis. The analysis could be refined in the future to support updates to the GSP or additional consideration of threshold levels. The information presented in this appendix is developed to illustrate the general magnitude of costs, benefits, and the associated tradeoff.

The benefit of higher MTs is the avoided cost of replacing dewatered domestic wells and the avoided energy cost of additional pumping lifts from lower groundwater levels. Dewatered domestic well costs would fall on individual domestic well owners. Additional pumping costs would fall on Subbasin groundwater users in the vicinity of the monitoring well (defined by Thiessen polygons). In contrast, the incremental cost of setting higher MTs is due to more rapid (and larger scale) implementation of projects and management actions. For example, preventing additional declines in groundwater levels may require larger recharge projects, and these projects would need to be implemented more rapidly. This imposes additional costs on groundwater users in the Subbasin.

The benefit-cost ratio is calculated from the monetized benefits and costs over the relevant planning horizon (in this case, the 20-year GSP implementation period). When the benefit-cost ratio is greater than 1, the benefits are at least as large as the cost, suggesting it could be cost-effective to make the MTs shallower in selected areas.

The following costs were considered in the economic analysis of groundwater level MTs:

1. Capital cost of replacing or refurbishing potentially dewatered domestic wells. For the purposes of this analysis, a domestic well is defined as dewatered, and completely replaced when the groundwater level MT is below the total well depth. In practice, pumping impacts would occur earlier depending on the screened interval of the well and other aquifer- and well-specific characteristics. The domestic well inventory in the Subbasin is based on DWR's Well Completion Report (WCR) data (see GSP Chapter 3).
    a. The capital cost of well replacement is set at $40,000 per well based on costs for domestic well replacement used in other GSPs[1] and adjusted for inflation. These costs generally include drilling at $40 per foot, a sanitary seal for $2,500, and a pump for $5,000. This does not include permit costs. Actual costs will vary based on the costs of materials and supply and demand for well drilling services.

[1] Madera Joint GSP. Technical Appendix 3C: Economic Analysis and Framework for Potential Domestic Well Mitigation Program.

2. Additional energy costs caused by additional pumping lifts that would affect all groundwater users in the Subbasin. Lower groundwater levels increase the energy cost to pumpers (domestic and agriculture) in the Subbasin.

    a. Agricultural pumping energy cost depends on lift, pump efficiency, and the power rate which varies by time of use and size of load. For purposes here, the analysis used an average over several 2021 PG&E agricultural power rates to get a total variable pumping cost of about $0.52 per acre-foot per foot of lift.

The following benefits (avoided costs) were considered in the economic analysis of groundwater level MTs:

1. Cost of demand management (reducing pumping) to prevent additional declines in groundwater levels. The cost of demand management is used instead of the cost of specific projects because demand management could be implemented more rapidly than most projects (there is no construction required). It is noted that demand management is not a planned PMA in the Subbasin, and these costs are used as a proxy for the costs of other projects. Chapter 6 Appendix 6B describes the cost of demand management in the Subbasin. The costs include the direct cost of land idling only, and do not include any additional indirect costs or administrative costs to set up and implement a demand management program.

Existing domestic well infrastructure in the Subbasin is based on WCR available in DWR's database[2]. The WCR data generally include all historical wells that have been reported in the system, which may include old wells that are no longer operational or have been refurbished. The domestic well inventory for the Subbasin will be addressed with other data gaps in the Subbasin to support GSP implementation (see Chapter 3).

An analysis was developed to evaluate the WCR data regarding well depths for the wells in the inventory. For each well in a Thiessen polygon, the reported well depth was compared to the historical low groundwater level recorded prior to January 1, 2015. The purpose of the analysis was to establish what share of domestic wells in the WCR database may have been previously dewatered and/or are no longer used. Wells that were shallower than the historic low were flagged, counted, and compared to the total domestic wells for each Thiessen polygon. In total, approximately 46 percent of the domestic wells in the WCR database for the Subbasin show a total depth that is shallower than the historic groundwater level low. The results of the analysis for each Thiessen polygon are summarized in Table 1.

[2] Available at: https://data.cnra.ca.gov/dataset/well-completion-reports

Table 1. Benefit-Cost Analysis of an Incremental Increase in MT (by 5 feet bgs)

Monitoring Well #	Total Domestic Wells	Wells Shallower than Historic low before 1/2015	Share
13N02W20H002	180	28	0.16
14N02W22A002	16	NA	-
14N03W24C001	26	8	0.31
14N03W14Q003	23	14	0.61
16N02W25B002	368	2	0.01
15N03W08Q001	56	0	0.00
16N04W02P001	24	0	0.00
16N03W14H003	45	0	0.00
15N03W20Q001	85	4	0.05
17N03W32H001	43	0	0.00
14N02W29J001	97	5	0.05
13N01W07G001	181	34	0.19
13N01W22P002	52	0	0.00
12N01E06D004	7	NA	-
16N02W05B001	32	0	0.00
14N02W13N001	20	0	0.00
13N02W15J001	196	43	0.22
13N02W12L001	61	6	0.10
14N01W04K003	117	7	0.06
13N01E11A001	8	0	0.00
13N01W13P001	8	0	0.00
14N01E35P001	26	0	0.00
15N02W19E001	201	1	0.00
20N02W18R005	71	3	0.04
20N03W07E001	94	41	0.44
19N04W14M002	265	1	0.00
17N03W08R001	80	0	0.00
17N02W09H002	38	2	0.05
21N02W33M001	50	39	0.78
21N02W01F001	40	3	0.08
21N03W34Q002	173	121	0.70
21N03W23D001	118	101	0.86
21N03W01R002	109	24	0.22
21N02W04G002	69	18	0.26
21N04W12A004	636	591	0.93
15N01W05G001	111	6	0.05
18N02W36B001	107	2	0.02
19N02W33K001	108	2	0.02
18N02W18D001	41	0	0.00

Monitoring Well #	Total Domestic Wells	Wells Shallower than Historic low before 1/2015	Share
20N02W33B001	52	0	0.00
19N02W08Q001	176	2	0.01
17N02W30J002	10	0	0.00
22N03W24E001	1,677	1,589	0.95
20N02W25F001	105	0	0.00
22N02W30H002	173	168	0.97
21N02W36A002	97	38	0.39
20N02W11A001	56	0	0.00
21N02W05M001	36	22	0.61
Total	6,364	2,925	0.46

Economic Analysis of Subbasin MTs

The economic analysis considers the Subbasin groundwater level MTs. It is important to note that the Subbasin will be managed to meet MOs, which are set substantially higher than MTs. The costs and benefits described in this TM are generally conservative, corresponding to Groundwater Level MTs that are lower than current groundwater levels, MOs, and observed historical levels in many areas.

Figure 1 illustrates the aggregate annual cost curve for an example Thiessen polygon (21N03W01R002) in the Subbasin. The same calculations are repeated for the other 47 polygons. A range of groundwater depths including the MT (155 feet bgs) specified in the GSP are evaluated. Costs increase as depth to groundwater increases. The capital cost of replacing dewatered domestic wells is annualized using a discount rate of 5 percent over a 30-year economic life. Pumping costs are the additional annual energy cost of pumping from a lower depth in that year. The total cost is the sum of the pumping cost and well replacement cost. All costs are additional (incremental) costs in addition to the current pumping costs at current groundwater depths.

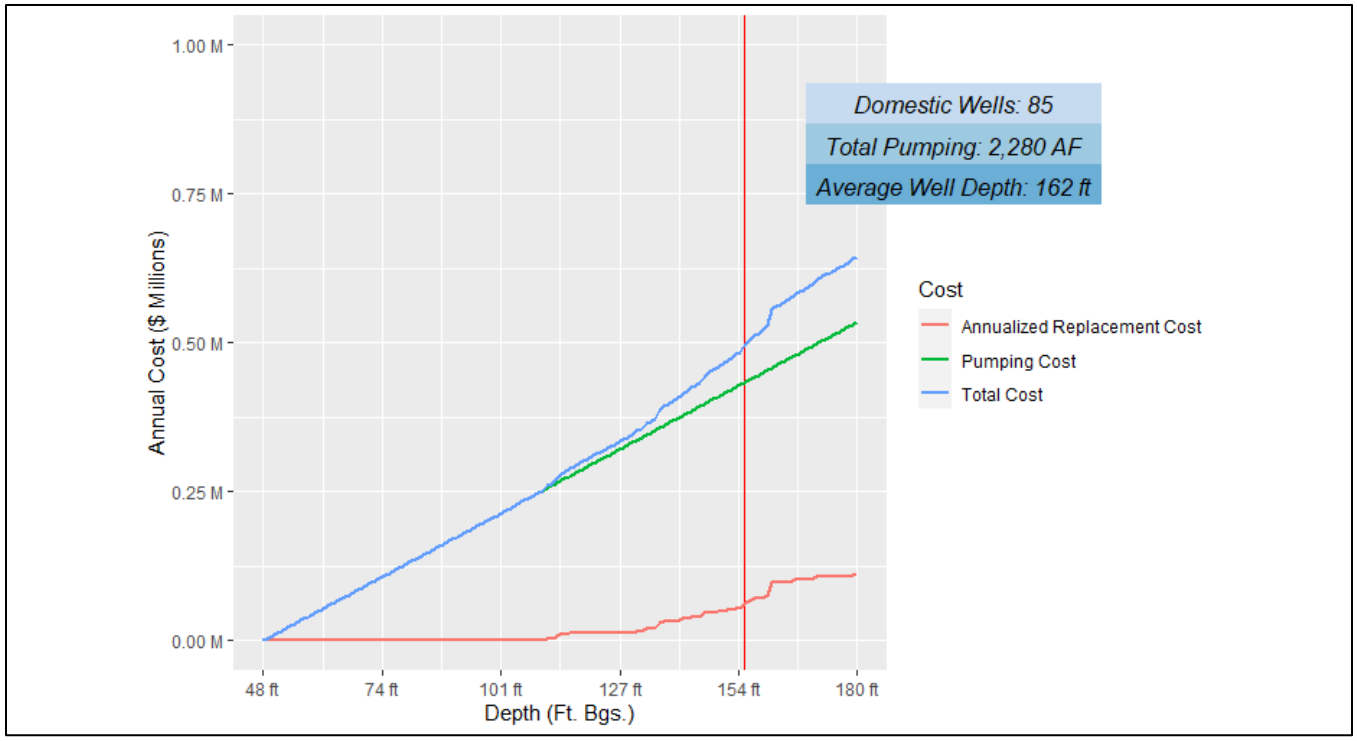
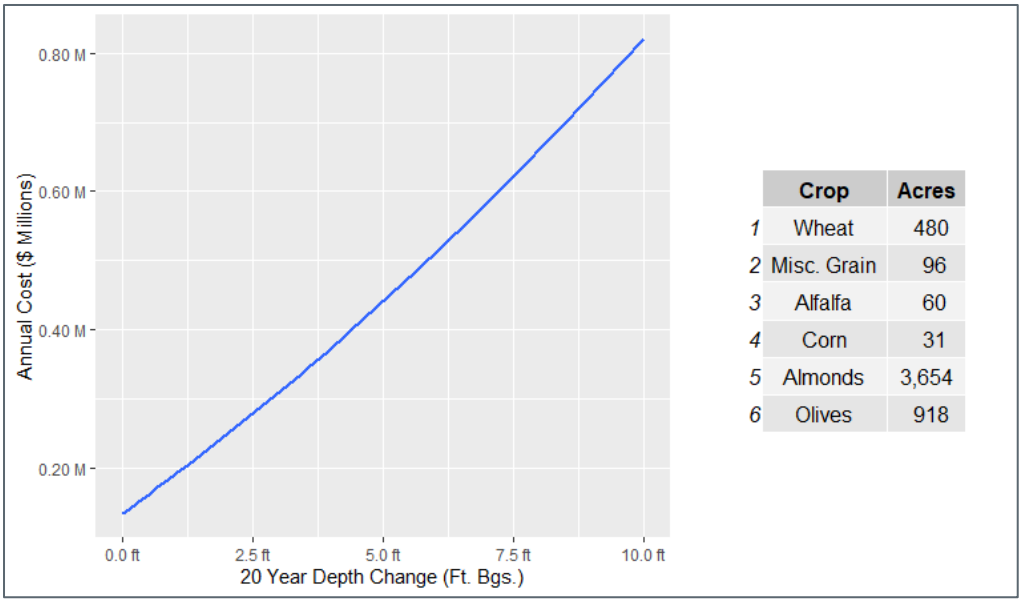


Figure 1. Colusa Subbasin Incremental Annual Cost by Depth to Groundwater

Figure 2 illustrates the benefit (avoided cost) of a change in the MT for the same example Thiessen polygon (21N03W01R002) in the Subbasin (1 of 48 total polygons). In contrast to the static pumping and well replacement costs shown in Figure 1, the benefit is an avoided cost and is therefore expressed as a change in depth to groundwater. The irrigated acreage within the Thiessen polygon is also shown in the figure. The mix of crops grown affects the cost of demand management. The example polygon is predominantly planted to permanent crops (almonds and olives), which are costly to idle due to higher net return relative to other annual crops and the substantial capital investment required to establish orchards. A range of projects and management actions that are specified in the GSP could be implemented to achieve a change in groundwater levels across the Subbasin (see Chapter 6). As described above, the cost of demand management to reduce pumping is used to develop the aggregate cost curve shown in Figure 2 (and the individual cost curves for each polygon). The change is shown over the full GSP implementation timeline (20 years).



	Crop	Acres
1	Wheat	480
2	Misc. Grain	96
3	Alfalfa	60
4	Corn	31
5	Almonds	3,654
6	Olives	918

Figure 2. Colusa Subbasin Incremental Demand Management Cost by Depth to Groundwater

As described in Chapter 5 and Appendices 5A and 5B, the MT for groundwater levels is set based on the lower of 50 percent below the historical low groundwater level or the 20th percentile of the domestic well depth within each of the 48 Thiessen polygons corresponding to the 48 monitoring wells. The benefit-cost analysis evaluates whether an incremental change in the MT would result in a positive benefit-cost ratio in each polygon. The analysis is developed for an incremental increase in the MT of 5 feet.

Table 2 summarizes the benefit-cost analysis of an incremental (defined as 5 feet) increase in the MT. This illustrates the central economic tradeoff: whether a change in the MT (in this case an increase in the MT level by 5 feet) would generate economic benefits for the Subbasin that are greater than the costs that would be incurred. The table summarizes each polygon and the annual benefits, costs, and net benefits. Since the analysis evaluates an incremental increase in the MT, the benefits are defined as the avoided pumping and well replacement cost. Costs are defined as the additional cost of idling land (demand management) to achieve the 5-foot increase in MT. The net benefit shows the absolute difference between benefits and costs, and the final column shows the associated benefit-cost ratio. A benefit-cost ratio greater than 1 shows benefits are greater than costs, implying that a 5-foot shallower MT would generate benefits greater than costs. The aggregate benefit-cost ratio over all polygons is 0.33 (each dollar of cost returns only 33 cents in benefits). There are five polygons where the benefit-cost ratio is slightly greater than 1 (between 1.0 and 2.1). However, the total annual net benefit across these five polygons is $70,000, which is less than 1 percent of the estimated -$3,800 thousand (-$3.8 million) in total annual net benefits across the Subbasin.

Table 2. Benefit-Cost Analysis of an Incremental Increase in MT (by 5 feet bgs)

Effect of Raising Groundwater Level MT 5 feet Relative to Proposed Groundwater Level MT				
Monitoring Well Polygon	**Pump + Well Cost Saving (Annual Benefit in thousands)**	**Idling Cost (Annual Cost in thousands)**	**Net Benefit (thousands)**	**B/C Ratio**
13N02W20H002	$25	$579	($554)	0.0
14N02W22A002	$42	$57	($15)	0.7
14N03W24C001	$30	$48	($18)	0.6
14N03W14Q003	$20	$469	($449)	0.0
16N02W25B002	$159	$170	($11)	0.9
15N03W08Q001	$2	$111	($109)	0.0
16N04W02P001	$9	$91	($82)	0.1
16N03W14H003	$13	NA	-	0.0
15N03W20Q001	$17	$167	($150)	0.1
17N03W32H001	$5	$157	($152)	0.0
14N02W29J001	$27	$52	($25)	0.5
13N01W07G001	$65	$65	$0	1.0
13N01W22P002	$41	$70	($29)	0.6
16N02W05B001	$47	$79	($32)	0.6
14N02W13N001	$45	$59	($14)	0.8
13N02W15J001	$39	$66	($27)	0.6
13N02W12L001	$13	$30	($17)	0.4
14N01W04K003	$117	$145	($28)	0.8
13N01E11A001	$8	$36	($28)	0.2
13N01W13P001	$28	$120	($92)	0.2
14N01E35P001	$38	$42	($4)	0.9
15N02W19E001	$45	$123	($78)	0.4
20N02W18R005	$75	$57	$18	1.3
20N03W07E001	$52	$277	($225)	0.2
19N04W14M002	$41	$198	($157)	0.2
17N03W08R001	$11	$399	($388)	0.0
17N02W09H002	$70	$388	($318)	0.2
21N02W33M001	$41	$45	($4)	0.9
21N02W01F001	$57	$43	$14	1.3
21N03W34Q002	$59	$69	($10)	0.9
21N03W23D001	$33	$73	($40)	0.5
21N03W01R002	$31	$29	$2	1.1

Effect of Raising Groundwater Level MT 5 feet Relative to Proposed Groundwater Level MT				
Monitoring Well Polygon	**Pump + Well Cost Saving (Annual Benefit in thousands)**	**Idling Cost (Annual Cost in thousands)**	**Net Benefit (thousands)**	**B/C Ratio**
21N02W04G002	$35	$31	$4	1.1
21N04W12A004	$100	$287	($187)	0.3
15N01W05G001	$79	$130	($51)	0.6
18N02W36B001	$64	$96	($32)	0.7
19N02W33K001	$50	$314	($264)	0.2
18N02W18D001	$25	NA	-	0.0
20N02W33B001	$20	NA	-	0.0
19N02W08Q001	$47	NA	-	0.0
17N02W30J002	$1	NA	-	0.0
22N03W24E001	$2	$65	($63)	0.0
20N02W25F001	$44	$184	($140)	0.2
22N02W30H002	$6	$38	($32)	0.2
21N02W36A002	$61	$29	$32	2.1
20N02W11A001	$4	$33	($29)	0.1
21N02W05M001	$11	$26	($15)	0.4
Total	$1,854	$5,547	($3,799)	0.33

Notes: "NA" or missing values reflect polygons with zero acreage or insufficient data to support the benefit-cost calculations.

Discussion

The results indicate that the cost of raising the MT would not be cost effective from a Subbasin-wide perspective, or for most individual polygons. The aggregate benefit-cost ratio of 0.33 shows each dollar of cost from setting MTs incrementally higher returns only 33 cents in benefits across the entire Subbasin. The avoided costs (fewer domestic wells requiring replacement and reduced pumping lifts) would be modest ($1.9 million) relative to the cost of lost agricultural net return from demand management ($5.5 million). The general conclusions are robust to the assumptions used – that is, results are not sensitive to reasonable ranges in key assumptions, including the loss in net return per acre-foot of demand management, additional pumping costs, or the cost of replacing a domestic well. The analysis is developed to support long-run planning for setting MTs. PMAs needed to support higher MTs require time to develop and implement and cannot be implemented rapidly in response to severe, unprecedented drought. The short-run costs of wells running dry during severe drought events can include other cost factors that were not explicitly analyzed. For example, in the crisis of a severe drought, local drilling capacity and well repair services can be limited, which can result in higher cost or increased wait times. This can place additional financial stress on households with domestic wells.

There are five polygons that show a benefit-cost ratio slightly greater than 1, indicating that benefits would be slightly greater than the costs. The total net benefit is $70,000 across these five polygons. The benefit-cost ratio for these polygons is between 1.1 and 2.1. These occur in polygons 21N02W36A002, 21N02W04G002,

21N03W01R002, 21N02W01F001, and 20N02W18R005.The total annual net benefit of $70,000 is less than 1 percent of the estimated -$3,800 thousand (-$3.8 million) in total annual net benefits across the Subbasin. In addition, the cost of setting higher MT includes the direct cost of demand management only, and does not include other program administrative costs, or potential third-party impacts that may occur in the Subbasin. Including these costs would push the benefit-cost ratio below one in these areas. Finally, it is noted that the inventory of domestic wells for each polygon includes all wells in the DWR WCR database. Many wells are shallower than the historical low groundwater level observed prior to January 1, 2015. These wells would have been dewatered based on historical groundwater levels that occurred in the Subbasin prior to the implementation of SGMA. Removing these wells from the database would reduce the benefit of increasing MT, further reducing the benefit-cost ratio in all polygons.

The conclusion of the economic analysis is that it would not be cost-effective from a Subbasin or polygon-wide perspective to raise Groundwater Level MTs in the Subbasin. Therefore, the proposed MTs were viewed as an acceptable balance between avoiding significant and unreasonable impacts to domestic (and other shallow) wells and allowing sufficient flexibility for conjunctive management of Subbasin surface and groundwater supplies. In addition, as summarized in Table 1 and described in Appendices 5A and 5B, a substantial share of domestic wells in the WCR database appear to be shallower (total depth) than the observed low groundwater levels in each of the Thiessen polygons.

It is important to emphasize again that groundwater levels will be managed for MOs, which are set substantially above MTs. MTs are set below where the Subbasin is expected to be operated, defining the levels that would not be exceeded to avoid increasing risk of Undesirable Results. However, recognizing the importance of protecting domestic wells in the Subbasin, the GSP includes a potential management action in which the GSAs would develop a domestic well impact mitigation program (see Chapter 6). This would provide an additional safety net for domestic well users by providing potential compensation for impacts to domestic wells that are associated with GSP implementation.

Appendix 5D

Electrical Conductivity Historical Trends, Minimum Thresholds, and Measurable Objectives

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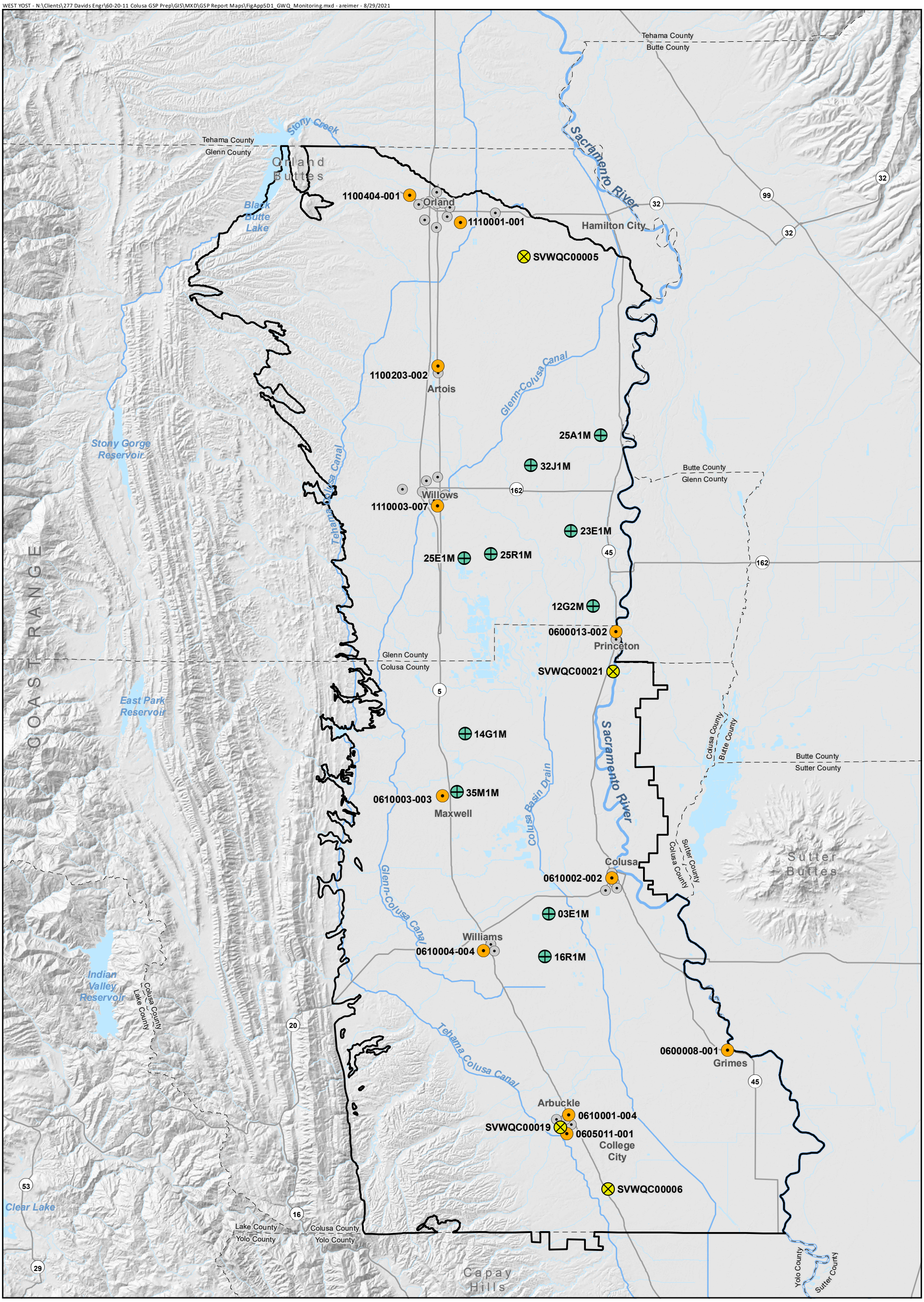

Colusa Subbasin

Active Public Water Supply Well

Representative Groundwater Quality Monitoring Network Well

Representative Public Water Supply Well

Representative California Rice Commission Groundwater Monitoring Well

Representative Sacramento Valley Water Quality Coalition Groundwater Monitoring Well

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

N

0 2.5 5

Scale in Miles

Figure 5D-1

Representative Groundwater Quality Monitoring Network

Colusa Groundwater Authority and Glenn Groundwater Authority

Colusa Subbasin

Groundwater Sustainability Plan

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Figure 5D-2. Del Oro Water Company - Black Butte District Representative Well: Well 1100404-001 (Well 1)

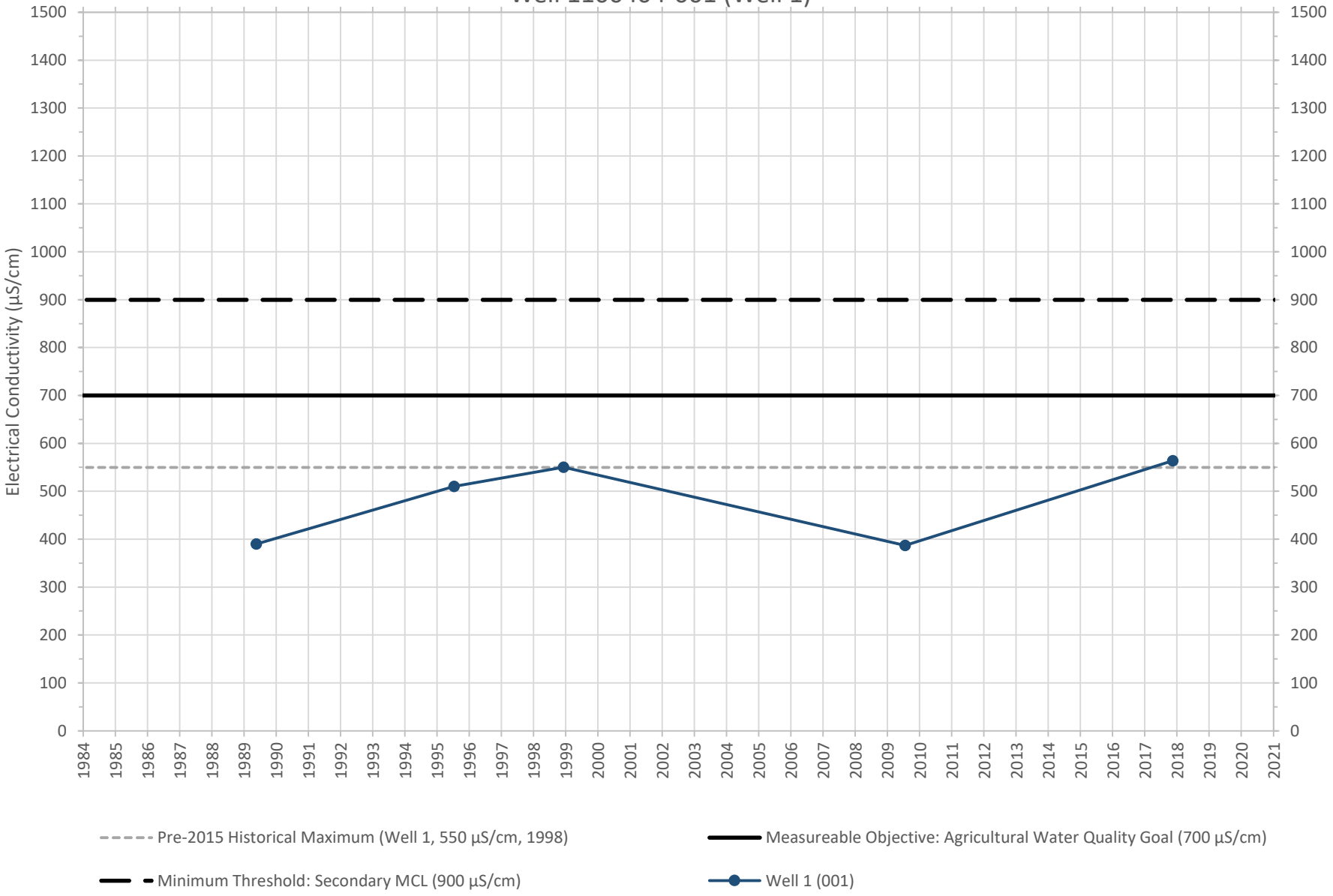


Figure 5D-3. City of Orland Representative Well:
Well 1110001-001 (Lely Aquatic Park Well)

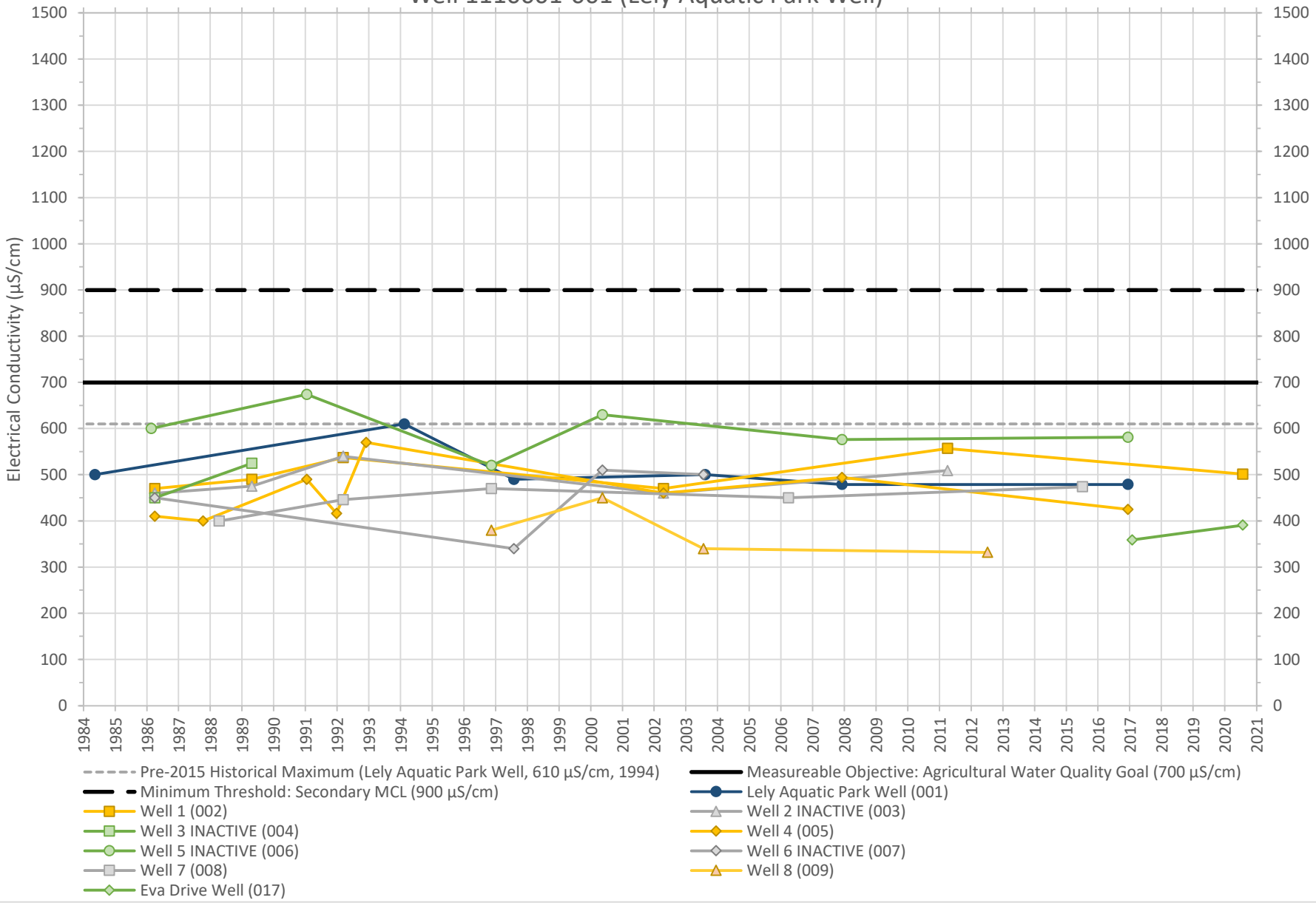


Figure 5D-4. Artois Community Service District Representative Well:
Well 1100203-002 (North Well)

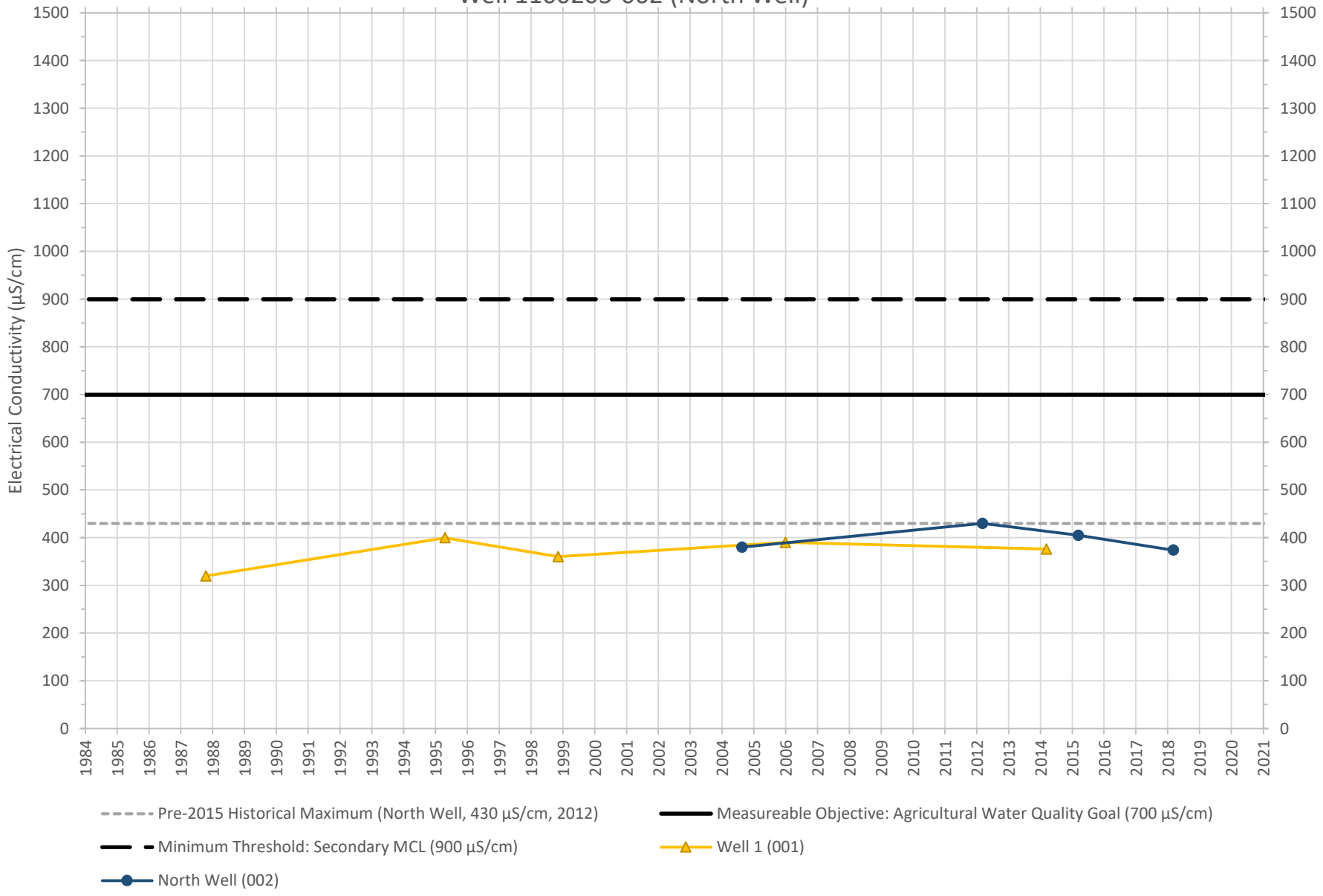


Figure 5D-5. Cal-Water Service Company - Willows Representative Well: Well 1110003-007 (Well 8)

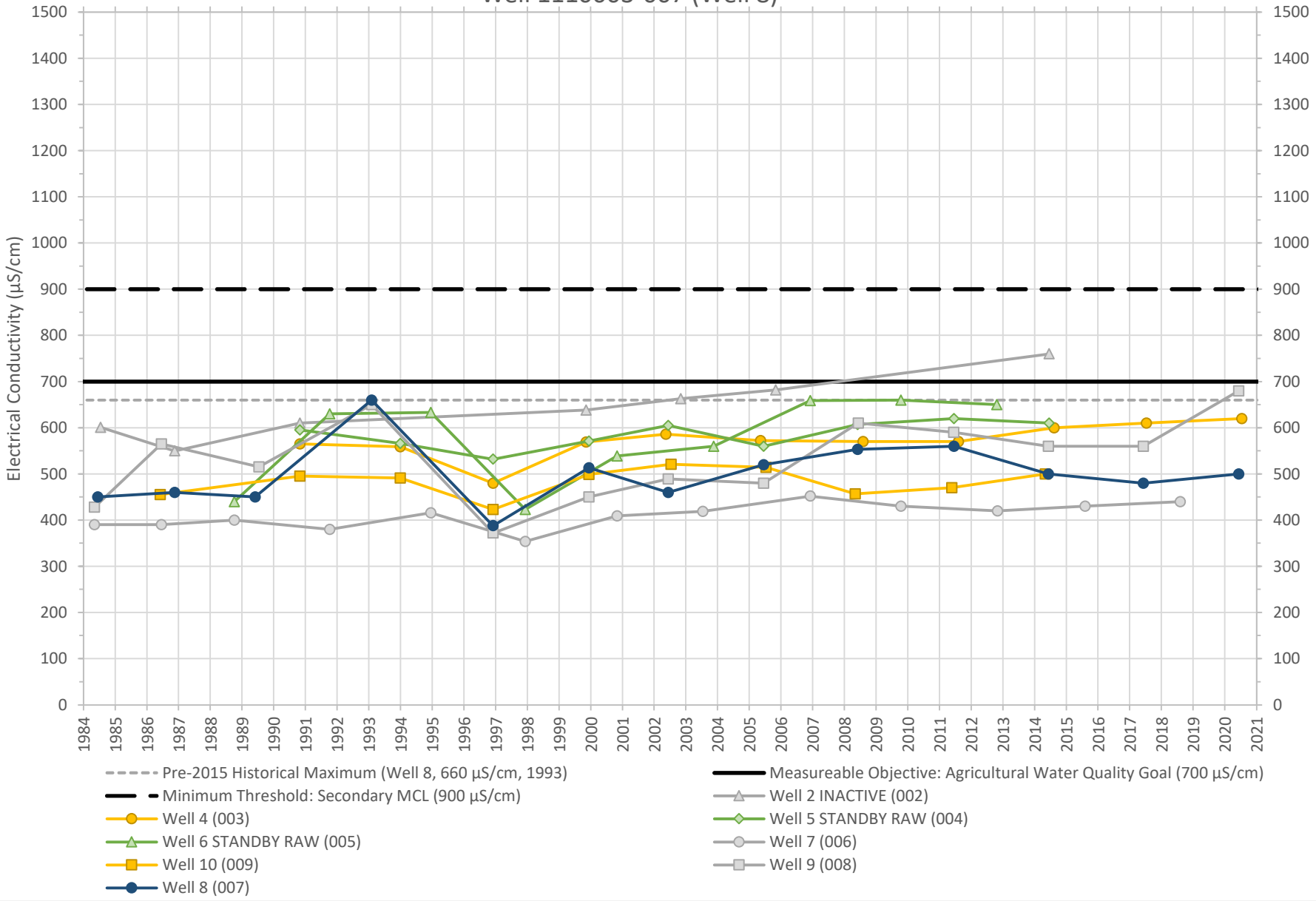


Figure 5D-6. Colusa County WWD #2 - Princeton Representative Well: Well 0600013-002 (Well 2)

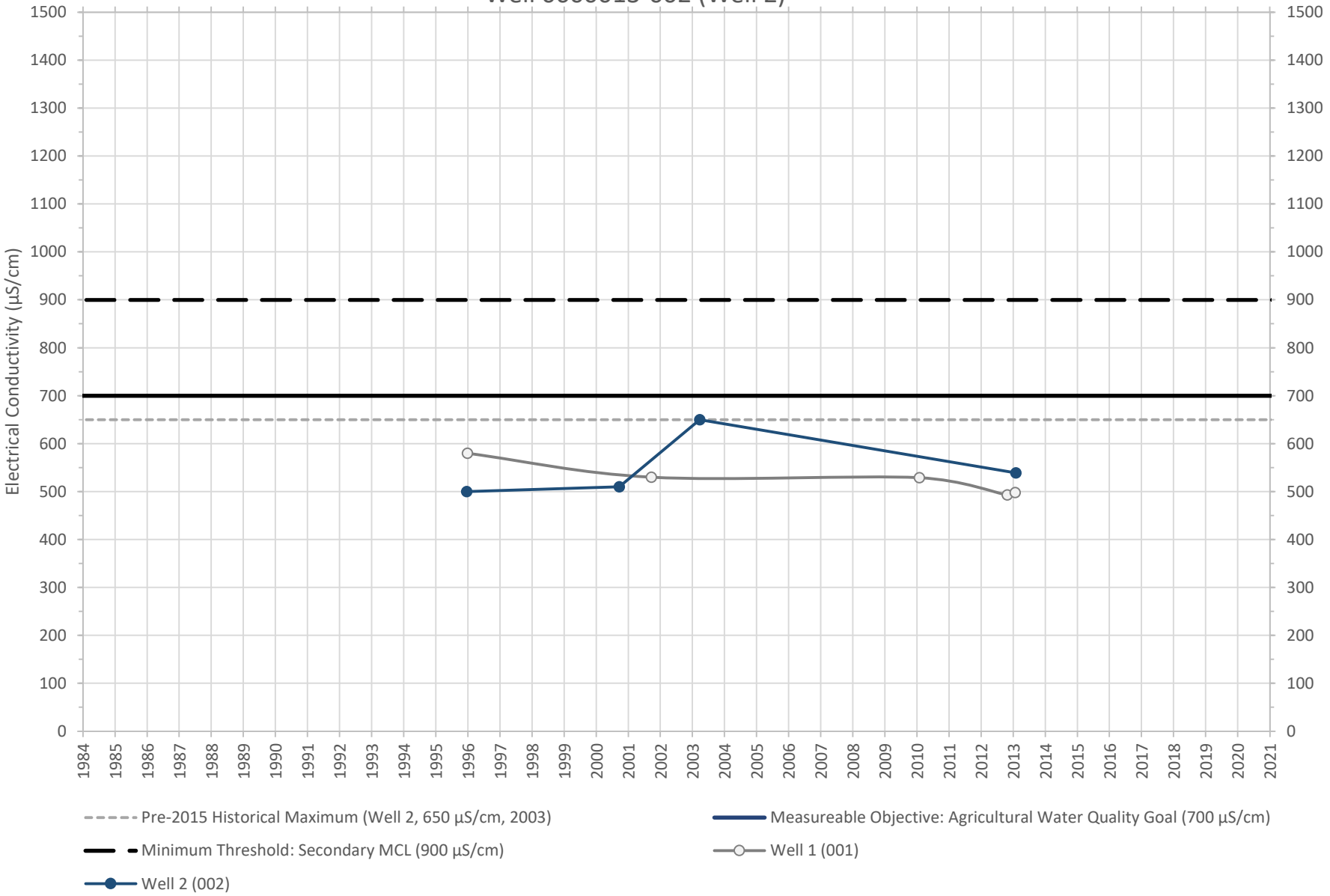


Figure 5D-7. Maxwell Public Utility District Representative Well:
Well 0610003-003 (Well 4)

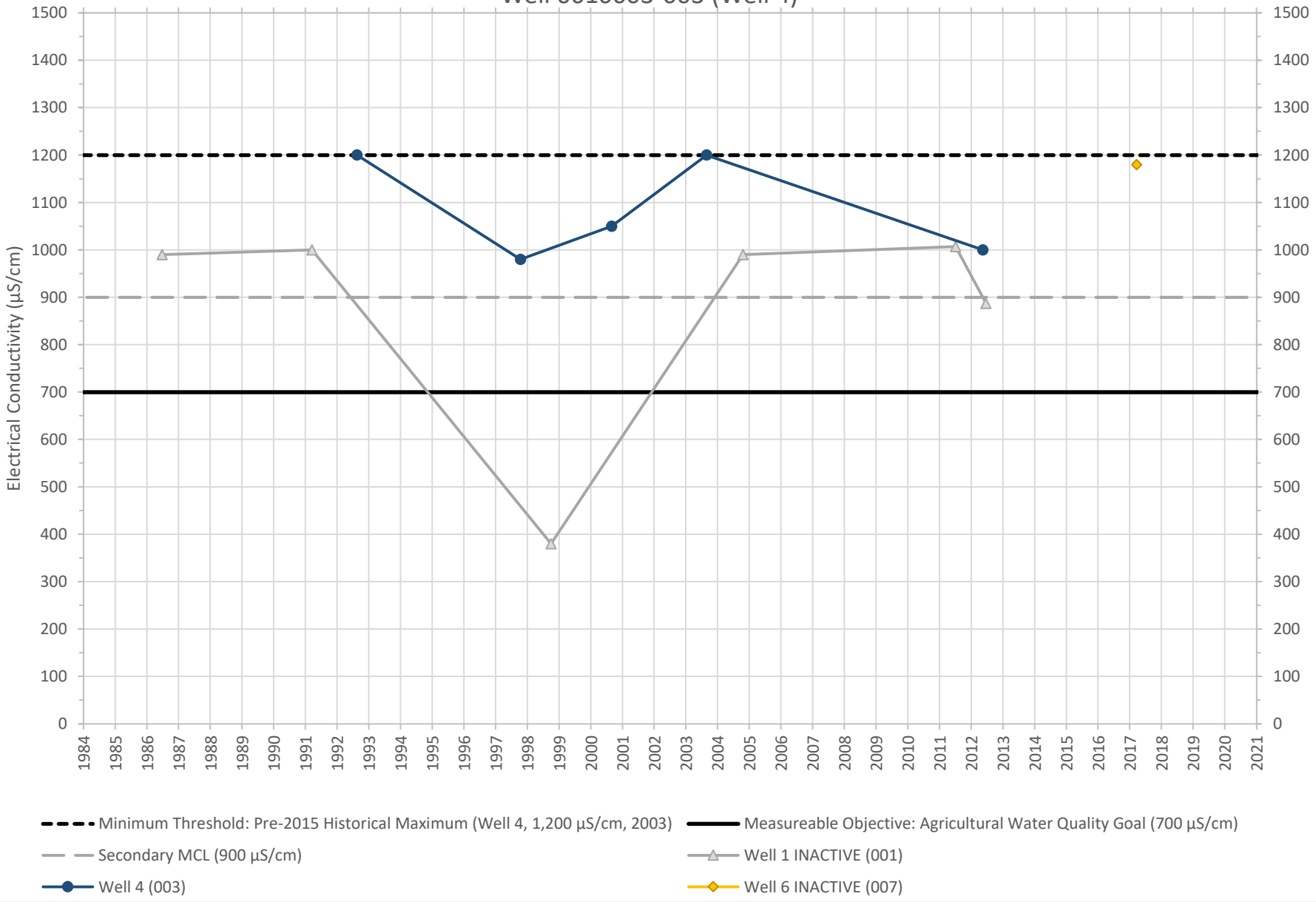


Figure 5D-8. City of Colusa Representative Well:
Well 0610002-002 (Well 2)

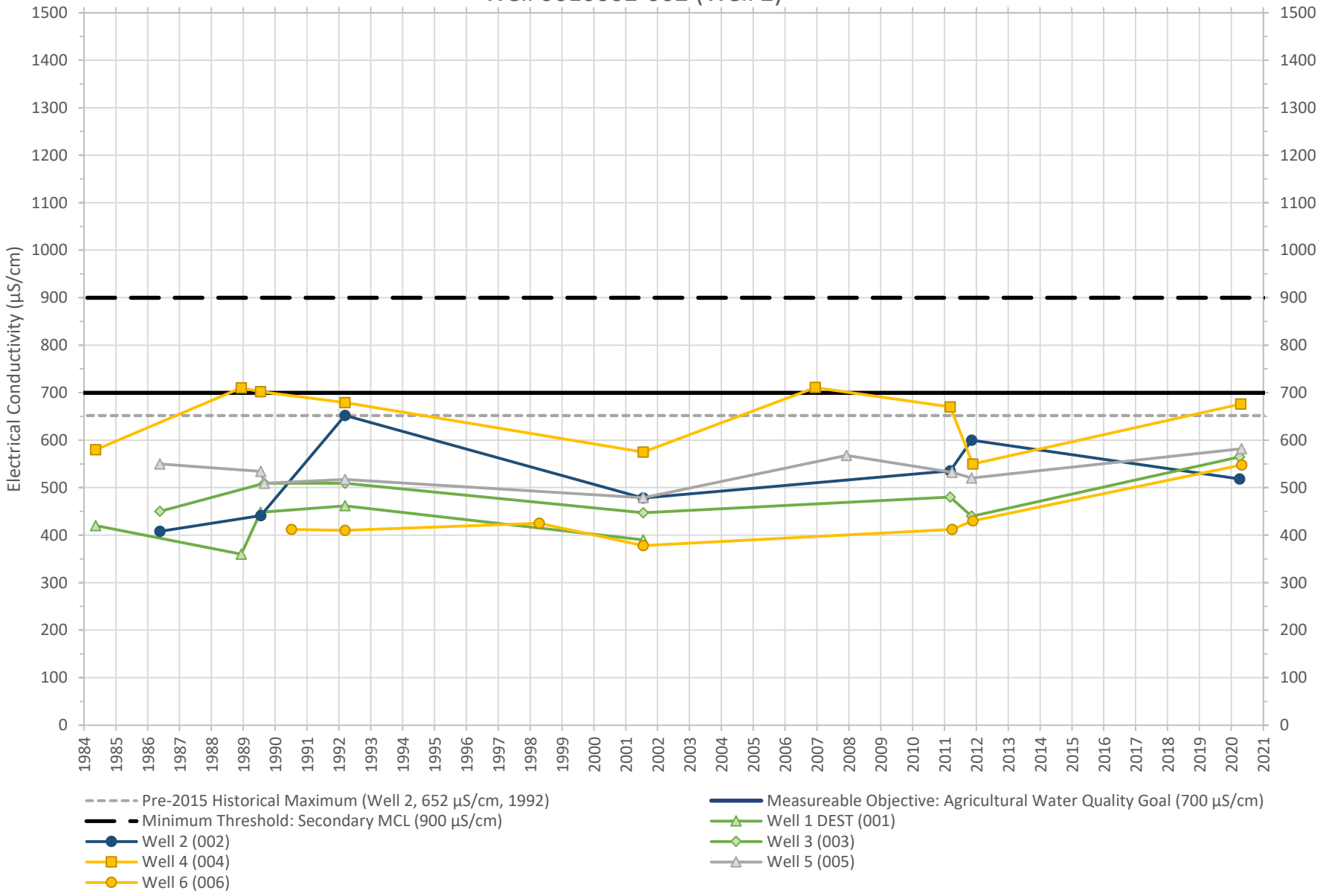


Figure 5D-9. City of Williams Representative Well:
Well 0610004-004 (Well 8)

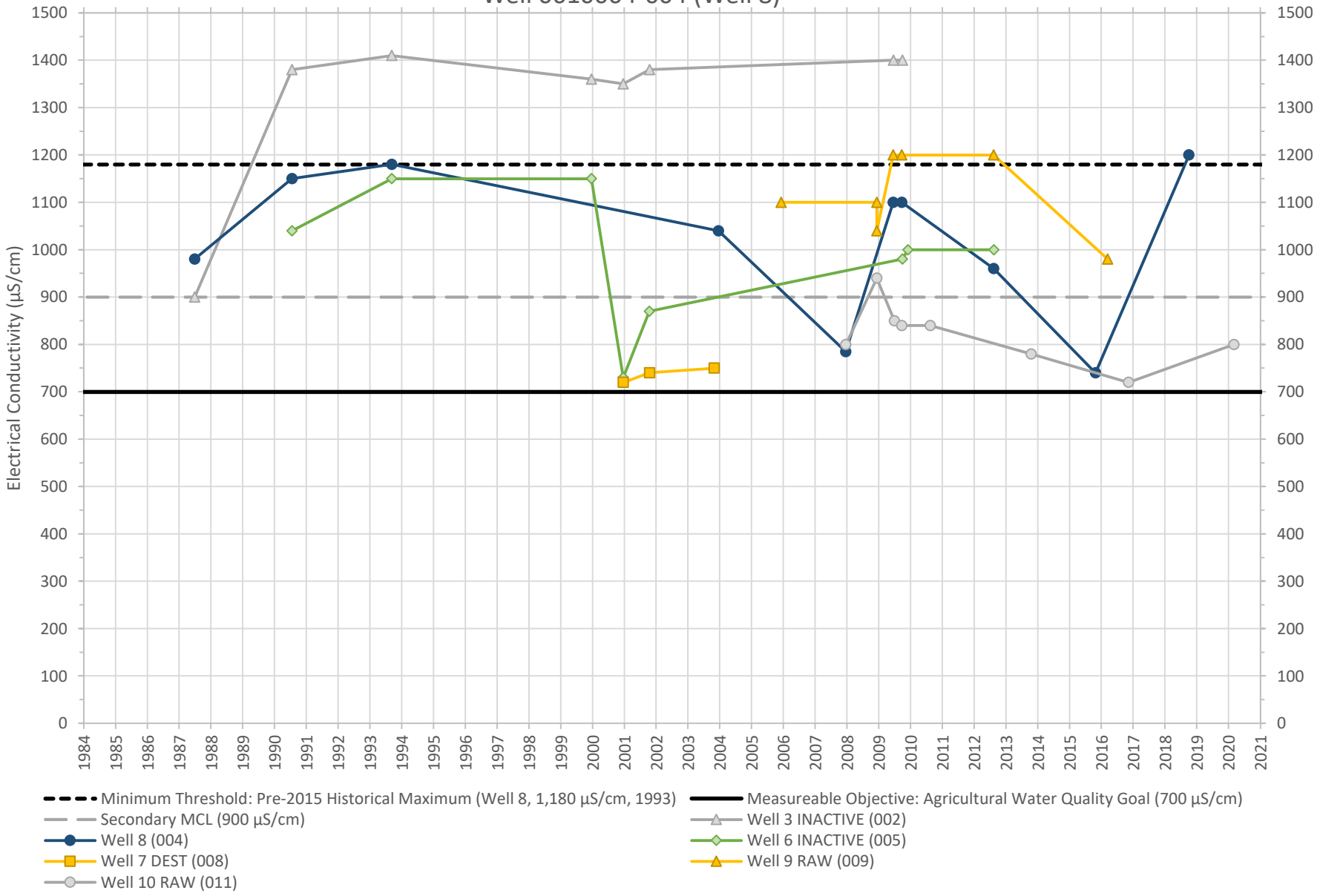


Figure 5D-10. Colusa County WWD #1 - Grimes Representative Well: Well 0600008-001 (Well 1)

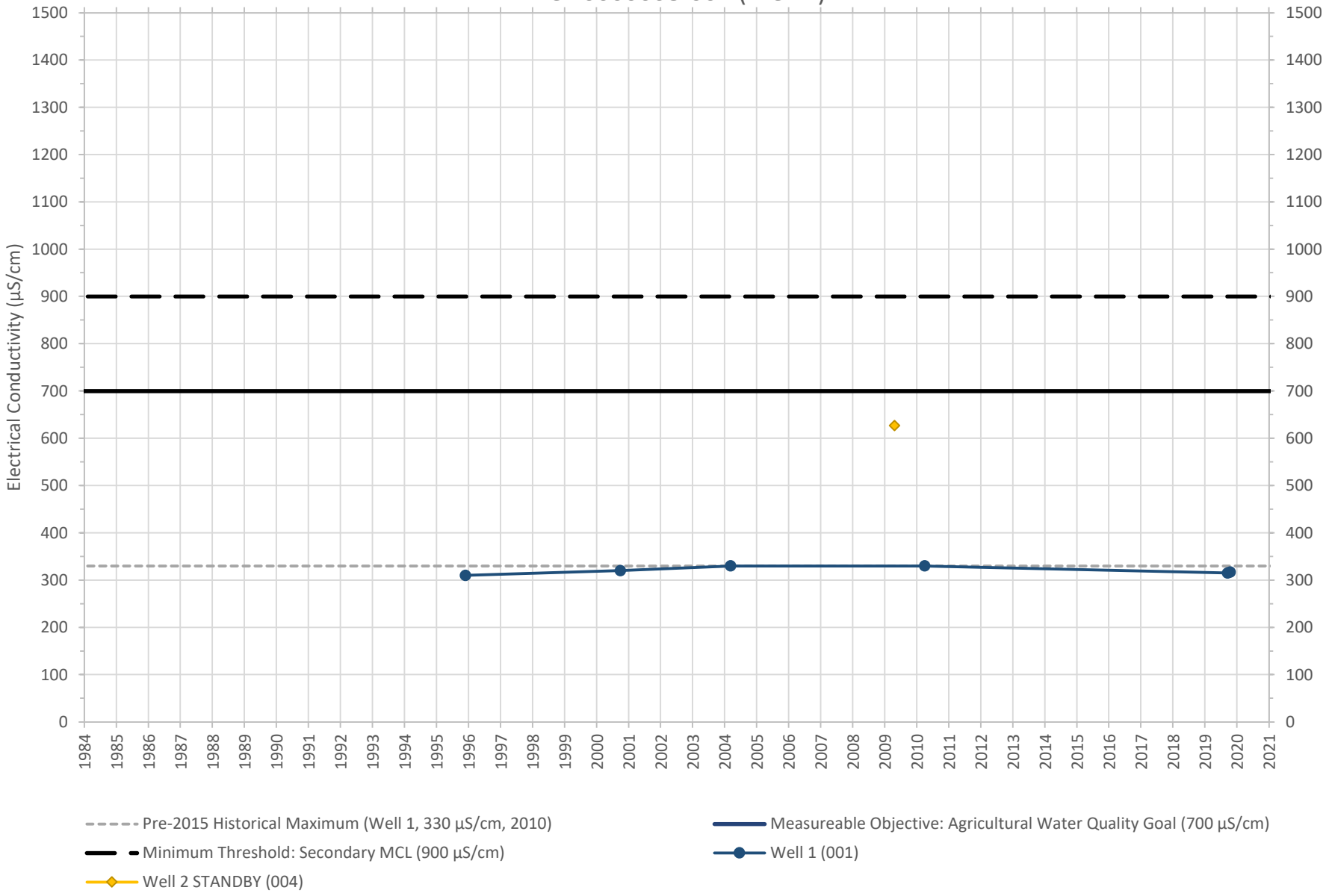


Figure 5D-11. Arbuckle Public Utility District Representative Well: Well 0610001-004 (Well 3A)

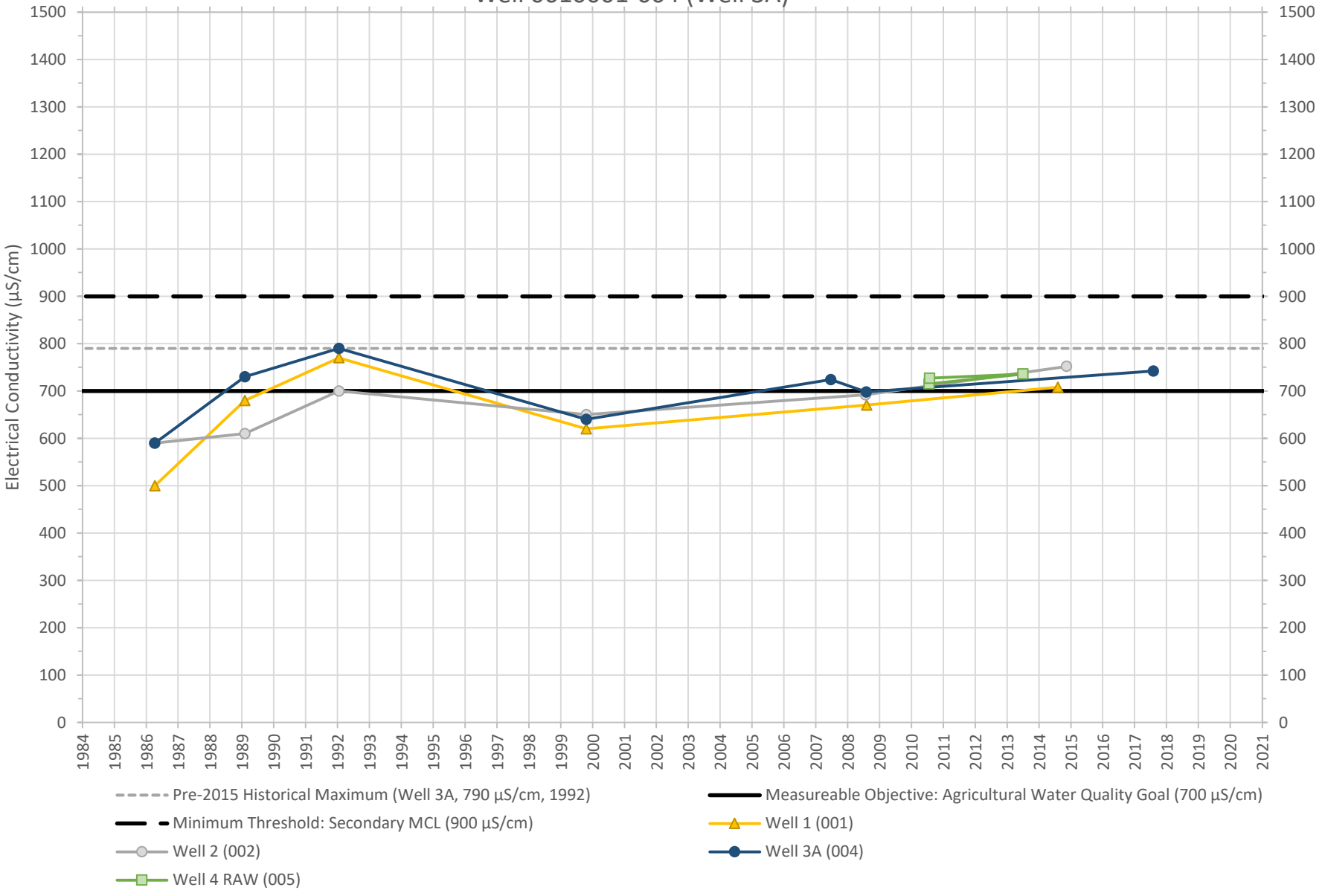


Figure 5D-12. Del Oro Water Company - Arbuckle District Representative Well: Well 0606011-001 (Well 1)

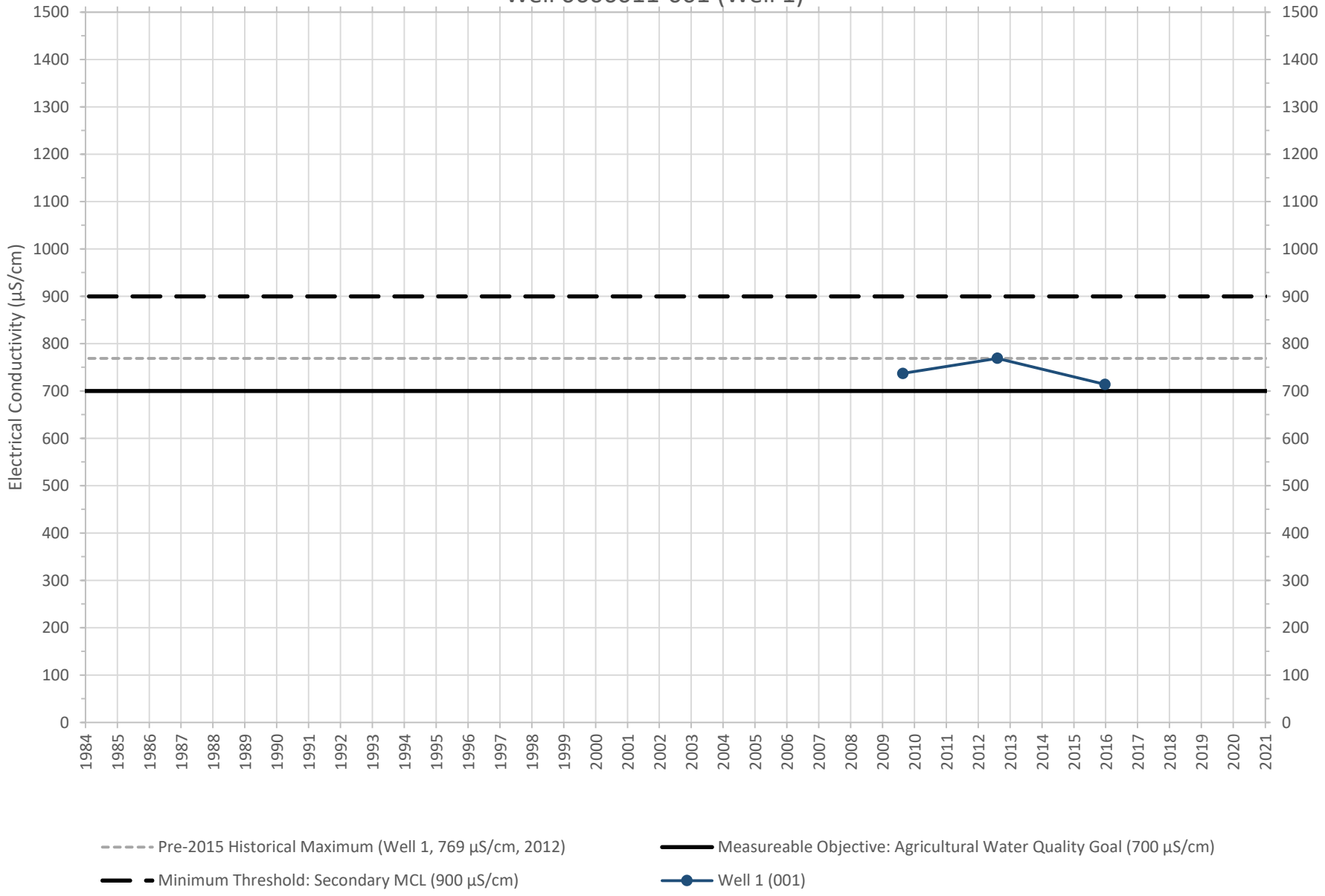


Figure 5D-13. Electrical Conductivity: CRC Well 25A1M (Screened Depth: 25-30 ft)

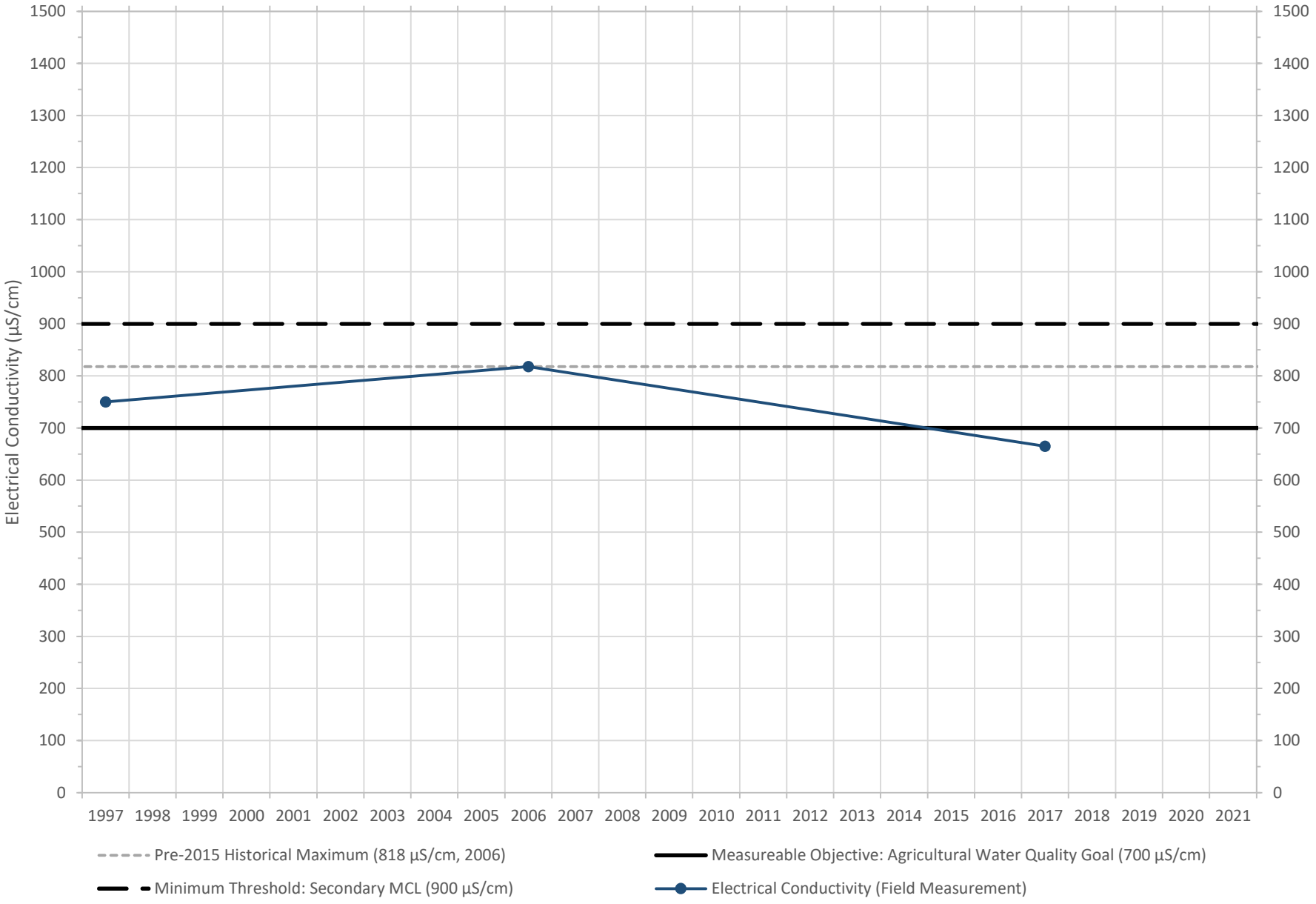


Figure 5D-14. Electrical Conductivity: CRC Well 32J1M (Screened Depth: 25-30 ft)

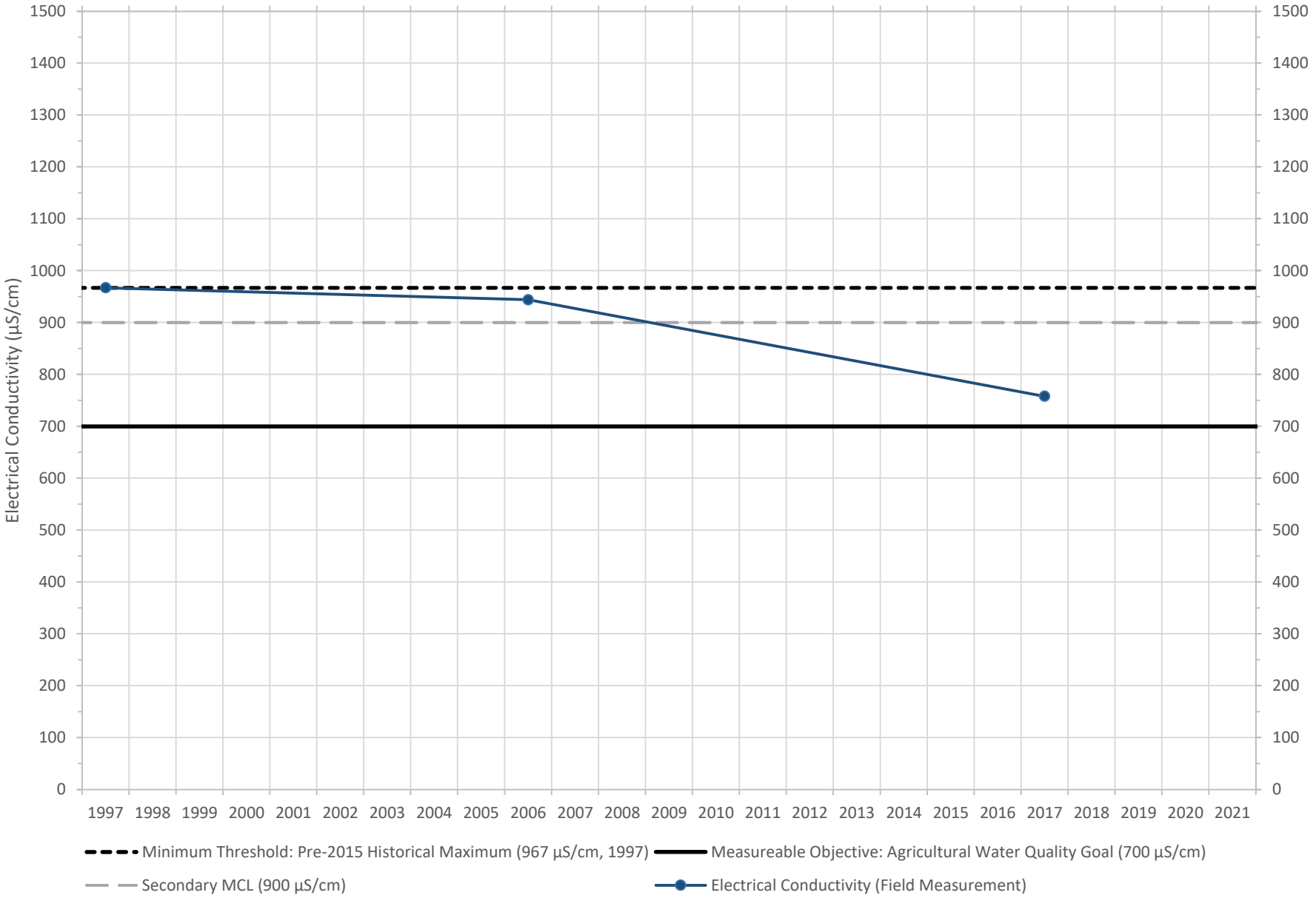


Figure 5D-15. Electrical Conductivity: CRC Well 23E1M (Screened Depth: 25.5-30.5 ft)

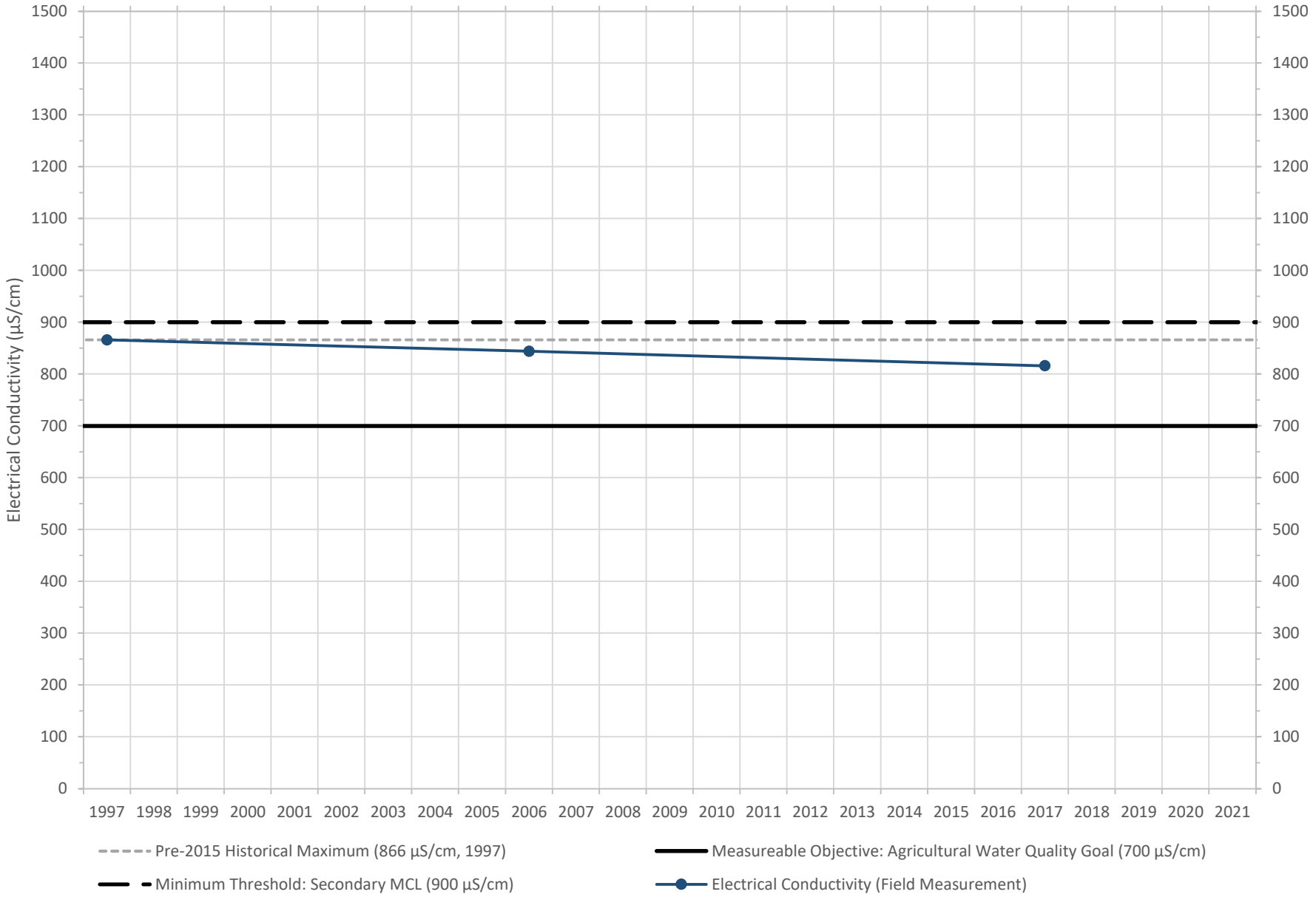


Figure 5D-16. Electrical Conductivity: CRC Well 25E1M (Screened Depth: 25-30 ft)

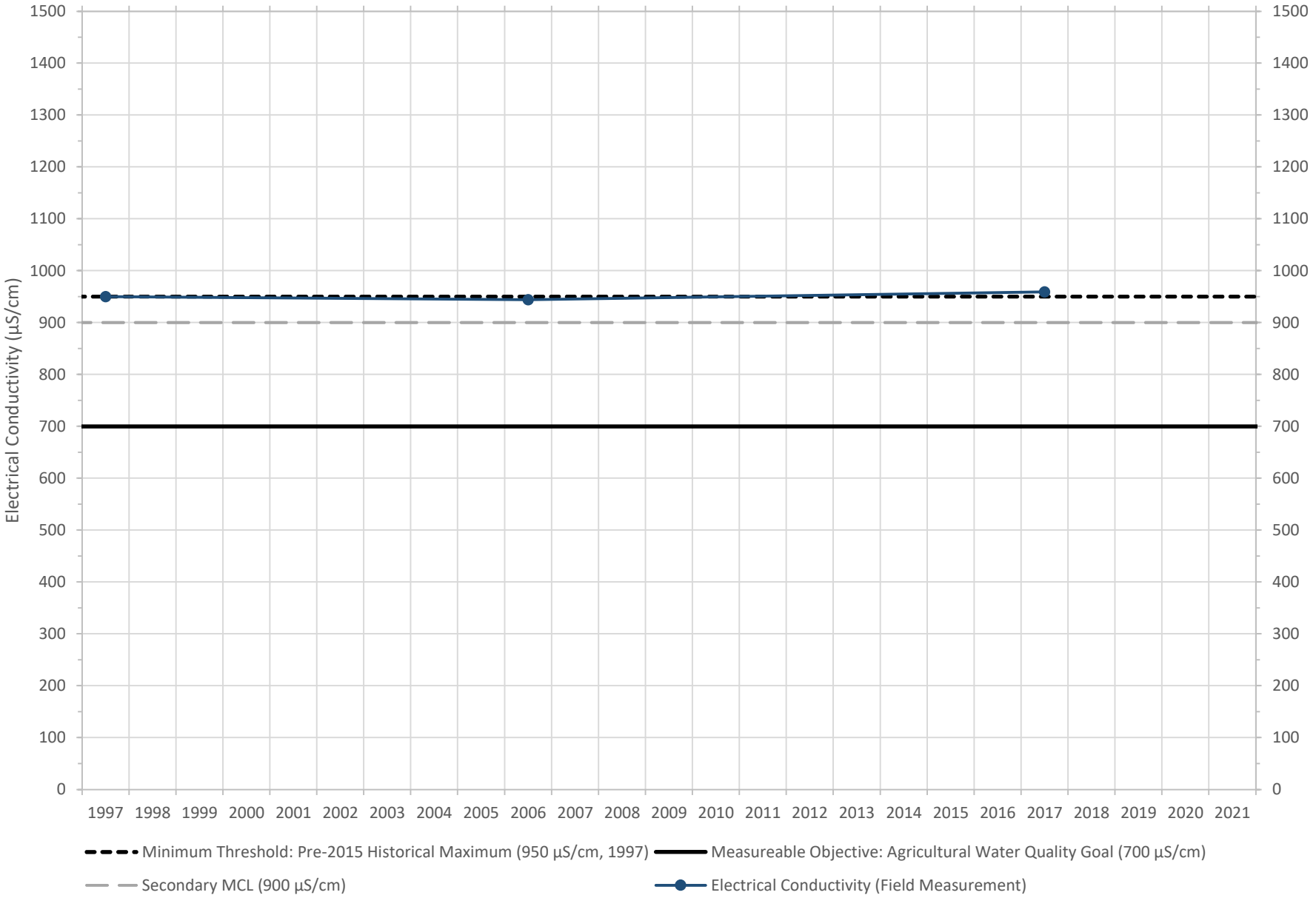


Figure 5D-17. Electrical Conductivity: CRC Well 25R1M (Screened Depth: 28.5-33.5 ft)

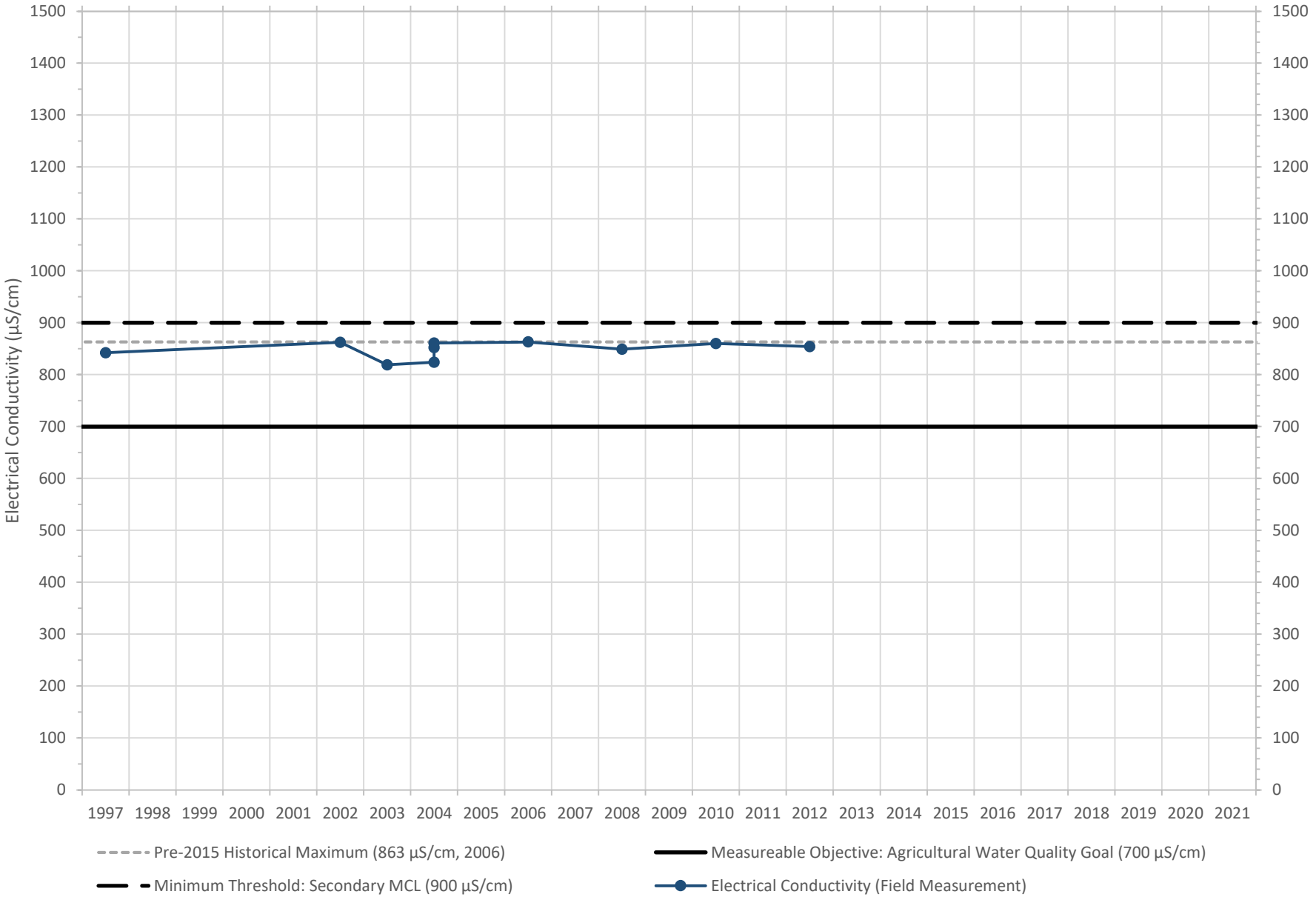


Figure 5D-18. Electrical Conductivity: CRC Well 12G2M (Screened Depth: 25-30 ft)

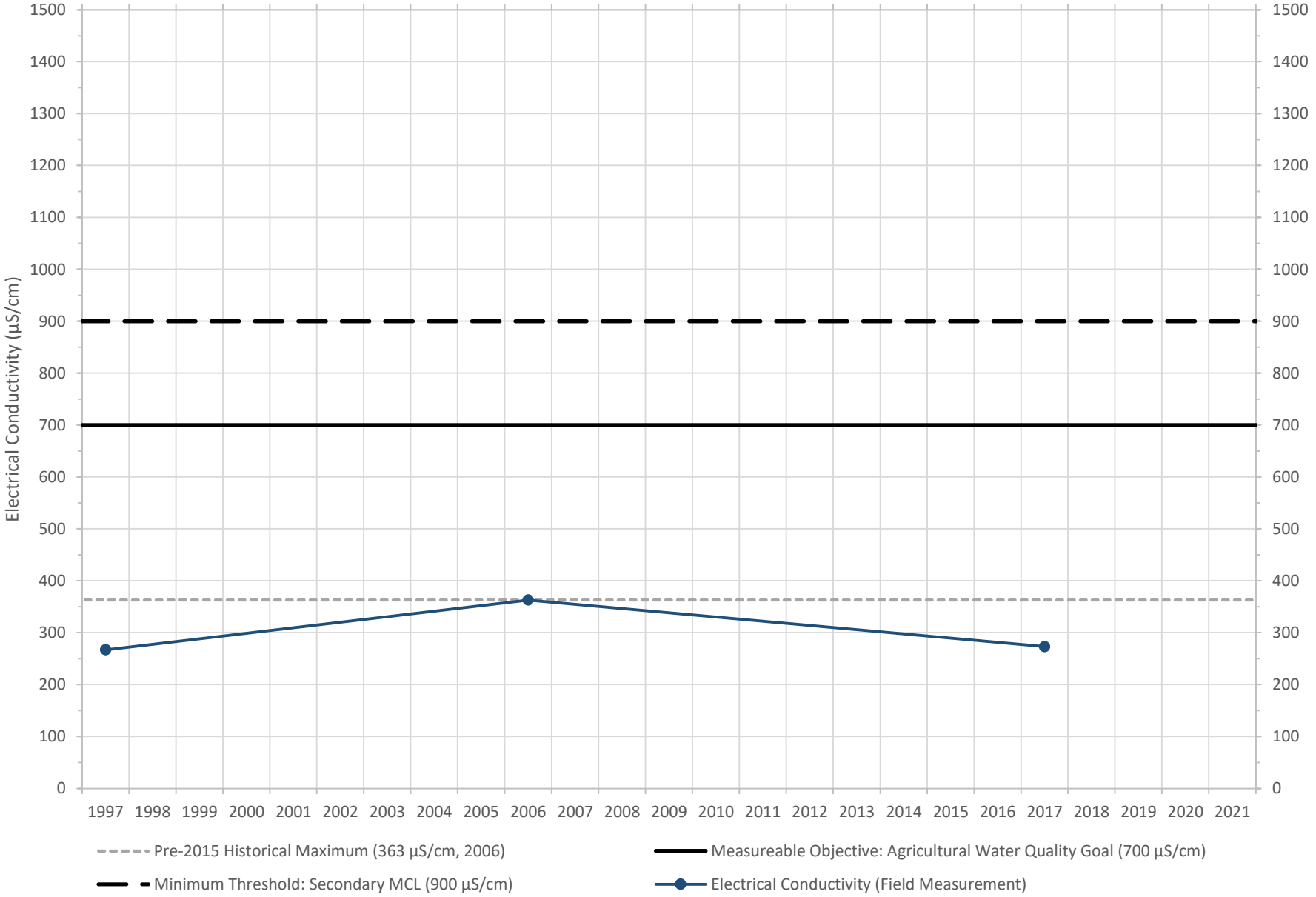


Figure 5D-19. Electrical Conductivity: CRC Well 14G1M (Screened Depth: 25-30 ft)

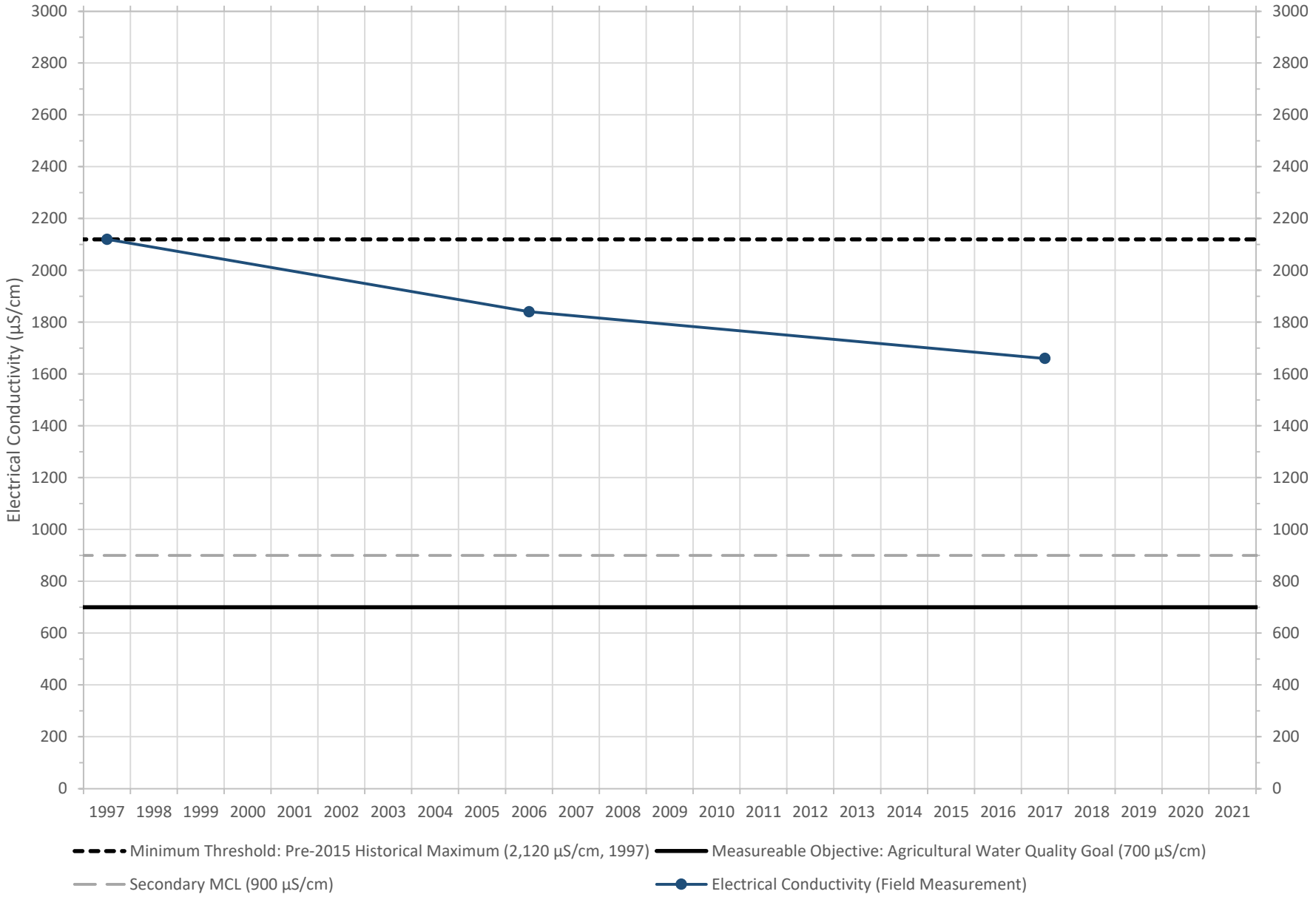


Figure 5D-20. Electrical Conductivity: CRC Well 35M1M (Screened Depth: 25-30 ft)

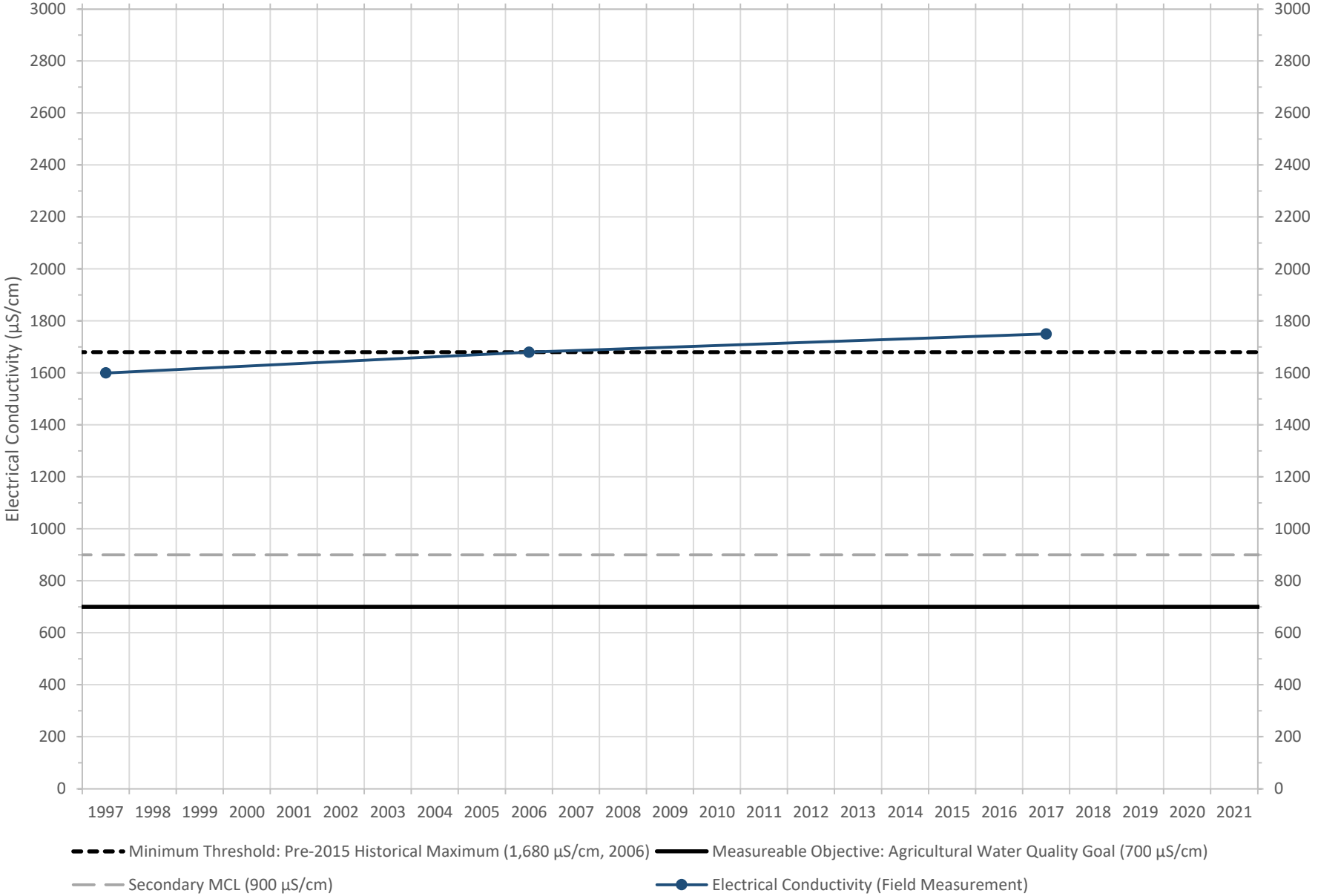


Figure 5D-21. Electrical Conductivity: CRC Well 03E1M (Screened Depth: 25-30 ft)

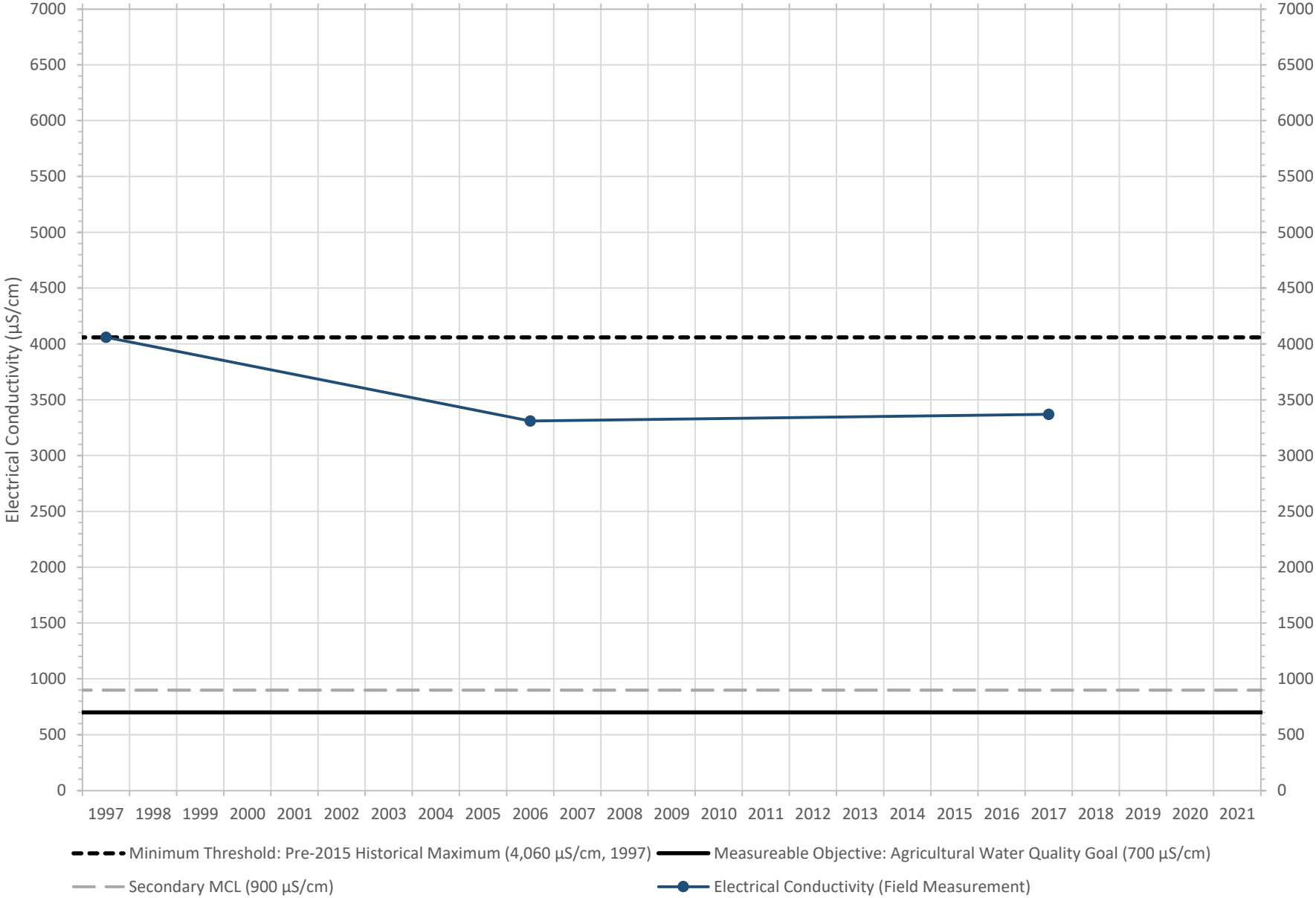


Figure 5D-22. Electrical Conductivity: CRC Well 16R1M (Screened Depth: 25-30 ft)

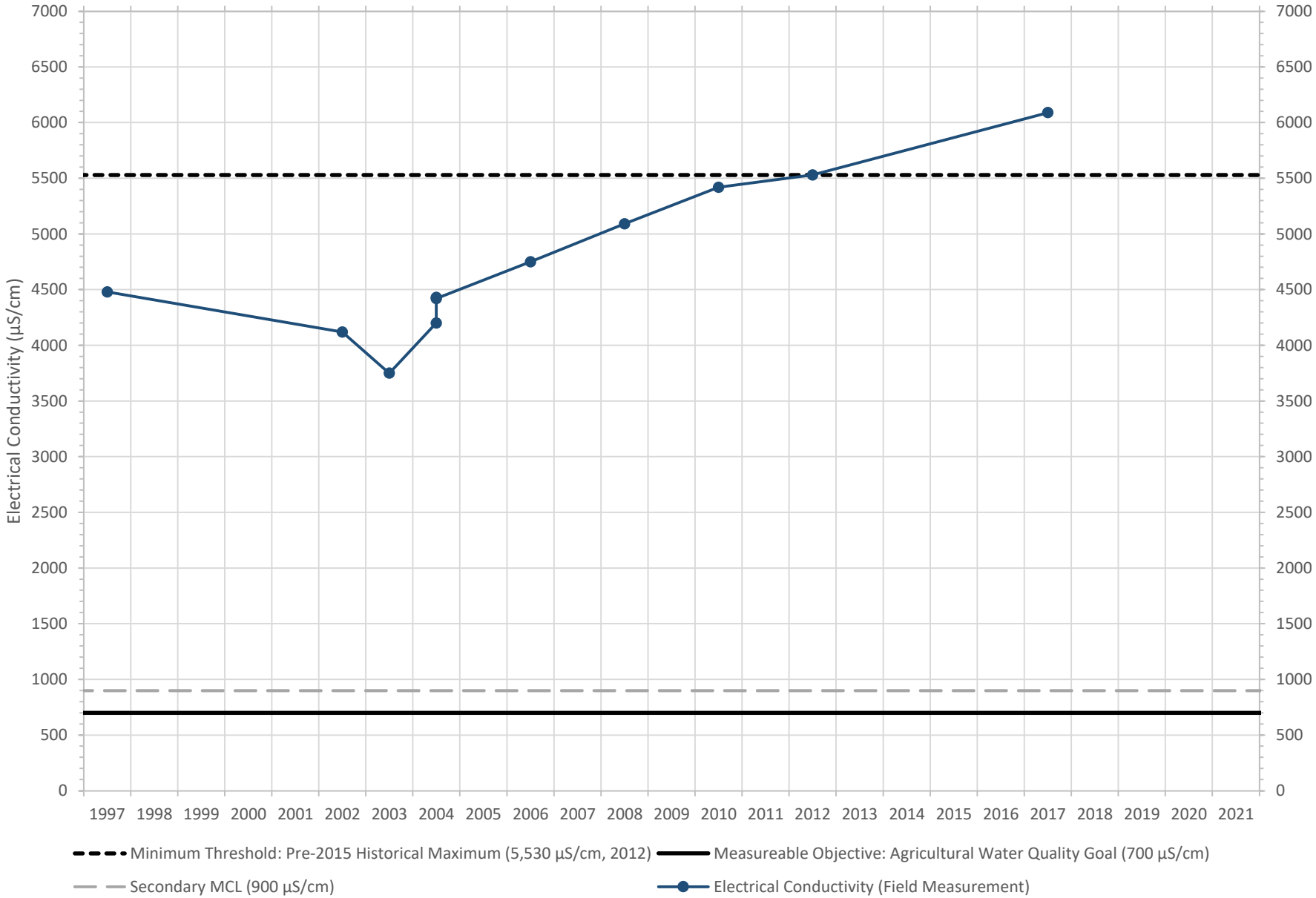


Figure 5D-23. Electrical Conductivity: SVWQC Well SVWQC00005 (Screened Depth: 145-225 ft)

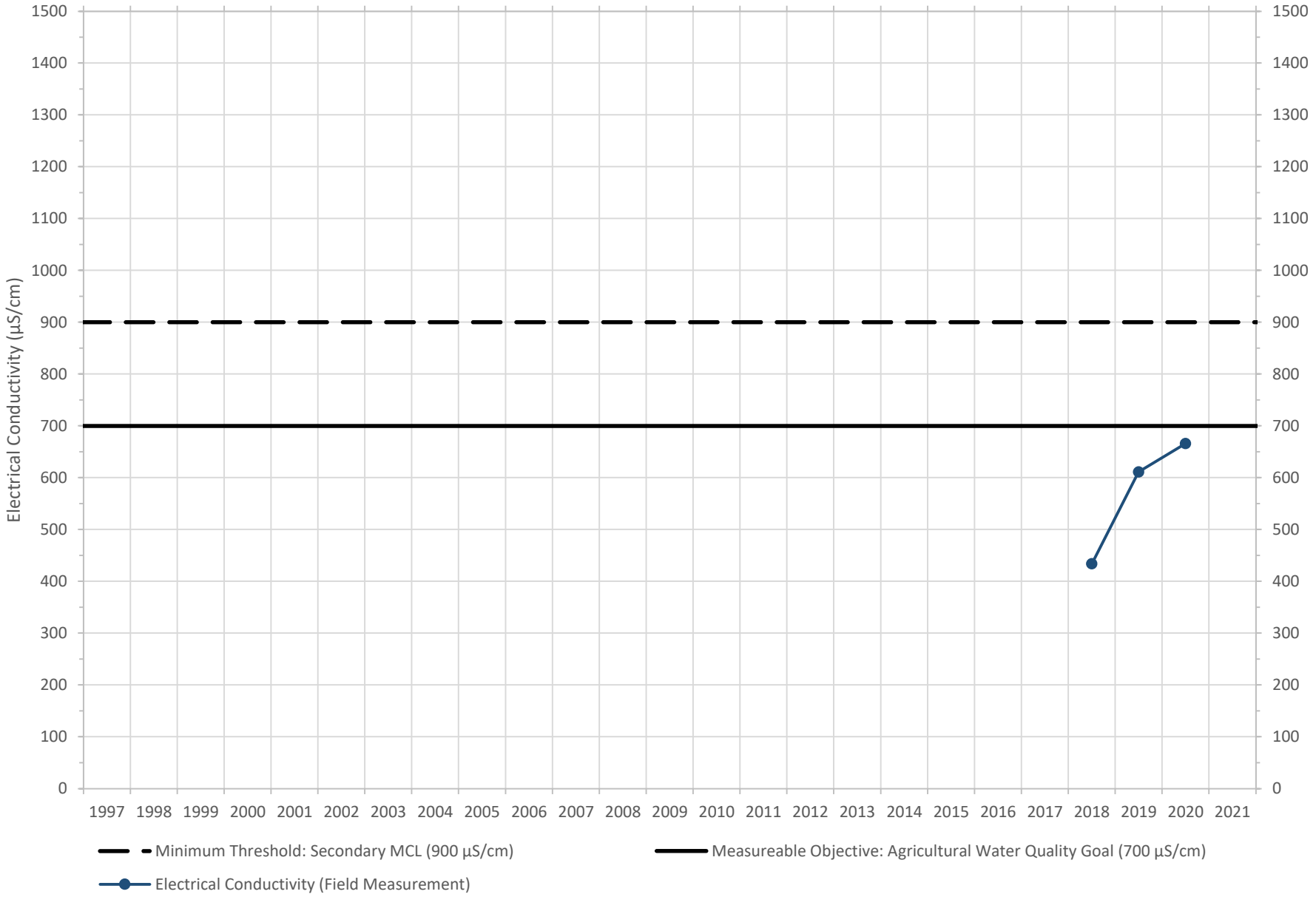


Figure 5D-24. Electrical Conductivity: SVWQC Well SVWQC00021 (Screened Depth: 90-120 ft)

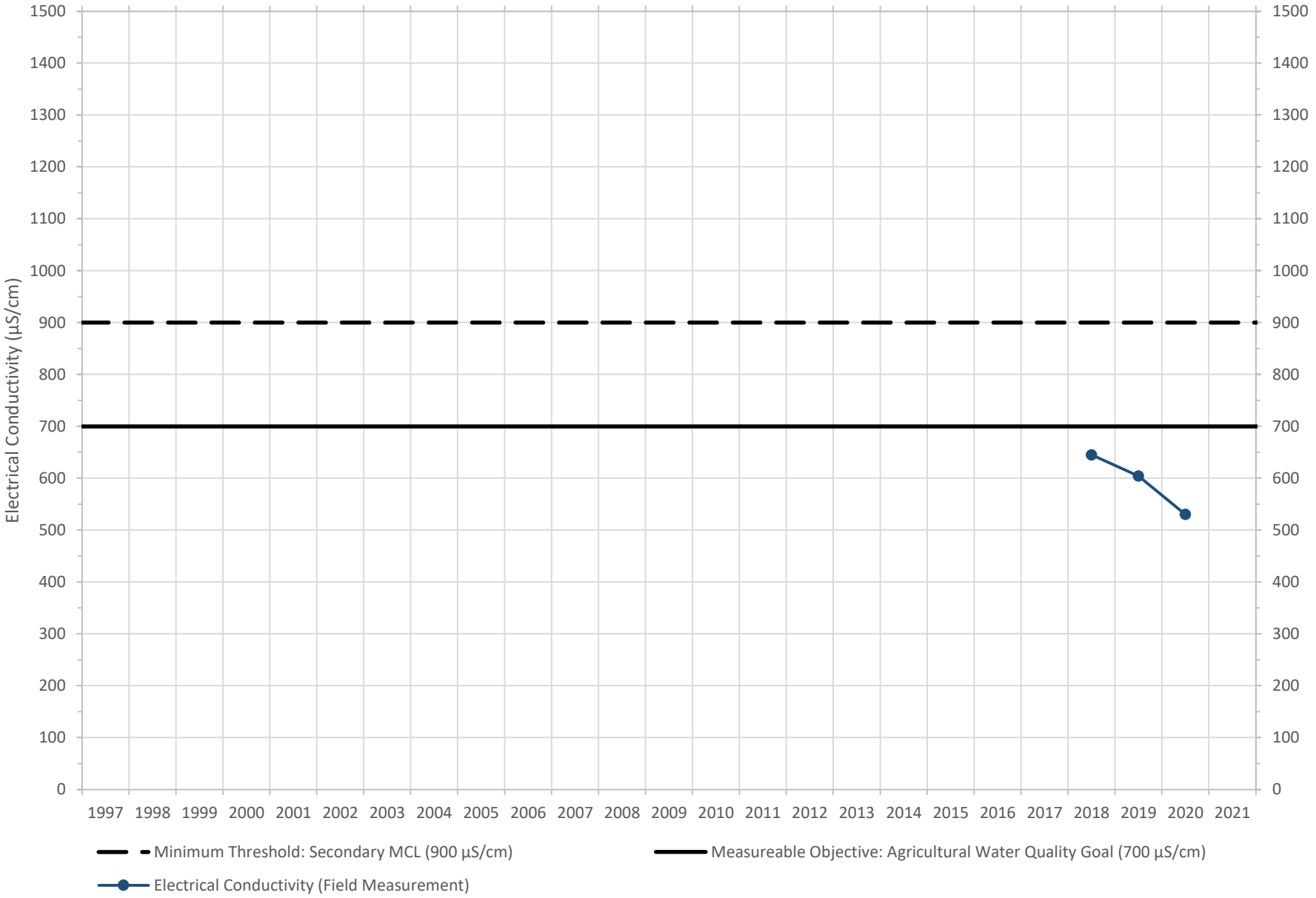


Figure 5D-25. Electrical Conductivity: SVWQC Well SVWQC00019 (Screened Depth: <126 ft)

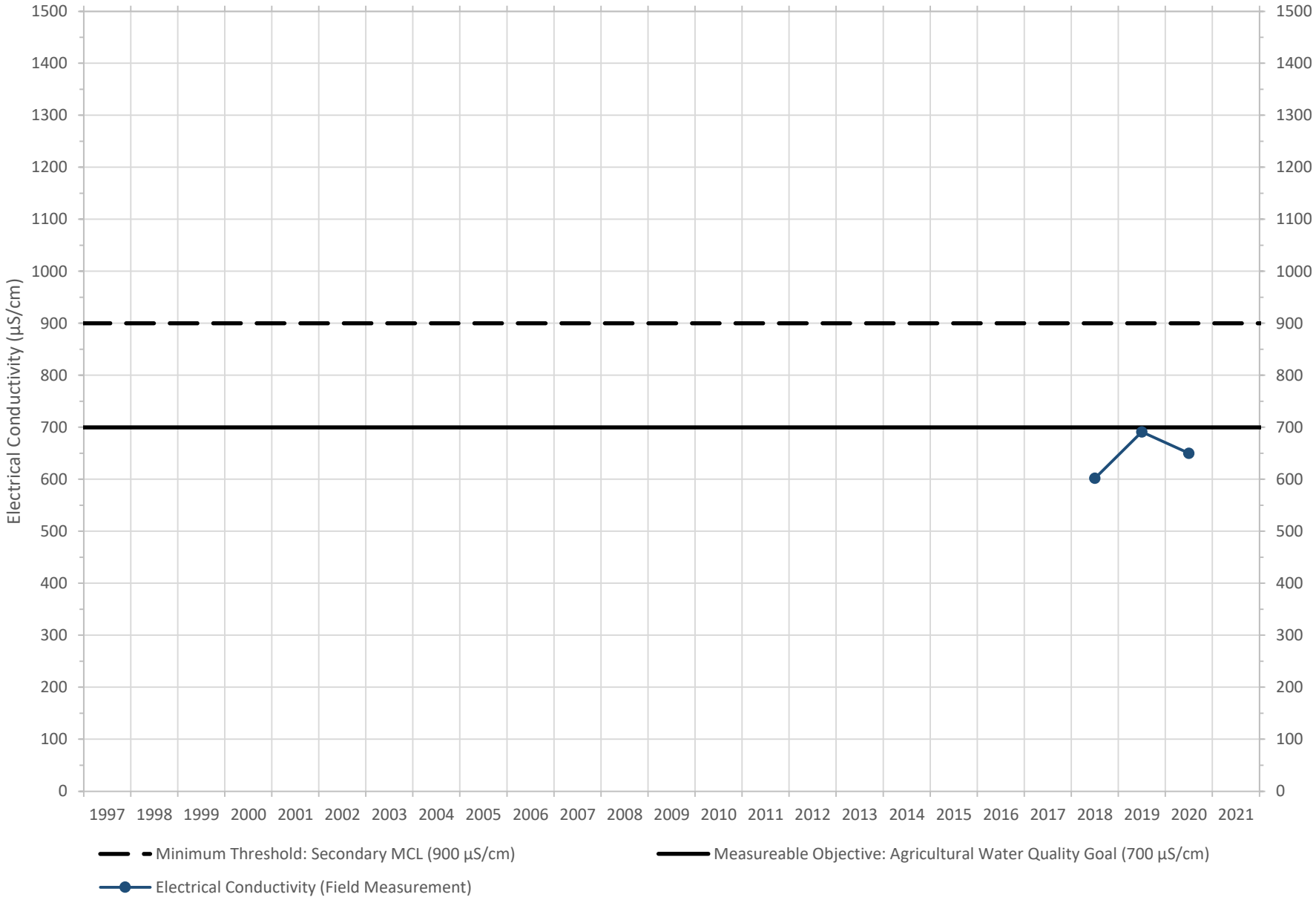
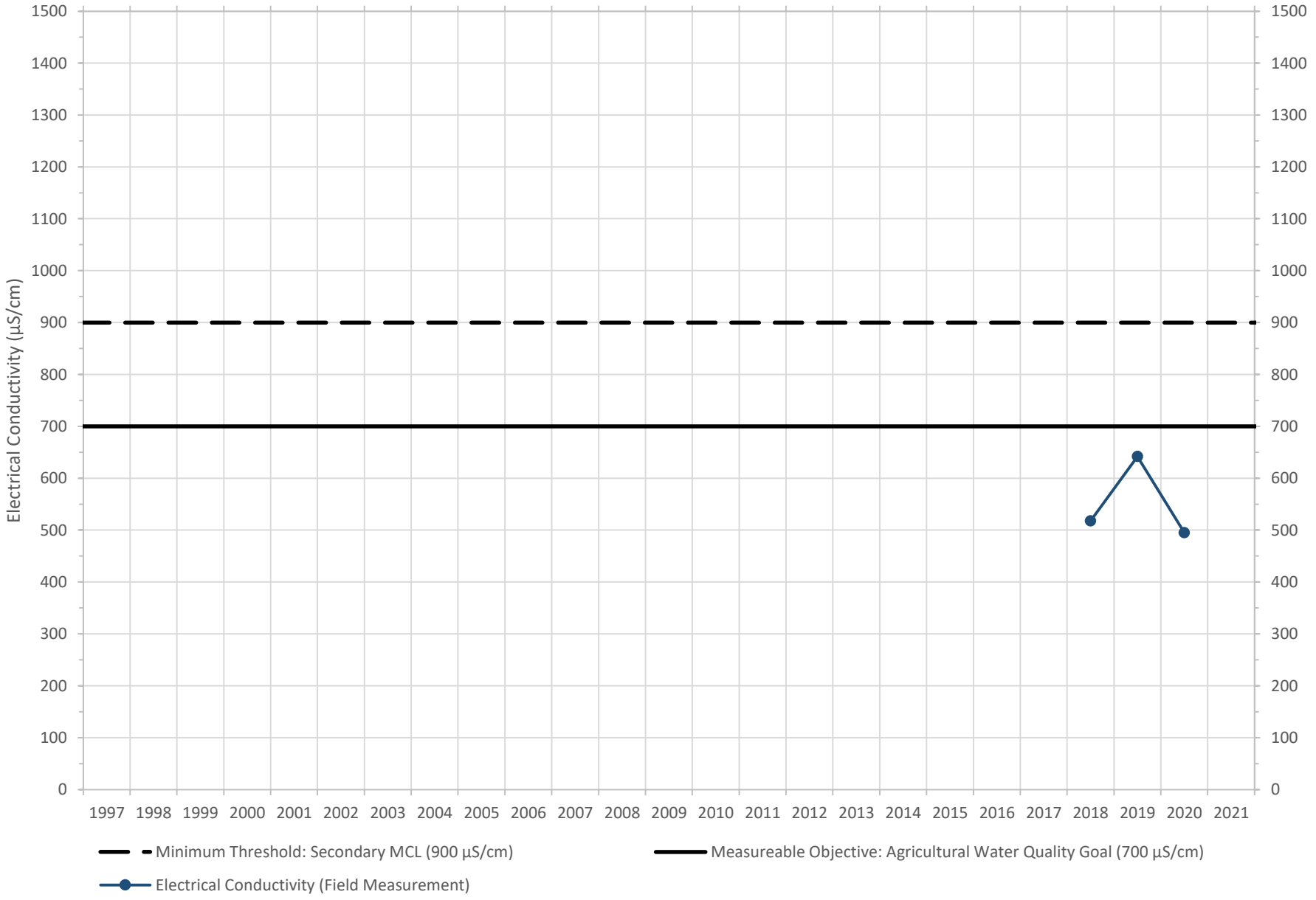


Figure 5D-26. Electrical Conductivity: SVWQC Well SVWQC00006 (Screened Depth: 180-260 ft)



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Appendix 6A

Surface Water Available for Recharge and Financial Incentives in the Colusa Subbasin

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Technical Memorandum

To: Glenn and Colusa Groundwater Authorities

From: Davids Engineering and ERA Economics

Date: July 1, 2021

Subject: **Surface Water Available for Recharge and Financial Incentives**

Purpose

More than 30 projects and management actions (PMAs) are included in the Colusa Subbasin GSP to achieve and maintain sustainable groundwater management. Five of the PMAs are on track for implementation, six are ongoing, with the remaining PMAs being in various stages of investigation and evaluation. The five projects on track for implementation are all groundwater recharge projects involving the use of surface water for direct or in-lieu recharge. Three of the five projects are substantial in-lieu recharge projects, meaning that they will require regulated surface water sources available on an irrigation demand schedule. All three projects are planning to acquire all or most of the required surface water through transfers of Central Valley Project (CVP) water supplies that are surplus to the needs of other CVP water supply contractors or Sacramento River Settlement Contractors (Settlement Contractors).

All three in-lieu recharge projects on track for implementation include incentivizing landowners to utilize existing CVP supplies. CVP supplies in some years are surplus to CVP contractor needs in some cases because contractors are still building out their systems and acreage over time to use the CVP water, but in other cases, the cost of CVP supply is too high to be competitive with groundwater pumping or other local transfers. Growers currently using groundwater also benefit from the convenience of having a clean, reliable, on-demand supply from their pumps and not having to order water for delivery through local district conveyance.

This appendix serves two purposes. First, it summarizes the three in-lieu recharge projects and the potential sources of surface water available for irrigation use to enable reduction of groundwater pumping. Second, it provides an overview of the current costs of CVP water, how those costs are changing, and provides a discussion of financial incentives to increase use of those supplies for some contractors in some years. The description uses information for two districts, Orland-Artois Water District and Colusa County Water District, but the concept could be applied to other districts as well.

Colusa Subbasin In-Lieu Recharge Projects On-track for Implementation

The three substantial in-lieu groundwater recharge projects that are on track for implementation are described below.

Colusa County Water District In-Lieu Groundwater Recharge

Colusa County Water District (CCWD) has a total service area of approximately 46,000 acres of which 39,875 are currently irrigable with existing district infrastructure. This area is planted to predominantly permanent crops. The district delivers surface water to approximately 35,000 acres, with the remaining acres being idle or irrigated with privately pumped groundwater. CCWD has a CVP water supply contract that provides a maximum

of 62,200 acre-feet (AF) annually. The district also holds a CVP contract water supply for 5,666 AF that was part of a Colusa County subcontract assigned to CCWD in 2006. Both contracts are subject to curtailments determined by the Bureau of Reclamation (Reclamation) each year based on Sacramento River watershed hydrologic conditions and planned CVP operations.

Additionally, CCWD typically transfers in additional CVP water supplies to augment water available under its CVP contract. Historical transfers have been primarily from Westside Water District and, more recently, from Reclamation District 108 (RD108) under a five-year pilot transfer agreement that ends in 2022. Despite the availability of district surface water, some CCWD growers choose to pump groundwater because is it less expensive than surface water (and because groundwater requires less screening and filtering compared to district surface water).

Under the CCWD In-Lieu Groundwater Recharge project, the district will acquire additional surface water and incentives will be put in place to make the cost of surface water the same or less expensive than pumped groundwater, thereby incentivizing growers who would otherwise use groundwater to use surface water. The additional surface water is expected to be acquired under long-term water transfer agreements with other CVP contractors, including Sacramento River Settlement Contractors, and potentially other sources. The plan is to acquire and deliver 30,000 acre-feet per year (AF/yr) except in Shasta Critical years[1] when groundwater banked through in-lieu recharge in prior years would be used. It is estimated that the average additional surface water use over the long term would be approximately 27,000 AF/yr.

Colusa Drain MWC In-Lieu Groundwater Recharge

The Colusa Drain Mutual Water Company (CDMWC) encompasses approximately 46,000 acres of agricultural land and environmental habitat located adjacent to the Colusa Basin Drain (Drain) in the Colusa Subbasin (Subbasin). Shareholders in CDMWC divert water for summer irrigation from the Drain under a combination of appropriative water rights held individually by the shareholders, a long-term water supply agreement with Reclamation, and annual and multi-year transfer agreements with neighboring Sacramento River Settlement Contractors. Historically, many CDMWC diverters use both groundwater and surface water for irrigation because flow in the Drain is often insufficient and unreliable to fully satisfy all irrigation requirements on a timely basis.

For the period 1990 through 2015, average surface water diversions from the Drain were estimated to be 48,000 AF/yr while groundwater pumping during the same period was estimated to be 40,000 AF/yr. It is estimated that approximately 70 percent of the historical groundwater pumping can be eliminated through the provision of additional surface water, provided that the surface water cost is approximately equal to the cost of groundwater. The cost comparison of surface and groundwater would include the full cost of each source (e.g., filtering, system costs, and other on-farm costs in addition to the delivery charge per AF of surface water and variable cost to pump groundwater). The potential in-lieu recharge is estimated to be 28,000 AF/yr on average across all years, and 31,000 AF in Shasta Non-Critical years. The planned source of additional surface water is primarily upstream Sacramento River Settlement Contractors that can discharge water into the Drain for use downstream by CDMWC shareholders.

Orland-Artois Water District Land Annexation and Groundwater Recharge

Orland-Artois WD (OAWD) has an existing service area of about 29,000 acres and delivers water to district landowners through 110 miles of pipelines and 300 metered deliveries. Surface water delivered by the district is available under a CVP water supply contract with Reclamation and through short- and long-term transfer

[1] In general, Shasta Critical conditions are declared when the forecast inflow to Lake Shasta for a particular water year is equal to or less than 3.2 million AF.

agreements with other CVP water contractors and Sacramento River Settlement Contractors. The district's water supply contract provides a maximum of 53,000 AF/yr, subject to curtailments determined by Reclamation each year based on Sacramento River watershed hydrologic conditions and planned CVP operations. Historically, water transfers have been from Maxwell Irrigation District, Princeton-Codora-Glenn Irrigation District, and others.

The district is working with a group of neighboring, non-district landowners to annex approximately 12,000 acres of groundwater-dependent agriculture into the district. Additional surface water for the annexed lands would be secured through multi-year purchase or transfer agreements with willing sellers, conveyed through the existing Tehama-Colusa Canal[2] (TCC), and distributed to the annexed lands through new distribution facilities. Potential transferors include CVP water supply contractors and Sacramento River Settlement Contractors. The plan is to acquire and deliver 25,000 AF/yr of surface water to the annexed lands except in Shasta Critical years when groundwater banked through in-lieu recharge in prior years would be used. It is estimated that the average additional surface water use, and thus in-lieu groundwater recharge, over the long term would be about 23,000 AF/yr.

Sources of Surface Water for In-Lieu Recharge

The aggregate volume of water needed for the three in-lieu recharge projects described above is 86,000 AF/yr, in Shasta Non-Critical years, as summarized in Table 1.

Table 1. Proponents and Water Needs Associated with Colusa Subbasin In-Lieu Groundwater Recharge Projects on Track for Implementation

Project	Average Additional Surface Water Needed in Shasta Non-Critical Years (acre-feet)
Colusa County Water District	30,000
Colusa Basin Drain Mutual Water Company	31,000
Orland Artois Water District	25,000
Total	86,000

Potential surface water sources to meet these requirements are discussed below:

Full use of Available CVP Contract Water

In recent years, both CCWD and OAWD have not used all the water available under their respective CVP water supply contracts, due primarily to the high cost of the upper two price tiers according to Reclamation pricing policy. The cost of CVP water is determined by CVP pricing policy and cost allocation. Up until recently, all CVP water contracts in the Tehama-Colusa Service Area were Water Service Contracts, and the water price was calculated using three[3] components: The O&M (operations and maintenance) charge, the capital component

[2] The Tehama-Colusa Canal has a maximum capacity of approximately 2,530 cubic feet per second at the canal inlet (Stene, 1994), and a capacity of approximately 1,700 cubic feet per second at the southern end of the canal. Considering historical canal operations, it is likely that conveyance capacity is available to facilitate such a program, subject to certain conditions (see Attachment A).

[3] Contractors also pay for power use and a restoration charge, which is currently about $11 per AF.

(paid back without interest), and the full cost rate that includes O&M and capital plus interest. The sum of the O&M and capital components is called the cost of service rate. Some or all of the rate's capital component could be removed as "ability-to-pay" relief, and many of the area contractors have received this in the past. The resulting contract rate (cost of service potentially reduced by ability-to-pay relief) applies to the first 80 percent of the contract maximum. The full cost rate includes cost of service plus interest on the capital component and is generally substantially greater than the cost of service rate. In 2020 for example, OAWD's contract rate (cost of service) was about $60 per AF and its full cost rate was about $218 per AF, calculated according to section 205(a)(3) of the Reclamation Reform Act. According to federal law (the CVP Improvement Act of 1992), CVP irrigation (and M&I) water supply contracts required payment of tiered water rates for contractual water entitlements, which are summarized as follows:

- Tier 1: The Cost of Service water rate developed through the federal water rate setting process. The Tier 1 rate applies to the first 80% of the delivered contractual water entitlement.
- Tier 2: The rate is the numerical average of the Tier 1 rate and the Tier 3 rate. The Tier 2 rate applies to the next 10% of the delivered contractual water entitlement.
- Tier 3: This rate is the full cost rate developed through the federal water rates setting process. Tier 3 applies to the last 10% of the delivered contractual water entitlement.

Even when blended with Tier 1 water, using Tier 2 and Tier 3 water resulted in excessive water cost, and so some or all of the Tier 2 and Tier 3 water went unused.

Incentivizing Utilization of CVP Supplies

As of 2021, Tehama-Colusa Canal (TCC) CVP water service contractors have converted their contracts to repayment contracts, thus paying off and removing the capital component from their CVP water rates. The new repayment rates (not including restoration charges and other power charges) are $23.43 per AF for CCWD and $26.67 per AF for OAWD. Under the revised rates, these contractors intend to use all of their CVP contract water. The additional CVP water (the difference between what OAWD and CCWD would have used under their old rate structure versus under their new repayment rate) can fulfill a portion of the in-lieu recharge quantities shown.

Repayment of CVP capital required the contractors to borrow money that they will be paying off over the next 15 years or more. Contractors vary in how they recover that fixed cost. Some, like OAWD, have acreage assessments on lands in the district. Others, like CCWD, include more fixed costs in their water rate, so when CVP delivery goes down, the water rates must go up to cover the fixed costs. Due to critical drought conditions, the CVP has announced no contract deliveries to the Tehama Colusa Service Area in 2021. As a result, CCWD's announced water rate for 2021 is currently estimated to be $288 per AF, though this may change as conditions and availability of water transfers change.

OAWD has estimated that its water rate after conversion to the repayment contract would be about $42 per AF under conditions of full CVP supply and $62 per AF with a 50 percent supply.[4] CCWD has estimated that its water rate after conversion to the repayment contract would be in the range of $70 per AF under conditions of full CVP supply.[5]

Depending on the relative costs of district supply versus groundwater, under the repayment contracts, the districts' rates may be low enough already to encourage full use of CVP supply. However, if groundwater pumping remains a lower cost alternative to CVP water for some growers, incentivizing their use of CVP water in lieu of pumping would require paying at least the difference between district surface supply and the variable

[4] According to a Proposition 218 informational presentation to the OAWD Board in August 2020.

[5] This is a rough estimate based on personal communication with CCWD Manager, Shelly Murphy, June 30, 2021.

cost of pumping groundwater. Other advantages of groundwater over delivered surface water include the growers' convenience of having a clean, reliable, on-demand supply from their pumps. Some groundwater users also may need to incur some on-farm water distribution costs to take surface water.

A program to incentivize CVP use would be specific to individual districts. Therefore, a full evaluation was not developed for the GSP. It is anticipated that an economic analysis to establish incentives and program design would be completed as part of GSP implementation activities. The economic analysis would generally include the following components:

- The initial evaluation would include estimating the incentive payments needed to achieve greater or full use of CVP contract water. The payments should compensate for the difference between CVP water cost (full cost as delivered by the district) and variable cost of groundwater pumping in areas receiving the in-lieu recharge, plus the value of any additional advantages or cost savings of groundwater over surface water.
- Estimate the projected total annual cost of the incentive payments, considering the payments per AF (which may vary by area) and the expected additional amounts of CVP water purchased and used in lieu of pumping. The estimate should account for variability in CVP supply by year and the costs of other supplies or activities related to that variability. In addition, economic benefits should be quantified and assigned to project beneficiaries.
- Estimate the recharge benefits to the GSA or to subareas within the GSA, considering avoided pumping costs and/or cost of other PMAs that could be avoided by this action. This would include an assessment and assignment of economic benefits that accrue to different parties and over time.
- Consider and evaluate other policies that may be used to assure that increased use of CVP water is effective as in-lieu groundwater recharge and does not simply enable expansion of irrigated area with little or no effect on groundwater recharge.
- Using the results of the cost and benefits calculations developed in the economic analysis described above, develop a method for assigning (if necessary) project costs in proportion to benefits received.

It is important to note that the switch to repayment contracts could provide alternative ways to incentivize use of CVP supplies with districts. An economic analysis could develop strategies to shift and restructure district charges to lower the effective cost of CVP water. This would generally include recovering a greater proportion of fixed costs as land-based charges rather than through variable water rates. For example, OAWD's recent approval of an acreage assessment to recover costs of its CVP capital conversion loan effectively reduces the per AF cost of CVP water. As a result, its water rate is substantially lower than before it converted to a repayment contract. This approach could be explored by other districts if they find that their water rate discourages full use of available CVP supply.

Transfers of Other Unused CVP Contract Project Water

Other CVP water contractors (not Sacramento River Settlement Contractors) within and outside the Colusa Subbasin, including members of the Tehama Colusa Canal Association served by the TCC, also have contract water available for transfer in some years. Historically, some but not all of this water has been transferred under the provisions of Section 3405(a) of the Central Valley Project Improvement Act (CVPIA) (Title 34 of Public Law 102-575).

Transfers of Available Settlement Contract Water

There are 127 Sacramento River Settlement Contractors. The total surface water supply quantities associated with each settlement contract have a "base supply" component and a "project water" component[6]. In general, project water can be transferred in-basin under the provisions of CVPIA Section 3405(a) and base supply cannot[7].

There are 17 Sacramento River Settlement Contractors with total contract supplies of 10,000 AF or more (Table 2). The aggregate base supply for these entities is approximately 1.7 million AF, and the project water supply is about 296,000 AF. The 110 remaining, smaller Settlement Contractors, have aggregate base supplies of about 92,000 AF and project water supplies of about 34,000 AF. Thus, the total quantity of project water under the settlement contracts is about 330,000 AF.

It is estimated that in Shasta Non-Critical years about 25 percent of this volume, or approximately 83,000 AF, is available for transfer. Glenn Colusa Irrigation District and RD108, the two largest Settlement Contractors, estimate that they could provide approximately 40,000 AF and 14,000 AF of project water for transfer in Shasta Non-Critical years, respectively. The combined quantity of 54,000 AF constitutes roughly two-thirds of the estimated 83,000 AF of project water available for transfer.

[6] Base supply is intended to replace water that could have been diverted under each entity's underlying, senior water right(s), while project water is an additional amount negotiated as part of the settlement to supply supplemental water during the summer that might not have been available under the underlying rights. All settlement contracts have a base supply component and most, but not all, also have a project water component.

[7] Base supply can be transferred to the extent its use is reduced by land fallowing, groundwater substitution, or conservation.

Table 2. Sacramento River Settlement Contractors with Total Supplies of 10,000 AF or More

Name	Contract Number	Base Supply	Project Supply	Total Supply
Glenn-Colusa Irrigation District	14-06-200-855A-R-1	720,000	105,000	825,000
Sutter Mutual Water Company	14-06-200-815A-R-1	169,500	56,500	226,000
Reclamation District No. 108	14-06-200-876A-R-1	199,000	33,000	232,000
Natomas Central Mutual Water Company	14-06-200-885A-R-1	98,200	22,000	120,200
Reclamation District No. 1004	14-06-200-890A-R-1	56,400	15,000	71,400
Princeton-Codora-Glenn Irrigation District	14-06-200-849A-R-1	52,810	15,000	67,810
Meridian Farms Water Company	14-06-200-838A-R-1	23,000	12,000	35,000
Sycamore Family Trust	14-06-200-2146A-R-1	22,000	9,800	31,800
Anderson-Cottonwood Irrigation District	14-06-200-3346A-R-1	121,000	7,000	128,000
Maxwell Irrigation District	14-06-200-6078A-R-1	11,980	6,000	17,980
Provident Irrigation District	14-06-200-856A-R-1	49,730	5,000	54,730
Redding, City of	14-06-200-2871A-R-1	17,850	3,150	21,000
Pleasant Grove-Verona Mutual Water Company	14-06-200-5520A-R-1	23,790	2,500	26,290
Bardis, Christo D., et al. (Broomieside Farms)	14-06-200-1286A-R-1	8,070	2,000	10,070
Pacific Realty Associates, L.P. (M&T Chico Ranch)	14-06-200-940A-R-1	16,980	976	17,956
Conaway Preservation Group, LLC	14-06-200-7422A-R-1	50,190	672	50,862
River Garden Farms Company	14-06-200-878A-R-1	29,300	500	29,800
	Total	1,669,800	296,098	1,965,898

Summary

There are three in-lieu groundwater recharge projects on track for implementation in the Colusa Subbasin with a combined surface water requirement of approximately 86,000 AF in Shasta Non-Critical years. Each project intends to acquire the necessary surface water primarily via water transfers from other entities with available CVP contract supplies and CVP Settlement Contract project water under the provisions of CVPIA Section 3405(a). Transfer of available project water supplies under settlement contracts alone would nearly meet these needs, with full use of existing contract supplies (CCWD and OAWD only) and potential transfers of surplus CVP contract supplies adding to that amount.

It is recognized that the actual feasibility of acquiring the water is subject to the willingness of both buyers and sellers, and the negotiation of mutually acceptable contract terms. These negotiations have been initiated informally and will be continued as the projects move toward implementation.

A key element of all three projects will be creating incentives for growers to use the surface water made available rather than pumping groundwater. The preliminary analysis presented in this appendix suggests that the variable cost to pump groundwater may already be greater than the district rate under the new repayment contracts in some districts. In other districts, the water rate is around $10 to $25 per AF greater than the variable cost to pump groundwater. These are just the variable costs of water supply, and do not include additional on-farm costs associated with each source. As described above, incentivizing use of surface water can be accomplished by developing an incentive program funded by the beneficiaries of such a program, or through adjustments to the district water rate structure. It is anticipated that these specific incentive structures would be evaluated and developed as part of project implementation.

It is also noted that the in-lieu recharge volumes referred to above are maximum quantities. Based on monitoring of project performance and groundwater conditions, it may be possible to operate the Subbasin within its sustainable yield with less than the maximum in-lieu recharge quantities described above.

References

Stene, E.A. 1994. Sacramento River Diversion, Central Valley Project. United States Bureau of Reclamation.

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Attachment A. Personal Communication with J. Sutton Regarding the Tehama-Colusa Canal Capacity.

From: Jeffrey P. Sutton (Tehama-Colusa Canal Authority)
Sent: Tuesday, August 10, 2021, 4:55 PM
To: Grant Davids (Davids Engineering, Inc.)
Cc: Katherine Klug (Davids Engineering, Inc.)
Subject: RE: TCC Capacity

Grant,

Caveated with the following first blush comments (reserve the right to add to this list), I respond:

1. TCCA will not be responsible for providing the subject water rights or water supply that is diverted for this purpose.
2. TCCA will not be responsible for any permits, mitigation, or other regulatory responsibilities associated with such a program.
3. CCWD and OAWD will be responsible for any and all charges, contracting, Warren Act or other fees and/or costs associated with such a program.
4. TCCA will be paid appropriate conveyance charges pursuant to the rates in the TCCA JPA Agreement that CCWD and OAWD currently pay or other rates as agreed.

I respond to your question as follows: Currently, it is my opinion that under most (in fact all that I currently think of) scenarios experienced, there would be plenty of pumping/diversion capacity (currently maxed out at 2000 cfs) and conveyance capacity in the TC Canal (2500 cfs at the top of the canal, 2100 cfs at Funks Reservoir, 1700 cfs at the south end of the canal) to facilitate such a program. However, historical operations are not always a good predictor of future conditions. In a typical year, we typically divert/convey a maximum amount of water of around 1300-1500 cfs. I would also add that I have not yet discussed particulars details of such a program (because I have not been provided such details until this time) with my Board of Directors. Bill Vanderwaal and Emil Cavagnolo did generally outline the recharge concept being explored at my last meeting, which the Board was generally supportive of - notwithstanding the need to hear the details. However, I anticipate that this water would have to somewhat take a second tier position in the atypical case of a conflict over the available diversion/conveyance capacity.

I hope this is helpful Grant, sorry for the long caveated answer. But I don't want to give the misimpression of complete acquiescence or create a reliance on a simple statement of "sure we have capacity" until all of the details are more fully vetted and the necessary terms have been contemplated. I will leave it to your discretion on how you wish to articulate capacity availability in the Colusa GSP based on the foregoing.

Jeffrey P. Sutton

General Manager
Tehama-Colusa Canal Authority

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Appendix 6B

Economic Analysis of Demand Management and Conceptual Allocation Approaches

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ERA Economics
Environment • Resources • Agriculture

Technical Memorandum

To: Glenn and Colusa County Groundwater Authorities

From: ERA Economics

Date: November 19, 2021

Subject: **Economic Analysis of Demand Management and Conceptual Allocation Approaches**

Introduction

More than 30 projects and management actions (PMAs) are included in the Colusa Subbasin GSP to achieve and maintain sustainable groundwater management. Five projects are on track for implementation, which are all groundwater recharge projects that use surface water for direct and/or in-lieu recharge. Recognizing that projects can take several years to develop, and in light of the current severe drought conditions across the Colusa Subbasin (Subbasin) and state, the GSP includes two "backstop" demand management actions that could be implemented relatively quickly, primarily because they do not require construction of new infrastructure. These management actions include a targeted demand management program that would incentivize temporary pumping reductions (and/or local water transfers) in periods of extreme drought, and a broader demand management program that would incentivize pumping reductions, if necessary, due to future groundwater conditions in the Subbasin.

Demand management can be implemented fairly quickly and can be included as part of a cost-effective mix of PMAs to achieve and maintain sustainable groundwater conditions. This appendix describes the direct economic costs of demand management in the Subbasin. It also describes considerations for, and the process of setting, a groundwater allocation. It is noted that a groundwater allocation is not required to implement the demand management programs included in the GSP, but it does generate incentives to manage demand and increase supply. To provide some context for the costs of demand management, a general summary of agricultural water use, economic values, and Subbasin conditions is presented first. This is followed by a summary of an economic analysis of the direct costs associated with two example demand management programs: one targeted to specific areas with groundwater sustainability concerns, and another targeted more broadly across the Subbasin. The allocation discussion is presented last.

Economic Value of Agriculture in the Colusa Subbasin

Glenn and Colusa County agriculture includes a diverse mix of rice, nut crops, seed, feed, and other field and row crops. Farming activities to raise these crops support jobs, income, and economic activity for a range of transportation, processing, manufacturing, and retail industries in the Subbasin. These activities support the local tax base as well as jobs and income in businesses not directly related to agriculture. Changes in the cost and availability of water under the PMAs included in the GSP, as well as potential demand management programs, can have important implications for the local economies and communities in the Subbasin. This section describes the current contribution of agriculture to the Subbasin economies.

The Subbasin spans most of Glenn and Colusa counties. The annual economic activity, measured as value-added, across all industries (including agriculture) in the counties is around $7.4 billion. These industries support around 26,000 full-time equivalent (FTE) jobs, mostly for individuals that both live

and work in the counties. Table 1 summarizes the top ten industry sectors by value, and the direct jobs associated with each industry. Eight of the top 10 industry sectors are agriculture and related industries. Notable exceptions include local government industries and the wholesale trade sector. However, wholesale trade includes warehousing and storage industries that are closely linked to the agricultural sector.

Table 1. Top 10 Industries, Glenn, and Colusa Counties

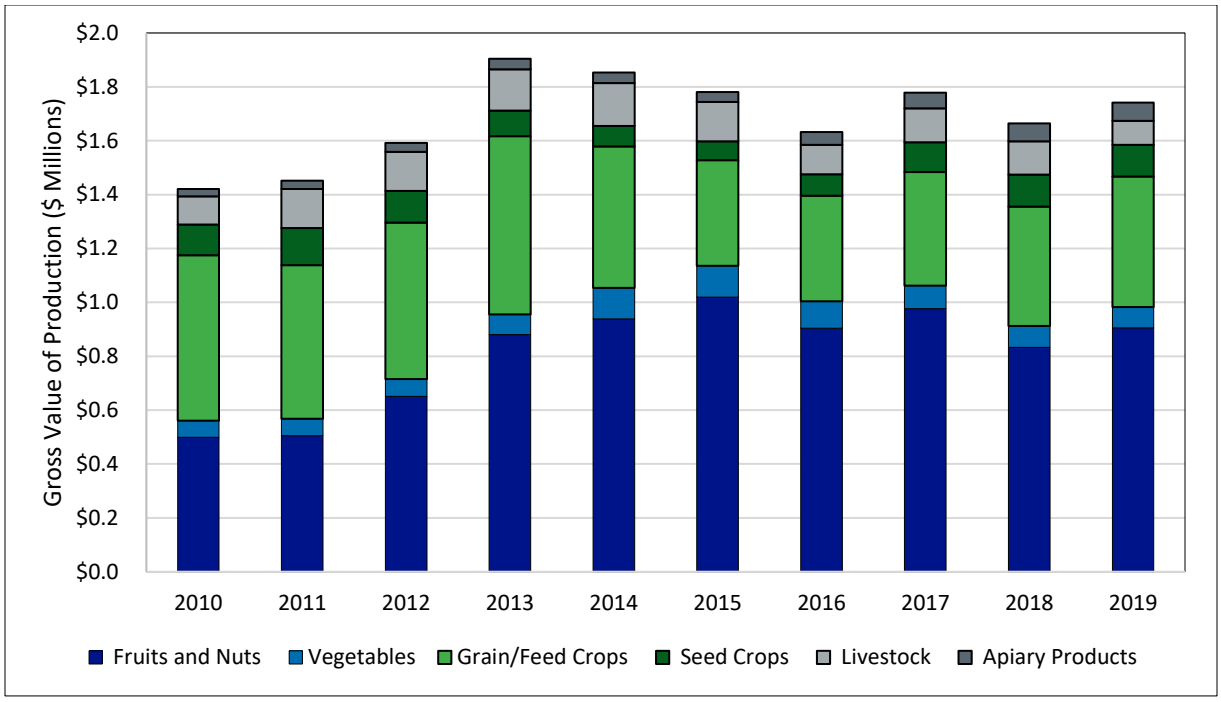
Rank	Industry	Annual Value Added ($ in Millions)	Direct FTE Jobs
1	Tree nut farming	$965	2,790
2	Rice milling	$750	450
3	Local government	$625	3,750
4	Grain farming	$500	405
5	Wholesale trade	$475	1,620
6	Canned fruits and vegetables manufacturing	$470	695
7	Vegetable and melon farming	$180	630
8	Dairy cattle and milk production	$160	155
9	Support activities for agriculture and forestry	$145	1,690
10	Other animal food manufacturing	$145	70

Source: IMPLAN 2014 R3 multipliers, current USDA crop prices and returns, current 2021 dollars

A substantial share of local economic activity is directly or indirectly related to farming. A conservative analysis using the IMPLAN model data shows that at least one in three jobs depend on farming activities in the Subbasin. Similarly, a substantial share of local wage income for employees, value added, and gross output are a result of farming-related industries in the Subbasin.

The primary crops produced in the Subbasin include rice, walnuts, and almonds. The total rice acreage footprint has been largely steady for several years, with annual fluctuations in planted acreage based on rice market conditions and water availability in the Sacramento and San Joaquin Valleys. On average, Colusa and Glenn counties produce around 45 percent of California's annual rice crop. The share of acreage planted to almonds and walnuts has been steadily increasing, driven by favorable market conditions and consistent with trends across the state. Relative to annual crops, these permanent plantings require a substantial capital investment to establish and require consistent irrigation in all years. This has led to hardening of irrigation water demand in areas with increasing permanent plantings.

Figure 1 illustrates recent trends in the gross value of production by crop type in Glenn and Colusa Counties. The gross output value of the crops produced in the Subbasin is around $1.75 billion per year, with fruit and nut crops accounting for more than half of the total value in recent years. Fruit and nut crops accounted for around 30 percent of gross value in 2010, increasing to nearly 60 percent by 2015.



Source: Glenn and Colusa County Crop Reports

Figure 1. Trends in Gross Value of Crop Production, 2010 – 2019

The trends in crop acreage and value in Glenn and Colusa counties are consistent with trends in other parts of the state. Robust export demand for California almonds and walnuts through the mid-2010's supported strong prices and profitability. This led to increasing plantings that are continuing across the state. However, new plantings of nut trees have slowly leveled-off in response to softer prices caused by increasing supply (production) in California and other regions (e.g., Australia) and a weaker export market (e.g., tariffs and macroeconomic conditions including a stronger U.S. dollar). Groundwater concerns in Critically Overdrafted subbasins in the San Joaquin Valley may continue to push permanent plantings north into the Sacramento Valley, and as such this general trend appears likely to continue in Glenn and Colusa Counties for the next several years.

The agricultural industries in the Subbasin create a substantial share of local jobs, business, and economic activity. Demand management programs can be structured in ways to minimize the economic costs to growers and the regional economy. The following section quantifies the direct costs of potential demand management programs in the Subbasin.

Demand Management Costs

Demand management generally refers to actions that reduce the net consumptive use of water, which in turn reduces net groundwater pumping[1] in the Subbasin, or selected areas of the Subbasin. Areas selected for demand management would be determined by the GSAs in consideration of local groundwater conditions and sustainability indicators.

This appendix summarizes the results of an analysis that establishes the potential costs of demand management in the Subbasin. The results of the analysis can be used for multiple purposes. Demand management costs can be compared to the cost of potential projects to support developing a cost-effective portfolio of PMAs. In addition, demand management costs are interpreted as the minimum willingness to accept payment to forgo irrigation, which can be used to structure potential incentives to reduce groundwater pumping under applicable PMAs.

To illustrate the cost of demand management, two scenarios are developed. The cost of a specific demand management program will ultimately depend on the location, scale, and market conditions at the time the program is implemented. The outputs summarized in this report are intended to support PMA development for the GSP, and comparison of demand management with other projects and management actions. These cost estimates would be refined in the future and would be specific to each PMA. The final section in this appendix describes the general steps for this future analysis.

The cost of demand management depends on the location, scale, and timing of the program. For the purposes of this analysis, it was assumed that the timing of the program would be the GSP implementation period (2022 – 2042). The scale of the program (i.e., total volume of demand management achieved in each year) was developed over a range consistent with preliminary changes in groundwater storage shown in the initial GSP water budgets (see Chapter 3). Lastly, two alternatives were developed for the location of the program. The first alternative would apply Subbasin-wide and the second would target demand management to specific areas of concern near the Orland and Arbuckle areas in the Subbasin (as generally defined below).

The direct cost of demand management is estimated here as the loss of net return to irrigated lands and is expressed on a per acre-foot (AF) basis for comparison to other PMA costs. Costs were established in the Subbasin using a standard economic analysis that considers the water budget (e.g., quantity of water applied and consumed by Subbasin crops), costs and returns to farming, and current market conditions for major Subbasin crops. The results of the analysis show how the cost of demand management changes over an increasing scale of a potential program, and how those costs vary across different areas.

Reduced net return from crop production may, in turn, lead to secondary losses to other sectors within the local economy. The extent of such losses would depend on how irrigated agriculture on other lands changes. For example, if production shifts to other lands within the same regional economy (e.g., the broader Sacramento Valley), then regional secondary effects on input suppliers, trucking, processing, farm labor, and other businesses may be small. But if this does not occur, then secondary economic impacts may warrant more analysis and quantification. These secondary impacts have not been quantified in this appendix. In addition, this analysis does not quantify any additional administrative costs for the GSAs to develop and administer a demand management program. These indirect costs would be assessed as part of demand management program design in the future.

[1] Net groundwater pumping would be defined as part of the demand management program. In general, it would include crop ETAW plus any unrecoverable return flows.

Methods

The cost of demand management fundamentally depends on supply and demand for irrigation water. Examples of factors that affect supply include annual water year conditions, carry-over storage, CVP allocation, GSA costs, water supply costs, and other GSP implementation (e.g., PMAs). Examples of factors that affect demand include export and domestic market conditions for California crops that affect returns to farming and willingness to pay for water.

An economic model of the Subbasin was applied to evaluate the supply and demand for water and establish the cost of demand management. It reflects the local water supplies and uses, financial data on returns to farming, and current crop market conditions for Sacramento Valley crops. This includes current crop prices and yields. Production costs are representative averages based on University of California Cooperative Extension crop budgets. The model is calibrated to the GSP water budget (applied water and evapotranspiration of applied water) and geospatial land use data described in Chapter 3 of the GSP. A technical description of the economic calibration method is beyond the scope of this technical appendix. The method applied is a standard, peer-reviewed economic analysis approach that is widely applied for valuation of water supply and water supply projects in California[2]. This same technical approach was applied for calibration of an economic optimization model of the Subbasin.

The model quantifies the effect of changes in water supply availability and cost on farm income (e.g., net income and gross farm revenues) and simulates how the agricultural sector would respond to changes in water availability and cost. Responses include switching to higher value and/or lower water use crops, adjusting input use, and idling land. The decision to switch crops and/or idle land depends on agricultural market conditions simulated by the model under increasing levels of a range of (hypothetical) demand management. The economic analysis quantifies the direct economic cost of changing crops and idling land under implementation of demand reduction. For this technical appendix, costs are expressed on a per acre-foot basis for comparability to other PMAs in the GSP.

The analysis reflects average water supply conditions. That is, the results of the analysis are the incremental cost of demand management in an average water supply year, not under critical drought conditions, or conversely, years with above-average supplies. The framework can be extended to evaluate these factors as part of future program design.

The economic model is developed on a geospatial scale that can be refined to evaluate Subbasin-wide demand management and demand management in specific areas. Two “areas of concern” were defined in the model. Figure 2 illustrates areas of concern and crop types[3] in the economic model for the Subbasin. Areas of concern are more precisely defined based on hydrogeologic conditions that are described in Chapter 3 of the GSP. Areas shown below include two broad regions: North (around Orland) and South (between Williams and Arbuckle).

[2] See the following references for example:

Department of Water Resources. Water Plan Update. 2009. Data and Tools Technical Appendix. Economic Modeling of Agriculture and Water in California using the Statewide Agricultural Production Model.

U.S. Bureau of Reclamation. 2019. CVP Long Term Operations EIS. Appendix 12A: Statewide Agricultural Production Model (SWAP) Documentation.

[3] Crop types are aggregated into seven groups for map display purposes. The economic analysis has 20 crop types that better reflect the unique costs, returns, and markets for each crop.

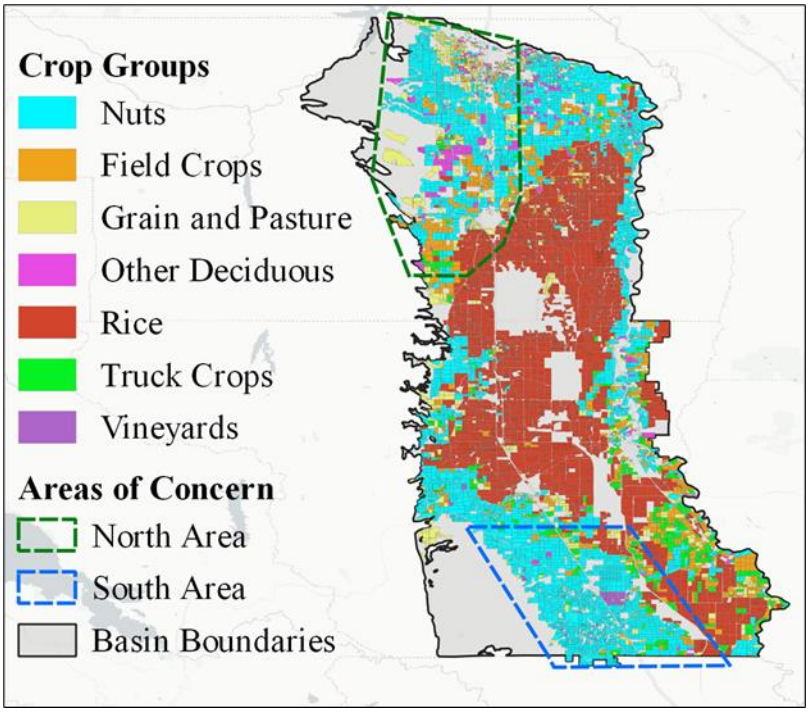


Figure 2. Colusa Subbasin Crops

Colusa Subbasin Demand Management Costs

This section summarizes the direct cost of demand management for the following alternatives:

- **Colusa Subbasin-wide demand management**. This assumes demand management would occur across the entire Subbasin. That is, demand management is not targeted to specific areas. The implicit assumption is that water can be moved (exchanged, conveyed, in-lieu) across the Subbasin.
- **Targeted demand management**. This assumes demand management would occur in specific areas defined as the North and South areas of concern.

For each alternative, the cost of demand management was estimated as the mix of crops that could be idled at the lowest loss in net return. This is based on the aggregate supply of the crops produced in the Subbasin evaluated as part of the economic analysis (i.e., the lowest net return is not a static accounting measure of the least profitable crop). This is the minimum cost of the demand management program, defined by the opportunity cost of water for the crops that would be idled (the net return that the water would have provided on those crops).

Costs of Demand Management Applied to Entire Colusa Subbasin

This section summarizes the results of the demand management costs for the scenario where demand management is applied broadly to the entire Subbasin.

Figure 3 illustrates the range of demand management costs over a program scale of 2,500 and 25,000 AFY reduction in irrigation water demand. The cost ranges from around $120 per AF at 2,500 AFY of demand management to $210 per AF at 25,000 AFY. These are the direct cost of idling land, inclusive of groundwater pumping cost. The analysis estimates that the lowest net return lands and crops would idle first (hence the low cost for the smallest scale program), with higher net return lands included as the program scale increases.

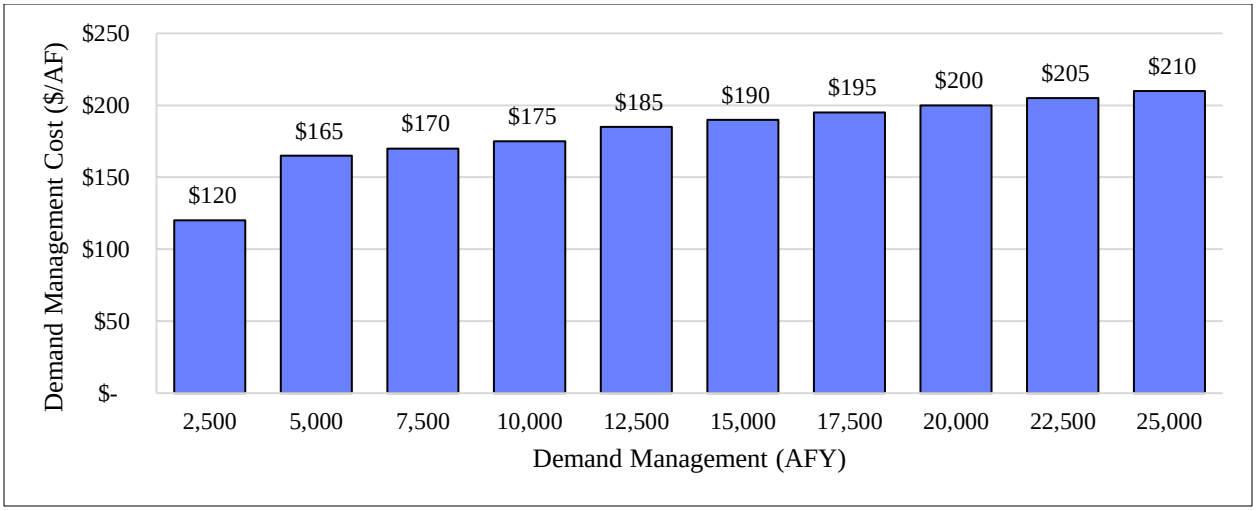


Figure 3. Costs of Demand Management Applied to Entire Subbasin

Costs of Demand Management Targeted to Areas of Concern

This section summarizes the results of the demand management costs for the scenario where demand management is targeted to two areas of concern. The specific lands are not identified. Rather, the demand management program is broadly defined for the general region.

Figure 4 illustrates the range of demand management costs for a demand management program between 1,250 and 12,500 AFY. The demand management volumes are specific to each region (e.g., 1,250 AFY in the north area and south area, separately). A smaller scale program for each region (up to 12,500 rather than 25,000 AFY) is shown because the total level of demand management is independent in each region. The cost ranges from $115 to $185 per AF in the north area of concern and $115 to $250 per AF in the south area of concern. These higher values reflect the crop mix in these areas – more permanent crops with less flexible water demand and higher-value annual crops. These are the direct cost of idling land, inclusive of groundwater pumping cost.

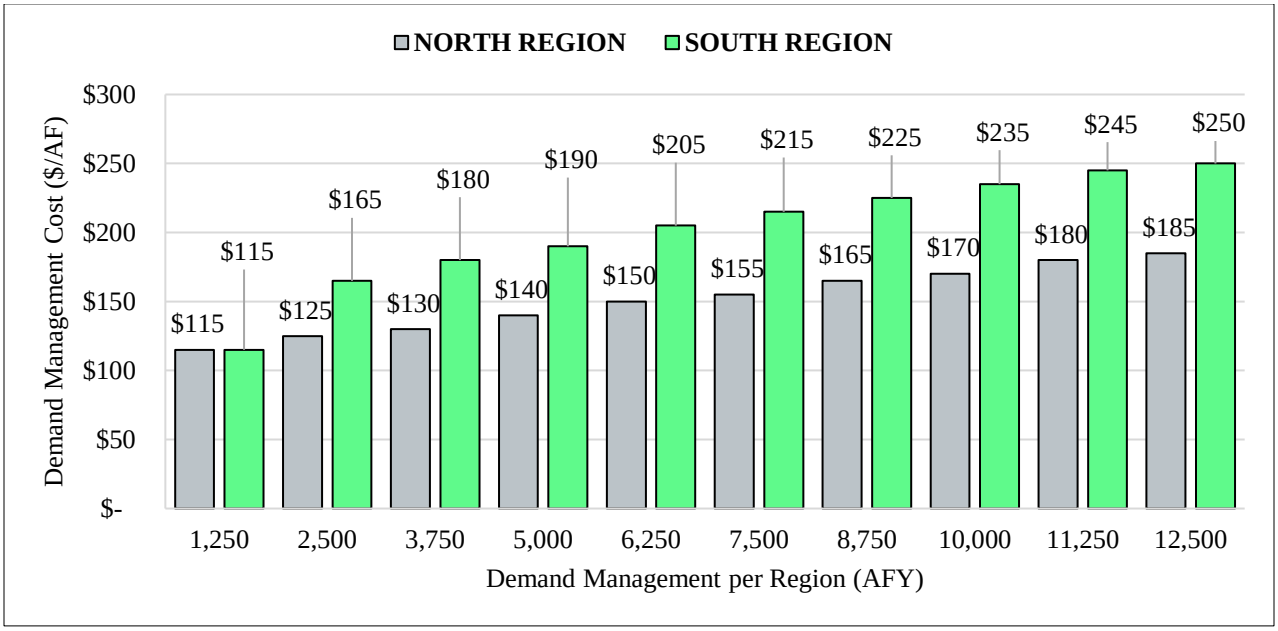


Figure 4. Costs of Demand Management Targeted to Areas of Concern

Groundwater Allocation Concepts

Demand management can be achieved without a groundwater allocation, so long as the program is able to quantify and verify the program demand management targets are achieved. However, an allocation can support implementation of a demand management program. It can also provide incentives for other PMAs (e.g., recharge) by defining the amount of groundwater available, and the additional quantities that would be associated with the development of new projects.

This section provides an overview of concepts and approaches related to allocation of groundwater in a Subbasin with diverse water users, water rights, and sources of recharge. It is not an allocation plan for the Subbasin, it is a discussion of the analysis that would be completed to set an allocation at a future date, if the GSAs decide to do so, either separately or together.

Introduction and Definitions

A groundwater allocation specifies quantities of groundwater available to groundwater pumpers, which for the purposes of GSP development would include irrigators in the Subbasin. According to the Sustainable Groundwater Management Act (SGMA) and its regulations, *de minimis* pumpers (defined as less than two AF per year) would not be limited by an allocation. This section provides a general overview of allocation approaches, technical considerations, and summary of economic implications of alternative approaches. It is not an allocation plan for the Subbasin and it does not address all necessary considerations for defining and implementing an allocation. Developing a specific allocation would require careful analysis of the legal, hydrogeologic, economic, and engineering implications, and would require vigorous and informed discussions with stakeholders.

Allocation involves setting an overall amount of permissible net groundwater extraction for the subbasin and the apportionment of that overall amount among pumpers. It is important to note that implementing an allocation does not necessarily result in reducing groundwater use. For example, if the allocation is greater than historical use and it is apportioned in a way that all pumpers receive more than their historical use, then the allocation would not constrain groundwater users and would not result in less consumptive groundwater use. In the context of GSP implementation, the first step – the overall allocation – is typically tied to the sustainable yield (defined below) of the Subbasin. The second step – apportioning the allocation among users – can be based on different factors related to, for example, land use, recent water use, location, and other policy goals. Apportionment of the overall allocation can be made to individual wells, parcels, farming operations, or other defined entities. When the sustainable yield (including yield of other PMAs like recharge projects) is less than current pumping, the effect of an allocation is an overall reduction in net groundwater use.

Allocation based on sustainable yield often considers the various components of the subbasin water balance that contribute to sustainable yield. This is useful because the components vary geographically across the basin, under future conditions, and PMAs may affect those components over time. Defining the different types of groundwater and components of sustainable yield typically involves substantial data, modeling, and stakeholder input. Sources of groundwater that can be included in the allocation can include native/natural recharge, percolation of water developed and imported into the basin, other intentional recharge, and net subsurface groundwater flow into the basin from/to adjacent areas. Some concepts used in discussing allocation are defined below:

- **Native/natural recharge**. Native or natural recharge is recharge that is from deep percolation of precipitation or losses through natural water ways and channels in the Subbasin. These are sources of groundwater recharge that do not rely on the action of any individual entity within the basin, although certain actions (e.g., conversion of native land to urban uses) can affect their quantity.

- **Imported/developed water recharge**. Imported or developed sources of groundwater recharge are a result of investments by specific entities in the subbasin. For example, groundwater recharge from unlined canals developed, and paid for, by a district to import and deliver surface water rights. This is considered separately from native/natural recharge because it would not have contributed to groundwater recharge in the Subbasin without the investments of the district. A substantial amount of the developed water recharge is percolation from applied irrigation of developed water supply, some occurs during conveyance of the developed water, and some is the result of projects designed specifically to recharge groundwater, either in dedicated recharge areas, spread over lands during uncropped or dormant periods of the season (Flood MAR)[4]. Another kind of recharge, in-lieu recharge, does not increase percolation but rather reduces or avoids the net extraction of groundwater by providing a replacement supply.
- **Net subsurface flow.** Groundwater flows laterally across the Subbasin boundaries to and from adjacent areas outside the subbasin, driven by the gradients resulting from groundwater elevation differences. Many subbasins have groundwater flowing both in from some adjacent areas and out to other adjacent areas. The net flows change over time according to changes in precipitation, land use, and groundwater management both in the subbasin and in adjacent areas.
- **Transitional pumping**. Transitional pumping is also referred to as planned depletion of groundwater storage. SGMA provides for GSAs to transition to sustainable yield over a period of twenty years. In areas where current groundwater extraction is greater than the sustainable yield, an allocation will need to be less than current groundwater use. PMAs typically require time to implement, during which time growers subject to an allocation must reduce pumping, for example, by switching crops or idling land. A gradual time path for adjustment helps lessen the economic costs of this type of adjustment. Transitional water is effectively an overdraft that, consistent with SGMA and the GSP, decreases to zero over time as extraction is brought into balance with recharge.

Time Dimension of Allocations

Allocation quantities are typically defined on an annual basis using long-run average components of the current and projected water balances. However, an allocation need not be the same every year; it can include transitional water that declines over time or it can be reduced or increased annually according to conditions, so long as on average it follows the path to sustainability laid out in the GSP. For example, the allocation can be increased in drought years to allow better conjunctive use of surface and groundwater, and then reduced in non-drought years to offset the increases in pumping in drought years. The yearly pattern of allocation could vary by subregion within the GSA (or subbasin) according to the situation. For example, lands fully dependent on groundwater may do better on a more consistent allocation, whereas lands with access to both ground and surface water might benefit from a variable allocation.

Another option to implement and manage a groundwater allocation is to allow growers to carryover some or all of their assigned allocation. The ability to carryover unused allocation may vary by different components. For example, unused natural recharge allocation may be carried over and used in subsequent years, but transitional pumping may not. In addition, carryover could be limited to a not-to-exceed amount each year, limited in the number of years an allocation carryover can be used, or even subject to annual "losses". The ability to "borrow" current pumping against next year's allocation could

[4] These sources of developed recharge are typically part of GSP PMAs, which can be included as separate categories of recharge under an allocation, but are discussed jointly here.

be considered. Essentially a carryover could be implemented like a bank account, where growers take responsibility to manage their account over time within the rules defined by the GSA.

The allocation can be and probably will be adjusted over time. Transitional allocation has already been described above. In addition, periodic reassessment of quantities will be made as more current data is acquired (e.g., as data gaps are filled), changes in hydrologic conditions (e.g., climate change) are observed, and PMAs are implemented.

Spatial Dimension of Allocations

An overall allocation is typically developed initially at a subbasin, or GSA-level based on the water balance. It is also possible to subdivide the GSA into smaller subareas or zones based on important variations in the components of an allocation, and with respect to groundwater conditions. For example, some zones may receive percolation from imported surface water that is included in their allocation, whereas other zones do not. Or some smaller areas may support and pay for a recharge project to boost their allocation while another zone does not need to do this. These kinds of differences can be easier to understand and manage if the allocation is built up from components rather than a single, annual amount.

Another possible rationale for subregional differences can involve sustainability criteria other than groundwater elevation. Groundwater dependent ecosystems, streamflow effects, and subsidence are examples of other conditions that may be considered in subregional allocations.

Apportionment of the Allocation

After the components of groundwater are defined and the overall allocation is determined (either for the entire GSA or for subareas), the next step in groundwater allocation is defining how to apportion the allocation among the irrigators in the subbasin.

Some important considerations include:

- **Allocation eligibility**. Once the volume for different components of a groundwater allocation is defined, it is necessary to determine which lands and users are eligible for an allocation and how specific volumes are assigned. This could vary by groundwater component. For example, native recharge could be allocated on a per acre basis to all eligible parcels in the subbasin. Transitional water could be allocated in the same manner, or it could be allocated based on historical use. The yield from a recharge project could be assigned according to proportionate contributions to the cost of the project. Allocations may also consider other non-consumptive uses, such as habitat benefits.
- **Non-irrigated parcels**. A topic of much discussion during development of many GSPs (and GSP implementation in Critically Overdrafted subbasins) is whether and how non-irrigated lands are included in the allocation. Non-irrigated parcels can include parcels that were never irrigated and parcels that were previously irrigated but are not currently irrigated. Never irrigated parcels may not be economically feasible to develop into irrigated agriculture, whereas currently unirrigated parcels may have been temporarily retired for various reasons. An allocation typically includes defining a point in time where a parcel is defined as non-irrigated (e.g., if it has not been irrigated since a specific date). Non-irrigated parcels may be eligible for some components of the groundwater allocation. This may include portions of the sustainable yield, but typically does not include any transitional water. Additional considerations may include lands near sensitive habitat areas.

Additional Considerations and Analysis

Developing a groundwater allocation should include consideration of legal, economic, engineering, hydrogeologic, and political considerations. In areas with both ground and surface water supplies, the ability to use them conjunctively can provide sufficient water (from delivered surface water and groundwater allocation) during droughts.

In areas where the groundwater allocation is less (and in some cases substantially less) than current groundwater use, there can be important economic implications for different allocation design approaches. An analysis to inform allocation development typically includes quantifying the economic implications of alternative groundwater allocation design approaches. This includes evaluating financial impacts to individual groundwater users (e.g., growers) as well as the regional economic implications.

Assigning quantities of groundwater available to individual pumpers can incentivize them to think about the costs and benefits of reducing their water use or developing new recharge opportunities. An allocation effectively creates a scarcity of groundwater, whereby the value of groundwater is driven by the economic value (net return) it can produce. Economic effects of an allocation depend on many factors, including: the size of the allocation relative to crop water demand (how limiting is the allocation); the sources, costs, and distribution of current and prospective surface supplies; and the flexibility allowed to growers in how they manage their allocation.

A strict allocation and apportionment are a rigid method for implementing demand management. They effectively limit water use on a well, parcel, or operation basis. Economic analysis can illustrate the advantages, both to individual growers and to the regional economy, of increasing the flexibility of allocations. Allowing growers to move their allocated groundwater freely (subject to some review) is one step to increase flexibility. Rather than allocating pumping to each well or parcel, a grower can make choices about distributing allocation among fields and crops, in maximize return, and reduce the costs of demand management. A more ambitious step is to allow growers to buy and sell allocation among themselves, using either short-term or long-term agreements. A number of other GSAs in California are currently evaluating and pilot-testing groundwater trading markets for this purpose.

Administering an Allocation

If a GSA, or subbasin, decides to adopt an allocation and defines the mechanism to calculate how to assign allocation to different individuals, entities, or wells, it must then monitor pumping and enforce the allocation. If carryover across years is allowed, the GSA must also track that and incorporate it in the annual water budget accounting. Most groundwater management entities outside the state use some form of measurement, including wellhead metering, to track allocations. In California, many GSAs are proposing or considering direct measurement or using crop type and/or ET calculations to estimate water use and groundwater pumping. Estimation versus measurement is a GSA policy decision that can have important effects on the cost and its ability to manage the allocation effectively.

Summary of Steps in Considering and Implementing an Allocation

1. Develop the key components of the GSP – baseline conditions, water budgets, criteria and thresholds, and PMAs.
2. Determine if an allocation is necessary and useful to achieve targets and implement PMAs, particularly demand management actions, effectively.

3. If an allocation is warranted, use data and analysis to evaluate, compare, and select allocation amounts and other characteristics that best meet the needs of the GSA.
4. Monitor conditions and pumping over time to verify the effectiveness of the allocation and to modify as needed.

Discussion

This appendix summarized an analysis of the cost of demand management for two hypothetical programs: one covering the entire Subbasin, and another targeted to two areas of concern. The cost of demand management is estimated as the loss in net return to farming. It does not include program administrative costs or any secondary impacts, and it does not consider what the market price for water would be under a local groundwater market. Secondary economic impacts should be considered in future iterations of this analysis to support implementation of PMAs.

Implementing an annual allocation can provide a strong impetus for growers to adopt demand management and may be a prerequisite for effective demand management in some cases. It is not clear that an allocation is warranted at this time for the Subbasin, though it may become more useful in the future. Developing a specific allocation would require careful analysis of the legal, hydrogeologic, economic, and engineering implications, and would require vigorous and informed discussion with stakeholders.

Future analysis of demand management program costs and allocation design would be specific to the program being considered in the Subbasin. For example, under the "targeted demand management" PMA summarized under Chapter 6 Section 6.5.2, the economic analysis would be developed for the regions that would participate in the program (both buyer and seller regions). This would define incentives to participate in the program. The general steps to define a demand management program costs include:

1. Define the location, scale, and timing of the program. Prepare economic data specific to the program areas and define any program-specific conditions that would affect participation.
2. If a groundwater allocation will be included, define the groundwater allocation approach and specify the allocation to lands/entities in the Subbasin. Prepare an economic analysis and hydrogeologic analysis of the impacts of alternative groundwater allocation designs.
3. Use the general method described above to quantify the direct cost of demand management in each area. The analysis would additionally consider the opportunity cost of water in other, non-farming, uses, such as a local or regional water transfer market. Market prices can exceed the values in irrigated agriculture in some years and would drive demand management program costs in these years.
4. Evaluate potential secondary economic impacts, and to whom those impacts may occur. Also consider any benefits associated with the program, and to whom those benefits accrue. For example, this may include broader groundwater level benefits in the area, and regions down-gradient. Monetize any anticipated secondary economic impacts and benefits.
5. Use the results of the steps above to develop an appropriate incentive structure (accounting of costs and benefits) that would support demand management program design. See Section 6.5.2 of GSP Chapter 6 for a summary of different types of potential demand management programs.

Appendix 6C

Overview of Projects and Management Actions

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Specialists in Agricultural Water Management

Technical Memorandum

To: Glenn and Colusa County Groundwater Authorities

From: Davids Engineering

Date: November 19, 2021

Subject: **Overview of Projects and Management Actions**

Introduction

More than 30 projects and management actions (PMAs) are included in the Colusa Subbasin GSP to achieve and maintain sustainable groundwater conditions in the Colusa Subbasin (Subbasin). PMAs are categorized and presented in this appendix according to the current status of implementation and development:

- **Planned Projects and Management Actions** are PMAs that the GSAs or other project proponents are working to implement that will support sustainable groundwater management in the Subbasin, and mitigate historical and current drought effects. Five projects are currently planned for implementation, all of which are groundwater recharge projects that use surface water for direct and/or in-lieu recharge.
- **Ongoing Projects and Management Actions** are PMAs that are ongoing and will support sustainable groundwater management in the Subbasin. In accordance with 23 CCR §354.44(a), these are PMAs that would allow GSAs to achieve the sustainability goal for the Subbasin and avoid reaching the minimum thresholds defined in this GSP under future, changing conditions. Six PMAs are currently ongoing in the Subbasin.
- **Potential Projects and Management Actions** are PMAs that may be implemented if necessitated by groundwater conditions in the Subbasin. These may have been studied by the project proponent or in earlier regional water planning documents, but most project design, cost estimates, and planning work have yet to be completed, and would only be initiated if the project is eventually triggered for implementation as a result of continued monitoring of groundwater conditions. There are more than 20 potential PMAs proposed for the Subbasin.

Each of the PMAS are designed to support the long-term sustainability of groundwater resources of the Subbasin. The information currently available for each of these PMAs is provided in Tables 1 through 6 below. These tables summarize the following information:

- Table 1. Brief Description of all Projects and Management Actions
- Table 2. Project Type, Category, Proponent, and Location for all Projects and Management Actions.
- Table 3. Implementation Criteria, Notice Process, Permitting and Regulatory Process, and Timeline for all Projects and Management Actions.
- Table 4. Anticipated Benefits of all Projects and Management Actions.
- Table 5. Benefit Evaluation and Water Source for all Projects and Management Actions.

- Table 6. Legal Authority Requirements, Estimated Cost, and Potential Funding Sources for all Projects and Management Actions.

The fields in these tables have been designed to meet the requirements for PMAs as described in the California Code of Regulations (CCR); when applicable, a reference to a specific CCR location is provided as the first row of each table.

Table 1. Brief Description of all Projects and Management Actions.

CCR § 354.44	CCR §354.44(a)
Project/Management Action Name	**Brief Project Description**
Planned	
Colusa County Water District (CCWD) In-Lieu Groundwater Recharge	CCWD will utilize up to an additional 30 thousand acre-feet (taf) of surface water for irrigation in all years but Shasta Critical years for in-lieu recharge (an average of 27 taf per year). The additional surface water will be made available through full use of the CCWD's existing CVP contract and annual and multi-year water purchase and transfer agreements. The additional water will be conveyed through the existing Tehama-Colusa Canal (TCC) and CCWD facilities. It is expected to be used on existing district lands, though as an optional component of this project CCWD is considering relatively small annexations of lands adjoining the district and supplying surface water to these lands (currently dependent on groundwater, requiring additional infrastructure for surface water delivery), resulting in in-lieu groundwater recharge through reduction of groundwater pumping.
Colusa Drain MWC (CDMWC) In-Lieu Groundwater Recharge	CDMWC encompasses approximately 46,000 acres of agricultural land and environmental habitat adjacent to the Colusa Basin Drain (Drain). Shareholders in CDMWC divert water for summer irrigation from the drain under a combination of appropriative water rights held individually by the shareholders, a long-term service supply agreement with USBR and annual and multi-year transfer agreements with neighboring USBR settlement contractors. Historically, many CDMWC diverters use both groundwater and surface water for summer irrigation because physical supplies of water in the Colusa Drain are often unreliable and insufficient to satisfy those irrigation requirements. This project would provide additional surface supplies averaging approximately 28 taf per year, allowing CDMWC diverters to increase their diversions of surface water from the Drain to provide in-lieu groundwater recharge and decrease groundwater pumping by an equal amount.
Colusa Subbasin Multi-Benefit Groundwater Recharge	The Nature Conservancy (TNC) is partnering with growers and the Colusa and Glenn Groundwater Authorities for an on-farm, multi-benefit groundwater recharge incentive program. Program objectives are to benefit disadvantaged communities and other communities in the Subbasin by replenishing critical domestic and agricultural water supplies, growers economically through incentive payments, migratory shorebirds through the creation of critical winter habitat on farms, and groundwater conditions (via groundwater recharge). Surface water from the Sacramento River, subject to availability, is conveyed to and applied to flood and maintain ponds on selected fields using existing diversion, conveyance, and on-farm infrastructure. The pilot program was initiated in Colusa County in 2018 and concluded in the spring of 2021, with plans to expand and continue into the future. DWR will be participating in the Colusa Subbasin Multi-Benefit Groundwater Recharge project as it is expanded into a larger program.

Table 1. Brief Description of all Projects and Management Actions.

CCR § 354.44	CCR §354.44(a)
Project/Management Action Name	**Brief Project Description**
Orland-Artois Water District (OAWD) Land Annexation and Groundwater Recharge	OAWD is working with a group of neighboring non-district landowners to annex approximately 12,000 acres of groundwater-dependent agriculture into the district. Surface water for the annexed lands would be secured through multi-year purchase or transfer agreements with willing sellers, conveyed through the existing TCC, and distributed to the annexed lands through new distribution facilities. It is estimated that a long-term average of approximately 23 taf per year of surface water would be available, reducing groundwater pumping by 23 taf per year. Additionally, certain annexed lands with high infiltration characteristics would be configured for direct recharge by surface spreading, primarily using Section 215 water. Preliminary project design shows seven proposed recharge areas totaling 371 acres in the project. OAWD is evaluating recharge potential and will refine these estimates. The direct recharge capacity has not yet been estimated. This project will address an area within the Subbasin where groundwater levels have been in decline in recent years due to drought and increasing water demands being met through increasing groundwater pumping.
Sycamore Slough Groundwater Recharge Pilot Project	Proctor and Gamble (P&G) and Davis Ranches have entered into a cooperative agreement to implement a 10-year groundwater recharge pilot project. The project will apply surface water diverted from the Sacramento River to a 66-acre field on Davis Ranches for groundwater recharge and to provide habitat for migrating shorebirds for 30 to 45 days during the fall or winter each year. The timing of the project may be targeted to provide fall and winter habitat for migratory shorebirds, in addition to groundwater recharge benefits. However, the precise timing of the project is flexible to accommodate changes in water availability and other factors between years. Sacramento River water is available to Davis Ranches under riparian rights and a Sacramento River settlement contract with Reclamation. If the project starts before November 1, settlement contract water would be used. Otherwise, riparian water rights would be exercised for beneficial use (habitat). The goal is to recharge 5,000 af over the 10-year study period and to revegetate a portion of Sycamore Slough. Monitoring of groundwater conditions will be done in eight existing groundwater wells, including dedicated monitoring wells and production wells. If the project is successful and cost effective, it could be continued in perpetuity to sustain long-term groundwater recharge and environmental benefits. Subject to acquisition of funding, an expansion of the project is planned for recharge and revegetation in the neighboring Sycamore and Dry Sloughs.

Table 1. Brief Description of all Projects and Management Actions.

CCR § 354.44	CCR §354.44(a)
Project/Management Action Name	**Brief Project Description**
Ongoing	
Reclamation District 108 (RD 108) and Colusa County Water District (CCWD) Agreement for Five-Year In-Lieu Groundwater Recharge Project	CCWD (and Dunnigan Water District [DWD] located in the Yolo Groundwater Subbasin) purchase surface water from RD108 for distribution within their service areas under a five-year agreement, expiring after 2022. Under the five-year agreement, 10,000 af is purchased by and transferred to CCWD and DWD, with 80 percent to CCWD and 20 percent to DWD. This project supplies additional surface water to CCWD and DWD that provides in-lieu recharge to meet water demands that otherwise would be met through groundwater pumping.
Glenn-Colusa Irrigation District (GCID) Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits	GCID holds a 1999 water right permit to divert Sacramento River water for irrigation and rice straw decomposition between November 1 and March 31; water used under the permit is referred to as "winter water." The potential exists to increase the groundwater recharge and habitat enhancement benefits of winter water use by increasing winter use for rice straw decomposition, winter irrigation, and frost control provided that certain constraints can be alleviated. Under this project, working in collaboration with partners within the subbasin and with environmental advocacy groups, GCID will investigate opportunities to increase winter water use by alleviating these constraints.
Sycamore Marsh Farm Direct Recharge Project	Sycamore Marsh Farm has been in process of developing a groundwater recharge plan to store water in our aquifer by several different methods. The plan provides for 205 acres of year-round recharge basins and 163 additional acres of winter recharge areas.
Glenn-Colusa Irrigation District (GCID) Expansion of In-Basin Program for In-lieu Groundwater Recharge	In cooperation with Reclamation, GCID has developed temporary arrangements to supply district surface water to neighboring non-district agricultural lands that primarily use groundwater. These temporary arrangements were implemented under agreements that recently expired in 2020. There is interest in continuing and expanding this in-basin surface water use. GCID is currently working in cooperation with Reclamation to renew these agreements and expand this program for the purpose of reducing groundwater pumping and in-lieu groundwater recharge.
Orland Unit Water Users Association (OUWUA) Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping	Continue the modernization of the association's southside irrigation conveyance and distribution system; these improvements are expected to result in more reliable and flexible farm deliveries that will provide incentive for growers to use more surface water and less groundwater.
Urban Water Conservation in Willows	California Water Service - Willows District is implementing urban water conservation measures through water waste prevention ordinances, metering, conservation pricing, public education and outreach, programs to assess and manage distribution system real loss, water conservation program coordination and staffing support, and other demand management measures. These are described in greater detail in Chapter 9 of the 2020 UWMP for California Water Service - Willows District.

Table 1. Brief Description of all Projects and Management Actions.

CCR § 354.44	CCR §354.44(a)
Project/Management Action Name	**Brief Project Description**
Potential	
Colusa County Public Water System Water Treatment Plant	Construct a water treatment plant on the Sacramento River between Colusa and Grimes to provide fresh drinking water to public water supply systems in Colusa and possibly Sutter and Yolo Counties.
Delevan Pipeline Colusa Basin Drain Intertie	Construct an intertie between the proposed Delevan Pipeline component of the Sites Reservoir Project and the Colusa Basin Drain. Currently, the only proposed intertie is the Dunnigan intertie. This intertie will provide a connection to downstream water users to utilize surface water storage from Sites Reservoir, improve conjunctive use, and potentially decrease groundwater pumping. This intertie will also provide protection for the ecosystems upstream of the proposed Dunnigan intertie and redundancy in case the TCC becomes inoperable due to subsidence or earthquake damage.
Sycamore Slough Colusa Basin Drain Multi-Benefit Recharge Project	Restoration of portions of Sycamore Slough through voluntary landowner participation in a multi-benefit recharge project. The recharge site will be hosted by Davis Ranches, a participating landowner within the Sycamore Mutual Water Company service. Water would be sourced from the Sacramento River during high flows in the system. The Sycamore Mutual Water Company is a Sacramento River Settlement Contractor, and could use a portion of its settlement contract water supplies for recharge if the project is initiated prior to November 1. If the project is initiated after November 1, water could be accessed using existing riparian water rights exercised for beneficial use (habitat). Field flooding would provide recharge, restoration, and multi-benefits such as winter floodplain habitat for migrating shorebirds/waterfowl, or habitat restoration for monarch butterflies and other pollinator species. Excess flows in winter could be diverted from the Colusa Basin Drain for recharge, and restoration could include a multi-benefit focus with environmental benefits such as habitat restoration for monarch butterfly or other pollinator species.
Tehama-Colusa Canal (TCC) Trickle Flow to Ephemeral Streams	The TCC has existing gates that are used to dewater sections of the canal. The gates discharge into ephemeral streams that intersect the canal. Water could be discharged from the TCC into these streams at a rate where they do not flow out of the subbasin, but recharge the groundwater system. Flow measurement devices would need to be added to the gates. Surface water for recharge would be Sacramento River available water under existing Bureau of Reclamation water supply contracts held by TCC contractors, existing water rights settlement contracts, and annual Section 215 contracts.
Westside Streams Diversion for Direct or In-lieu Groundwater Recharge	There are a number of ephemeral streams that originate in the Coastal Range to the west of the Subbasin and flow eastward into the Subbasin. During periods of flow in the winter and spring, a portion of these flows could be diverted for either (1) off-stream storage and subsequent use for irrigation or (2) direct groundwater recharge through Flood-MAR, dedicated recharge basins, or modified stream beds.
Reduce Non-beneficial Evapotranspiration/Invasive Species Eradication (Arundo, Eucalyptus, Tamarisk, etc.)	Removal of invasive, non-native plant species (i.e., arundo donax, eucalyptus, tamarisk, etc.) from riparian corridors, and other areas they may be present, will provide both a reduction in evapotranspiration from shallow groundwater and native ecosystem restoration.

Table 1. Brief Description of all Projects and Management Actions.

CCR § 354.44	CCR §354.44(a)
Project/Management Action Name	**Brief Project Description**
Enhanced Infiltration of Precipitation on Agricultural Lands	Current cultural practices, particularly in almond orchards, tend to reduce infiltration and increase runoff of precipitation. Development and adoption of on-farm cultural practices to reduce precipitation runoff and increase infiltration would result in increased storage of precipitation in the crop root zone, thereby reducing irrigation water requirements. Additionally, to the extent that infiltrated precipitation percolates through the root zone, this would result in direct groundwater recharge. This project is proposed as a potential research management action, for example, a collaborative initiative between the GSAs and other interested organizations.
Colusa Subbasin Flood-MAR	The CGA and GGA, in coordination with landowners and other agencies, would investigate, develop, and implement a program to divert flood waters within the Subbasin, when available, for spreading across agricultural lands or other working landscapes for direct groundwater recharge.
Reclamation District 108 "Boards In" Program	RD108 would institute a voluntary or financially incentivized program in which landowners leave their spill board in place during the winter to capture rainfall and hold it on the fields for recharge.
Glenn-Colusa Irrigation District (GCID) In-lieu Groundwater Recharge	Despite GCID having highly reliable surface water supplies, a small percentage of district lands rely primarily on groundwater for irrigation supply. GCID will investigate, develop, and implement measures to incentivize associated growers to utilize surface water supplied by GCID, which will provide in-lieu recharge through reduced groundwater pumping.
Glenn-Colusa Irrigation District (GCID) Water Transfers to TCCA CVP Contractors	GCID is exploring the possibility of transferring surface water to Central Valley Project (CVP) contractors served by the Tehama Colusa Canal to provide in-lieu groundwater recharge and reduce groundwater pumping. Transferred water would be diverted into the TCC at the Red Bluff Pumping Plant and Fish Screen facility rather than at the GCID pumping plant and fish screen facility north of Hamilton City.
Orland-Artois Water District (OAWD) Direct Groundwater Recharge	OAWD would directly recharge groundwater through Managed Aquifer Recharge (MAR) on agricultural land to improve aquifer conditions, especially in the groundwater cone of depression to the west of Artois. A pilot project for MAR was conducted in 2017 on the VanTol site using water from a Section 215 Temporary Water Contract from USBR. Section 215 water is low-cost, but is only available during high flow conditions in rivers and streams.
Orland Unit Water Users Association (OUWUA) Flood Water Conveyance	During periods of high flow and reservoir release on Stony Creek, divert water at OUWUA's south diversion and convey it to various locations for direct recharge within the OUWUA service area.
Sites Reservoir	The Sites Project would utilize existing infrastructure to divert unregulated and unappropriated flow from the Sacramento River at Red Bluff and Hamilton City and convey water to a new off stream reservoir west of the town of Maxwell. New and existing facilities would move water into and out of the reservoir. Depending on project operation and yield, there is potential for groundwater benefits to accrue to the Subbasin using water from Sites Reservoir.

Table 1. Brief Description of all Projects and Management Actions.

CCR § 354.44	CCR §354.44(a)
Project/Management Action Name	**Brief Project Description**
Colusa Subbasin In-lieu Recharge & Banking Program	Incentivize landowners to take surplus contract surface water in-lieu of pumping groundwater. A predetermined portion of the additional water brought into the districts would be dedicated to contributing to local groundwater sustainability and some portion of the remaining quantities would be available for delivery, directly or by exchange, to South Valley members in the San Joaquin Valley.
Sycamore Marsh Farm In-lieu Recharge Project	Sycamore Marsh Farm is in the process of developing an in-lieu groundwater recharge plan. Sycamore Marsh Farm encompasses approximately 420 acres in the Colusa Drain Mutual Water Company (CDMWC) and has an additional 449 acres that could potentially be annexed into the CDMWC, allowing for diversion of surface water from CDMWC.
Westside Off-stream Reservoir and In-Lieu Groundwater Recharge	TCCA Contractors would construct off-stream surface reservoirs along the western edge of the Subbasin and up-slope from the TCC diverting surplus Sacramento River flows (e.g., Section 215 water) into these storage reservoirs. Stored water would be released into the TCC for irrigation supply to enable reduction of groundwater pumping (i.e. in-lieu groundwater recharge). New facilities on the TCC and new storage impoundments would need to be planned, designed and constructed subject to a determination of economic and environmental feasibility.
Domestic Well Mitigation Program	Groundwater level measurable objectives (MOs) adopted for sustainable management of the Subbasin operation should be highly protective of domestic water supply wells. However, it is possible that in certain portions of the Subbasin, groundwater levels will fall. Projects and management actions will be implemented for recovery of groundwater levels, but some domestic wells may go dry. To mitigate the effects of domestic well stranding due to groundwater level decline, the CGA and GGA will investigate implementing domestic well mitigation programs in their respective portions of the subbasin.
Strategic Short-Term Demand Management	The program would be focused in specific local areas with sustainability challenges and would provide GSAs with a voluntary, flexible, short-run response to alleviate impacts of drought. It would be voluntary and provide financial incentives (payments) to encourage participation. Payment terms and other conditions would be specified as part of program design. Two potential structures for the program are idling lands in drought-affected areas of the subbasin with groundwater sustainability challenges or idling lands in participating surface water-using portions of the Subbasin and conveying the saved surface water to the drought-affected areas with groundwater sustainability challenges.
Long-Term Demand Management Action	Demand management broadly refers to any water management activity that reduces the consumptive use of irrigation water. A demand management action is one that incentivizes, enables, or possibly requires water users to reduce their consumptive use.
Well Abandonment Outreach and Funding Program	The CGA and GGA will coordinate with Colusa and Glenn counties, respectively, to create a program providing outreach and education to landowners regarding the proper procedures for well decommissioning and abandonment, as well as a funding source to assist landowners with these procedures. This program is anticipated to improve the subbasin well inventory and potentially have water quality benefits, as improperly abandoned wells are a potential point source for water quality contaminant transport from the ground surface to the underlying groundwater system.

Table 1. Brief Description of all Projects and Management Actions.

CCR § 354.44	CCR §354.44(a)
Project/Management Action Name	**Brief Project Description**
Preservation of Lands Favorable for Recharge	The CGA and GGA will coordinate with those agencies having authority over land use planning in and Glenn counties, respectively, to investigate, design, and implement a program providing incentives to landowners with lands favorable to groundwater recharge to preserve them as agricultural or undeveloped lands on which groundwater recharge will be possible in perpetuity.
Review of County Well Permitting Ordinances	Review and revise the county well permitting processes in the Subbasin to ensure that future well permitting aligns with the Subbasin sustainability goal and that future changes to well permitting are reviewed by the GSAs. The GSAs would work with the counties to review and suggest revisions to ordinances (these are outside of the jurisdiction of the GSAs).
Drought Contingency Planning for Urban Areas	The CGA and GGA will coordinate with cities, towns and other municipal and industrial water suppliers, which are all fully dependent on groundwater in the Subbasin, to encourage drought contingency planning and drought preparedness in a manner consistent with sustainable groundwater management according the GSP.
Development of a Dedicated Network of Shallow Monitoring Wells for GDE Monitoring	Evaluate and develop a dedicated network of shallow monitoring wells specifically planned and sited for monitoring conditions in areas of the Subbasin where GDEs are most likely to be found. This action is also expected to incorporate biological monitoring to inform the location of new shallow monitoring wells and monitor whether GDEs are being impacted by changing groundwater conditions

Table 2. Project Type, Category, Proponent, and Location for all Projects and Management Actions.

CCR § 354.44				
Project/Management Action Name	**Project Type**	**Project GSP Category (Planned, Ongoing, or Potential)**	**Project Proponent**	**Project Location**
Planned				
Colusa County Water District In-Lieu Groundwater Recharge	In-lieu Groundwater Recharge	Planned	CCWD	CCWD
Colusa Drain MWC In-Lieu Groundwater Recharge	In-lieu Groundwater Recharge	Planned	CDMWC	CDMWC
Colusa Subbasin Multi-Benefit Groundwater Recharge	Direct Groundwater Recharge	Planned	CGA, GGA and TNC	Colusa County
Orland-Artois Water District Land Annexation and Groundwater Recharge	Direct and In-lieu Groundwater Recharge	Planned	OAWD	OAWD
Sycamore Slough Groundwater Recharge Pilot Project	Direct Groundwater Recharge	Planned	Davis Ranches	Sycamore Slough
Ongoing				
Reclamation District 108 and Colusa County Water District Agreement for Five-Year In-Lieu Groundwater Recharge Project	In-lieu Groundwater Recharge	Ongoing	RD108 and CCWD	CCWD
Glenn-Colusa Irrigation District Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits	Direct and In-lieu Groundwater Recharge	Ongoing	GCID	GCID
Sycamore Marsh Farm Direct Recharge Project	Direct Groundwater Recharge	Ongoing	Sycamore Marsh Farm	Sycamore Marsh Farm
Glenn-Colusa Irrigation District Expansion of In-Basin Program for In-lieu Groundwater Recharge	In-lieu Groundwater Recharge	Ongoing	GCID	GCID and Neighboring Areas

Table 2. Project Type, Category, Proponent, and Location for all Projects and Management Actions.

CCR § 354.44				
Project/Management Action Name	**Project Type**	**Project GSP Category (Planned, Ongoing, or Potential)**	**Project Proponent**	**Project Location**
Orland Unit Water Users Association Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping	In-lieu Groundwater Recharge	Ongoing	OUWUA	OUWUA
Urban Water Conservation in Willows	Management Action	Ongoing	California Water Service - Willows District	Willows
Potential				
Colusa County Public Water System Water Treatment Plant	In-lieu Groundwater Recharge	Potential	Ben King (stakeholder)	Colusa County
Delevan Pipeline Colusa Basin Drain Intertie	Direct and In-lieu Groundwater Recharge	Potential	Ben King (stakeholder)	Intersection of Colusa Basin Drain and Proposed Delevan Pipeline
Sycamore Slough Colusa Basin Drain Multi-Benefit Recharge Project	Direct Groundwater Recharge	Potential	Ben King (stakeholder)	Sycamore Slough (Davis Ranches)
Tehama-Colusa Canal Trickle Flow to Ephemeral Streams	Direct Groundwater Recharge	Potential	Bill Vanderwaal (RD 108)	At TCC and ephemeral stream crossings
Westside Streams Diversion for Direct or In-lieu Groundwater Recharge	Direct and In-lieu Groundwater Recharge	Potential	CGA and GGA	Colusa and Glenn Counties
Reduce Non-beneficial Evapotranspiration/Invasive Species Eradication (Arundo, Eucalyptus, Tamarisk, etc.)	Reduce Groundwater Demand	Potential	CGA and GGA	Subbasin-wide
Enhanced Infiltration of Precipitation on Agricultural Lands	Direct Groundwater Recharge	Potential	CGA and GGA	Subbasin-wide
Colusa Subbasin Flood-MAR	Direct Groundwater Recharge	Potential	CGA and GGA	Subbasin-wide

Table 2. Project Type, Category, Proponent, and Location for all Projects and Management Actions.

CCR § 354.44				
Project/Management Action Name	**Project Type**	**Project GSP Category (Planned, Ongoing, or Potential)**	**Project Proponent**	**Project Location**
Reclamation District 108 "Boards In" Program	Direct Groundwater Recharge	Potential	Bill Vanderwaal (RD 108)	RD108 / Subbasin-wide
Glenn-Colusa Irrigation District In-lieu Groundwater Recharge	In-lieu Groundwater Recharge	Potential	GCID	GCID
Glenn-Colusa Irrigation District Water Transfers to TCCA CVP Contractors	In-lieu Groundwater Recharge	Potential	GCID	Participating TCCA CVP Contractors
Orland-Artois Water District Direct Groundwater Recharge	Direct Groundwater Recharge	Potential	OAWD	OAWD
Orland Unit Water Users Association Flood Water Conveyance	Direct Groundwater Recharge	Potential	OUWUA	OUWUA
Sites Reservoir	Direct and In-lieu Groundwater Recharge	Potential	Sites Project Authority	Antelope Valley (to west of Colusa Subbasin)
Colusa Subbasin In-lieu Recharge & Banking Program	In-lieu Groundwater Recharge	Potential	South Valley Water Resources Authority	Within any districts willing to participate
Sycamore Marsh Farm In-lieu Recharge Project	In-lieu Groundwater Recharge	Potential	Sycamore Marsh Farm	Sycamore Marsh Farm
Westside Off-stream Reservoir and In-Lieu Groundwater Recharge	In-lieu Groundwater Recharge	Potential	TCCA Contractors	Participating TCCA CVP Contractors
Domestic Well Mitigation Program	Management Action	Potential	CGA and GGA	Subbasin-wide
Strategic Short-Term Demand Management	Management Action	Potential	CGA and GGA	Subbasin-wide
Long-Term Demand Management Action	Management Action	Potential	CGA and GGA	Subbasin-wide
Well Abandonment Outreach and Funding Program	Management Action	Potential	CGA and GGA	Subbasin-wide

Table 2. Project Type, Category, Proponent, and Location for all Projects and Management Actions.

CCR § 354.44				
Project/Management Action Name	**Project Type**	**Project GSP Category (Planned, Ongoing, or Potential)**	**Project Proponent**	**Project Location**
Preservation of Lands Favorable for Recharge	Management Action	Potential	CGA and GGA	Subbasin-wide
Review of County Well Permitting Ordinances	Management Action	Potential	CGA and GGA	Subbasin-wide
Drought Contingency Planning for Urban Areas	Management Action	Potential	CGA, GGA, and cities (GSA member agencies)	Subbasin-wide
Development of a Dedicated Network of Shallow Monitoring Wells for GDE Monitoring	Management Action, Closing Data Gaps	CGA and GGA	CGA and GGA	Subbasin-wide

Table 3. Implementation Criteria, Notice Process, Permitting and Regulatory Process, and Timeline for all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(1)(A)	CCR §354.44(b)(1)(B)	CCR §354.44(b)(3)	CCR §354.44(b)(4)		
Project/Management Action Name	**Implementation and Termination Timing/Criteria for Implementation**	**Public and/or Inter-Agency Notice Process**	**Required Permitting and Regulatory Process or Status of Permitting**	**Current Status (Ongoing, Planned, Potential or Concept)**	**Anticipated Start Date (Year)**	**Anticipated Completion Date (Year)**
Planned						
Colusa County Water District In-Lieu Groundwater Recharge	Planning currently ongoing; no construction of new facilities needed.	See Note 2 below	See Note 4 below	Planned	2022	See note 6 below
Colusa Drain MWC In-Lieu Groundwater Recharge	Planning currently ongoing	See Note 3 below	See Note 5 below	Planned	See Note 6 below	See Note 6 below
Colusa Subbasin Multi-Benefit Groundwater Recharge	Planning currently ongoing	See Note 2 below	See Note 4 below	Planned (pilot project complete)	2021	See Note 6 below
Orland-Artois Water District Land Annexation and Groundwater Recharge	Planning currently ongoing; intent is to proceed expeditiously to design and construction of new facilities	See Note 2 below	See Note 4 below	Planned	2020	2025
Sycamore Slough Groundwater Recharge Pilot Project	See Note 1 below	See Note 3 below	See Note L2 below	Planned	See Note 6 below	See Note 6 below
Ongoing						
Reclamation District 108 and Colusa County Water District Agreement for Five-Year In-Lieu Groundwater Recharge Project	See Note 1 below	See Note 3 below	See Note 5 below	Ongoing and Planned	See Note 6 below	See Note 6 below
Glenn-Colusa Irrigation District Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits	Currently ongoing	See Note 2 below	See Note 4 below	Ongoing	2021	See Note 6 below
Sycamore Marsh Farm Direct Recharge Project	Currently ongoing	See Note 2 below	See Note 4 below	Ongoing	2020	See Note 6 below

Table 3. Implementation Criteria, Notice Process, Permitting and Regulatory Process, and Timeline for all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(1)(A)	CCR §354.44(b)(1)(B)	CCR §354.44(b)(3)	CCR §354.44(b)(4)		
Project/Management Action Name	**Implementation and Termination Timing/Criteria for Implementation**	**Public and/or Inter-Agency Notice Process**	**Required Permitting and Regulatory Process or Status of Permitting**	**Current Status (Ongoing, Planned, Potential or Concept)**	**Anticipated Start Date (Year)**	**Anticipated Completion Date (Year)**
Glenn-Colusa Irrigation District Expansion of In-Basin Program for In-lieu Groundwater Recharge	Currently ongoing	See Note 2 below	See Note 4 below	Ongoing	2021	See Note 6 below
Orland Unit Water Users Association Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping	See Note 1 below	See Note 3 below	See Note 5 below	Ongoing	See Note 6 below	See Note 6 below
Urban Water Conservation in Willows	Currently ongoing	See Note 2 below	See Note 4 below	Ongoing	2016	See Note 6 below
Potential						
Colusa County Public Water System Water Treatment Plant	See Note 1 below	See Note 3 below	See Note 5 below	Potential	See Note 6 below	See Note 6 below
Delevan Pipeline Colusa Basin Drain Intertie		See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below
Sycamore Slough Colusa Basin Drain Multi-Benefit Recharge Project		See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below
Tehama-Colusa Canal Trickle Flow to Ephemeral Streams		See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below
Westside Streams Diversion for Direct or In-lieu Groundwater Recharge	See Note 1 below	See Note 3 below	See Note 5 below	Potential	See Note 6 below	See Note 6 below
Reduce Non-beneficial Evapotranspiration/Invasive Species Eradication (Arundo, Eucalyptus, Tamarisk, etc.)	See Note 1 below	See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below

Table 3. Implementation Criteria, Notice Process, Permitting and Regulatory Process, and Timeline for all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(1)(A)	CCR §354.44(b)(1)(B)	CCR §354.44(b)(3)	CCR §354.44(b)(4)		
Project/Management Action Name	**Implementation and Termination Timing/Criteria for Implementation**	**Public and/or Inter-Agency Notice Process**	**Required Permitting and Regulatory Process or Status of Permitting**	**Current Status (Ongoing, Planned, Potential or Concept)**	**Anticipated Start Date (Year)**	**Anticipated Completion Date (Year)**
Enhanced Infiltration of Precipitation on Agricultural Lands	See Note 1 below	See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below
Colusa Subbasin Flood-MAR	See Note 1 below	See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below
Reclamation District 108 "Boards In" Program	See Note 1 below	See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below
Glenn-Colusa Irrigation District In-lieu Groundwater Recharge	See Note 1 below	See Note 3 below	See Note 5 below	Potential	See Note 6 below	See Note 6 below
Glenn-Colusa Irrigation District Water Transfers to TCCA CVP Contractors	See Note 1 below	See Note 3 below	See Note 5 below	Potential	See Note 6 below	See Note 6 below
Orland-Artois Water District Direct Groundwater Recharge	See Note 1 below	See Note 2 below	See Note 4 below	Concept (pilot project complete)	See Note 6 below	See Note 6 below
Orland Unit Water Users Association Flood Water Conveyance	See Note 1 below	See Note 3 below	See Note 5 below	Potential	See Note 6 below	See Note 6 below
Sites Reservoir	See Note 1 below	See Note 3 below	See Note 5 below	Concept, developing funding	See Note 6 below	See Note 6 below
Colusa Subbasin In-lieu Recharge & Banking Program	See Note 1 below	See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below
Sycamore Marsh Farm In-lieu Recharge Project	See Note 1 below	See Note 2 below	See Note 4 below	Concept	See Note 6 below	See Note 6 below
Westside Offstream Reservoir and In-Lieu Groundwater Recharge	See Note 1 below	See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below
Domestic Well Mitigation Program	See Note 1 below	See Note 3 below	See Note 5 below	Potential	See Note 6 below	See Note 6 below
Strategic Short-Term Demand Management	See Note 1 below	See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below

Table 3. Implementation Criteria, Notice Process, Permitting and Regulatory Process, and Timeline for all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(1)(A)	CCR §354.44(b)(1)(B)	CCR §354.44(b)(3)	CCR §354.44(b)(4)		
Project/Management Action Name	**Implementation and Termination Timing/Criteria for Implementation**	**Public and/or Inter-Agency Notice Process**	**Required Permitting and Regulatory Process or Status of Permitting**	**Current Status (Ongoing, Planned, Potential or Concept)**	**Anticipated Start Date (Year)**	**Anticipated Completion Date (Year)**
Long-Term Demand Management Action		See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below
Well Abandonment Outreach and Funding Program	See Note 1 below	See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below
Preservation of Lands Favorable for Recharge	See Note 1 below	See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below
Review of County Well Permitting Ordinances	See Note 1 below	See Note 3 below	See Note 5 below	Concept	See Note 6 below	See Note 6 below
Drought Contingency Planning for Urban Areas	See Note 1 below	See Note 3 below	See Note 5 below	Potential	See Note 6 below	See Note 6 below
Development of a Dedicated Network of Shallow Monitoring Wells for GDE Monitoring	See Note 1 below	See Note 3 below	See Note 5 below	Potential	See Note 6 below	See Note 6 below

Notes:

1. This project is currently in the early conceptual stage. Thus the implementation and termination dates have yet to be determined. Criteria for implementation may, among other factors, be linked to the measurable objectives and provided in annual reports.
2. Public and/or Inter-Agency Noticing is being facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
3. Public and/or Inter-Agency Noticing will be facilitated through GSA board meetings, GSA and/or cooperating agency website(s), GSA newsletter, member agency newsletter, inter-basin coordination meetings, member agency governing body public meetings, GSP annual report(s), public scoping meetings and environmental/regulatory permitting notification.
4. Required permitting and regulatory review is being initiated through consultation with applicable governing agencies. Governing agencies for which consultation is being initiated may include, but is not limited to: the California Department of Water Resources (DWR), the California State Water Resources Control Board (SWRCB), the California Department of Fish and Wildlife (CDFW), the Central Valley Flood Protection Board (Flood Board), Regional Water Boards, the United States Bureau of Reclamation (Reclamation or USBR), the United States Army Corps of Engineers (USACE), the United States Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), Local Agency Formation Commissions (LAFCO), the Counties of Colusa and/or Glenn, and the California Air Resources Board (CARB).
5. Required permitting and regulatory review will be project specific and initiated through consultation with applicable governing agencies. Governing agencies for which consultation is being initiated may include, but is not limited to: DWR, SWRCB, CDFW, Flood Board, Regional Water Boards, USBR, USACE, USFWS, NMFS, LAFCO, Counties of Colusa and/or Glenn, and CARB.
6. This project is currently in the early conceptual stage. Thus, the start and completion dates for this project have yet to be determined and will be provided in annual reports when known.

Table 4. Anticipated Benefits of all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(5)			
Project/Management Action Name	**Measurable Objectives Expected to Benefit**	**Multi-Benefits Expected**	**Serves Disadvantaged Community (If so, which one?)**	**Expected Yield**
Planned				
Colusa County Water District In-Lieu Groundwater Recharge	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	27,000 af/year
Colusa Drain MWC In-Lieu Groundwater Recharge	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	28,000 af/year
Colusa Subbasin Multi-Benefit Groundwater Recharge	Groundwater levels, groundwater storage, and depletions of interconnected surface water	Ponded habitat for migratory birds	See Note 1 below	5,200 af/year
Orland-Artois Water District Land Annexation and Groundwater Recharge	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	23,000 af/year
Sycamore Slough Groundwater Recharge Pilot Project	Groundwater levels, groundwater storage, and depletions of interconnected surface water	Ponded habitat for migratory birds	See Note 1 below	5,000 af over 10 years
Ongoing				
Reclamation District 108 and Colusa County Water District Agreement for Five-Year In-Lieu Groundwater Recharge Project	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	8,000 af/year
Glenn-Colusa Irrigation District Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits	Groundwater levels, groundwater storage, and depletions of interconnected surface water	Increased ponded habitat for migratory birds and improved air quality through reduced rice straw burning	See Note 1 below	See Note 2 below

Table 4. Anticipated Benefits of all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(5)			
Project/Management Action Name	**Measurable Objectives Expected to Benefit**	**Multi-Benefits Expected**	**Serves Disadvantaged Community (If so, which one?)**	**Expected Yield**
Sycamore Marsh Farm Direct Recharge Project	Groundwater levels, groundwater storage, depletions of interconnected surface water, land subsidence, and potentially groundwater quality	Ponded habitat for migratory birds	See Note 1 below	See Note 2 below
Glenn-Colusa Irrigation District Expansion of In-Basin Program for In-lieu Groundwater Recharge	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	See Note 2 below
Orland Unit Water Users Association Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	See Note 2 below
Urban Water Conservation in Willows	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	2 af/year
Potential				
Colusa County Public Water System Water Treatment Plant	Groundwater levels, groundwater storage, and depletions of interconnected surface water	Improved drinking water quality; Arbuckle and Dunnigan face loss of well supply; Grimes and Princeton have drinking well arsenic contamination; Williams has elevated salinity (TDS) levels	See Note 1 below	See Note 2 below
Delevan Pipeline Colusa Basin Drain Intertie	Groundwater levels, groundwater storage, depletions of interconnected surface water, and land subsidence (to the extent that project yield is dedicated to recharge projects)		See Note 1 below	See Note 2 below

Table 4. Anticipated Benefits of all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(5)			
Project/Management Action Name	**Measurable Objectives Expected to Benefit**	**Multi-Benefits Expected**	**Serves Disadvantaged Community (If so, which one?)**	**Expected Yield**
Sycamore Slough Colusa Basin Drain Multi-Benefit Recharge Project	Groundwater levels, groundwater storage, and depletions of interconnected surface water	Ponded habitat for migratory birds, along with other environmental benefits	See Note 1 below	See Note 2 below
Tehama-Colusa Canal Trickle Flow to Ephemeral Streams	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	See Note 2 below
Westside Streams Diversion for Direct or In-lieu Groundwater Recharge	Groundwater levels, groundwater storage, depletions of interconnected surface water, land subsidence	Reduced flood impacts to the extent that diversions reduce the severity of downstream flooding	See Note 1 below	Dependent on scale of implementation; between roughly 1,000 to 16,000 af/year
Reduce Non-beneficial Evapotranspiration/Invasive Species Eradication (Arundo, Eucalyptus, Tamarisk, etc.)	Groundwater levels, groundwater storage, and depletions of interconnected surface water	Decreased ET; increased native vegetation / habitat; decreased sediment trapping	See Note 1 below	See Note 2 below
Enhanced Infiltration of Precipitation on Agricultural Lands	Groundwater levels, groundwater storage, and depletions of interconnected surface water	Increased groundwater recharge	See Note 1 below	See Note 2 below
Colusa Subbasin Flood-MAR	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	See Note 2 below
Reclamation District 108 “Boards In” Program	Groundwater levels, groundwater storage, and depletions of interconnected surface water	Possible ponded habitat for migratory birds	See Note 1 below	Dependent on scale of implementation; estimated 1,800 af/year (if 20% of rice fields in RD108 participate)
Glenn-Colusa Irrigation District In-lieu Groundwater Recharge	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	See Note 2 below

Table 4. Anticipated Benefits of all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(5)			
Project/Management Action Name	**Measurable Objectives Expected to Benefit**	**Multi-Benefits Expected**	**Serves Disadvantaged Community (If so, which one?)**	**Expected Yield**
Glenn-Colusa Irrigation District Water Transfers to TCCA CVP Contractors	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	See Note 2 below
Orland-Artois Water District Direct Groundwater Recharge	Groundwater levels, groundwater storage, and depletions of interconnected surface water	Possible ponded habitat for migratory birds depending on timing of flooding	See Note 1 below	See Note 2 below
Orland Unit Water Users Association Flood Water Conveyance	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	See Note 2 below
Sites Reservoir	Groundwater levels, groundwater storage, depletions of interconnected surface water, and land subsidence (to the extent that project yield is dedicated to recharge projects).	Increased local, regional, and statewide water supply reliability, climate change resiliency, recreation, increased cold water pool for endangered salmon	See Note 1 below	See Note 2 below
Colusa Subbasin In-lieu Recharge & Banking Program	Groundwater levels, groundwater storage, depletions of interconnected surface water, land subsidence, and potentially groundwater quality		See Note 1 below	See Note 2 below
Sycamore Marsh Farm In-lieu Recharge Project	Groundwater levels, groundwater storage, depletions of interconnected surface water, land subsidence, and potentially groundwater quality		See Note 1 below	See Note 2 below
Westside Off-stream Reservoir and In-Lieu Groundwater Recharge	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	See Note 2 below
Domestic Well Mitigation Program	None		See Note 1 below	None

Table 4. Anticipated Benefits of all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(5)			
Project/Management Action Name	**Measurable Objectives Expected to Benefit**	**Multi-Benefits Expected**	**Serves Disadvantaged Community (If so, which one?)**	**Expected Yield**
Strategic Short-Term Demand Management	Groundwater levels, groundwater storage, and depletions of interconnected surface water in areas with potential sustainability challenges	Yes, potential for multi-benefits on temporarily idled lands, depending on program design	See Note 1 below	See Note 2 below
Long-Term Demand Management Action	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	See Note 2 below
Well Abandonment Outreach and Funding Program	Water quality		See Note 1 below	None
Preservation of Lands Favorable for Recharge	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	See Note 2 below
Review of County Well Permitting Ordinances	Potentially: groundwater levels, groundwater storage, depletions of interconnected surface water, land subsidence, and groundwater quality		See Note 1 below	See Note 2 below
Drought Contingency Planning for Urban Areas	Groundwater levels, groundwater storage, and depletions of interconnected surface water		See Note 1 below	See Note 2 below
Development of a Dedicated Network of Shallow Monitoring Wells for GDE Monitoring	Groundwater levels, groundwater storage, and depletions of interconnected surface water	GDEs, riparian habitat	See Note 1 below	See Note 2 below

Notes:

1. The majority of the areas within the Colusa Subbasin are classified as either Severely Disadvantaged Communities, Disadvantaged Communities, or Economically Distressed Areas.
2. This project is currently in the early conceptual stage. Thus, the expected yield of this project has yet to be determined and will be reported in annual reports when known.

Table 5. Benefit Evaluation and Water Source for all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(5)	CCR §354.44(b)(6)	
Project/Management Action Name	**Benefit Evaluation Methodology**	**Water Source**	**Water Source Reliability**
Planned			
Colusa County Water District In-Lieu Groundwater Recharge	See Note 1 below	Sacramento River through CCWD's existing CVP contract and annual and multi-year water purchases and transfer agreements	Water purchases and transfers in all but Critical years
Colusa Drain MWC In-Lieu Groundwater Recharge	See Note 2 below	Sacramento River through CDMWC contractual rights with USBR together with annual and multi-year transfer agreements with USBR settlement contractors utilizing the Colusa Basin Drain.	To be determined
Colusa Subbasin Multi-Benefit Groundwater Recharge	See Note 1 below	Sacramento River under a variety of water rights, contracts, and water purchase and transfer agreements	Uncertain at this time
Orland-Artois Water District Land Annexation and Groundwater Recharge	See Note 1 below	Sacramento River through annual and multi-year water purchases and transfer agreements for in-lieu recharge, and Section 215 water for direct recharge	Water purchases and transfers in all but Critical years; Section 215 water subject to hydrology and river system conditions
Sycamore Slough Groundwater Recharge Pilot Project	See Note 2 below	Sacramento River	Uncertain at this time
Ongoing			
Reclamation District 108 and Colusa County Water District Agreement for Five-Year In-Lieu Groundwater Recharge Project	See Note 2 below	Sacramento River water available to RD108 through contractual rights under Sacramento River Settlement Contract 14-06-200-876A between RD108 and the Bureau of Reclamation	Settlement contract water supply subject to 25% reductions in Shasta critical years
Glenn-Colusa Irrigation District Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits	See Note 1 below	Appropriative water right for diversion and use of "winter water" from November 1 through March 31 each year	Appropriative winter water supplies subject to availability and curtailments according to water right Term 91

Table 5. Benefit Evaluation and Water Source for all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(5)	CCR §354.44(b)(6)	
Project/Management Action Name	**Benefit Evaluation Methodology**	**Water Source**	**Water Source Reliability**
Sycamore Marsh Farm Direct Recharge Project	See Note 1 below	Colusa Basin Drain	To be determined
Glenn-Colusa Irrigation District Expansion of In-Basin Program for In-lieu Groundwater Recharge	See Note 1 below	Sacramento River under GCID's contractual and appropriative rights	Supplies potentially available only in Shasta Non-Critical years; reliable during those years
Orland Unit Water Users Association Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping	See Note 2 below	Stony Creek water available to the OUWUA under the Angle Decree	Highly reliable with significant shortages historically occurring once every 10 to 20 years on average
Urban Water Conservation in Willows	See Note 1 below	N/A	N/A
Potential			
Colusa County Public Water System Water Treatment Plant	See Note 2 below	Sacramento River under new appropriative water rights	Uncertain at this time
Delevan Pipeline Colusa Basin Drain Intertie	See Note 2 below	Sacramento River under new appropriative water rights (conveyed to Sites Reservoir and through Delevan Pipeline)	Uncertain at this time
Sycamore Slough Colusa Basin Drain Multi-Benefit Recharge Project	See Note 2 below	Sacramento River (settlement contracts before November 1; riparian rights at other times)	Expected to be reliable, but the precise volume of available water is uncertain at this time
Tehama-Colusa Canal Trickle Flow to Ephemeral Streams	See Note 2 below	Sacramento River (conveyed through TCC)	Uncertain at this time
Westside Streams Diversion for Direct or In-lieu Groundwater Recharge	See Note 2 below	Westside Streams: Willow Creek, Logan Creek, Hunters Creek, Funks Creek, Stone Corral Creek, Salt Creek, and potentially smaller streams	Only available during periods of runoff occurring during heavy precipitation events or wet years
Reduce Non-beneficial Evapotranspiration/Invasive Species Eradication (Arundo, Eucalyptus, Tamarisk, etc.)	See Note 2 below	N/A	N/A

Table 5. Benefit Evaluation and Water Source for all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(5)	CCR §354.44(b)(6)	
Project/Management Action Name	**Benefit Evaluation Methodology**	**Water Source**	**Water Source Reliability**
Enhanced Infiltration of Precipitation on Agricultural Lands	See Note 2 below	Precipitation	Variable
Colusa Subbasin Flood-MAR	See Note 2 below	To be determined	To be determined
Reclamation District 108 "Boards In" Program	See Note 2 below	Precipitation	Variable
Glenn-Colusa Irrigation District In-lieu Groundwater Recharge	See Note 2 below	Sacramento River under GCID's contractual rights according to its Sacramento River Water Right Settlement contract and under an appropriative water right for diversion and use of "winter water" from November 1 through March 31 each year.	Settlement contract water supplies subject to 25% reductions in Shasta Critical years; appropriative winter water subject to availability and curtailments according to water right Term 91
Glenn-Colusa Irrigation District Water Transfers to TCCA CVP Contractors	See Note 2 below	Sacramento River under GCID's contractual rights according to its Sacramento River Water Right Settlement contract	Settlement contract water supply subject to 25% reductions in Shasta Critical years
Orland-Artois Water District Direct Groundwater Recharge	See Note 1 below	Sacramento River Section 215 water	Highly variable; available only during periods of high flow in Sacramento River and tributaries
Orland Unit Water Users Association Flood Water Conveyance	See Note 2 below	Stony Creek flood releases that cannot be held in Stony Creek reservoirs	Highly variable year to year depending on hydrology
Sites Reservoir	See Note 2 below	Sacramento River under new appropriative water rights	New water rights would have junior priority and therefore would be subject to senior rights and water right Term 91
Colusa Subbasin In-lieu Recharge & Banking Program	See Note 2 below	To be determined	To be determined
Sycamore Marsh Farm In-lieu Recharge Project	See Note 1 below	Colusa Basin Drain	To be determined

Table 5. Benefit Evaluation and Water Source for all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(5)	CCR §354.44(b)(6)	
Project/Management Action Name	**Benefit Evaluation Methodology**	**Water Source**	**Water Source Reliability**
Westside Off-stream Reservoir and In-Lieu Groundwater Recharge	See Note 2 below	Sacramento River Section 215 water	Highly variable; available only during periods of high flow in Sacramento River and tributaries
Domestic Well Mitigation Program	See Note 2 below	N/A	N/A
Strategic Short-Term Demand Management	See Note 2 below	N/A	N/A
Long-Term Demand Management Action	See Note 2 below	N/A	N/A
Well Abandonment Outreach and Funding Program	See Note 2 below	N/A	N/A
Preservation of Lands Favorable for Recharge	See Note 2 below	N/A	N/A
Review of County Well Permitting Ordinances	See Note 2 below	N/A	N/A
Drought Contingency Planning for Urban Areas	See Note 2 below	N/A	N/A
Development of a Dedicated Network of Shallow Monitoring Wells for GDE Monitoring	See Note 2 below	N/A	N/A

Notes:

1. Evaluation of benefits will be based on analysis of pre- and post-project measurements supported by modeling. These analyses may include: flow measurement consistent with SBx7-7 (23 CCR §931-938), ET analysis, reductions in GW use, well monitoring, determination of infiltration rates, water balance analysis, as-built drawings and stream gaging. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.
2. Evaluation of benefits is based on analysis of pre- and post-project measurements supported by modeling. These analyses may include: flow measurement consistent with SBx7-7 (23 CCR §931-938), ET analysis, reductions in GW use, well monitoring, determination of infiltration rates, water balance analysis, as-built drawings and stream gaging. Modeling will be done with the C2VSimFG-Colusa model used for GSP development.

Table 6. Legal Authority Requirements, Estimated Cost, and Potential Funding Sources for all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(7)	CCR §354.44(b)(8)	
Project/Management Action Name	**Legal Authority Required**	**Estimated Cost**	**Potential Funding Sources**
Planned			
Colusa County Water District In-Lieu Groundwater Recharge	As a water district formed under state law, CCWD has the legal authority to annex land into the district and provide water service to annexed lands	Under development; 10% design and capital cost estimate expected August 2021.	See Note 2 below
Colusa Drain MWC In-Lieu Groundwater Recharge	GSAs, Districts and individual project proponents have the authority to plan and implement projects	$1,725,000	See Note 2 below
Colusa Subbasin Multi-Benefit Groundwater Recharge	GSAs, Districts and individual project proponents have the authority to plan and implement projects	Under development	See Note 2 below
Orland-Artois Water District Land Annexation and Groundwater Recharge	As a water district formed under state law, OAWD has the legal authority to annex land into the district and provide water service to annexed lands	$20 million estimated capital cost; $2.63 million per year (water supply cost and other O&M cost)	See Note 2 below
Sycamore Slough Groundwater Recharge Pilot Project	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Ongoing			
Reclamation District 108 and Colusa County Water District Agreement for Five-Year In-Lieu Groundwater Recharge Project	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Glenn-Colusa Irrigation District Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Sycamore Marsh Farm Direct Recharge Project	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Glenn-Colusa Irrigation District Expansion of In-Basin Program for In-lieu Groundwater Recharge	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below

Table 6. Legal Authority Requirements, Estimated Cost, and Potential Funding Sources for all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(7)	CCR §354.44(b)(8)	
Project/Management Action Name	**Legal Authority Required**	**Estimated Cost**	**Potential Funding Sources**
Orland Unit Water Users Association Irrigation Modernization for Increased Surface Water Delivery and Reduced Groundwater Pumping	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Urban Water Conservation in Willows	GSAs, Districts and individual project proponents have the authority to plan and implement projects	Cost covered by rate structure of Cal Water - Willows Division	See Note 2 below
Potential			
Colusa County Public Water System Water Treatment Plant	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Delevan Pipeline Colusa Basin Drain Intertie	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Sycamore Slough Colusa Basin Drain Multi-Benefit Recharge Project	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Tehama-Colusa Canal Trickle Flow to Ephemeral Streams	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Westside Streams Diversion for Direct or In-lieu Groundwater Recharge	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Reduce Non-beneficial Evapotranspiration/Invasive Species Eradication (Arundo, Eucalyptus, Tamarisk, etc.)	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Enhanced Infiltration of Precipitation on Agricultural Lands	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Colusa Subbasin Flood-MAR	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Reclamation District 108 “Boards In” Program	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Glenn-Colusa Irrigation District In-lieu Groundwater Recharge	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below

Table 6. Legal Authority Requirements, Estimated Cost, and Potential Funding Sources for all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(7)	CCR §354.44(b)(8)	
Project/Management Action Name	**Legal Authority Required**	**Estimated Cost**	**Potential Funding Sources**
Glenn-Colusa Irrigation District Strategic Winter Water Use for Groundwater Recharge and Multiple Benefits	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Glenn-Colusa Irrigation District Expansion of In-Basin Program for In-lieu Groundwater Recharge	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Glenn-Colusa Irrigation District Water Transfers to TCCA CVP Contractors	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Orland-Artois Water District Direct Groundwater Recharge	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Orland Unit Water Users Association Flood Water Conveyance	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Sites Reservoir	GSAs, Districts and individual project proponents have the authority to plan and implement projects	$5.2 billion	See Note 2 below
Colusa Subbasin In-lieu Recharge & Banking Program	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Sycamore Marsh Farm In-lieu Recharge Project	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Westside Off-stream Reservoir and In-Lieu Groundwater Recharge	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Domestic Well Mitigation Program	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Strategic Short-Term Demand Management	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Long-Term Demand Management Action	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Well Abandonment Outreach and Funding Program	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Preservation of Lands Favorable for Recharge	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below

Table 6. Legal Authority Requirements, Estimated Cost, and Potential Funding Sources for all Projects and Management Actions.

CCR § 354.44	CCR §354.44(b)(7)	CCR §354.44(b)(8)	
Project/Management Action Name	**Legal Authority Required**	**Estimated Cost**	**Potential Funding Sources**
Review of County Well Permitting Ordinances	GSAs, Districts and individual project proponents have the authority to plan and implement projects, and Counties have the authority to review and modify county well permitting ordinances	See Note 1 below	See Note 2 below
Drought Contingency Planning for Urban Areas	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below
Development of a Dedicated Network of Shallow Monitoring Wells for GDE Monitoring	GSAs, Districts and individual project proponents have the authority to plan and implement projects	See Note 1 below	See Note 2 below

Notes:

1. This project is currently in the early conceptual stage. Thus, the anticipated costs of this project have yet to be determined and will be reported in GSP annual reports and five-year updates when known.

Potential funding sources are being evaluated as project planning continues; they include, but are not limited to, the following: grants, loans, bonds, assessment fees, and cost-sharing programs. Potential funding sources will be reported in GSP annual reports and five-year updates when known.

Appendix 6D

Development of Modeling Parameters for Simulating Projects and Management Actions in the Colusa Subbasin

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Specialists in Agricultural Water Management
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Technical Memorandum

To: Colusa Groundwater Authority and Glenn Groundwater Authority

From: Davids Engineering

Date: July 14, 2021

Subject: **Development of Modeling Parameters for Simulating Projects and Management Actions in the Colusa Subbasin**

Introduction

The Groundwater Sustainability Plan (GSP) emergency regulations, described in 23 CCR §354.44[1], require Groundwater Sustainability Agencies (GSAs) to describe projects and management actions (PMAs) that will achieve the sustainability goal for the basin and respond to changing conditions in the basin. Among other required information, GSAs must describe the benefits that are expected to be realized from the PMAs and how those benefits will be evaluated (23 CCR §354.44(b)(5)). The development and description of PMAs must be supported by the best available information and best available science (23 CCR §354.44(c)).

This technical memorandum (TM) describes the modeling approach and model inputs that were used to simulate the expected benefits of planned PMAs in the Colusa Subbasin (Subbasin) using the C2VSimFG-Colusa model (model). The model inputs reflect the anticipated volume and timing of surface water supply available through specific PMAs for direct and in-lieu groundwater recharge. The model inputs also characterize where that water would be beneficially used within the Subbasin.

In addition to the model inputs, this memorandum summarizes model results from the PMA simulations that represent the quantitative benefits of these PMAs on projected future groundwater conditions in the Subbasin. At the time of GSP development, the model is considered to provide the best available information on groundwater conditions in the Subbasin, and the accuracy of this information is generally sufficient to support GSP preparation, including description of PMA benefits.

[1] California Code of Regulations, Title 23, Division 2, Chapter 1.5, Subchapter 2 Groundwater Sustainability Plans, Article 5, Section 354.28 Minimum Thresholds.

Overview of Modeled PMAs

There are five planned projects described in the Colusa Subbasin GSP that are on track for implementation. Three of those projects were selected for simulation in the model in order to gain initial insights into the magnitude of impacts from these projects. These three projects are substantial recharge projects that could have large effects on groundwater conditions relative to other PMAs. Model inputs and model results for the three modeled projects are the focus of this TM. However, the modeling approach and inputs described for these projects can be adapted to simulate other similar projects.

General background on the three modeled projects is provided below. Additional information about these PMAs and others is included in Chapter 6 of the Colusa Subbasin GSP, Projects and Management Actions.

Colusa County Water District In-Lieu Groundwater Recharge

Colusa County Water District (CCWD) has a total service area of approximately 46,000 acres, of which 39,875 acres are currently irrigable with existing District infrastructure. The majority of irrigated land is used to cultivate permanent crops. CCWD delivers surface water to approximately 35,000 acres, with the remaining acres being idle or irrigated with privately pumped groundwater. Currently, CCWD has access to Central Valley Project (CVP) water supplies through its own contracts and through transfers primarily from Westside Water District and, more recently, from Reclamation District 108 (RD108). Despite the availability of surface water, some CCWD growers choose to pump groundwater because it is less expensive than surface water and because groundwater requires less screening and filtering compared to district surface water.

Under the CCWD In-Lieu Groundwater Recharge project, CCWD will acquire additional surface water and will establish incentives to make the cost of surface water the same or less than the cost of pumping groundwater, thereby incentivizing growers who would otherwise use groundwater to use surface water. The additional surface water is expected to be acquired under long-term water transfer agreements with other CVP contractors, including Sacramento River Settlement Contractors (settlement contractors), and potentially other sources. The plan is to acquire and deliver 30,000 acre-feet per year (AF/yr) except in Shasta Critical years (approximately one in 10 years[2]) when groundwater stored through in-lieu recharge in prior years would be used.

Orland-Artois Water District Land Annexation and In-Lieu Groundwater Recharge

Orland-Artois Water District (OAWD) has an existing service area of about 29,000 acres and delivers water to district landowners through 110 miles of pipelines and 300 metered delivery points. Surface water delivered by OAWD is available under a CVP water supply contract with the United States Bureau of Reclamation (Reclamation) and through short- and long-term transfer agreements with other CVP water contractors and settlement contractors. Historically, water transfers have been from Maxwell Irrigation District, Princeton-Codora-Glenn Irrigation District, and others.

As part of the OAWD Land Annexation and In-Lieu Groundwater Recharge project, OAWD is working with a group of neighboring non-district landowners to annex approximately 12,000 acres of groundwater-dependent agricultural land into the district. Additional surface water for the annexed lands would be secured through multi-year purchase or transfer agreements with willing sellers, conveyed through the existing Tehama-Colusa (TC) Canal, and distributed to the annexed lands through

[2] Over the 50-year period from 1966-2015, five years were declared “Shasta Critical.”

new distribution facilities. Potential transferors include CVP water supply contractors and settlement contractors. The plan is to acquire and deliver 25,000 AF/yr of surface water to the annexed lands except in Shasta Critical years (approximately one in 10 years) when groundwater banked through in-lieu recharge in prior years would be used.

Colusa Subbasin Multi-Benefit Groundwater Recharge

The Colusa Groundwater Authority (CGA) and The Nature Conservancy (TNC) collaborated in a multi-benefit pilot project from 2018 through 2021 to demonstrate the project benefits to direct groundwater recharge and creation of habitat for migrating shorebirds. In the pilot project, multi-benefit recharge was conducted by recharging groundwater through normal farming operations at strategic times of year in order to provide critical wetland habitat for shorebirds migrating along the Pacific Flyway, and potential ancillary benefits for water levels near disadvantaged communities in the Subbasin. The pilot project concluded that multi-benefit recharge is feasible and does generate the intended recharge and habitat benefits, serving as an example of how the Subbasin-wide program could work.

The planned Colusa Subbasin Multi-Benefit Groundwater Recharge project would expand on the pilot project to identify and contract with willing landowners who will participate in the program, and to develop program incentives and funding opportunities that will encourage enrollment, especially in areas that are most suitable for multi-benefit recharge. Each year, multi-benefit recharge would be implemented by applying surface water to participating fields and maintaining a shallow depth (4 inches maximum) for typically four to six weeks in the late summer and early fall (July 15 to October 15) and/or spring (March 15 to April 15),) when migratory bird habitat is needed.

While the actual location and scale of the project will depend on voluntary landowner participation, areas in the Subbasin that are potentially favorable for multi-benefit recharge have already been identified through preliminary mapping based on:

- Land use and crop characteristics that are suitable for recharge and could accept flooding in late summer and early fall (the period prioritized for modeling), with minimal impacts to crops and farming operations
- Soil characteristics that are suitable for recharge, using the Soil Agricultural Groundwater Banking Index (SAGBI[3]) rating
- Availability of surface water supplies for field-flooding during prime periods when migratory bird habitat is needed
- Proximity to the Sacramento River, as those lands are expected to have the greatest positive impact on streamflows

[3] SAGBI is a suitability index indicating the potential for groundwater recharge on agricultural land, determined according to five main factors: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. SAGBI ratings for lands in California are developed by the California Soil Resource Lab at UC Davis and UC-ANR, and are available online at: https://casoilresource.lawr.ucdavis.edu/sagbi/.

Analytic Approach

Modeling Approach

The quantitative benefits of the three modeled projects to groundwater conditions in the Subbasin were evaluated using the C2VSimFG-Colusa model (model), an integrated hydrologic flow model for the Subbasin. Development and refinement of this model to support GSP development is described in Appendix 3D. The C2VSimFG-Colusa model was adapted from the Fine Grid California Central Valley Groundwater-Surface Water Simulation Model (C2VSimFG).

The model simulates inflows and outflows between the Subbasin surface water system and groundwater system in a grid of land elements, stream nodes, and groundwater nodes that span and surround the Subbasin. The model calculates a water budget for each element and node on a monthly timestep for different historical, current, and projected (future) scenarios described in the GSP. Results of these element and node-level water budgets are aggregated to quantify the historical, current, and projected water budgets for the entire Subbasin, as required in the GSP regulations.

Among their many functions, user-defined model inputs are used to determine when, where, and how much water is applied to lands and ultimately recharges the groundwater system. Key water budget parameters that were evaluated to quantify the groundwater recharge benefits of the three modeled projects include:

- Surface Water Diversions: Surface water diverted from a stream node and delivered to elements. Surface water diversions are a user-defined model input, and are summarized to describe the average annual surface water volume diverted for the PMA.
- Groundwater Pumping: Groundwater pumped to meet water demand in elements. For these projects, groundwater pumping is calculated by the model to meet the remaining irrigation demand after surface water is applied.
- Seepage: For these projects, seepage represents water that is lost from streams, canals, or conveyance systems, flowing through the soil and to the groundwater system. Seepage is a component of groundwater recharge, and is calculated by the model.
- Deep Percolation: For these projects, deep percolation represents the fraction of water applied to fields that flows through the soil and to the groundwater system. Deep percolation is a component of groundwater recharge, and is calculated by the model.

Additional information about how the model operates, its inputs, and assumptions are provided in the model documentation and Appendix 3D.

Modeled Project Areas

Three project areas were explicitly defined in the C2VSimFG-Colusa model to quantify the effects and benefits of PMAs on the Subbasin water budget, specifically those related to groundwater conditions. These project areas, shown in Figure *1*, include:

1) **Planned CCWD Project Area**: a group of elements that approximately represents the CCWD service area
2) **Planned OAWD Project Area**: a group of elements that approximately represents the existing OAWD service area and the 12,000 acres that OAWD plans to annex

3) **Multi-Benefit Recharge Project Area:** a group of elements that represents a hypothetical selection of potential recharge areas, containing fields identified through the process described later in this TM

Each project area is represented by a group of elements that approximately represents the areas in which specific projects are expected to occur. Model inputs developed for the three modeled PMAs were applied and simulated in the elements represented in each project area.

The C2VSimFG-Colusa model calculates the water budget for each model element for each monthly timestep, including the elements in each project area. For all elements in each project area, the element-level water budget results were summed to aggregate project area water budget results.

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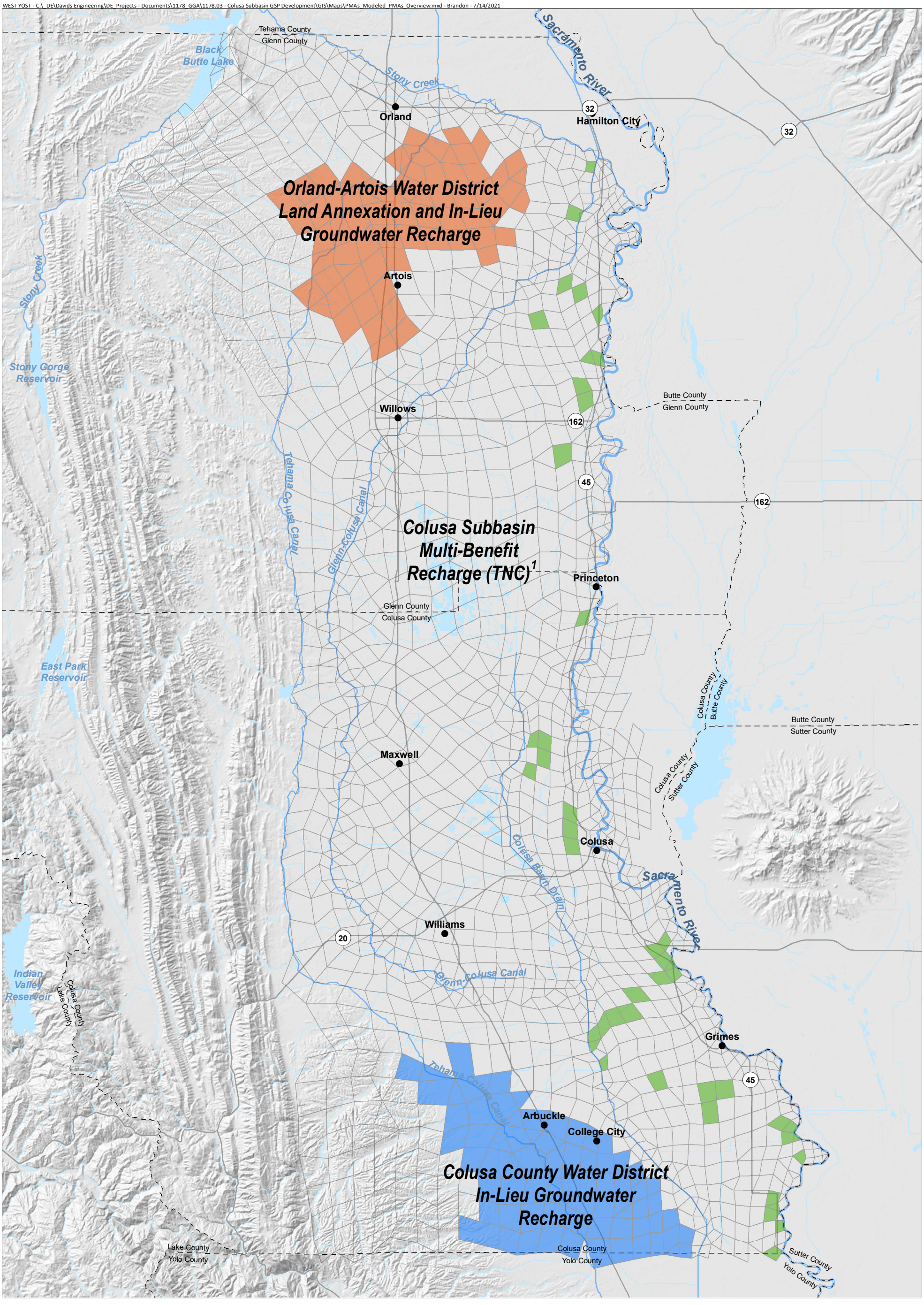

Planned CCWD PMA Project Area
Multi-Benefit Recharge PMA Project Area
Planned OAWD PMA Project Area
Model Elements Without Modeled PMAs
Colusa Subbasin Boundary

Horizontal Datum: North American Datum of 1983 (NAD 83), California State Plane Zone II, feet.

Note:
1. Multi-benefit recharge locations will depend on grower enrollment and could be anywhere within the Colusa Subbasin where surface water supplies are available and recharge conditions are favorable. For purposes of modeling project impacts, elements were selected based on lands with cropping schedules that allow for flooding during bird migration periods and total roughly 4,000 acres.

N

0 2.5 5

Scale in Miles

Figure 1

Modeling Projects and Management Actions

Colusa Groundwater Authority and Glenn Groundwater Authority
Colusa Subbasin
Groundwater Sustainability Plan

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Model Scenarios

Two model scenarios were considered for quantifying the effects and benefits of PMAs on the Subbasin:

- **Without-Projects Scenario**—Projected Future Conditions with 2070 Climate Change and without Projects. This is the projection of future conditions over the 50-year period from 2016 through 2065, assuming climate change effects are occurring, but that no groundwater recharge or other types of projects are implemented. Climate change adjustments were made to the precipitation, evapotranspiration, and surface water supply model inputs to reflect the estimated effects of climate change based on the 2070 Central Tendency climate change datasets provided by DWR to support GSP development.[4] The main effect of these adjustments is an estimated increase in future crop water requirements, which result in the need for increased groundwater pumping.
- **With-Projects Scenario**—Projected Future Conditions with 2070 Climate Change and with Projects. This is the same as the "without-projects" scenario, except that it is assumed that the three modeled projects are in operation during the full duration of the 50-year simulation.

Hereinafter, for convenience, these model scenarios are referred to as the "without-project" and "with-project" scenarios, respectively. The model inputs differ only due to projects; thus, differences in model results between these scenarios are due entirely to the effects of the projects.

The analysis period and assumptions about hydrology, land use, and water supplies associated with each model scenario are summarized in **Table 1**. Projected future water supplies and land use are expected to vary depending on Shasta watershed hydrologic conditions and related CVP operations plans prepared by Reclamation. Water supplies and flows through the Subbasin may be reduced in hydrologic years designated by Reclamation as Shasta Critical[5], such as 2015, resulting in reduced cropped acreage in those years. In Shasta Non-Critical years, water supplies and land use are expected to be similar to current conditions in recent non-drought years, such as 2013. In the future analysis period (2016-2065), future years are mapped to a series of historical years that were selected to represent historical hydrology as the baseline for estimating future hydrology (23 CCR §354.18(c)(3)). The Shasta Critical or Non-Critical designation of those historical years was also mapped to the corresponding future years.

Additional information on these scenarios is provided in Chapter 3, Section 3.3, of the Subbasin GSP.

[4] Climatological, hydrological, and water operations datasets, change factors, and the DWR Climate Change Resource Guide are available at: https://data.cnra.ca.gov/dataset/sgma-climate-change-resources.

[5] In general, Shasta Critical conditions are declared when the forecast inflow to Lake Shasta for a particular water year is equal to or less than 3.2 million AF. Conversely, Shasta Non-Critical conditions are declared when the forecast inflow to Lake Shasta for a particular water year exceeds 3.2 million AF. Between 1966-2015, five years were "Shasta Critical," or approximately 1 in 10 years.

Table 1. Summary of Water Budget Assumptions Used for the Without-Projects Scenario and With-Projects Scenario

Model Scenario	Analysis Period[1]	Hydrology	Land Use	Water Supplies
Without-Projects Scenario: Projected Future Conditions with 2070 Climate Change and without Projects	2016 to 2065	Historical (1966 to 2015), adjusted based on 2070 Central Tendency climate change datasets	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Same as Current (see above), adjusted for 2070 Central Tendency climate change
With-Projects Scenario—Projected Future Conditions with 2070 Climate Change and with Projects.	2016 to 2065	Historical (1966 to 2015), adjusted based on 2070 Central Tendency climate change datasets	Current (2013 and 2015) used for Shasta Non-Critical and Shasta Critical, respectively	Same as Current (see above), adjusted for 2070 Central Tendency climate change

[1] Results over the analysis period are summarized by water year (October 1 through September 30)

Model Inputs for PMAs

As described above, model inputs for the three modeled PMAs reflect the anticipated volume and timing of surface water supply available through the PMAs for direct and in-lieu groundwater recharge. The model inputs also characterize where that water is beneficially used within the Subbasin. Model inputs developed for each of the three modeled PMAs are described below.

Colusa County Water District In-Lieu Groundwater Recharge

Under the CCWD In-Lieu Groundwater recharge project, CCWD plans to acquire and deliver 30,000 AF/yr of additional surface water except in Shasta Critical years (approximately one in 10 years[6]).

For modeling, it was assumed in the with-project scenario that an additional 30,000 AF/yr will be delivered to all irrigated agricultural land in model elements that approximately represent the CCWD service area (Figure *1*) during Shasta Non-Critical years in the 2016-2065 analysis period. The 30,000 AF is in addition to surface water supplies delivered in the without-project scenario. In Shasta Critical years, no additional surface water is delivered to those elements.

Orland-Artois Water District Land Annexation and Groundwater Recharge

As part of the OAWD Land Annexation and In-Lieu Groundwater Recharge project, OAWD plans to annex approximately 12,000 acres of groundwater-dependent agricultural land into the district. OAWD also plans to acquire and deliver 25,000 AF/yr of surface water to the annexed lands except in Shasta Critical years (approximately one in 10 years).

For modeling, it was assumed in the with-project scenario that an additional 25,000 AF/yr will be delivered to all irrigated agricultural land in the OAWD project area (Figure *1*) during Shasta Non-Critical years in the 2016 to 2065 analysis period. The OAWD project area contains model elements that approximately represent the OAWD service area as well as the 12,000 acres that OAWD plans to annex. The 25,000 AF/yr is in addition to surface water supplies delivered in the without-project scenario. In

[6] Over the 50-year period from 1966-2015, five years were declared "Shasta Critical."

Shasta Critical years, no additional surface water is delivered to the OAWD service area and groundwater is the sole irrigation supply source for the annexed area.

Colusa Subbasin Multi-Benefit Groundwater Recharge

In the Colusa Subbasin Multi-Benefit Recharge project, voluntarily participating growers will apply surface water to fields and maintain a shallow depth (4 inches maximum) for typically four to six weeks in the late summer and early fall (July 15 to October 15) and/or spring (March 15 to April 15),) when migratory shorebird habitat is needed.

For modeling the multi-benefit groundwater recharge project, key assumptions and analyses were developed to identify one hypothetical project configuration as a "bookend" scenario, in which maximal grower participation occurs in areas with the greatest multi-benefit groundwater recharge potential. In practice, the actual location and scale of the project will depend on voluntary landowner participation from year to year. The assumptions and analyses underpinning the with-project scenario model inputs were formulated to estimate:

- Where the greatest potential combination of multi-benefits could occur (considering groundwater recharge potential, habitat creation suitability, and other factors of interest)
- When the project would be implemented (on a monthly and annual basis)
- How much voluntary participation could occur (assuming, at a maximum, that all lands with the greatest potential combination of multi-benefits will participate each year water is available)

The specific approach and assumptions are as follows:

- A geospatial analysis was completed to identify all "potential recharge areas" in the Subbasin. All lands with the following characteristics were identified as potentially suitable for multi-benefit groundwater recharge, and were assumed to enroll in the program in the with-project scenario:
    - Location:
        - Within the service area of a surface water supplier (Lands were assumed to have access to surface water supplies)
        - Within six miles of the Sacramento River (Lands were considered to allow maximum mitigating effects on streamflow depletion, a factor of interest to modeling; this may not necessarily be a factor in actual program implementation)
    - Soil characteristics: Soils that are suitable for groundwater recharge (indicated by a SAGBI rating of "moderately good," "good," or "excellent")
    - Land use: Crops that are suitable for recharge and could accept flooding in late summer and early fall (the period prioritized for modeling), with minimal impacts to crops and farming operations (excluded lands include: non-agricultural land uses (urban, native vegetation, riparian), permanent crops, ponded crops, and other crops with growing seasons incompatible with flooding between August-October)

- Minimum size of 25 acres

  A total of 4,122 acres were found to satisfy these criteria, and are located within the model elements identified in Figure *1*. These "potential recharge areas" were assumed to all participate in multi-benefit groundwater recharge.

- For all potential recharge areas, it was assumed that:
  - Shasta Non-Critical years: Multi-benefit groundwater recharge would occur and lands would be flooded with surface water for 30 days (during the month of September)
  - Shasta Critical years: Normal farming and irrigation practices would continue, without multi-benefit groundwater recharge due to likely surface water shortages in those years.
- For all potential recharge areas, model inputs for the with-project scenario were changed from the without-project scenario as follows:
  - Crop assignment: In Shasta Non-Critical years, lands were classified as non-ponded crops planted in March or April and harvested by August. In Shasta Critical years, lands remained in their original crop assignment.
  - Soil characteristics: In September, target soil moisture (TSM) was set equal to the total porosity of the soil to simulate ponding. In other months, TSM was estimated as the weighted average TSM of all lands identified from the geospatial analysis.
  - Irrigation period: Set to March or April through September in all years.
  - Crop evapotranspiration: In Shasta Non-Critical years, crop evapotranspiration was estimated as the weighted average evapotranspiration of all lands identified from the geospatial analysis, with adjustment for idle lands that are typically unirrigated. In Shasta Critical years, crop evapotranspiration returned to the original crop assignment.
  - Diversions:
    - In Shasta Non-Critical years: Additional diversions to potential recharge areas were estimated based on a simulation of average additional water demand in project area elements in September of Shasta Non-Critical years. The additional diversions were then specified as new supply from the Sacramento River, and applied to project area elements.
    - In Shasta Critical years: No additional diversions were specified.

Model Results for PMAs

This section compares the model results in the with-projects and without-projects scenarios. The difference between the without-project and with-project model results represents the net effect of the project on those water budget parameters.

Results for Each Modeled Project Area

The tables below summarize key results of the without-project and with-project model scenarios for each of the three modeled PMAs. Results are averaged over the entire 2016 to 2065 projected future period, including Shasta Critical years (approximately 10 percent of all years) when it is expected that

additional surface water supplies will be unavailable for projects. The results are aggregated from the water budgets of elements in the project areas identified in Figure *1*.

The average net benefit to the groundwater system of each modeled project is reported as "net recharge from the surface water system," calculated as the sum of all groundwater recharge (seepage and deep percolation) minus the sum of all groundwater extraction (groundwater pumping) in the project area and model scenario. Positive values indicate that more recharge is occurring, on average, while negative values indicate that more extraction is occurring.

On average across all years, the CCWD In-Lieu Groundwater Recharge project is expected to provide approximately 27,000 AF/yr of additional surface water to the CCWD project area, offsetting a similar volume of groundwater pumping (**Table 2**). The average net benefit to the groundwater system of the CCWD project is estimated to be approximately 27,000 AF/yr.

The OAWD Land Annexation and In-Lieu Groundwater Recharge project is expected to provide approximately 22,500 AF/yr of additional surface water to the OAWD project area, offsetting a similar volume of groundwater pumping on average across all years (**Table 3**). The average net benefit to the groundwater system of the OAWD project is estimated to be approximately 22,500 AF/yr.

The Colusa Subbasin Multi-Benefit Groundwater Recharge project is expected to provide approximately 11,500 AF/yr (2.8 AF per acre [AF/ac]) of surface water to potential recharge areas for field flooding (**Table 4**). A portion of this water results in deep percolation (approximately 4,000 AF/yr, or 1.0 AF/ac) or additional seepage (approximately 900 AF/yr, or 0.2 AF/ac). The average net benefit to the groundwater system of the OAWD project is estimated to be approximately 5,200 AF/yr (1.25 AF/ac).

Table 2. Key Model Results from the Colusa County Water District In-Lieu Groundwater Recharge Project (Average AF/yr, 2016 to 2065)

Scenario	Surface Water Diversions	Groundwater Pumping	Seepage	Deep Percolation	Net Recharge from the Surface Water System[1]
Without-Project	65,859	63,314	0	48,460	-14,854
With-Project	92,901	36,140	0	48,403	12,263
Difference (With-Project – Without-Project)	27,042	-27,174	0	-57	27,117

[1] Net Recharge from the Surface Water System = Seepage + Deep Percolation – Groundwater Pumping

Table 3. Key Model Results from the Orland-Artois Water District Land Annexation and In-Lieu Groundwater Recharge Project (Average AF/yr, 2016 to 2065)

Scenario	Surface Water Diversions	Groundwater Pumping	Seepage	Deep Percolation	Net Recharge from the Surface Water System[1]
Without-Project	48,026	62,067	0	45,324	-16,742
With-Project	70,534	39,520	0	45,307	5,788
Difference (With-Project – Without-Project)	22,509	-22,547	0	-17	22,530

[1] Net Recharge from the Surface Water System = Seepage + Deep Percolation – Groundwater Pumping

Table 4. Key Model Results from the Colusa Subbasin Multi-Benefit Groundwater Recharge Project (Average AF/yr, 2016 to 2065)

Scenario	Surface Water Diversions	Groundwater Pumping	Seepage	Deep Percolation	Net Recharge from the Surface Water System[1]
Without-Project	34,151	7,521	5,037	7,565	5,081
With-Project	45,683	7,212	5,924	11,540	10,252
Difference (With-Project – Without-Project) (AF/yr)	11,533	-308	886	3,976	5,171
Difference (With-Project – Without-Project) (AF/ac[2])	2.8	-0.1	0.2	1.0	1.25

[1] Net Recharge from the Surface Water System = Seepage + Deep Percolation – Groundwater Pumping

[2] Calculated assuming 4,122 acres of "potential recharge area" will participate in multi-benefit groundwater recharge.

Results for the Colusa Subbasin

The tables below summarize key results of the without-projects and with-projects model scenarios for the entire Subbasin. Results are averaged over the entire 2016 to 2065 projected future period, including Shasta Critical years (approximately 10 percent of all years) when it is expected that additional surface water supplies will be unavailable for projects. The results are aggregated across all model elements in the Subbasin.

Table 5 summarizes the water budget results for the Subbasin surface water system. On average across all years, all three modeled projects are expected to reduce groundwater pumping by approximately 49,000 AF/yr and increase the total surface water inflows to the Subbasin by approximately 27,000 AF/yr. Stream gains from groundwater are also expected to increase by nearly 15,000 AF/yr

compared to the without-projects scenario.[7] Deep percolation in the with-projects scenario is expected to slightly increase (approximately 4,000 AF/yr), while seepage is expected to slightly decrease (approximately 10,000 AF/yr) compared to the without-projects scenario.

Table 6 summarizes the water budget results for the Subbasin groundwater system. In the without-projects scenario, the average annual change in groundwater storage across all years is expected to be approximately -7,000 AF/yr, indicating an average net decline in groundwater storage. When all three modeled projects are in effect, the average annual change in groundwater storage across all years is expected to be approximately 0 AF/yr, indicating no net decrease in groundwater storage.

These model results suggest that planned projects in the Subbasin are sufficient to support sustainable management of groundwater extractions and recharge to ensure that chronic lowering of groundwater levels or depletion of supply during periods of drought is offset by increases in groundwater storage during other periods (23 CCR §354.44(b)(9)).

[7] A more detailed assessment of projected streamflow accretion-depletion is presented in Appendix 3-G. The analysis considers the Sacramento River, Stony Creek, and the Colusa Drain individually and collectively, and evaluates temporal accretion-depletion patterns over the 50-year simulation period.

Table 5. Without-Projects and With-Projects Surface Water System Water Budget Results for the Entire Colusa Subbasin (Average AF/yr, 2016 to 2065)

Component	Without-Projects	With-Projects	Difference (With-Projects – Without-Projects)
Inflows			
Surface Water Inflows	12,714,561	12,741,210	26,649
Sacramento River Diversions	1,195,939	1,255,291	59,352
Stony Creek Diversions	90,707	90,707	0
Sacramento River Inflows	11,335,460	11,302,757	-32,703
Other Inflows from Boundary Streams	92,455	92,455	0
Precipitation	1,257,503	1,257,503	0
Groundwater Pumping	558,561	509,702	-48,859
Agricultural	515,996	466,936	-49,059
Urban and Industrial	10,098	10,098	0
Managed Wetlands	32,467	32,668	201
Stream Gains from Groundwater	322,713	337,389	14,676
Total Inflow	**14,853,338**	**14,845,804**	**-7,534**
Outflows			
Evapotranspiration	1,900,935	1,902,885	1,949
Agricultural	1,596,222	1,597,393	1,171
Urban and Industrial	28,407	28,410	3
Managed Wetlands	73,292	73,292	0
Native Vegetation	167,144	167,146	2
Canal Evaporation	35,869	36,643	774
Deep Percolation	411,004	415,312	4,308
Precipitation	156,055	157,003	947
Applied Surface Water	158,089	170,370	12,281
Applied Groundwater	96,859	87,940	-8,919
Seepage	400,727	391,052	-9,675
Streams	252,897	242,325	-10,572
Canals and Drains	147,829	148,727	898
Surface Water Outflows	12,140,789	12,136,608	-4,180
Precipitation Runoff	59,795	60,180	384
Applied Surface Water Return Flows	90,012	91,563	1,551
Applied Groundwater Return Flows	20,352	20,096	-256
Sacramento River	11,186,667	11,156,439	-30,227
Colusa Basin Drain	773,816	786,947	13,130
Colusa Weir to Sutter Bypass	0	0	0
Other Outflows to Boundary Streams[1]	10,146	21,384	11,238
Total Outflow	**14,853,455**	**14,845,858**	**-7,597**
Change in Storage (Inflow - Outflow)	**-117**	**-53**	**63**
Stream gains minus seepage	-78,014	-53,663	24,351

Table 6. Without-Projects and With-Projects Groundwater System Water Budget Results for the Entire Colusa Subbasin (Average AF/yr, 2016 to 2065)

Component	Without-Projects	With-Projects	Difference (With-Projects – Without-Projects)
Inflows			
Subsurface Water Inflows	208,855	196,891	-11,964
Deep Percolation	411,004	415,312	4,308
Precipitation	*156,055*	*157,003*	947
Applied Surface Water	*158,089*	*170,370*	12,281
Applied Groundwater	*96,859*	*87,940*	-8,919
Seepage	400,727	391,052	-9,675
Streams	*252,897*	*242,325*	-10,572
Canals and Drains	147,829	148,727	898
Total Inflow	**1,020,586**	**1,003,255**	**-17,330**
Outflows			
Subsurface Water Outflows	146,626	156,416	9,790
Groundwater Pumping	558,561	509,702	-48,859
Agricultural	547,769	498,906	-48,862
Urban and Industrial	10,098	10,098	0
Managed Wetlands	34,672	34,870	198
Stream Gains from Groundwater	322,713	337,389	14,676
Total Outflow	**1,027,899**	**1,003,507**	**-24,392**
Change in Storage (Inflow - Outflow)	**-7,314**	**-252**	**7,062**

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Appendix 7A

Funding, Financing, and Cost Allocation

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Technical Memorandum

To: Glenn and Colusa County Groundwater Authorities

From: ERA Economics

Date: November 19, 2021

Subject: **Funding and Financing Mechanisms and Cost Allocation Overview for the Colusa Subbasin**

Introduction

Development of the Colusa Subbasin GSP was primarily funded through a Proposition 1 Sustainable Groundwater Planning Grant. Additional funding for Glenn and Colusa Groundwater Authorities (GGA and CGA) activities to support GSP development was from fees collected under rate studies covering the five-year period spanning fiscal years 2019/20 through 2023/24. These were prepared as property-related fees for water service under Proposition 218[1]. The rate study fees supported GSP development, which was estimated to cost approximately $465,000 per year in the CGA and $450,000 to $550,000 per year in the GGA. The fee is up to approximately $1.09 and $1.60 per assessable acre in the CGA and GGA in the current fiscal year (actual fees are less than the max).

After submission of the GSP to Department of Water Resources (DWR), CGA and GGA activities will shift from GSP development to GSP implementation[2]. Implementation of the GSP will be a substantial undertaking, encompassing continuing activities for GSP development (e.g., outreach and coordination) as well as new activities to support implementation (e.g., projects and management actions and addressing data gaps in the Subbasin). Implementation will likely require GSAs and other local entities to fund these required activities. As described in Chapter 7 of the GSP, total GSP implementation costs are estimated to increase from approximately $1.5 million to around $9.5 million per year at full implementation of planned projects and management actions (including annualized capital costs).

GSAs and other local entities implementing projects and management actions will develop a GSP financing plan that will likely include a combination of fees, assessments, and taxes, as well as additional outside funding, grants, and low interest borrowing. The financing plan will, among other items, identify funding and financing sources for components of GSP implementation. This will include consideration of allocation of those costs to different entities—and ultimately water users—in the subbasin. This technical memorandum/appendix to the GSP describes options for GSP funding and financing and introduces cost allocation concepts and approaches that may be considered.

[1] Fee Study for the Glenn Groundwater Authority. May 2019.

Fee Study for the Colusa Groundwater Authority. May 2019.

[2] There is substantial overlap between development activities covered under the existing rate study and implementation activities. For example, GSA administration and technical development work, to support refinements to the GSP, are largely the same.

Colusa Subbasin GSP Implementation Costs

The total cost of GSP implementation is approximately $9.5 million per year once planned projects and management actions are fully implemented. GSP implementation costs are broken into the following four categories, which are appropriate for different funding and financing mechanisms:

- **GSA Administration and Studies**. These include general GSA administrative and operating costs for management of the GSP, GSA coordination, other coordination with local entities, annual and five-year reports, and management of technical tasks. Studies include technical work that the GSAs will do to support GSP implementation. Total costs are around $1 million per year. GSA administration and studies are annual costs that are typically covered under local assessments.
- **Project and Management Action Capital Repayment**. Projects and management action (PMAs) capital repayment costs are estimated at approximately $1 million. The total capital outlay is around $20 million, which is primarily attributed to the Orland-Artois Water District (OAWD) land annexation and in-lieu recharge project. Project capital costs may be funded under future bond funding opportunities and other grant solicitations. Low interest borrowing options may be used to finance project capital.
- **Other PMA Capital and Studies**. These include project and management action development technical studies and non-debt financed capital. The estimated cost is $0.4 to $1 million per year. Project capital and studies may be eligible for some sources of grants but are typically paid on a pay-go basis.
- **Project Operations and Maintenance**. Annual O&M for projects is approximately $4 to $6.7 million per year. These are annual costs for the project. A substantial share of project O&M costs are attributed to water purchases for in-lieu recharge projects providing approximately 84,000 acre-feet (af) of benefits at full implementation.

Figure 1 illustrates the estimated costs over the first five years of GSP implementation. The largest single component is the cost to purchase water included in the PMA O&M estimate. The timing of costs may vary from what is shown on Figure 1. For example, some projects and management actions may be implemented more (less) rapidly resulting in accelerated (delayed) costs associated with capital and project operations and maintenance. The financing plan for GSP implementation would be updated to reflect these changes over time.

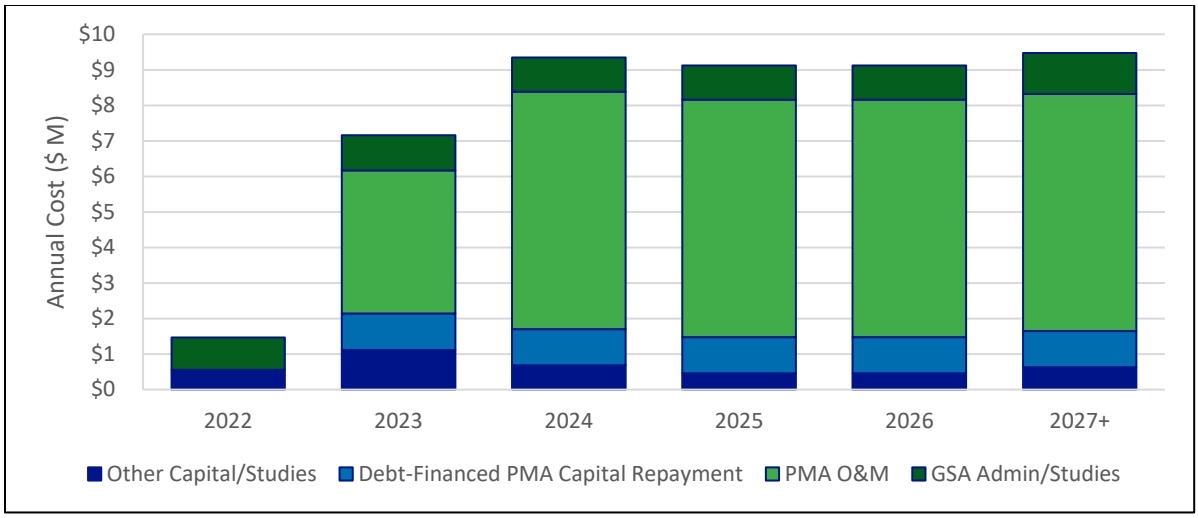

Figure 1. Colusa Subbasin GSP Implementation Cost Summary

Funding and Financing Mechanisms

Administering the GSP, groundwater monitoring, reporting, and project and management action implementation is projected to cost approximately $9.5 million per year across the Colusa Subbasin (Subbasin). GSA annual budgets and GSP implementation costs will be reviewed, revised if needed, and updated by the GSAs based on subbasin conditions, actual expenditures, and the immediate future needs. Expected costs will be adjusted over time as the GSP implementation costs are better understood through sustainable management activities and guidance from DWR on the submitted GSP and subsequent reporting.

Covering the costs of PMAs and general GSP implementation requires evaluating both financing and funding mechanisms. Financing relates to identifying sources of capital (typically state/federal grants, bonds, and bank loans) to pay for project capital expenses. Funding relates to sources of money required to cover capital repayment (pay back the debt-financed projects) as well as project O&M, GSA administration, and other annual expenses.

The agencies in the Subbasin have the powers and authority to impose fees and assessments and pursue other financing sources for capital projects and funding sources for repayment of debt, operations, and other ongoing expenses. The GSAs also have explicit fee authorities under Sustainable Groundwater Management Act (SGMA) legislation (Water Code §10730 and §10730.2). Table 1 summarizes potential financing and funding sources that may be used by GSAs for GSP implementation.

Table 1. Potential Funding and Financing Sources for GSP Implementation

Capital Financing	Considerations
State (DWR) Grants (Prop. 68 and future bonds)	Solicitations are typically targeted to general types of projects and specific benefits that are in the State's interest
US Bureau of Reclamation WaterSmart Grants	Project-specific funding that can support planning studies (e.g., water market strategy grants)
Other targeted potential grant programs (e.g., AB 252)	Potential for multi-benefit projects
Local bond issuance	Local borrowing based on agency authority
Private borrowing	Current low interest rate environment may make these options attractive
State or Federal low interest loans	This could include future bond-funded loan programs
Funding Sources	**Considerations**
Fee – General	General options for legal authority pre- and post-GSP development: Prop. 26, Prop. 218, Water Code §10730, Water Code §10730.2
Regulatory Fee	Typically, pre-GSP fee that is related to regulatory cost. Prop. 26 and Water Code §10730
Service Fee	Related to cost of service. Prop 218 and Water Code §10730.2. Subject to majority protest vote
Special Tax	Subject to 2/3 majority approval vote
Special Benefit	Special benefit assessment subject to majority protest vote

Capital Financing

Capital financing options include a mix of grants and low interest loans. There are typically limits on what costs can be covered by the funding source, or what specific benefits can be paid for. These can be specified in statute or defined by agencies administering the programs.

State opportunities for project capital funding under voter-authorized bonds are a common source of cost share for project capital. For example, Proposition 68, the Parks and Water Bond Act of 2018, bonds support the California DWR Sustainable Groundwater Management (SGM) Grant Program Implementation Grants. Project funding applications are submitted in a competitive process under grant proposal solicitation packages (PSP) administered by DWR. PSP guidelines define the requirements for project applications, eligibility for funding, and the desirable public benefits provided by the proposed project. The 2020 PSP for GSP implementation focused heavily on recharge opportunities and benefits to local disadvantaged communities. Planned GSP projects should be reviewed in advance and positioned for eligibility for future PSPs.

Multi-benefit projects have received increasing attention as part of GSP development and for state grant opportunities. The Governor's Executive Order N-10-19 directed state agencies to work together to prepare a "water resilience portfolio that meets the needs of California's communities, economy, and the environment through the 21st century" and prioritizes multi-benefit projects/policies. The 2020 DWR SGM PSP provided explicit definition of multi-benefit types, minimum requirements for grant eligibility, and weights assigned to project scoring.

Other opportunities for multi-benefit project funding are related to SGMA implementation. For example, AB 252 Department of Conservation: Multi-benefit Land Repurposing Program outlines a potential program for providing state grants to support agricultural land repurposing under GSP implementation[3]. The Governor's May Revise budget included a proposal for a similar $500 million program for drought support administered by the Department of Conservation for "Multi-Benefit Land repurposing[4]" in collaboration with the Department of Food and Agriculture. The program concept is to "prioritize ecosystem-based strategies that are implemented with landowners" to support land repurposing from irrigated agriculture to other uses. While the program would primarily be targeted to the Critically Overdrafted Subbasins, potential multi-benefit recharge projects included in the Colusa Subbasin GSP (see Chapter 6) may be eligible under this or similar programs.

Grant funding opportunities can define specific public benefits that are eligible. Various state and federal laws have established some benefit types as public eligible for public funding. For example, Proposition 1, the Water Quality, Supply, and Infrastructure Improvement Act of 2014, defined five public benefit categories eligible for funding under the Water Storage Investment Program. Flood control benefits have often been considered to include a mix of public (state or federal) and private (local) benefits, so a cost share approach is common. Ecosystem benefits that accrue to the entire state are considered public benefits.

Grants and low interest loans are expected to be an important option for reducing the cost of SGMA to local communities. The Colusa Subbasin GSAs will continue to pursue these opportunities to help fund planning studies, projects, and other GSA activities. However, grants and low-interest loans are not expected to cover most GSA operating costs for GSP implementation or annual operating and maintenance costs of projects. In addition, these rely on relatively unpredictable funding (e.g., state general obligation bonds that require voter approval) and are subject to changing rules and requirements.

Funding Sources

Example funding methods that are available to GSAs to fund projects, studies, and operations were reviewed. Groundwater extraction fees and groundwater permit fees are specifically included in the SGMA legislation (California Wat Code 10730 et seq), but other methods may be available to a GSA, depending on the agency's authorities under law. All methods adopted must comply with the requirements of statute and the California Constitution. The following summary includes many common funding methods but is not necessarily comprehensive.

Assessments based on costs of service or special benefits under Proposition 218 could include a per-acre (or per-parcel) charge to cover GSA costs, or other fees under Proposition 26. For example, benefits of a recharge project might accrue differentially across the Subbasin. The assessment could be calculated in proportion to the special benefit received (by subarea and/or user class), as calculated in the reports supporting the rate study. For cost-based fees and charges (including extraction and permit fees), the report would calculate the cost of providing the service to each parcel or to categories of parcels. Categories would be based on costs imposed on the program and could be based on location, level of use, or other characteristics related to costs.

Another option for funding GSP implementation is taxes. Taxes do not have to be directly tied to the cost or benefit of the service provided. Potential taxes could include general property related taxes that are not directly related to the benefits or costs of a service (ad valorem and parcel taxes), or special taxes imposed for specific purposes related to GSA activities. Based on an initial review of GSA funding

[3] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB252

[4] May Revised Budget. Submitted 5/14/2021.

approaches in Critically Overdrafted Subbasins, this is not a common funding mechanism for GSP implementation.

Other fees and charges may include permitting fees for new wells or development, transaction fees associated with contemplated groundwater markets, or commodity-use fees, all directed at aiding with sustainability objectives. Depending on the justification and basis for a fee, it may be considered a property-related fee subject to voting requirements of Article XIII D of the California Constitution (passed by voters in 1996 as Proposition 218) or a regulatory fee exempt from such requirements.

Some of the potential funding approaches can affect the cost of water for specific uses in the Subbasin. For example, districts supplying surface water recognize that recovering GSP related costs as part of their surface water charge can be counter-productive by disincentivizing surface water use. All agencies are concerned that any fees, charges, or assessments will affect business (farm) income and, if large, may affect cropping decisions and farming practices in the Subbasin. Based on groundwater monitoring, land use changes, and other future conditions, the GSAs will reconsider or adjust fees/assessments as needed to achieve sustainability.

Funding and Financing Mechanisms in Example GSAs

A brief review of some GSA funding approaches was developed to illustrate examples of the different bases for their fee or assessment structure. Most of the rate studies were for GSP development. This includes studies stating that the GSA is exempt from voting requirements (see the Kings River East GSA below).

- McMullin Area GSA

  McMullin Area GSA is in central Fresno County within the Kings Subbasin. It adopted a property-based fee to fund GSA costs, calculated as the annual cost of service divided by the number of acres served. The adopted fee excludes parcels that are less than two acres, which it determines are “de minimis” groundwater users under SGMA. The resulting annual fee of $19 per acre was adopted as a water service fee under Proposition 218 after a public hearing at which a majority of land subject to the fee did not protest. The rate study suggested that the agency may consider converting some or all of its fee to a volumetric basis in the future but did not at the time have the information to do so.

- South Fork Kings GSA

  The South Fork Kings GSA is in the Tulare Lake Subbasin. It adopted an annual charge to fund its costs, following requirements for a public hearing and protest vote. Its charge was authorized for five years, beginning at up to $9.80 per acre for 2019 (the first year after the rate study). The amount per acre is calculated as the costs of specified implementation and administrative costs divided by assessable acres within the boundaries of the GSA, except for the City of Lemoore. A separate amount is calculated annually for the City of Lemoore by negotiated agreement. The GSA generally refers to the proposed charge as an assessment and describes the process for justifying a benefit assessment apportioned among parcels according to special benefit received. However, it also describes the fee as apportioned among parcels according to cost of providing the service.

- Kings River East GSA

  The Kings River East GSA is in the Kings Subbasin. It prepared a groundwater fee study to calculate and justify a volumetric fee per af pumped. It used a cost-of-service approach to determine appropriate fees for different areas and jurisdictions within its boundaries. The agency argued that, under Proposition 26, the fee is a regulatory fee that covers the cost of compliance with SGMA, and therefore it is exempt from the public voting requirement. Fees were calculated according to area, land use, and water use. Some areas were not charged a volumetric fee because of their "lack of deep groundwater pumping from the alluvium"; they were only charged a nominal, fixed annual fee to cover a share a share of fixed administrative costs. Other areas were charged $1.45 per af of estimated pumping. Pumping is not currently metered in the area, so the fee was based on land use and a water balance calculation to estimate pumping.

Cost Allocation and Cost Recovery for GSP Implementation

The fee and assessment methods summarized in the previous section allow (and in most cases require) agencies to consider the relative benefits and costs, and to whom they accrue, in setting rates or amounts.

Cost allocation is a multi-step process that determines how costs of implementation components will be spread among and recovered from entities and areas covered by the GSP. The implementation plan includes several categories of activities that must be paid for: administration, projects and management actions, monitoring, and studies. The categories may have their costs spread in different ways (among different entities and areas) depending on discussions and policy decisions about issues like: who is responsible for a cost, who benefits from an activity, what is fair, what is legally allowed or possible, what are the requirements for determining and justifying a cost allocation?

An initial step in cost allocation is to determine which agency (or agencies) are responsible for financing and funding. This may vary based on fairness and equity concerns, and across different GSP PMAs. For example, the lead agency for a specific GSP project may work to secure financing and explore funding mechanisms. Alternatively, the GSA could lead some of these activities and in turn recover costs from the lead agency (or agencies). Under both approaches, the cost allocation would consider the share of benefits received from the project. Using the four GSP cost categories defined above, example considerations for each category include:

- **GSA Administration and Studies**. General GSA administrative costs and required studies to support GSP implementation (e.g., address data gaps) generally provide a benefit to the entire Subbasin. This could be viewed as a basis for allocating costs broadly across all groundwater users. However, some areas may receive a disproportionate share of benefits from the actual implementation of the GSP and this could be reflected in how general costs are allocated. Potentially, some areas could be judged as not responsible for groundwater issues or benefitting from groundwater management.
- **Project and Management Action Capital Repayment**. Projects typically have a single project proponent that has specific financing and funding options available. Project benefits may primarily accrue to the proponent. However, under SGMA requirements for subbasin-wide sustainability, other entities and areas may derive some potential indirect benefits of sustainability. In addition, there may be direct project-related benefits (e.g., higher groundwater elevations that reduce pumping costs or reduce stream depletions) that accrue to other parties.

- **Other PMA Capital and Studies**. Project capital costs that will not be debt-financed and project study costs could be treated similar to PMA capital costs. However, the GSA may initiate studies to support GSP implementation and cover a portion of costs. Some of these studies have been initiated under GSP development (e.g., subbasin conditions, data management system, and data gaps).
- **Project Operations and Maintenance**. Specific PMA O&M costs could be paid by the project proponent. A portion of costs could be allocated to other parties that receive direct or indirect benefits from the project, or to the entire Subbasin for general SGMA benefits.

Cost allocation for a GSP that incorporates many agencies may occur at multiple levels, perhaps including basin-wide, within a GSA, or within an individual entity such as a water district or other local agency. The general steps in cost allocation are:

- Determine costs of implementation activities and when they are to be incurred. Generally, the different cost components of an activity need to be aggregated in a consistent way to allow for a fair and objective allocation. This is especially important if cost components (e.g., capital costs versus annual O&M) may be paid by different parties. A life-cycle cost approach is commonly used, in which all costs over the life of the activity are adjusted for when they occur (using standard financial discounting) and expressed as an annual or lump-sum amount.
- Based on stakeholder discussions and technical support, make decisions about which costs apply across the entire GSA versus apply to subareas or specific agencies. For GSP activities that serve the entire GSA (perhaps GSA administration or certain monitoring costs), the GSA would lead the discussions and policy decisions; for projects proposed by or to be developed by a specific member agency, that agency could take the lead. Discussions and decisions may also address which groups or users will be included in the cost allocation for a particular activity – for example, the discussion could consider a group's past or current use of groundwater.
- Develop information to support the actual calculations needed to allocate and recover costs, which may include cost of service and benefit information. This step is based on the policy decisions and will help determine who pays for the GSP activity. Defensible information is required to meet legal requirements. An open and fair process is essential for the political support needed to implement activities and recover costs.

Allocating and recovering costs involve policy decisions and technical analysis and must follow a process that meets legal requirements. Costs of projects and activities that serve large areas and multiple groups are typically allocated using cost-of-service principles, whereby the total project cost is split based on each area or group's demonstrated proportional split of total cost. Costs can also be allocated based on benefits received (for example the California Constitution allows for assessments to be based on special benefits received). Ultimately, decisions about cost allocation must involve meaningful input from affected parties so that the outcome is viewed both as fair and technically justified.

Summary

Cost allocation and repayment are important and difficult decisions that require ongoing and open discussions. The GSAs are already implementing financing mechanisms to pay for their administrative costs. Development of a financing plan will require making further decisions with stakeholders and member agencies using a timely process that supports the subbasin sustainability goal and GSP implementation schedule.

This memorandum/appendix provides a general overview of funding and financing methods available to Subbasin agencies. Methods generally allow agencies to consider the distribution of costs and benefits when setting a fee or assessment. An analysis to establish a financing plan for the Subbasin would:

- Review specific issues that affect the distribution of costs and benefits within the subbasin. This would include establishing potential project costs and beneficiaries. It would also consider the agency (or agencies) that would be responsible for recovering the costs of different activities.
- Listen to different groups' perspectives on fairness, contribution to groundwater issues, and benefits from groundwater management.
- Coordinate with GSA legal counsel and agency legal counsel to evaluate fee and assessment options.
- Prepare technical analyses to support cost allocation and repayment. This potentially can include some options or examples that illustrate different allocations of fees/assessments, for a specific project or management action with multiple payers and beneficiaries to demonstrate how fees can be calculated when benefits or costs are assigned to different areas and/or customer groups.

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